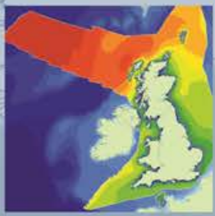
Marine Institute

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

Report VIII: Vegetation Dominated Communities (saltmarsh and seagrass)

Report R.2053
October 2013

Creating sustainable solutions for the marine environment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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 vegetation dominated communities (Saltmarsh and seagrass) 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 vegetation dominated communities (saltmarsh and seagrass). 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.

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Report VIII: Vegetation Dominated Communities (saltmarsh and seagrass)

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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 vegetation dominated communities (saltmarsh and seagrass) 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 saltmarsh and seagrass (*Zostera*) 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;
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 (this report).

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 saltmarsh and seagrass (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.

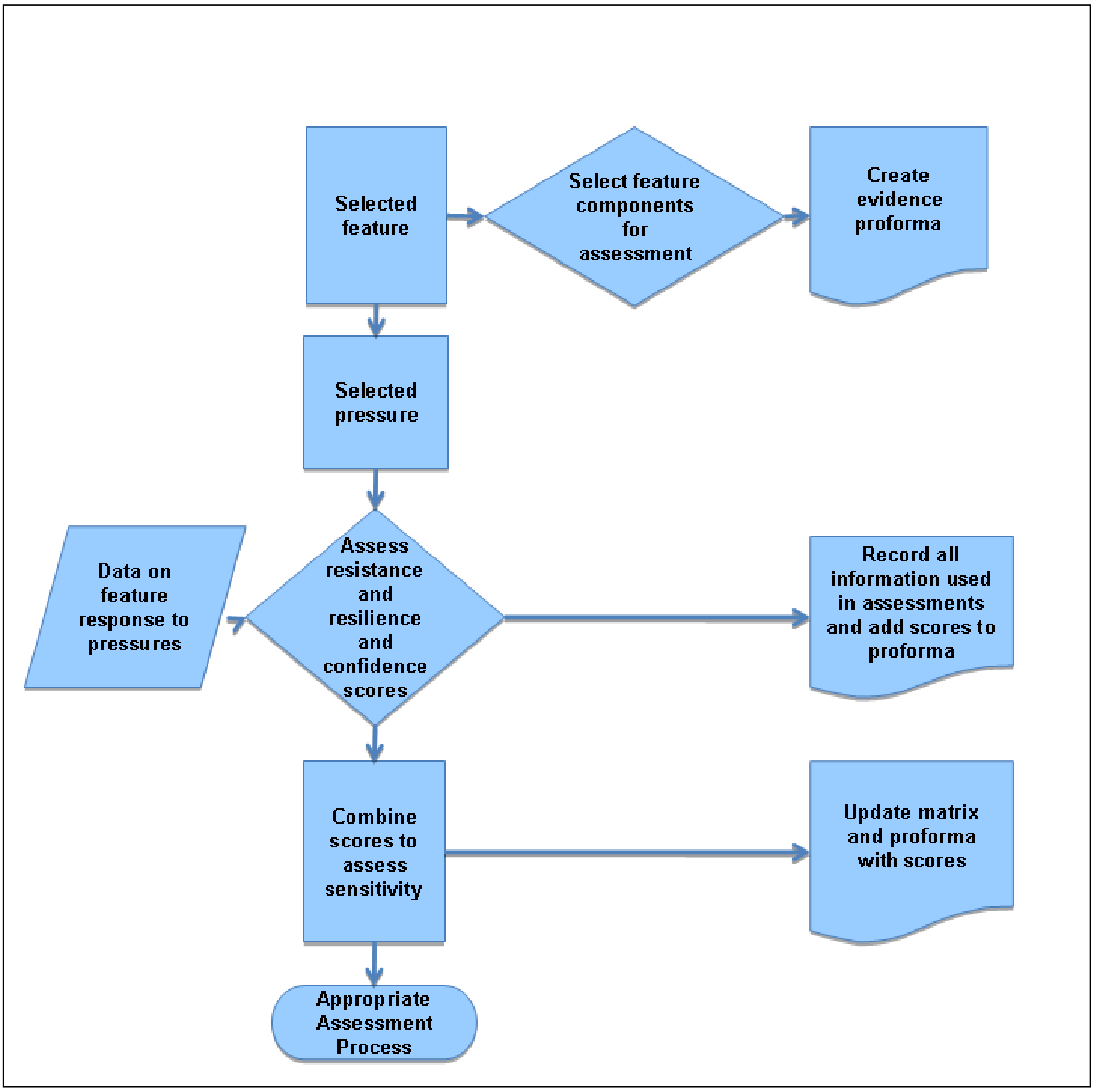

Figure 1. Sensitivity Assessment methodology used to populate the Sensitivity Matrix with assessments

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' (NE).

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' (NA) in the matrix.

For a limited number of features the assessment 'No Evidence' (NEv) 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.

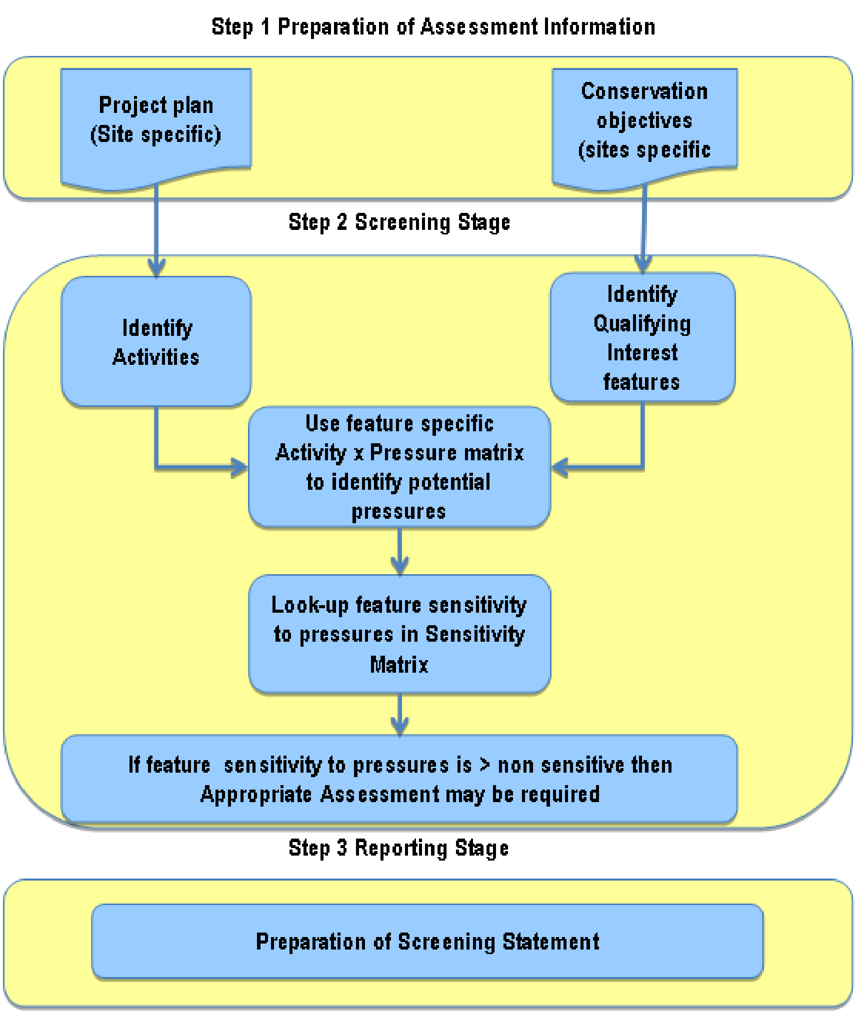

Figure 2. Outline of Screening Stage of Appropriate Assessment

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

Pressure	Footprint (Huntington et al. 2006)
Decrease in oxygen levels (water column)	Zone A
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

	Sensitivity			
Exposure	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?

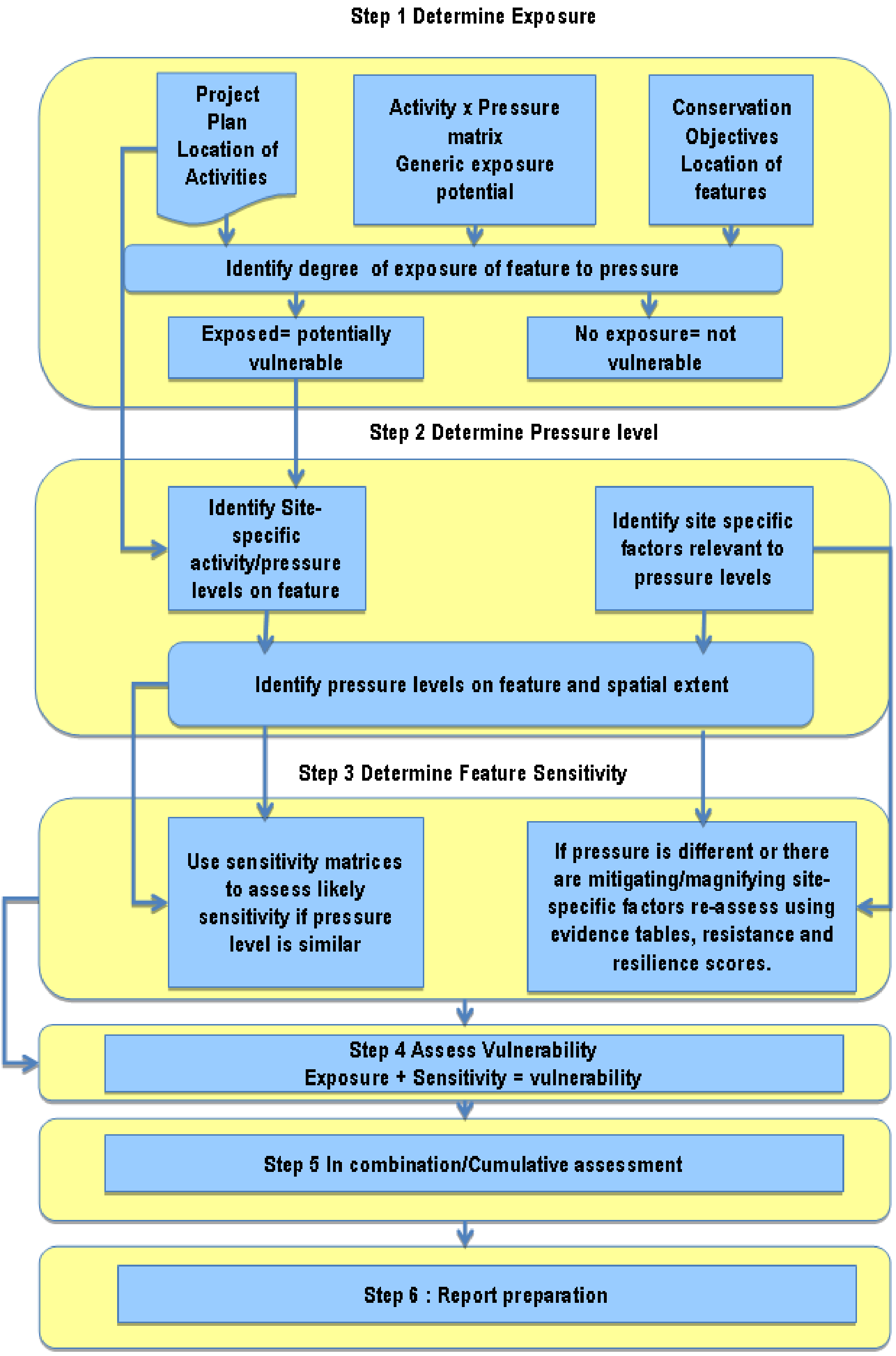

Figure 3. Flow diagram outlining the suggested steps to develop an Appropriate Assessment using project deliverables

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.
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 vegetation dominated communities (saltmarsh and seagrass). 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.

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Appendices

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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 Activities 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]								OF

	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
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

Atlantic salt meadows (saltmarsh) Sensitivity Matrix (including resistance, resilience and sensitivity scores (see Report Sections 2 and 3 for further information)

Pressure		Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)
Physical damage	Surface Disturbance	M (**)	VH (**)	L (**)
	Shallow Disturbance	M (*)	H (*)	L (*)
	Deep Disturbance	L (*)	L-M (*)	M-H (*)
	Trampling - Access by foot	M (**)	VH (**)	L (**)
	Trampling - Access by vehicle	L (**)	M-H (**)	M (**)
	Extraction	L (*)	L-M (*)	M-H (*)
	Siltation	M-H(***)	H-VH (*)	NS-L (*)
	Smothering	N (*)	L-M(*)	H-VH (*)
	Collision risk			NE
Disturbance	Underwater Noise			NS
	Visual - Boat/vehicle movements			NS
	Visual - Foot/traffic			NS
Change in Habitat Quality	Changes to sediment - Increased coarseness	H (*)	VH (*)	NS (*)
	Changes in sediment increased fines	H (*)	VH (*)	NS(*)
	Changes to water flow	L (*)	L-M (*)	M-H(*)
	Increased suspended sediment/ turbidity	H (*)	VH (*)	NS
	Decreased suspended sediment/ turbidity	H (*)	VH (*)	NS (*)
	Organic enrichment - Water column	H (*)	VH (*)	NS (*)
	Organic enrichment of sediments - Sedimentation	H (*)	VH (*)	NS (*)
	Increased removal of primary production - phytoplankton			
	Decrease in oxygen levels - Sediment	H (*)	VH (*)	NS (*)
	Decrease in oxygen levels - Water column	H (*)	VH (*)	NS (*)
Biological Pressure	Genetic impacts			
	Introduction of non-native species			NS
	Introduction of parasites/pathogens			
	Removal of Target Species			NS
	Removal of Non-target species			NS
	Ecosystem Services - Loss of biomass			NS
Chemical Pressures	Introduction of Medicines			NEv
	Introduction of hydrocarbons	N-L (***)	L (***)	H-VH (***)
	Introduction of antifoulants			NEv
Physical pressures	Prevention of light reaching seabed/ features	N (*)	L-M (*)	H-VH (*)
	Barrier to species movement			NE

Seagrass (*Zostera*) Sensitivity Matrix (including resistance, resilience and sensitivity scores (see Report Sections 2 and 3 for further information)

Pressure		Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)
Physical Damage	Surface Disturbance	L (***)	L-H (***)	M-H (***)
	Shallow Disturbance	L-M (***)	L-H (***)	M-VH(***)
	Deep Disturbance	N-L (***)	L-M (***)	M-VH (***)
	Trampling - Access by foot	L (***)	L-H (***)	M-H (***)
	Trampling - Access by vehicle	L (***)	L-H (***)	M-H (***)
	Extraction	N (*)	L-H (***)	M-VH (***)
	Siltation	N (***)	L (***)	VH (***)
	Smothering	N (*)	L (***)	VH (***)
	Collision risk			NE
Disturbance	Underwater Noise			NS
	Visual - boat/vehicle movements			NS
	Visual - foot/traffic			NS
Change in Habitat Quality	Changes to sediment composition - increased coarseness	M (*)	M (*)	M (*)
	Changes in sediment composition - increased fines	M (***)	M (***)	M (***)
	Changes to water flow	M (***)	M (*)	M (*)
	Changes in turbidity/suspended sediment - Increase	L (***)	L(***)	H (***)
	Changes in turbidity/suspended sediment - Decrease	H (*)	VH (*)	NS (*)
	Organic enrichment - water column	L (***)	L (***)	H (***)
	Organic enrichment of sediments - sedimentation	L (***)	L (***)	H (***)
	Increased removal of primary production - phytoplankton	H (*)	VH (*)	NS (*)
	Decrease in oxygen levels - sediment	N-L (***)	L (*)	H-VH (*)
	Decrease in oxygen levels - water column	N-L (*)	L (*)	H-VH (*)
Biological Pressure	Genetic impacts			NE
	Introduction of non-native species	L (**)	L (***)	H (**)
	Introduction of parasites/pathogens			NE
	Removal of Target Species			NS
	Removal of Non-target species			NS
	Ecosystem Services - Loss of biomass			NA
Chemical Pressures	Introduction of Medicines			NEv
	Introduction of hydrocarbons	H (***)	VH (***)	NS (***)
	Introduction of antifoulants			NEv
Physical pressures	Introduction of litter			NA
	Prevention of light reaching seabed/ features	N (**)	L-M (**)	H-VH (**)
	Barrier to species movement			

Appendix F

Evidence Proformas

Appendix F - Evidence Proformas

Section VIII Vegetation Dominated Communities: Atlantic salt meadows (Saltmarsh) and Seagrass (*Zostera*) Habitats

Structure of Section VIII - Appendix F

This Appendix consists of the following Sections:

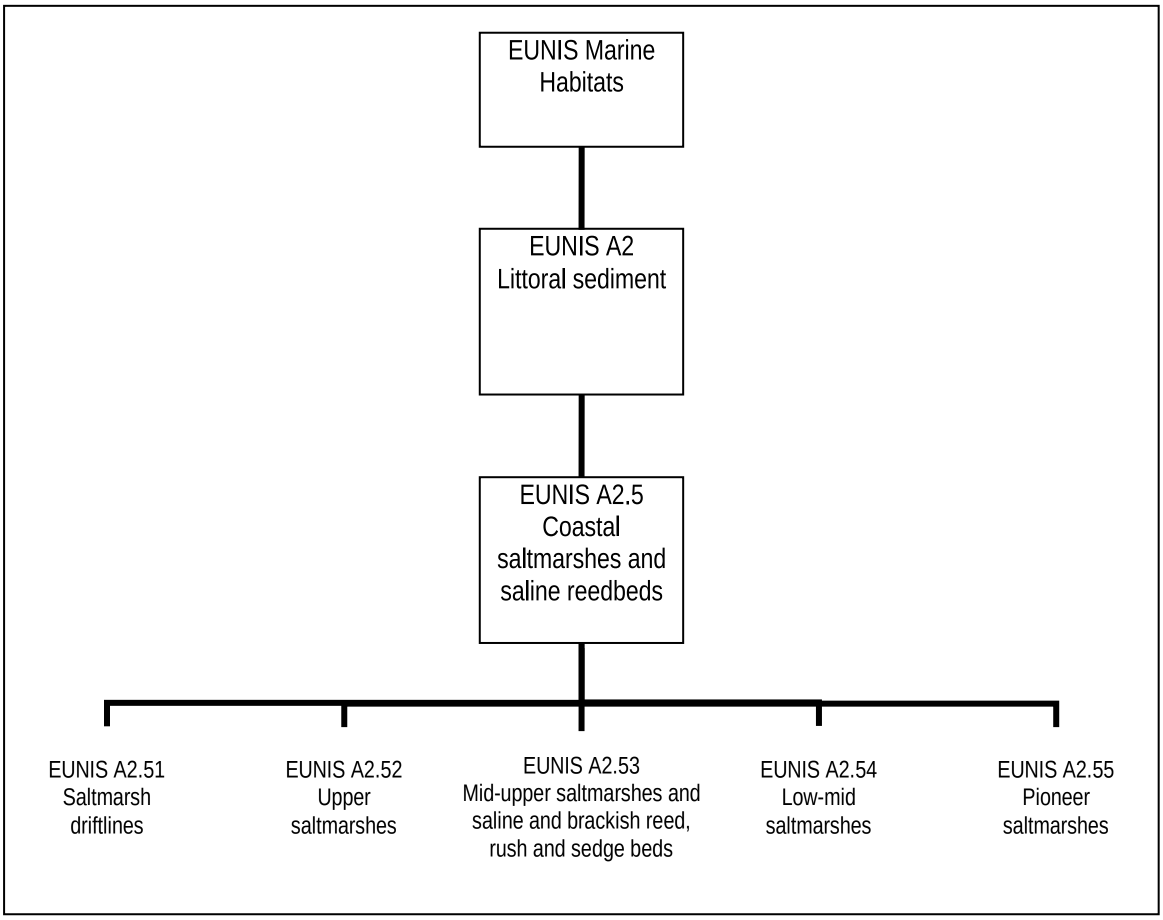
Introduction VIII A (this document)
Saltmarsh habitats Sensitivity Assessment (EUNIS A2.5)

Introduction VIII B Seagrass beds (*Zostera*) Introduction)
Zostera habitats Sensitivity Assessment (EUNIS A2.6 and A5.5)

Saltmarsh Introduction

Saltmarsh habitats occur in the intertidal (littoral) sediment and fall within the EUNIS level A2.5 category. Annex 1 features which form a component of this habitat include; *Salicornia* and other annuals colonising mud and sand and Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*).

Figure VIII.1 Hierarchical Diagram showing relevant elements of the EUNIS descriptive framework for Saltmarsh



Coastal saltmarshes and saline reedbeds (EUNIS A2.5)

This habitat includes angiosperm-dominated stands of vegetation, occurring on the extreme upper shore of sheltered coasts and periodically covered by spring high tides. The vegetation develops on a variety of sandy and muddy sediment types and may have admixtures of coarser material. The character of the saltmarsh communities is affected by height up the shore, resulting in a zonation pattern related to the degree or frequency of immersion in seawater.

Information from JNCC habitat description (LS.LMp.Sm Saltmarsh)

Saltmarsh vegetation is generally well studied; its classification is fully covered by the UK National Vegetation Classification, where 26 types are defined (Rodwell, 2000). Differing plant communities characterise the different saltmarsh biotopes.

Information from Natural England (Coastal saltmarshes and saline reedbeds)

Saltmarshes link the land and sea, and they are found above the muddy shores of sheltered estuaries and inlets. The flowering plants that comprise them are very specialised, as only a few types can tolerate the salty conditions. Saltmarshes may die back in winter, as the temperature falls and storms batter the shore, but they will expand again during the summer. This is particularly the case for the Salicornia spp. - dominated pioneer saltmarsh communities at the lower end of the saltmarsh zone

Saltmarshes form a natural coastal defence because they trap and stabilise sediments and also dampen the effects of waves. They are important for wading birds and wildfowl, which take refuge there when the tide covers the mudflats in which they feed. The life on and beneath the saltmarsh plants includes an abundance of marine worms, shrimp-like creatures and tiny snails.

Saltmarshes and reedbeds are at risk from land reclamation or drainage for agriculture or coastal development, although large scale reclamation is now rare. Saltmarshes may also be ‘squeezed out’ in areas where their landward retreat in response to erosion or rising sea levels is prevented by the presence of flood defences, roads or buildings. They are also damaged by grazing, encroachment of hardy land plants, pollution and other changes to water quality.

References

EUNIS website: http://eunis.eea.europa.eu/habitats/20/general.

JNCC website:
http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001526.

Natural England website: http://www.naturalengland.org.uk/ourwork/marine/mpa/mcz/features/broadhabitats/coastalsaltmarshesandsalinereedbeds.aspx.

Atlantic Salt Meadows (saltmarsh): Introduction and Habitat Assessment Information (EUNIS A2.5)

Introduction

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, 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 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 and a record of the confidence in the assessment made.

Feature Description

Saltmarsh forms a component of the Annex 1 features: Estuaries, Lagoons, Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) and *Salicornia* and other annuals colonising mud and sand.

Saltmarshes comprise the upper vegetated portions of intertidal mudflats, lying approximately between the mean high water neap and mean high water spring tide water levels. These habitats are usually restricted to relatively sheltered locations such as estuaries and saline lagoons. The vegetation develops on a variety of sandy and muddy sediment types and may have admixtures of coarser material. Saltmarsh vegetation is composed of a limited number of salt-tolerant species adapted to regular immersion, with more diverse plant communities found in the mid-upper marsh compared to the low-mid marsh.

This feature refers to coastal saltmarshes and saline reedbeds. This assessment has been structured following the EUNIS framework (see Introduction).

Associated Biological Community

The character of the saltmarsh communities is affected by elevation, resulting in a zonation pattern related to the degree or frequency of immersion in seawater. Saltmarsh vegetation is generally well studied; its classification is fully covered by the UK National Vegetation Classification, where 26 types are defined (Rodwell, 2000). Characteristic infaunal species of saltmarsh communities include: *Hediste diversicolor*, *Manayunkia aestuarina*, *Enchytraeidae*, *Corophium volutator* and *Hydrobia ulvae* (Connor et al. 2004).

The following descriptions of the main biological communities associated with the feature are taken from EUNIS.

EUNIS A2.51 Saltmarsh driftlines
The top level of saltmarsh, not covered by all tides. *Vigorous Atriplex* spp., *Beta vulgaris*, *Elymus* spp., *Matricaria maritima* may be fertilized by drift decomposition.

EUNIS A2.52 Upper saltmarshes
Salt scrubs with *Arthrocnemum*, *Halocnemum*, *Suaeda*. Stands, sometimes rather open of *Juncus acutus*, *Juncus maritimus*. Numerous other salt-tolerant species, some communities being quite species-rich.

EUNIS A2.53 Mid-upper saltmarshes and saline and brackish reed, rush and sedge beds
Closed saltmarsh meadows, more species-rich than in low-mid saltmarsh, dominated by graminoids *Blysmus rufus*, *Carex extensa*, *Festuca rubra*, *Juncus gerardi*, *Puccinellia* spp.; also *Armeria maritima*, *Artemisia maritima*, *Frankenia laevis*. Marine saline or brackish beds of *Hippuris tetraphylla*, *Juncus maritimus*, *Phragmites australis*.

EUNIS A2.54 Low-mid saltmarshes
Saltmarshes with more or less closed angiosperm vegetation. Included are grassy salt meadows dominated by *Puccinellia festuciformis* or *Aeluropus littoralis* in the Mediterranean and by *Puccinellia maritima* in northern Europe. Also characteristic are *Glaux maritima*, *Halimone portulacoides*, *Limonium vulgare*, *Plantago maritima*.

EUNIS A2.55 Pioneer Saltmarshes
Saltmarshes at the lowest level of non-aquatic angiosperms; vegetation open and very species-poor, typically with *Salicornia* spp. or *Spartina* spp., less often with *Arthrocnemum* spp., *Aster tripolium*, *Sagina maritima*, *Salsola kali* or *Suaeda* spp.

Key Ecosystem Function Associated with Habitat

Saltmarshes provide numerous ecosystem services (reviewed in Fletcher et al. 2011). For example, saltmarshes act as a natural coastal defence because they trap and stabilise sediments and also dampen the effect of waves. Saltmarshes have high primary productivity, provide habitat and refuge for a wide variety of species and function as nursery areas for many birds, juvenile fish, crustaceans and molluscs (Pennings and Bertness, 2001). They are also an important resource for wading birds and wildfowl, providing high tide refuges for birds feeding on adjacent mudflats, breeding sites for waders, gulls and terns and offering a source of food for passerine birds particularly in autumn and winter (Maddock, 2008).

Habitat Classification

Table VIII.1 Types of Saltmarsh habitats recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (Source: EUNIS, 2007; Connor et al. 2004)

Annex I Habitat containing feature	EUNIS Classification of feature	Britain and Ireland Classification of feature	OSPAR Threatened and declining species or habitat
Estuaries, Lagoons, Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) and *Salicornia* and other annuals colonising mud and sand	A2.5	LS.LMp.Sm	No
	A2.51	LS.LMp.Sm_	No
	A2.52	No equivalent	No
	A2.53	LS.LMp.Sm_	No
	A2.54	LS.LMp.Sm_	No
	A2.55	LS.LMp.Sm_	No

Features Assessed

Although this feature comprises a number of biotope complexes, this assessment is based on the wider saltmarsh and plant community as the key structuring component of these habitats (i.e. at the EUNIS level A2.5) due to the general lack of evidence relating to the specific biotopes. Where information was available relating to specific biotopes e.g. the MarLIN sensitivity assessments for *Puccinellia maritima* saltmarsh community (A2.541; Tyler-Walters, 2008a) and pioneer saltmarsh (A2.55; Tyler-Walters, 2008b) this has been referred to in the text.

Recovery

Tyler-Walters (2008a) reported that in *Puccinellia maritima* saltmarsh communities rates of recovery and recolonisation depend on the level of damage or disturbance, and will probably be protracted where the sediment has been more heavily disturbed (Beeftink, 1979). In general, where disturbance is slight, or only the aerial parts of the plant are damaged, recovery is likely to be rapid due to regrowth (immediate in the summer months, longer in winter) but overall probably taking less than 6 months, including recolonisation by most invertebrates and algae. However, where the sediment has been extensively disturbed and plants lost, recovery of plant communities together with infauna may take between 4 -10 years.

Pioneer saltmarsh will probably recover within less than 5 years of disturbance. Where the sediment has been eroded, recovery will probably be delayed until the sediment level has built up again (Tyler-Walters, 2008b).

Studies in Californian saltmarshes have shown that recovery rates are species-specific and generally occur through vegetative in-growth of plants surrounding a disturbed spot or by growth of buried plants through the sediment. Seedling establishment was rare (Allison, 1995).

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table VIII.3 (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 resistance scale is categorised as None (N), Low (L), Medium (M) and High (H). Similarly resilience is scored as Low (L), Medium (M), High (H) and Very High (VH). Sensitivity is categorised as Not Sensitive (NS), Low (L), Medium (M), High (H) and Very High (VH). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the primary source(s) of information used, this is assessed as Low (*), Medium (**) and High (***). These scores are explained further in Table VIII.2a and are combined, as in Table VIII.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 features 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 VIII.4 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 VIII.2a).

Table VIII.2a Guide to Confidence Levels for resistance and resilience assessments

Confidence Level	Primary Source of Information	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 VIII.2b Sensitivity Assessment Confidence Levels

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

Table VIII.3 Saltmarsh 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 (**)	Abrasion in saltmarsh biotopes is likely to result from trampling and vehicle use (see trampling – access by foot/vehicle). In a sensitivity assessment of saltmarsh habitat, undertaken through a combination of literature review and expert judgement at workshops, Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised saltmarshes as having low sensitivity to surface abrasion caused by nets and long-lines at all levels of intensity that they assessed from (>9 pairs of anchors/area 2.5nm by 2.5nm fished daily to a single pass of fishing activity in a year overall). Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised saltmarsh as having low sensitivity to all levels of casual gathering (> 10 people fishing per hectare often using vehicles to a single visit by individual per day). Saltmarshes were judged to have high sensitivity to professional hand gathering at high and moderate intensities (> 10 people fishing per hectare often using vehicles. Large numbers of individuals mainly concentrated in one area, with the activity occurring daily. Moderate- 3-9 people fishing per hectare per day. Medium sensitivity to low levels of intensity (1-2 people fishing per hectare per day) and low sensitivity to a single visit by a professional per day. Resistance to surface abrasion was assessed as less than 25% of feature and recovery as taking between 2-10 years at an expert workshop convened to assess sensitivity of features to human pressures (Tillin et al. 2010) Resistance to surface abrasion is assessed as ‘Medium’, however, abrasion events at high intensity and frequency will lead to progressive reduction in vegetation cover. Recovery from single or infrequent events is predicted to be ‘High’, with recovery rates more rapid in summer in the growing season than in winter.
	Shallow Disturbance	Direct impact from surface (to 25mm)	M (*)	H (*)	L (*)	Shallow disturbance in saltmarsh biotopes is likely to result from trampling and vehicle use (see trampling – access by foot/vehicle).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
		disturbance				Resistance to surface abrasion was assessed as less than 25% of feature and recovery as taking between 2-10 years at an expert workshop convened to assess sensitivity of features to human pressures (Tillin et al. 2010). Shallow disturbance will remove the vegetation cover and impact the sediment resulting in reduction in vegetation cover, based on Tillin et al. 2010, resistance was assessed as 'Medium' and recovery as 'Medium-High', so that sensitivity is categorised as 'Low'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance	L (*)	L-M (*)	M-H (*)	Deep disturbance in saltmarsh biotopes is likely to result from trampling and vehicle use (see trampling – access by foot/vehicle). Resistance to deep disturbance was assessed as low, with 25-75% of feature removed and recovery as taking between 2-10 years at an expert workshop convened to assess sensitivity of features to human pressures (Tillin et al. 2010). Based on Tillin et al. (2010), resistance was assessed as 'Low' and recovery as 'Medium-High' so that sensitivity was assessed as 'Medium-High'.
	Trampling-Access by foot	Direct damage caused by foot access, e.g. crushing	M (**)	VH (**)	L (**)	Evidence from MarLIN In coastal plant communities trampling may favour plants with high growth rates, basal meristems, and low growth forms. Low levels of trampling encourage growth and species richness but these fall as trampling increases (Packham and Willis, 1997). It is likely that succulents, such as *Salicornia* sp. are intolerant of trampling. Trampling may also affect the substratum, either through destabilisation of creek walls and loss of vegetation, or may result in compaction of sediments and reduced aeration. Some plants will be damaged and invertebrates may be displaced but effects are likely to be restricted in area (Tyler-Walters, 2008b). In a study of Danish coastal habitats, Andersen (1995; cited in Tyler-Walters and Arnold, 2008) noted that, compared to sand dune and coastal grassland habitat, saltmarsh vegetation was the most resistant to trampling. Chandrasekara and Frid (1996) assessed the effect of human trampling on macro-benthic fauna across

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						a footpath on the emergent marsh and tidalflat at Lindisfarne National Nature Reserve. The authors concluded that the susceptibility of the saltmarsh infauna to human trampling depended upon the intensity of the trampling disturbance and the nature of the habitat. It was noted that continual trampling along the 'old track' reduced vegetation cover and increased the area of bare mud. Reviewing these studies, Tyler-Walters and Arnold (2008) summarised that saltmarsh is relatively resistant to foot trampling. Hall et al. (2008) also stated that saltmarsh was considered to have a low sensitivity to trampling associated with site access. With respect to fisheries activities, while bait-digging is not usually carried out in saltmarshes themselves it may involve access across saltmarshes with resulting damage from trampling (Boorman, 2003). Note, Fowler et al. (1999) refer to incidents of bait digging in saltmarsh habitats, hence its inclusion in the surface disturbance section. Assessment based on surface disturbance.
	Trampling-Access by vehicle	Direct damage, caused by vehicle access	L (**)	M-H (**)	M (**)	Detrimental impacts on saltmarsh habitats as a result of vehicles accessing intertidal fisheries were widely reported by those contacted Tyler-Walters and Arnold, 2008). Morecambe Bay and several other sites along the North West coast suffered rutting of salt marshes, although the damage was superficial with the habitat recovering relatively quickly over a period of 1-2 years. Damage from vehicle access on salt marshes in the Burry Inlet reportedly resulted in erosion and a subsequent ditch up to 8ft deep in places. This created access problems and the route was therefore abandoned, and another established. The use of vehicles and quad bikes again resulted in rutting of salt marsh in the Three Rivers Estuary. In North Lincolnshire, the use of quad bikes, tractors and 4x4's in accessing fishing grounds over salt marshes was reported. This resulted in severe rutting of the saltmarsh that was still visible several years later. Brodhead and Godfrey (1979) assessed the impact of off-road vehicles (ORVs) on saltmarsh in the USA. The results showed only a few passes of an ORV were sufficient to severely damage saltmarsh species. ORV traffic in the 'low marsh' completely destroyed the vegetation and underlying peat substrate, producing a condition that delayed the rates of natural recovery. Traffic around the periphery

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						of the marsh created an increasing barren zone with erosion of adjacent dunes and continual degradation of both the marsh and dune habitats. The study showed that recovery began soon after protection from the pressure. It was noted that plants along the dune/marsh border (*Ammophila* and *Spartina patens* (erect) can recover in about two years and full colonization of a barren flat can occur in two years. However, there are more sensitive species that take longer to recover. For example, *Spartina alterniflora* begins invading disturbed peat substrate slowly but will develop nearly complete cover in four years. *S. patens* (decumbent), the 'flat' growth form, is the slowest marsh plant to recover following complete destruction. Packham and Willis (1997; cited in Tyler-Walters and Arnold, 2008) noted that the longevity of ruts caused by vehicles resulted in abrupt changes in vegetation, with ruts favouring damp tolerant plants such as *Salicornia* and *Puccinellia maritima*. The Countryside Council for Wales have reported localised damage to Atlantic salt meadow communities arising from the use of vehicles (primarily all-terrain vehicles) to access and harvest shellfish in estuaries (reported in Roberts et al. 2010). Detrimental impacts on saltmarsh habitats as a result of vehicles accessing intertidal fisheries were widely reported by those contacted Tyler-Walters and Arnold, 2008). Morecambe Bay and several other sites along the North West coast suffered rutting of salt marshes, although the damage was superficial with the habitat recovering relatively quickly over a period of 1-2 years. Damage from vehicle access on salt marshes in the Burry Inlet reportedly resulted in erosion and a subsequent ditch up to 8ft deep in places. This created access problems and the route was therefore abandoned, and another established. The use of vehicles and quad bikes again resulted in rutting of salt marsh in the Three Rivers Estuary. In North Lincolnshire, the use of quad bikes, tractors and 4x4's in accessing fishing grounds over salt marshes was reported. This resulted in severe rutting of the saltmarsh that was still visible several years later. Based on the evidence presented above, resistance was categorised as 'Low' and recovery as 'Medium to High' so that sensitivity was assessed as 'Medium'.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/ biogenic reef/ macroalgae	L (*)	L-M (*)	M-H (*)	An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed coastal saltmarsh as having 'no' (loss of 75% or greater) resistance to extraction (assessed as the removal of the top 30cm layer of sediment) and 'very low' resilience (negligible or prolonged recovery, at least 25 years) so that sensitivity was assessed as 'high' (Tillin et al. 2010). Assessment was based on deep disturbance as extraction would remove vegetation and sediment. Recovery would depend on habitat rehabilitation and would be mediated by the spatial scale of disturbance.
	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-H (***)	H-VH (*)	NS-L (*)	In a review of the sensitivity of coastal areas to pressures from aquaculture, Huntingdon et al. (2006) determined that there was an impact pathway via which aquaculture activities impacted on Atlantic and continental saltmarshes and salt meadows through siltation/sedimentation. Given that most saltmarsh communities and associated species are well adapted to levels of sedimentation and occasional smothering, in the sensitivity assessment, these authors concluded that saltmarsh communities have a high tolerance and recoverability to sedimentation and hence a low sensitivity to this pressure. The maximum annual rate of accretion a saltmarsh community can withstand will depend on the nature of the community and the evenness of the distribution of that accretion through the year. The pioneer communities appear to be the least sensitive and show a positive response even to quite high rates of accretion. Pioneer communities in the Wash show rates of accretion as high as 14–33 mm per year (Boorman, 2003 and references therein) without apparent adverse effects on the growth of vegetation. The low and middle saltmarsh plant communities of Dengie, Essex, have recorded accretion rates of up to 10 mm per year. The crucial factor would appear to be the evenness of distribution of the higher rates of accretion through the year. If 10 mm of accretion occurs during a single storm then it is likely to have a deleterious effect on middle and upper saltmarsh communities. In the longer term a single period or very few periods such as this are likely to have the effect of a degree of rejuvenation of the saltmarsh while regular recurrence of such events could lead to a major loss of vegetation cover resulting in erosion and reversion to pioneer plant communities (Boorman, 2003). *Previous Sensitivity Assessments*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Increased siltation may increase sedimentation rates above growth rates resulting in smothering, whereas decreases in siltation rates may reduce the rate of growth of the saltmarsh and subject it to increased erosion (Tillin et al. 2010). In a sensitivity assessment undertaken through a combination of literature review and expert judgement at workshops, Tillin et al. (2010) reported the sensitivity of coastal saltmarsh to siltation of up to 5cm in a single event as low, while the sensitivity to siltation of up to 30cm in a single event was assessed as medium. *Evidence from MarLIN* The following evidence is taken from MarLIN's sensitivity assessment of *Puccinellia maritima* saltmarsh community (Tyler-Walters, 2008a and references therein). *Puccinellia maritima* can tolerate accretion rates of 5cm/year (Packham and Willis, 1997). Swards of tall *Puccinellia maritima*, up to 80cm in height, are unlikely to be adversely affected by 5cm of silt for a month. However, in areas influenced by grazing, *Puccinellia maritima* may form prostrate growth, as little as 1cm high, which would be liable to smothering. Algal mats may not survive siltation of 5cm for a month. Burrowing infaunal species such as *Hediste diversicolor,* will probably be little affected, however, suspension feeding *Cerastoderma edule* and *Mya arenaria* may be adversely affected. The *Puccinellia* sward will probably survive, while some members of the community may be lost. The vascular plant sward and most of the community will probably recover in less than 6 months, although some bivalve species may take longer to return. The following evidence is taken from MarLIN's sensitivity assessment of Pioneer saltmarsh (Tyler-Walters, 2008b and references therein). Smothering of pioneer saltmarsh by 5cm of sediment may cover small plants, removing them from light. However, pioneer saltmarsh plants are adapted to accreting environments and may not be adversely affected by smothering for a month, depending on the species and the grain size of the smothering material e.g. die back of *Spartina anglica* in the Solent, southern England was associated with accumulation of very fine sediment. The intolerance of epifaunal burrowers and suspension feeders was higher than deep burrowing siphonate species (Hall, 1994). An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed coastal saltmarsh as having 'medium' (loss of <25%) resistance to changes in siltation rates (low- assessed as 5cm of fine material added to the seabed in a single event.) and 'high' resilience (full

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						recovery within 2 years) so that sensitivity was assessed as 'low' (Tillin et al. 2010). An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed coastal saltmarsh as having 'low resistance' (loss of 25-75%) to changes in siltation rates (high- assessed as 30cm of fine material added to the seabed in a single event.) and 'medium' resilience (full recovery within 2-10 years) so that sensitivity was assessed as 'medium' (Tillin et al. 2010). Based on the evidence above resistance to siltation is assessed as Medium-High (accounting for variability in depth and periodicity), with recovery assessed as High-High', so that sensitivity is categorised as 'Low-Not Sensitive'.
	Smothering (addition of materials biological or non-biological to the surface)	Physical effects resulting from addition of coarse materials	N (*)	L-M(*)	H-VH (*)	Meyer et al. (1997) assessed whether adding oyster cultch to the lower intertidal fringe of three created *Spartina alterniflora* marshes protected the marsh from erosion. Marsh edge vegetation stability and sediment erosion were compared between control (non-cultched) plots and cultched plots (where a band oyster cultch, 1.5m wide by 0.25m deep, was placed along the low tide fringe of the marsh) over a period of two years. The result showed significant differences in sediment accumulation occurred between the control and cultched plots, with areas upland of the marsh edge in the cultched treatment having an average accretion of 2.9cm and the non-cultched areas an average loss of 1.3cm. The addition of a layer of non-permeable materials would lead to significant or total mortality of saltmarsh so that resistance is assessed as 'None', recovery would require habitat rehabilitation and is predicted to not occur earlier than 3 years and may take longer than 6. Recovery is therefore assessed as Medium-Low, so that sensitivity is assessed as 'High-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. Abrasion pressures arising from trampling associated with foot and vehicular access 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	H (*)	VH (*)	NS (*)	Changes in sediment type may affect saltmarsh communities (Holt et al. 1995). In general saltmarsh develops on a variety of sandy and muddy sediment types and may have admixtures of coarser material. The character of the saltmarsh communities is affected by height up the shore, resulting in a zonation pattern related to the degree or frequency of immersion in seawater. It is considered unlikely that fishing or aquaculture activities would lead to changes in sediment, although access to grounds by foot or vehicles may lead to sediment disturbance and erosion following vegetation damage that could lead to washout of finer particles. The effects of such physical disturbances are discussed above. Siltation or smothering events that changed the nature of the sediment and altered the height of the shore may result in changes in immersion patterns that alter vegetation zonation. Such effects have not generally been considered in this pressure theme. Saltmarsh is considered to have some tolerance to an increase in coarser sediments e.g. from a mud to a sandier sediment and to have some tolerance to addition of coarse materials where the marsh remains largely intact. A broad scale change in sediment type e.g. to a coarse sand or gravel would significantly reduce habitat suitability and would be likely to remove this habitat but is not considered likely. Resistance to an increase in sand fraction is therefore assessed as High and recovery as High so that the feature is assessed as 'Not Sensitive'.
	Changes in sediment composition - Increased fine sediment proportion	Fine sediment fraction increases	H (*)	VH (*)	NS(*)	In a review of the sensitivity of coastal areas to pressures from aquaculture, Huntingdon et al. (2006) determined that there was an impact pathway via which aquaculture activities impacted on Atlantic and continental saltmarshes and salt meadows through siltation/sedimentation. Given that most saltmarsh communities and associated species are well adapted to levels of sedimentation and occasional smothering as noted above, in the sensitivity assessment, these authors concluded that saltmarsh communities have a High tolerance and recoverability to sedimentation and hence a low sensitivity to this pressure. It is assumed in this assessment that the accumulation of fine particles is also a result of this siltation and sedimentation. *Evidence from MarLIN*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Die back of *Spartina anglica* in the Solent, southern England was associated with accumulation of very fine sediment (Tyler-Walters, 2008b). It is not clear from the text whether this was due to coverage and damage of aerial parts (e.g. loss of ability to photosynthesise) or to sediment change. Saltmarsh forms on mudflats and hence resistance to an increase in fine sediment is assessed as 'High' with recovery as 'High' as natural levels of re-suspension and deposition may be high, especially in disturbance events such as storms. However as noted above sediment accumulating on leaves may reduce photosynthesis. The habitat 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	L (*)	L-M (*)	M-H (*)	In a review of the sensitivity of saltmarsh habitats to pressures arising from aquaculture, Huntingdon et al. (2006) stated that as saltmarsh develops in sheltered environments where sediments accumulate, reduced water flow rate could increase the deposition of sediments and lead to saltmarsh building. Hence, overall, these authors concluded that saltmarsh communities had low sensitivity to decreases in water flow. Evidence from MarLIN (saltmarsh LS.LMp.Sm) The following evidence is taken from MarLIN's sensitivity assessment of Pioneer saltmarsh (Tyler-Walters, 2008b). Change in water flow rate and hence the hydrographic regime will change the accretion and erosion rates in the saltmarsh. Increases in water flow rate may erode areas at the face of the raised salt marsh, resulting in a 'cliff' and may undermine the edges of creeks. Recovery will depend the accretion of eroded sediment and subsequent recruitment of the pioneer species (Tyler-Walters, 2008b) The following evidence is taken from MarLIN's sensitivity assessment of Puccinellia maritima saltmarsh community (Tyler-Walters, 2008a and references therein). Salt marshes develop in sheltered environments where sediments accumulate. Increased water flow rate will change the accretion and erosion rates in the saltmarsh, especially at low water exposed to immersion for longer periods. Increases in water flow rate may erode areas at the face of the raised salt marsh, resulting in a 'cliff' and may undermine the edges of creeks. Most of the invertebrate marine infauna may be adversely affected by increased water flow due to loss or changes in the sediment. Therefore, increases in water flow at the benchmark level are likely to remove lower marsh

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						communities such as Puccinellia dominated communities, their substratum and associated species and an intolerance of high has been recorded. Recovery will depend on recruitment of the plant communities and their invertebrate fauna and a recoverability of moderate has been recorded. Decrease in water flow rate- Salt marshes develop in sheltered environments and any further decrease in water flow is likely to increase sedimentation rates, especially in the lower marsh, but otherwise have minor effects. Decreased water flow may reduce the distribution and hence recruitment of saltmarsh species, e.g. of plants by seed and vegetative fragments and by insects due to rafting. Saltmarsh is assessed as 'Not Sensitive' to decreases in water flow and as having 'Low' resistance to increases in water flow with recovery assessed as 'Low to Medium' (3-6+ years), so that sensitivity is categorised as 'Medium–High'.
	Changes in turbidity/ suspended sediment - Increased suspended sediment/ turbidity	Increase in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	*Evidence from MarLIN* Saltmarshes are accreting habitats and thus generally occur in turbid environments. Turbidity reduces the light attenuation through water. However, the vascular plants that comprise saltmarshes photosynthesise at low tide and are probably not completely covered at high tides. Turbidity of the water is therefore probably not a relevant factor in the development of saltmarsh. The photosynthetic activity of macroalgal mats and microphytobenthos would be reduced when they are covered submerged by tides, but this will probably be compensated when they are exposed to air at low tides (Tyler-Walters, 2008a; 2008b). An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed coastal saltmarsh as not sensitive to changes in water clarity (assessed as a change in one rank, e.g. from clear to turbid for one year; Tillin et al. 2010). Based on the environmental position of this feature which means that periods of emersion are relatively short, saltmarshes were assessed as having 'High' resistance and therefore 'High' resilience to changes in turbidity, and they are therefore considered to be 'Not Sensitive'.
	Changes in turbidity/	Decrease in particulate matter	H (*)	VH (*)	NS (*)	Evidence from MarLIN Vascular plants photosynthesise at low tide and are probably not completely covered at high tides, so

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	suspended sediment - Decreased suspended sediment/ turbidity	(inorganic and organic)				turbidity of the water is probably not a relevant factor in the development of saltmarsh (Tyler-Walters, 2008a). Based on the environmental position of this feature which means that periods of emersion are relatively short, saltmarshes were assessed as having 'High' resistance and therefore 'Very High' resilience to changes in turbidity, they are therefore considered to be 'Not Sensitive'.
	Organic enrichment - Water column	Eutrophication of water column	H (*)	VH (*)	NS (*)	In a review of the sensitivity of coastal areas to pressures from aquaculture, in relation to saltmarsh communities, Huntingdon et al. (2006) identified a pathway for this pressure on saltmarsh from aquaculture activities. They stated that moderate enrichment with nutrients may be beneficial to both plant and infaunal communities, although care needed be taken when applying this conclusion to all saltmarshes (citing Holt et al. 1995). Higher nutrient levels have been associated with the proliferation of algal mats, which may smother some burrowing species. (Packham and Willis, 1997). The authors rated tolerance and recoverability as high and hence sensitivity as low *Previous Sensitivity Assessments* Evidence from MarLIN Moderate enrichment with nutrients may be beneficial to both plant and infaunal communities. Nitrogen was reported to be limiting in many saltmarsh ecosystems and added nitrogen resulted in increased primary production, decomposition and animal growth rates (Valiela and Teal, 1974; Long and Mason, 1983) although Holt et al. (1995) suggested care should be taken when applying this conclusion in all saltmarshes (Tyler-Walters, 2008a). However, excessive enrichment (eutrophication) of coastal waters by various plant nutrients, particularly nitrogen and phosphorus, can have damaging effects. Eutrophication of coastal waters can result in the rapid growth of certain fast-growing algal species (Pederson and Borum, 1996) and algal mats have been observed to smother the germination and growth of pioneer saltmarsh species such as *Salicornia* species (Boorman, unpublished data; cited in Boorman, 2003). Increased algal mats may also smother some burrowing species, such as *Mya arenaria* (Packham and Willis, 1997). Higher levels of nutrient enrichment may result in a decrease in the oxygen levels of the sediment (see decrease in

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						oxygen levels). It is unlikely that subtidal commercial aquaculture operations would lead to eutrophication of the intertidal areas where this feature is found. In addition this feature was assessed as 'Not Sensitive' as the erect saltmarsh plants which characterise this habitat are unlikely to be smothered by algal mats (recent smothering of sediments at a survey site by filamentous algae was observed not to affect sea aster plants which projected high above the sediment surface, pers comm. A. Pearson, ABPmer). Resistance was therefore assessed as 'High' and recovery as 'Very High'.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	H (*)	VH (*)	NS (*)	In a review of the sensitivity of coastal areas to pressures from aquaculture, in relation to saltmarsh communities, Huntingdon et al. (2006) identified a pathway for sedimentation on saltmarsh from aquaculture activities, we have assumed that this could lead to organic enrichment of sediments. Evidence from MarLIN. Plots of saltmarsh treated with sewage sludge in Massachusetts, USA, stimulated growth of *Spartina alterniflora* which eliminated other plants from the area (Long and Mason, 1983; cited in Tyler-Walters, 2008a; 2008b). An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed coastal saltmarsh as not sensitive to organic enrichment (assessed as a 100gC/m²/yr), Tillin et al. 2010). It is unlikely that subtidal commercial aquaculture installations would lead to excessive organic enrichment of the intertidal areas where this feature is found, as dissipation of organic matter from lower intertidal/subtidal operations would occur and some levels of enrichment may be beneficial. This feature was assessed as 'not sensitive' at the levels expected from aquaculture however, where local conditions lead to accumulation of wastes some changes in community structure may occur as noted in the evidence from MarLIN.
	Increased removal of primary	Removal of primary production above background rates by	H (*)	VH (*)	NS (*)	Not Sensitive this feature is a primary producer and would not be impacted by a reduction in primary production except indirectly where a decrease in water column turbidity would increase irradiance and photic depth, however given the environmental position it is unlikely that Saltmarsh would be affected

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	production - Phytoplankton	filter feeding bivalves				negatively or positively by changes in turbiditiy. Resistance was therefore assessed as 'High' and resilience as 'Very High' so that this feature is considered to be "Not Sensitive'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	H (*)	VH (*)	NS (*)	In general, vascular plants may not be sensitive to deoxygenation since photosynthesis produces oxygen; they are exposed for the majority of the tidal cycle, and in some species, e.g. *Spartina alterniflora*, air spaces in the leaf sheaths aid gas transport to the roots. However, other members of the community, such as infauna are less tolerant of deoxygenation (Tyler-Walters, 2008b). In a review of the sensitivity of coastal areas to pressures from aquaculture, Huntingdon et al. (2006) stated that the majority of infaunal polychaetes and oligochaetes within saltmarsh communities are probably tolerant of low oxygen conditions, while some species of oligochaete and nematode may be dependant on the locally oxygenated areas around the roots of vascular plants. These authors stated that the tolerance of saltmarsh communities to changes in biogeochemistry was high, recoverability was high and hence the sensitivity is low. The following evidence is taken from MarLIN's sensitivity assessment of *Puccinellia* saltmarsh community (Tyler-Walters, 2008a and references therein). The waterlogged soils of saltmarshes, favoured by *Puccinellia maritima* are generally anoxic. The vascular plants in this biotope may not be intolerant of deoxygenation for the reasons stated above. *Hydrobia ulvae* can tolerate emersion for several days and many insects live on stems and leaves of vascular plants and avoid anoxic conditions, e.g. aphids. However, *Cerastoderma edule* is probably intolerant to anoxic conditions and would be lost from the lower marsh. Overall, the vascular plants of this biotope are probably tolerant of anoxic soils and are exposed to the air at low tide, such that the *Puccinellia* communities would probably be little affected by prolonged exposure to low dissolved oxygen concentrations of 2mg/l for 1 week, whereas a few fauna may be lost. Recovery would probably be rapid. Saltmarsh was assessed as not sensitive as the aerial parts of the plant that respire are elevated above the sediment and due to limited immersion periods the plants would be able to respire during periods of emmersion.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	H (*)	VH (*)	NS (*)	Vascular plants may not be sensitive to deoxygenation since photosynthesis liberates oxygen, they are uncovered for the majority of the tidal cycle, and in some species, e.g. *Spartina alterniflora,* air spaces in the leaf sheaths aid gas transport to the roots (Tyler-Walters, 2008b). Saltmarsh was assessed as 'Not Sensitive' due to limited immersion periods so that the plants would be able to respire during periods of emmersion.
Biological Pressure	Genetic impacts on wild populations and translocation of indigenous populations	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 potential for introduction of non-natives in translocated stock	H (*)	VH (*)	NS (*)	There are 8 known invasive species in Irish Seas, of these cord grass (*Spartina anglica*) may affect saltmarsh and this species is not considered to be spread by aquaculture activities or boat movements. *S. anglica* is widespread on sheltered muds at tide level around the coast of 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. This in turn raises the general level of the marsh reducing tidal inundation, decreasing habitat suitability for some species and reducing the biodiversity of the marsh and mudflat. On intertidal mudflats it reduces the food available for wildfowl and wading birds, notably eel grass beds and invertebrates. (All information from Invasive species Ireland management toolkit; http://invasivespeciesireland.com/toolkit). Pacific oyster, *Crassostrea gigas*, cultivation in France may occur in saltmarsh where oysters are placed in salt marsh ponds ('claires') to enhance growth. Creating these would lead to extraction pressures but no information was found regarding the likelihood of these species escaping into the surrounding habitat or populating such areas without human intervention.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Commercial fishing activities and aquaculture are not pathways via which this species may be introduced so saltmarsh is assessed as 'Not Sensitive'. 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 (*)	*Salicornia europaea* (samphire) is collected for human consumption in some areas (Tyler-Walters, 2008b). However, extraction of this feature (the wider saltmarsh and plant community) is not considered to be an effect arising from commercial aquaculture or fishing activities. The feature is not considered to be functionally dependent on any organisms that may be commercially targeted and therefore is not considered to be sensitive to the biological effect of their removal. The process of removing target species is considered above in the physical disturbance theme (see surface disturbance and trampling). Based on the above considerations resistance was assessed as 'High' and recovery as 'Very High' so that Saltmarsh 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 (*)	The feature is not considered to be functionally dependent on target/non-target organisms and therefore is not considered to be sensitive to the biological effect of their removal. Resistance is therefore considered to be 'High' and recovery is 'Very High'.
	Ecosystem Services - Loss of biomass		H (*)	VH (*)	NS (*)	As a primary producer this feature is not dependent on any lower trophic levels and is therefore not considered to be sensitive to the loss of this ecosystem service. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
Chemical	Introduction of	Introduction of			NEv	In a review of environmental impacts of aquaculture in sensitive areas, Huntingdon et al. (2006)

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Pressures	Medicines	medicines associated with aquaculture.				reported that there was insufficient information available to determine the effects of 'chemical use' in aquaculture (including disinfectants sometimes used to treat disease; veterinary medicines; anaesthetics and hormones) on saltmarsh communities. However, the authors state that, given the ability of sediments to accumulate contaminants and the potential for toxicity, it is considered that tolerance at unregulated levels would be low and recoverability low. Sensitivity of saltmarsh communities to 'chemical use' would therefore likely be high. Due to the lack of specific evidence this pressure is not assessed.
	Introduction of hydrocarbons	Introduction of hydrocarbons	N-L (***)	Low (***)	H-VH (***)	Saltmarshes are very intolerant of oil spills since they trap sediments, adsorb oils, and occur in sheltered environments where the oils persist (Holt et al. 1995). The effect depends on the type of oil and its extent, with lighter oils being the most toxic. Heavy oils tend to cause death by smothering (Baker, 1979; cited in Tyler-Walters, 2008a, b). In successive experimental oilings Baker (1979) demonstrated different levels of intolerance to Kuwait crude oil, for example: ▪ Very susceptible; *Salicornia* sp., *Suaeda maritima* and seedling of all species were quickly killed by a single spill; ▪ Intermediate; species that recovered well from up to four spills but rapidly succumbed if further oiled, e.g. *Puccinellia maritima*, *Spartina anglica* and *Festuca rubra*; and ▪ Resistant due to underground storage organs e.g. *Armeria maritima*, *Plantago maritima* and *Triglochin maritima*. Annual species are most intolerant and are either killed or their reproduction is impaired. Shallow rooted *Salicornia* sp. and *Suaeda* sp. are susceptible since they have few food reserves, whereas plants with underground storage organs are resistant, e.g. *A. maritima and P. maritima*. Experiments show that most species succumbed after more than 4 oilings and 8-12 oiling resulted in significant die back (Baker, 1979). Chronic hydrocarbon pollution may also greatly affect saltmarsh communities. For example, Dicks and Hartley (1982; cited in Tyler-Walters, 2008a) reported that discharge of refinery effluent (containing oils and other chemicals), together with small accidental discharges from Fawley terminal, Southampton

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						(1953-1970) caused loss of vegetation from a large area of the adjacent saltmarsh (Holt et al. 1995). Trampling and disturbance caused by clean up operations may increase the levels of damage (Holt et al. 1995). Overall, saltmarsh habitats are considered to by highly sensitive to oil spills (Tyler-Walters, 2008a and references therein). Recovery depends on the retention of oil within the saltmarsh. After the Amoco Cadiz spill some areas of saltmarsh still had oily footprints 5 years later (Holt et al. 1995). Baker (1979) reported that the effects of oiling were still apparent 10 years after oiling. Dicks and Hartley (1982) reported that reduction of hydrocarbons content and discharge rate took place between 1970 and 1975 in the Fawley marsh. By 1980 vegetation had recolonised much of the area. Pioneer species such as *Salicornia* sp. and *Aster tripolium* recolonised quickly, followed, slowly by *S. anglica* but the sediment remained contaminated and supported an impoverished fauna, with rare oligochaetes and reduced numbers of *Nereis diversicolor*. Dicks and Levell (1989) reported that annual species (e.g. *Salicornia* sp. and *S. maritima*) and the perennial *S. anglica* had colonised most of the previously denuded area by 1987, although *S. anglica* recovery was aided by transplantation. Dicks and Levell (1989) suggested that areas recolonised by *S. anglica* in 1977 had begun to resemble healthy marshes by 1987 (10 years), although recovery of the whole area would probably take another 5-10 years. Overall, the above evidence suggests that annual species would probably recover within a few years while perennial species such as *S. anglica* would take between 10 to 20 years (information taken from Tyler-Walters, 2008b). Resistance was assessed as 'None-Low' and recovery as 'Low' so that saltmarsh was categorised as having 'High-Very High' sensitivity.
	Introduction of antifoulants	Introduction of antifoulants			NEv	Where antifoulants are used to prevent fouling of cages in aquaculture they are usually copper based. 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).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
						Sheltered, low energy areas (e.g. enclosed bays or estuaries) may act as a sink for sediment and a wide variety of contaminants. The sub-lethal or toxic effects will vary with between contaminants and may be mediated by the chemical form (speciation) concentration, the bio-availability of the contaminant, and the physiology of the affected organism. In sheltered areas with little dispersion contaminants with long half lives may remain in sediment for decades and natural or human disturbance may re-suspended and disperse materials. Recovery requires dilution, biodegradation or removal of the contaminant from the sediments. Beeftink (1979) demonstrated that *Puccinellia maritima* was one of the first species to recolonise areas of marsh denuded by herbicide treatment. Saltmarsh plants take up heavy metals through their roots; uptake is species specific but in general monocotyledons (such as *Puccinellia maritima*) tend to exclude heavy metals while dicotyledons tend to accumulate them (Tyler-Walters, 2008a). *Spartina alterniflora* was found to accumulate high levels of cadmium, lead and zinc in experiments with sewage sludge treatment in the USA (Long and Mason, 1983). Packham and Willis (1997) note that acute toxicity to heavy metals has not been reported in saltmarsh plants. However, different members of the community are likely to vary in their intolerance to heavy metal pollution. Overall, Holt et al. (1995) concluded that saltmarsh may be relatively tolerant of heavy metals. However, some marine infaunal species may be lost, or reduced in extent suggesting a loss of species richness (Tyler-Walters, 2008a; 2008b). In a review of environmental impacts of aquaculture in sensitive areas, Huntingdon et al. (2006) reported that there was insufficient information available to determine the effects of 'chemical use' in aquaculture (including disinfectants antifoulants and pesticides) on saltmarsh communities. However, the authors state that, given the ability of sediments to accumulate contaminants and the potential for toxicity, it is considered that tolerance at unregulated levels would be low and recoverability low. Sensitivity of saltmarsh communities to 'chemical use' would therefore likely be high. Due to the lack of specific evidence this pressure is not assessed.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence
Physical Pressures	Prevention of light reaching seabed/ features	Shading from aquaculture structures, cages, trestles, longlines	N (*)	L-M (*)	H-VH (*)	Saltmarsh habitats are dependent on light for photosynthesis and hence it has been assumed that permanent shading would lead to the death of saltmarsh plant communities so that resistance is assessed as 'None'. Recovery following removal of shading is predicted to require between 3-6+ years. Sensitivity is therefore categorised as 'High to Very High'.
	Barrier to species movement				NE	Not relevant to SAC habitat features.

Table VIII. 4 Confidence Levels for Resistance Assessments (see Table VIII.3a for category descriptions)

Pressure	Primary Source of Information	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*	**	N/A
Shallow Disturbance	*	**	N/A
Deep Disturbance	*	**	N/A
Trampling - Access by foot	***	***	***
Trampling - Access by vehicle	**	***	N/A
Extraction	N/A	N/A	N/A
Siltation	**	*	***
Smothering	***	***	N/A
Collision risk			
Underwater Noise			
Visual - Boat/vehicle			
Visual - Foot/traffic			
Changes to sediment composition - Increased coarseness	*	*	N/A
Changes to sediment composition - Increased fine sediment proportion	**	*	N/A
Change to another sediment/ substrate type.	**	*	N/A
Changes to water flow	**	*	N/A
Changes in turbidity/suspended sediment - Increased	**	*	N/A
Changes in turbidity/suspended sediment - Decreased	**	*	N/A
Organic enrichment - Water column	**	*	N/A
Organic enrichment of sediments	**	*	N/A
Increased removal of primary production - Phytoplankton	*	N/A	N/A
Decrease in oxygen levels - Sediment	**	*	
Decrease in oxygen levels - Water column	**	*	N/A
Genetic impacts			
Introduction of non-native species	N/A	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	***	**	***
Introduction of antifoulants	Not assessed. No evidence.		
Introduction of litter			
Prevention of light reaching seabed/ features	*	*	N/A
Barrier to species movement			

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Section VIII (B) Seagrass (*Zostera*) Habitats

Seagrass *(Zostera)* species are submerged, rooted, grass-like flowering plants. Two species of *Zostera* occur in the UK and Ireland, *Zostera marina* (common eelgrass) and *Zostera noltii* (dwarf eelgrass). In most UK literature another species *Zostera angustifolia* is regarded as distinct from *Z. marina* (Foden and Brazier, 2007). However, *Z. angustifolia* is currently regarded as a variant of *Z. marina* and not a distinct species (Den Hartog and Kuo, 2006).

Seagrass habitats can be broadly divided into intertidal (littoral) and subtidal (sublittoral) elements. Within the EUNIS level A2.6 and A5.5 categories there are three sub-units (see Figure VIII.2 below).

Zostera dominated communities are a component of the Annex 1 features 'Large shallow inlets and bays'; 'Lagoons, Estuaries, Intertidal mud and sand banks' and 'Sandbanks covered by sea water' at all times. *Zostera* species occupy a range of habitats characterised by variations in salinity, wave and current energies, nutrient content of sediments and substrates containing various amounts of sand, gravel, rock and mud. Subtidal *Zostera* beds are limited to shallow water habitats due to their dependence on relatively high levels of light. *Zostera* is the dominant seagrass genus around Ireland with two species generally recognised, the subtidal and intertidal *Zostera marina* and the intertidal *Zostera noltii*. (Dale et al. 2007).

Information modified from UK BAP descriptions (2008)

Seagrass beds develop in intertidal and shallow subtidal areas on sands and muds. They may be found in marine inlets and bays but also in other areas, such as lagoons and channels, which are sheltered from significant wave action. The plants stabilise the substratum, are an important source of organic matter, and provide shelter and a surface for attachment by other species. Seagrass is an important source of food for wildfowl, particularly brent goose and widgeon which feed on intertidal beds. Where this habitat is well developed the leaves of eelgrass plants may be colonised by diatoms and algae, stalked jellyfish and anemones. The soft sediment infauna may include amphipods, polychaete worms, bivalves and echinoderms. The shelter provided by seagrass beds makes them important nursery areas for flatfish and, in some areas, for cephalopods. Adult fish frequently seen in *Zostera* beds include pollack, two-spotted goby and various wrasse. Two species of pipefish, *Entelurus aequoraeus* and *Syngnathus typhie* are almost totally restricted to seagrass beds. The diversity of species will depend on environmental factors such as salinity and tidal exposure and the density of microhabitats, but it is potentially highest in the perennial fully marine subtidal communities and may be lowest in intertidal, estuarine, annual beds.

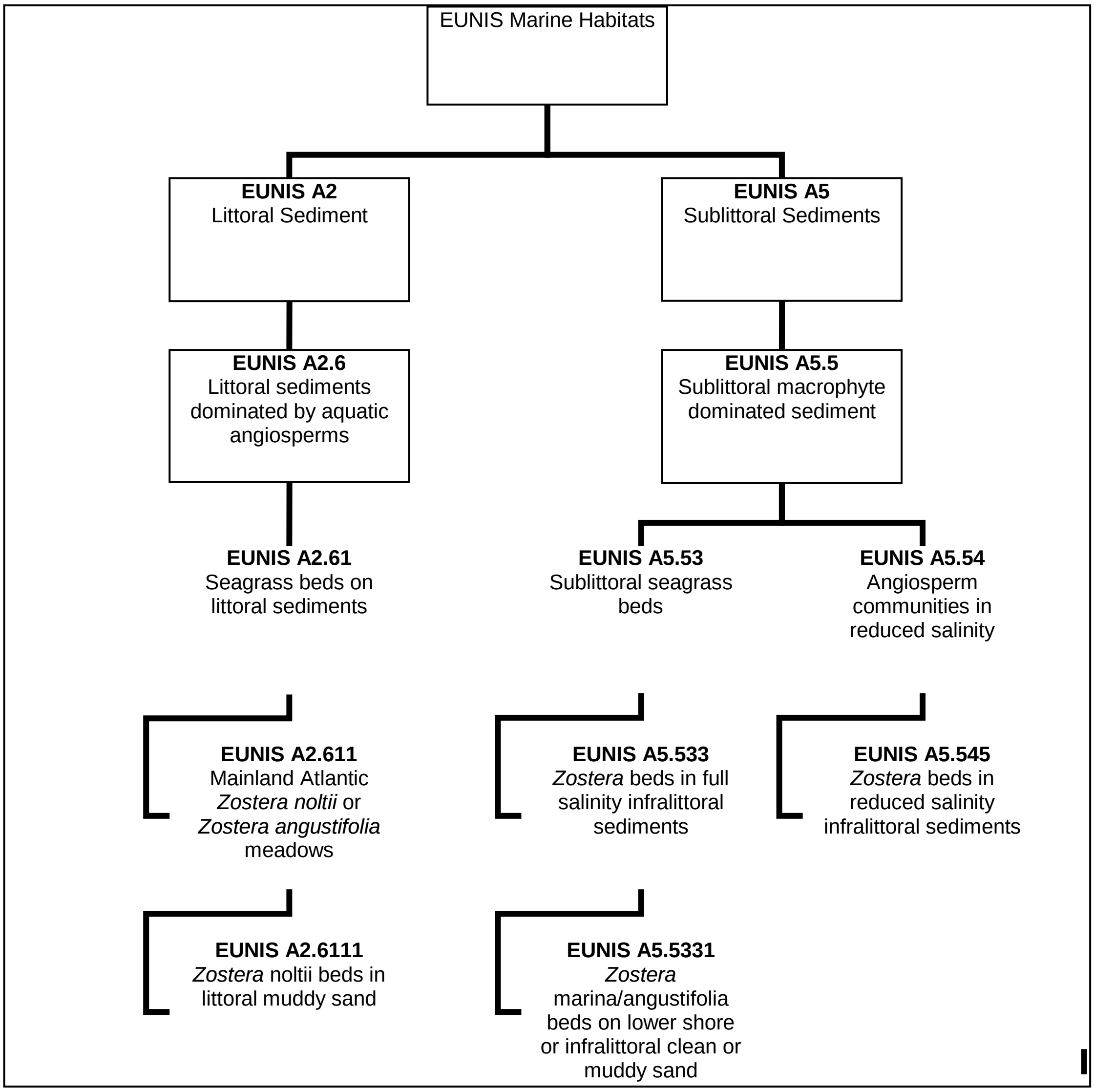

Figure VIII.2 Hierarchical Diagram showing relevant elements of the EUNIS descriptive framework for *Zostera* habitats

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Seagrass (*Zostera*) beds Introduction and Habitat Assessment Information (EUNIS A2.6 and A5.5)

Introduction

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, 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 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 and a record of the confidence in the assessment made.

The assessments refer primarily to subtidal *Zostera* as intertidal beds have not been identified for assessment from Irish SACs at this time (Octpber 2012). However information has been taken from intertidal studies and pressures relevant to intertidal beds only (trampling) have been assessed.

Feature Description

Seagrass (*Zostera*) species occupy a range of habitats characterised by variations in salinity, wave and current energies, nutrient content of sediments and substrates containing various amounts of sand, gravel, rock and mud. Subtidal *Zostera* beds are limited to shallow water habitats due to its dependence on relatively high levels of light.

A wide variety of invertebrate species occur on and among the plants of seagrass beds. Small gastropods graze on the algal epiphytes that occur on the leaves of seagrass, while the sediments underlying the beds support large numbers of polychaete worms, bivalve molluscs and burrowing anemones. Amphipod and mysid crustaceans are among the most abundant and important of the mobile fauna living amongst the leaves (Huntington et al. 2006).

This assessment has been structured following the EUNIS framework shown in Figure VII.2 (above). 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 and/or shore heights, depending on local conditions. Although the classification system has been based on the EUNIS framework, qualifying interest features and sub features of SACs may overlap and contain some species or characteristics of similar biotopes. This assessment refers primarily to subtidal *Zostera* beds but much of the information would have relevance for intertidal seagrass beds.

Associated biological community

The following species associated with the feature, identified within Irish SACs, are taken from the Conservation Objective supporting documents (NPWS, 2011a; 2011b). Species associated with the *Zostera* dominated communities have been supplied for the Roaring Water Bay and Clew Bay SACs.

The tables below (VIII.5 and VIII.6) show the species associated with the *Zostera* dominated communities taken from the SAC supporting documents. A high number of species were identified associated with these habitats, illustrating the contribution these habitats make to local diversity. *Zostera* marina is the single distinguishing species that is assessed as it was considered to characterise the habitat alone, e.g. the loss of this species would alter the assemblage identity to the extent the habitat/biotope would be re-classified.

Not all species could be assessed and it would not be considered desirable to do so in any case, for example some species are mobile and not dependent on the *Zostera* community, others were associated with the sediment rather than the plants. Some epiphytic species were identified within the supporting documents and, while these are found on a number of species the sensitivity of these could be considered as equivalent to the eelgrass, as removal of eelgrass removes their habitat. Finally it is acknowledged that eelgrass, by modifying local habitat conditions, by altering flow rates etc. may facilitate the presence of some of the species listed in the table. As eelgrass is likely to be more sensitive than many or all of these species (due to slow recovery rates of eelgrass beds), the assessment of *Zostera* can be considered to represent a more precautionary assessment than an assessment of these species alone. Where evidence was found on community recovery this is presented in the evidence table.

Table VIII.5 Species associated with *Zostera* beds in the Clew Bay SAC

Clew Bay Associated Species Categories	Species
Species assessed as distinguishing species	*Zostera marina*
Epiphytic species that are judged to have same sensitivity as eelgrass plants due to their habitat dependence	*Asparagopsis armata, Caprella acanthifera* (amphipod attached to algae and substrate), *Haliclystus auricular**, *Polysiphonia* sp., *Bonnemaisonia asparagoides, Anemonia viridis*, *Ceramium* sp., *Enteromorpha* sp.
Species assessed in other proformas and not considered functionally dependent on eelgrass	*Laminaria saccharina*
Species present in or on sediment and not dependent on eelgrass for habitat	*Ensis* sp., *Chamelea gallina, Anthopleura ballii, Sagartia elegans, Kefersteinia cirrata, Scolanthus callimorphus*
Species that are mobile epifauna and not assessed as these are not characterising species, a permanent part of fauna or dependent on this habitat type	*Carcinus maenas, Liocarcinus depurator Macropodia rostrata, Necora puber, Pagurus bernhardus, Echinocardium cordatum Asterias rubens, Abludomelita obtusata, Corophium bonnellii, Ampithoe gammaroides, Ericthonius* sp., *Eudesme virescens, Aora* sp., *Ericthonius difformis, Ericthonius punctatus, Microdeutopus vericulatus*
Algal community not considered dependent on seagrass	*Asperococcus compressus, Cladostephus spongiosus, Cystoseira bacatta, Desmerestia viridis, Dictyota dichotoma Lomentaria articulate, Plocamium cartilagineum*
* Assessment exists as part of MCZ work (Tillin et al. 2010), not considered here.	

Table VIII.6 Species associated with *Zostera* beds in the Roaring Water Bay SAC

Roaring Water Bay Associated Species Categories	Species
Habitat forming species assessed as distinguishing species	*Zostera marina*
Epiphytic species that are judged to have same sensitivity as eelgrass plants due to their habitat dependence	*Ulva* sp., *Ceramium rubrum*
Species present in or on sediment and not dependent on eelgrass for habitat	*Glycymeris glycymeris, Ensis* sp., *Anthopleura balli, Branchioma bombyx, Venus verruscosa, Gibbula magus, Anemonia viridis, Sabella pavonina*
Species that are mobile epifauna and not assessed as these are not, characterising species, a permanent part of fauna or dependent on this habitat type	*Carcinus maenas, Liocarcinus depurator, Pagurus bernhardus, Asterias rubens, Ascidiella aspersa*
Algal community not considered dependent on seagrass	*Dictyota dichotoma, Asperococcus compressus*

The following descriptions of the main biological communities associated with the feature are taken from EUNIS (Connor et al. 2004).

EUNIS A2.611 Mainland Atlantic Zostera noltii or Zostera angustifolia meadows

Formations of *Z. noltii* or *Z. angustifolia* of the Atlantic, North Sea and Baltic shores of continental Europe and of its continental shelf islands.

The biotope '*Zostera noltii* beds in littoral muddy sand' (Ls.LMp.LSgr.Znol) is found most frequently on lower estuary and sheltered coastal muddy sands. The presence of *Z. noltii* as scattered fronds does not change what is otherwise a muddy sand biotope. Exactly what determines the distribution of *Z. noltii* is not entirely clear. It is often found in small lagoons and pools, remaining permanently submerged, and on sediment shores where the muddiness of the sediment retains water and stops the roots from drying out. An anoxic layer is usually present below 5 cm sediment depth. The infaunal community is characterised by the polychaetes *Scoloplos armiger, Pygospio elegans* and *Arenicola marina*, oligochaetes, the spire shell *Hydrobia ulvae*, and the bivalves *Cerastoderma edule* and *Macoma balthica*. The green algae *Enteromorpha* spp. may be present on the sediment surface.

EUNIS A 5.53 Zostera beds in full salinity infralittoral sediments

These communities are generally found in extremely sheltered embayments, marine inlets, estuaries and lagoons, with very weak tidal currents. They may inhabit low, variable and full salinity marine habitats. Whilst generally found on muds and muddy sands they may also occur in coarser sediments.

The biotope '*Zostera marina/angustifolia* beds on lower shore or infralittoral clean or muddy sand' (SS.SMp.SSgr.Zmar), occurs on expanses of clean or muddy fine sand and sandy mud in shallow water and on the lower shore (typically to about 5m depth). This habitat can have dense stands of *Z. marina/angustifolia*. The community composition may be dominated by these *Zostera* species and therefore characterised by the associated biota. Other biota present can be closely related to that of areas of sediment not containing *Z. marina*, for example, *Laminaria saccharina*, *Chorda filum* and infaunal species such as *Ensis* spp. and *Echinocardium cordatum* (e.g. Bamber, 1993).

A number of sub-biotopes may be found within this biotope, dependant on the nature of the substratum, and it should be noted that sparse beds of *Z. marina* may be more readily characterised by their infaunal community. Furthermore, whilst the *Zostera* biotope may be considered an epibiotic overlay of established sedimentary communities it is likely that the presence of *Zostera* will modify the underlying community to some extent. For example, beds of this biotope in the south-west of Britain may contain conspicuous and distinctive assemblages of *Lusitanian* fauna such as *Laomedea angulata*, *Hippocampus* spp. and *Stauromedusae* (Connor et al. 2004).

Key Ecosystem Functions Associated with Habitat

In general, seagrass beds provide a number of key ecosystem functions. Bouma et al. (2009) describe seagrasses as ecosystem 'engineer' species which increase structural complexity and cause a large and/or distinct modification to the abiotic environment. The dense root network of the plants stabilise the underlying substratum and so act to reduce coastal erosion (Davison and Hughes, 1998). It is known that seagrass beds play an important role in the trophic status of marine and estuarine waters, acting as an important conduit or sink for nutrients (Connor et al. 2004). In addition, seagrass beds provide increased habitat complexity, increased substrate for other organisms to attach to, and protection from predation, hence providing valuable nursery and feeding grounds for fish and birds.

Habitat classification

Seagrass (*Zostera* species) beds are a Biodiversity Action Plan priority habitat and an OSPAR threatened habitat (OSPAR, 2008). Although seagrass beds are not listed as an Annex I habitat under the European Community (EC) Habitats Directive they are a recognized component of several of these habitats, namely 'Lagoons', 'Estuaries', 'Large shallow inlets and bays', 'Intertidal mud and sand banks' and 'Sandbanks covered by sea water at all times'.

Table VIII.7 Types of *Zostera* habitat recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland (Source: EUNIS, 2007; Connor et al. 2004)

Annex I Habitat containing feature	EUNIS Classification of feature	Britain and Ireland Classification of feature	OSPAR Threatened and declining species or habitat
Large shallow inlets and bays; Lagoons; Estuaries; Sand banks covered by seawater at all times; Intertidal mud and sand banks	A2.611	Ls.LMp.LSgr.Znol	*Zostera* beds
	A5.533	SS.SMp.SSgr.Zmar	*Zostera* beds

Features to be assessed

These assessments are based on the seagrass species *Zostera noltiii* and *Zostera marina/angustifolia* as the keystone structural species of subtidal *Zostera* dominated communities.

With regard to the associated biological community, the majority of species associated with intertidal *Zostera* beds are not restricted to the EUNIS A2.611 biotope, with the exception of the *Zostera* species (Asmus and Asmus, 2000b cited in Tyler-Walters and Wilding, 2008a). Similarly, other biota present in subtidal *Zostera* beds can be closely related to that of areas of sediment not containing *Z. marina* (although sparse beds of *Z. marina* may be more readily characterized by their infaunal community) (Tyler-Walters and Wilding, 2008b). Hence, there is likely to be an overlap of evidence for this feature with the sensitivity assessments for soft sediment habitats containing similar biological communities, for example, littoral muddy sand and sublittoral fine sand/muddy sand (see Reports II and III).

Recovery

Zostera beds within Ireland can undergo considerable annual and seasonal variation and the factors underpinning these changes are not always clear (Dale et al. 2007). Throughout the range intertidal populations are often annual and can undergo complete dieback in winter with recovery dependent on local seed supply (Holt et al. 1997). In perennial populations (lifespan over two years) die back of above ground parts is less significant and recovery is through vegetative growth. *Zostera* beds are also spatially dynamic, with advancing and leading edges causing changes in coverage. The beds expand either through vegetative growth from shooting rhizomes that have survived the winter, or sexually, by production of seed. Subtidal *Z. marina* beds in the UK are perennial and are believed to persist almost completely as a result of vegetative growth rather than by seed. Growth of individual plants occurs during the spring and summer. Recovery rates will therefore depend on supply of rhizomes. Given that fragmentation of beds can cause further losses, recovery may be slow, particularly in subtidal areas.

The slow recovery of *Zostera* populations since the 1920s-30s outbreak of wasting disease suggests that, once lost, seagrass beds take considerable time to re-establish. However, Phillips and Menez (1988) reported that displacement rhizomes and shoots can root and re-establish themselves if they settle on sediment long enough (cited in Huntingdon et al. 2006).

Recovery time of seagrass after disturbance should vary with seagrass species. The recovery of gaps in seagrass meadows has been described for a range of species. Gaps <25 m^2 in *Posidonia sinuosa* meadows were refilled over 50 years (Hastings et al. 1995). *Thalassia hemprichii* grew into experimental 0.25 m^2 gaps over 2 years, but *Enhalus acoriodes* was predicted to take 10 yr to refill these gaps (Rollon et al. 1999). *Halodule wrightii* beds can fill in small gaps in <6 months (Bell et al. 1999). *Zostera noltii* can fill in gaps of 0.13 m^2 in 1 month (Han et al. 2012 and preceding references therein). Disturbance size, disturbance intensity, sediment characteristics and seasonal time of disturbance are also likely to be a mediating factor. Seagrass can recover via lateral rhizome spread or via sexual reproduction and seed dispersal depending on location and species. The dispersal range of seagrass seeds is a very poorly studied aspect of their reproductive ecology, and robust estimates of dispersal events are only available for *Z. marina* populations, for which 95% of the seeds are retained within 30m from the source.

Z. noltii is able to recover relatively quickly compared to other seagrass species (Marba et al. 2004; cited in Tyler-Walters and Wilding, 2008a). However, potential recruitment of *Z. noltii* may be hampered by competition with infauna such as the ragworm *Hediste diversicolor* or lugworm *Arenicola marina* (Philippart, 1994a; Hughes et al. 2000; cited in Tyler-Walters and Wilding, 2008a). Hughes et al. (2000) noted that *Hediste diversicolor* consumed leaves and seeds of *Z. noltii* by pulling them into their burrow, therefore reducing the survival of seedlings.

Cooke and McMath (2001) calculated the likely recovery potential of *Z. marina* in response to human maritime activities, based on the recruitment, recolonisation and regenerative characteristics of the species. On a scale of 1-100 (where 1 represented excellent recovery following disturbance and 100 represented no species recovery), the authors calculated that *Z. marina* had an intermediate recovery score of 49.

Introduction to the Sensitivity Assessment Table and Accompanying Confidence Tables

Table VIII.9 (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 resistance scale is categorised as None (N), Low (L), Medium (M) and High (H). Similarly resilience is scored as Low (L), Medium (M), High (H) and Very High (VH). Sensitivity is categorised as Not Sensitive (NS), Low (L), Medium (M), High (H) and Very High (VH). The asterisks in brackets in the score columns indicate the confidence level of the assessment based on the primary source(s) of information used, this is assessed as Low (*), Medium (**) and High (***). These scores are explained further in Table VIII.8a and are combined, as in Table VIII.8b (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 features 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 VIII.10 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 VIII.8a).

Table VIII.8a Guide to Confidence Levels for resistance and resilience assessments

Confidence Level	Primary Source of Information	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 VIII.8b Sensitivity Assessment Confidence Levels

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

Sensitivity Assessment Note

As part of Marine Conservation Zone planning in the UK, ABPmer convened expert workshops and also contacted experts directly to produce sensitivity assessments of marine features. Expert opinions on the sensitivity of features did not always agree and in such cases a range of sensitivity was assigned to the feature to account for the underlying uncertainty. The project provided a range of sensitivities for *Zostera* sp., to human pressures as expert opinion differed widely on the resistance and resilience of seagrass beds (Tillin et al. 2010). Similar findings have been obtained during this study as often the literature does not agree on the direction and magnitude of effects. This suggests that responses can be very variable and may be mediated by a range of factors other than the species direct tolerances. *Zostera* are also found in a range of environmental conditions and this may account for some of the variance. The range is also partly explained by the range in predicted recovery times, as recovery from small impacts via vegetative growth occurs on a different time-scale to recovery from broad-scale impacts affecting an entire bed, where recovery may rely on seed (rare events) and where the recovery of biomass relies on slow growth.

Table VIII.9 *Zostera* Sensitivity Assessments

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
Physical Damage	Surface Disturbance	Abrasion at the surface only, hard substrate scraped	L (***)	L-H (***)	M-H (***)	The leaves and stems of seagrass plants project above the surface and the roots are shallowly buried so that they are exposed to surface abrasion. The naturally recorded rhizome depth of *Zostera noltii* was 0.6 ± 0.3 cm (from 0 to 1.4 cm) in the field, and the observed preferential depth was 0.3 to 0.8 cm (Han et al. 2012). In general, seagrass beds are not physically robust. *Zostera* beds are vulnerable to physical disturbance of the sediment by activities such as trampling, anchoring, digging, dredging, and power boat wash, which are likely to damage rhizomes and cause seeds to be buried too deeply to germinate (Fonseca, 1992). In a review of the ecological role of bivalve cultivation in estuarine environments, Dumbauld et al. (2009 and references therein) highlighted that seagrasses are sensitive to a variety of activities with some parallels to aquaculture harvest practices, for example dredge and fill, boat propellors, and boat anchor and mooring chain scars. Physical disturbance and removal of plants can lead to increased patchiness and destabilization of the seagrass bed, which in turn can lead to reduced sedimentation within the seagrass bed, increased erosion, and loss of larger areas of *Zostera* (Davison and Hughes, 1998). Physical disturbance can have positive consequences in certain circumstances. Rae (1979) found that small-scale sediment disturbance encouraged new growth of intertidal *Zostera* in the Moray Firth. It was suggested that this could be due to the opportunistic colonization of newly disturbed sediment when seeds or viable rhizome fragments were deposited in newly created hollows on the shore or when viable but deeply- buried seeds were brought closer to the surface where they could germinate successfully. *Activity Specific Information* *Zostera* can be damaged when motorized watercraft are piloted across meadows during low water conditions or by accidental groundings. Turbulence from propeller wash and boat wakes can break off leaves, dislodge sediments and uproot plants. Repeated shearing of leaves may reduce the productivity of meadows. The engine's propellers can shear leaves or cut into the bottom, damaging or destroying

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						rhizomes. In severe cases, propellers cutting into the bottom may completely denude an area (McCarthy and Preselli, 2007; study from the USA). In Chesapeake Bay, USA, scarring evident in seagrass meadows in aerial photographs were considered likely to be due to the propellers of fishing vessels (Orth et al. 2001). Such scars may remain unvegetated for a number of years. Studies done in Florida have estimated that scars typically require from three to seven years to revegetate, and possibly longer in severe cases involving very deep propeller scars and vessel groundings. In some cases scars expand and coalesce to form larger denuded areas. Revegetation rates, as well as the potential for scar expansion, depend upon a number of factors, including the species of seagrass, sediment characteristics, bathymetry and the prevailing wind and current patterns (McCarthy and Preselli, 2007). *Community Effects* Bishop (2008) compared the macroinvertebrate assemblages living on *Zostera capricornii* blades in a sheltered coastal lagoon in New South Wales, Australia before and after the seagrass beds were exposed to recreational boat wake. The results showed that in the wake-exposed areas, the total abundance of macroinvertebrates decreased five-fold and diversity (taxon richness) decreased two-fold immediately after the disturbance. In contrast, at an undisturbed control site, the abundance and richness of the invertebrate taxa remained fairly unchanged and in some cases increased. Although many of the invertebrates displaced were mobile species, the results indicated that the displaced fauna in the disturbed areas had not completely recolonised seagrass patches within one hour of the disturbance occurring. The authors concluded that in areas where boat traffic is relatively frequent, permanent reductions of abundances of macroinvertebrates in seagrass may occur (Bishop, 2008). *Previous Sensitivity Assessments* The following evidence, relating to key functional and important species within *Zostera* beds, is taken from MarLIN sensitivity assessments. Within intertidal *Zostera noltii* beds on upper to mid shore muddy sand, epifaunal gastropods, such as Littorina littorea and bivalves, such as Cerastoderma edule living near the surface may be damaged by abrasion (at a benchmark level of a force equivalent to a standard scallop dredge landing on or being

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						dragged across the organism as a single event), and infaunal polychaetes may be damaged by physical disturbance to the sediment (Tyler-Walters and Wilding, 2008a). However, the physical disturbance caused by fishing activities e.g. for cockles, is greater than the benchmark level assessed, and these are covered further in the 'deep disturbance' section below. Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised seagrass beds as having high sensitivity to high intensities of potting (lifted daily, more than 5 pots per hectare (i.e. 100m by 100m) and medium sensitivity to lower levels (Lifted daily, 2- 4 pots per hectare or <2 pots per hectare). Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised seagrass beds as having high sensitivity to static gear (nets and longlines) at high and moderate levels (>9 pairs of anchors/area 2.5nm by 2.5nm fished daily, Moderate- 3-8 pairs of anchors/area 2.5nm by 2.5nm fished daily) and medium sensitivity to lighter levels (2 pairs of anchors/area 2.5nm by 2.5nm fished daily). An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal seagrass beds as having low to medium resistance to surface abrasion (loss of <25% to 25-75% loss) and medium to high recovery rates (within 2 years although possibly taking as long as 10 years to recover from an abrasion event (Tillin et al. 2010). Based on the above evidence, seagrass beds are judged to have 'Low' resistance to surface abrasion (loss of 25-75% of impacted extent), recovery is judged to be 'Low to High' and be mediated by the extent of the impact. Where large areas are damaged then recovery will take longer that the infilling of small damaged areas by re-growth of damaged plants and vegetative reproduction. Sensitivity is therefore assessed as ranging from 'Medium-High'.
	Shallow Disturbance	Direct impact from subsurface (to 25mm) disturbance.	L-M (***)	L-H (***)	M-VH (***)	*Activity Specific Information* Otter trawling in beds of the seagrass species *Posidonia oceanica* has been shown to cause significant damage to the plants, leading to the loss of entire meadows (Ardizzone and Pelusi, 1983; Ardizzone et al. 2000). The otter doors, ground cable and net cause sediment scouring, plant damage, and uprooting

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						of sub-surface rhizomes. Boat anchoring/mooring has been identified as a potential threat to *Zostera marina* beds in the UK. Swing moorings led to the loss of seagrass and creation of bare sand patches in subtidal *Z. marina* beds in Salcombe, Devon (Rhodes et al. 2006). In Cornwall, it was observed that there was minimal *Z. marina* established in an area of the Helford River where the majority of yachts anchored (Sutton and Tompsett, 2000) compared to other areas along the river where there were substantial subtidal *Z. marina* beds (Sutton and Tompsett, 2000). Numerous studies in the Mediterranean on *P. oceanica* beds (e.g. Montefalcone et al. 2008; Francour et al. 1999; Milazzo et al. 2004) and in Australia on seagrass beds containing the species *Posidonia sinuosa*, *P. australis*, *Amphibolisa antartica* and *A. griffithii* (e.g. Walker et al. 1989; Hastings et al. 1995) have shown similar detrimental effects of swing boat moorings (causing loss of seagrass beds and ‘scours’) and anchoring (declines in seagrass shoot density, uncovering of rhizomes, broken and uprooted seagrass shoots) on seagrass beds. *Previous Sensitivity Assessments* Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised seagrass beds as having high sensitivity to all levels of fishing intensity by towed gears that contact the bottom. An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal seagrass beds as having low to medium resistance to shallow disturbance (loss of <25% to 25-75% loss) and medium to high recovery rates (within 2 years although possibly taking as long as 10 years to recover from an abrasion event (Tillin et al. 2010). Shallow disturbance will have the same effects on other key functional and characterising species of intertidal and subtidal seagrass beds as outlined above in the surface disturbance section. Based on the above evidence, seagrass beds are judged to have ‘No- Low’ resistance to shallow disturbance (loss of >75% or between 25-75% of impacted extent), recovery is judged to be ‘Low to High’ and be mediated by the extent of the impact. Where large areas are damaged then recovery will

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						take longer compared with faster recovery by infilling of small damaged areas by regrowth of damaged plants and vegetative reproduction. Sensitivity is therefore assessed as ranging from 'Medium-High'.
	Deep Disturbance	Direct impact from deep (>25mm) disturbance.	N-L (***)	L-M (***)	M-VH (***)	*Activity Specific Information* In a review by Dumbauld et al. (2009) the authors noted that the effects of clam harvesting appeared to relate to the extent and depth to which sediment is dislodged. For example, the effects of recreational clam harvest using rakes on *Z. marina* were undetectable, but digging clams with shovels reduced seagrass cover and biomass over the short term, although recovery occurred fairly rapidly (within months) in Yaquina Bay, USA (Boese, 2002, see above). Trawling and dredging for wild shellfish negatively affects seagrass (Fonseca et al. 1984; Peterson et al. 1987; Orth et al. 2002; Neckles et al. 2005, all studies from the USA and cited in a review by Dumbauld et al. 2009). Subtidal deployment of static or towed fishing gears can result in physical damage to the above surface part of the plants and the root systems which are found in the top 20cm of sediment. Leaf shearing results when leaves are cut and if this occurs repeatedly, it may cause plant death where most of the plant resources must be directed to leaf replacement (Roberts et al. 2010). Studies from the Mediterranean on *Posidonia* species has shown that trawling has major direct and indirect impacts on seagrass beds (Moore and Jennings, 2000); substrate is lost or destabilised, and seagrasses are uprooted and damaged (Tudela, 2004) and sediment resuspension (see increased turbidity) reduces light necessary for seagrass photosynthesis (Ardizzone et al. 2000). Recovery is variable and rapidity is dependent on extent of removal. Rates may be s' where adjacent seed sources and viable grass beds are present, but can be between 60-100 years where the removal of rhizomes has occurred (Gonzalez-Correa et al. 2004; Moore and Jennings, 2000). Several hard clam harvesting methods have been shown to reduce seagrass, including mechanical "clam kicking" with propeller wash (Peterson et al. 1987, study in North Carolina, USA; cited in Dumbauld et al. 2009) and hand digging when rhizomes were extensively fragmented (Cabaco et al. 2005, study in southern Portugal; cited in Dumbauld et al. 2009). *Zostera* is very sensitive to hydraulic bivalve fishing due to damage to rhizomes. Suction dredging for

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						cockles in the Solway Firth removed *Zostera* in dredged areas while *Zostera* was abundant in un-dredged areas (Perkins, 1988). Concerns over the sustainability of this fishing activity, including the impact on *Zostera*, led to the closure of this fishery to all forms of mechanical harvesting (Solway Firth Partnership, 1996; cited in Davison and Hughes, 1998; Sewell and Hiscock, 2005). The effects of multiple passes with a suction dredge were evaluated by Wadell (1964; cited in Dumbauld et al. 2009) who found up to 96% initial loss of seagrass biomass in Humboldt Bay with recovery taking up to 2 years. Fonseca et al. (1984) showed that scallop dredging in the USA (using 'toothless' dredges) on *Z. marina* beds grown in soft mud substrate resulted in a greater loss of vegetation biomass than dredging in beds grown in hard sand. The seagrass was more susceptible to damage (all shoots removed) in the softer substrates whereas on hard seabed about 15% of the seagrass per core remained. Increased dredging (i.e. increased number of tows of the gear) resulted in a significant reduction in vegetation biomass and number of shoots. *Experimental Studies* An experimental study on intertidal mud and sandflats in Strangford Lough showed that hand raking of sediment (a traditional method for harvesting cockles that can disturb the top 5-10cm of sediment) led to a 88% decrease in biomass of *Zostera* beds within 3 months of the disturbance (McLaughlin et al. 2007). Boese (2002) compared the effects of raking and digging for clams in seagrass beds over one season. The author examined the effect of mimicked, small scale, recreational digging and raking for clams on seagrass beds and their associated macro and megafauna. In raked treatments, some loss of plant biomass was noted imediately after raking, but no differences were found between treatment and control plots after two weeks indicating that seagrass beds recovered quickly following this type of disturbance. In contrast, sites where digging had taken place were slower to recover and differences between control and treatment plots were still evident 10 months after disturbance. No significant difference between macrofauna or megafauna was found between treatment and control plots for both raking and digging sites. The raking and digging disturbance were at higher intensities to normal

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						recreational raking and digging. The author concluded that recreational clamming was not a great threat to the seagrass beds in Yaquina bay, but that differences between the study site and the type of area normally used for clamming mean that these conclusions should be treated with caution (Boese, 2002; cited in Sewell and Hiscock, 2005). Results of experimental dredging, using a toothed metal dredge, at a relatively large scale (0.33 ha plots) in Willapa Bay, Washington showed that at a muddy site, seagrass initially declined 42%, where shoot and rhizome removal by the dredge implement was substantial, requiring 4 years for recovery. However, at a sandy site, the initial decline in seagrass was only 15% and recovery occurred in 1 year (Tallis et al. 2009; cited in Dumbauld et al. 2009). Neckles et al. (2005) studied the effect of commercial 'mussel dragging' (using a dredge with a heavy steel frame with an attached chain link bag towed across the seabed) on *Z. marina* in Maine, USA. The results showed that mussel dragging resulted in the removal of *Z. marina* plant material both above and below the seabed in most of the fished area. Substantial differences in *Z. marina* biomass between the fished sites and unfished (control) sites remained for up to seven years after the fishing had occurred. The authors predicted that about 10 years would be required for the most intensely disturbed areas to recover. *Previous Sensitivity Assessments* Hall et al. (2008) using the modified Beaumaris approach to sensitivity assessment, categorised seagrass beds as having high sensitivity to all levels of fishing intensity by towed gears that contact the bottom. An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal seagrass beds as having no resistance to shallow disturbance (loss of >75% of habitat) and low recovery rates (within 10-25 years to recover from deep disturbance so that sensitivity was assessed as high (Tillin et al. 2010). Based on the above evidence, seagrass beds are judged to have 'No- Low' resistance to shallow

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						disturbance (loss of >75% or between 25-75% of impacted extent), recovery is judged to be 'Medium-Low' (+6years) and be mediated by the extent of the impact. Where large areas are damaged then recovery will take longer that the infilling of small damaged areas by regrowth of damaged plants and vegetative reproduction. Sensitivity is therefore assessed as ranging from 'Medium-High'.
	Trampling-Access by foot	Direct damage caused by foot access, e.g. crushing	L (***)	L-H (***)	M-H (***)	Seagrass beds are not physically robust. Their root systems are located within the top 20cm of sediment and are therefore easily dislodged. Activities such as trampling are likely to damage rhizomes and cause seeds to be buried too deeply to germinate (Fonseca, 1992). Trampling damage to *Zostera marina* beds in Washington State, USA was reported by Thom (1993; cited in Holt et al. 1997). Major et al. (2004) conducted experimental trampling studies on *Z. japonica* beds in Washington State, USA and showed that more physical damage (a decrease in shoot density) occurred in soft muddy substrate compared to in sand substrate. Eckrich and Holmquist (2000) assessed the effect of trampling on a tropical seagrass species (*Thalassia testudinum*) in Puerto Rico and showed that heavy trampling (50 passes per month) reduced rhizome biomass by up to 72% and a loss of standing crop by up to 81%. The greatest biomass loss occurred at sites with softer substrates. Reviewing this literature Tyler-Walters and Arnold (2008) concluded that repeated heavy trampling resulted in large losses of seagrass biomass and standing crop and that this was compounded by a slow recovery rate. They also concluded that the effects of trampling are more pronounced in soft mud habitats. Based on the above evidence, seagrass beds are judged to have 'Low' resistance to repeated trampling (loss of 25-75% of impacted extent). Recovery is judged to be 'Low to High' and be mediated by the extent of the impact. Where large areas are damaged then recovery will take longer that the infilling of small damaged areas by regrowth of damaged plants and vegetative reproduction. Sensitivity is therefore assessed as ranging from 'Medium-High'.
	Trampling-Access by vehicle	Direct damage, caused by vehicle access.	L (***)	L-H (***)	M-H (***)	Hodges and Howe (1997) documented that vehicular access (associated with cleaning up after oil spill) on *Zostera angustifolia* beds in Angle Bay, Wales resulted in patchy seagrass beds criss-crossed with wheel ruts up to a metre deep. Prior to this, unauthorised vehicle access (e.g. associated with bait digging and use of motorbikes) created ruts that were visible over a year later. Based on the above evidence, seagrass beds are judged to have 'Low' resistance to trampling by

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						vehicles (loss of >75% to between 25-75% of impacted extent), repeated events will cause more damage. Recovery is judged to be 'Low to High' and be mediated by the extent of the impact. Where large areas are damaged then recovery will take longer that the infilling of small damaged areas by regrowth of damaged plants and vegetative reproduction. Sensitivity is therefore assessed as ranging from 'Medium-High'.
	Extraction	Removal of Structural components of habitat e.g. sediment/ habitat/ biogenic reef/ macroalgae	N (*)	L-H (***)	M-VH (***)	Seagrass rhizomes occupy the top 20 cm of the substratum. Hence substratum loss would result in the loss of the shoots, rhizome and probably the seed bank of *Z. marina* together with its associated biotope. *Experimental Studies* Reed and Hovel (2006), found that removal of 90% of the substrata (which included seagrass plant material both above and below ground) in large 16 m^2 plots resulted in a significant loss of diversity and abundance of the associated epifauna. It was also noted that species composition was significantly different. However in smaller plots, or with a lower level of substrate removal, there was no observed correlation between seagrass loss and reduction in density or diversity of epifaunal species. *Previous Sensitivity Assessments* Recoverability of *Z. marina* will depend on recruitment from other populations where extraction occurs on a large scale across an entire bed. Although *Z. marina* seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt et al. (1997) suggested that recovery would take between 5-10 years, but in many cases longer. The slow or total lack of recovery of *Zostera* populations since the 1920s-30s outbreak of wasting disease suggests that, once lost, seagrass beds take considerable time to re-establish, if at all (Tillin et al. 2010; Annex H). Polychaetes and gastropods may recolonise the sediment relatively quickly from surrounding areas or planktonic larvae. However, bivalve macrofauna may take longer (1-5 years) as recruitment is sporadic (Tyler-Walters and Wilding, 2008a). Pihl et al. (2006) demonstrated that the biomass, density and number of fish species was greater in seagrass beds than adjacent areas of sediment from which beds

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						had been lost. Juvenile cod density was reduced by 96% in areas that no longer contained seagrass. An expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having 'no' resistance (loss of >75%) to extraction (assessed as extraction of sediment to 30cm) and 'low to very low' resilience (recovery within 10-25 years to >25 years) so that sensitivity was assessed as 'high' (Tillin et al. 2010). Based on the above evidence and expert judgement, resistance to extraction was assessed as 'None'. Recovery rates are variable and are assessed as being Low- High. Recovery will be mediated by the spatial scale of the impact. Sensitivity is therefpre categorised 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)	N (***)	L (***)	VH (***)	Increased siltation in areas of Low water movement can lead to sediment deposition and accumulation on the leaves of *Zostera* plants, inhibiting production and growth and, if chronic, lead to plant mortality. Siltation can also lead to physical changes in the sediment (see also the changes in sediment composition interaction) and changes in sediment chemistry. Rapid burial that raises the sediment surface, would lead to a rise in the depth of sediment anoxia a upward toward the photosynthetic portions of the seagrass (Mills and Fonseca, 2003). This may result in sulphide intrusion into meristematic areas and buried tissues (Pedersen et al. 2004) and inhibit the plants' recovery from the burial event (Goodman et al. 1995) -see deoxygenation and organic enrichment interactions. *Activity Specific Information* A considerable amount of research on the impact of salmon farming on subtidal seagrass beds has been conducted in the Mediterranean, mainly on *Posidonia oceanica* beds. These studies, reviewed by Pergent-Martini (2006), confirm that organic waste deposition has severe impacts on seagrass beds. For example, studies have shown that *P. oceanica* disappears directly beneath fish cages and surrounding beds are significantly degraded (Delgado et al. 1997; Ruiz et al. 2001). Deterioration of seagrass beds may continue even after salmon farming activity ceases (Delgado et al. 1999). *Posidonia* plants growing near fish cages display growth abnormalities and carbon budget imbalances indicative of physiological stress (Cancemi et al. 2003; Marba et al. 2006). This literature indicates that the critical factor causing impacts appeared to be solid waste deposition and the consequent high organic loading and deoxygenation of sediments (Wilding and Hughes, 2010).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						Experimental Studies Manzanera et al. (1998) found that the addition of approximately 5cm of sediment on to *Posidonia oceanica* shoots and rhizomes led to significant mortality, with 100% mortality where 15cm of sediment was added for 200-300 days. Vermaat (1997), full paper not seen) suggested that, depending on the species, sedimentation rates of 2-13 cm yr-1 can probably be coped with. Greater tolerances for continuous rates of siltation rather than sudden deposition of materials was supported by Han et al. (2012) who manipulated erosion and sedimentation rates on *Z. noltii* in mesocosm and in-situ-experiments. The study showed that the intensity and frequency of burial or erosion have different effects on the survival, elongation rate and rhizome depth of *Z.noltii* and that surviving plants can rapidly acclimate to burial or erosion disturbances by relocating the newly produced rhizomes to a preferential depth (from 0.3 to 0.8 cm), both in the mesocosm and field experiments. Only 6% survived when individual rhizomes were subjected to 6 cm of sudden burial. Increased (sudden) burial depth of individual propagules also caused a strong decrease in the rhizome elongation rate of *Z. noltii* plants. Survival of *Z. noltii* plants was much higher under continuous burial (94 to 100%) compared to the effect of sudden burial. This can be explained because of the higher stress conditions that plants experienced during strong sudden burial (e.g. low light levels and anoxic conditions). Mills and Fonseca (2003) found that increasing burial of Z. marina significantly increased mortality and decreased productivity. Two types of sediment: (1) sand (6 and 0.2 % silt-clay and organic matter content, respectively); and (2) silt (27 and 3.3 % silt-clay and organic matter content, respectively). *Z. marina* was buried to 0, 25, 50, 75 and 100 % of its average aboveground height (16 cm) in an existing eelgrass bed using 2 types of sediment characterized as either silty or sandy. Increasing percentages of plant burial significantly increased mortality and decreased productivity. Survival and productivity of eelgrass were substantially reduced when only 25%of the plant height was buried. Plants buried 75%or more of their height was characterized by survival and productivity measures of 0. No statistically significant differences in plant mortality or productivity were found between the 2 sediment types in this experiment. Changes in morphology of the plants were detected in measures of leaf length and surface

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						area in a short duration (12 d) trial of the experiment, apparently in response to senescence, but etiolation was not observed. Results of this experiment indicate *Z. marina* can only tolerate rapid sedimentation events that cover less than half of its photosynthetic surfaces. Furthermore, the lowest levels of burial treatments (25% of plant height) resulted in mortality greater than 50%, indicating that even this small level of rapid sedimentation is significantly detrimental to Z. marina. Marbà and Duarte (1994) demonstrated that *Cymodocea nodosa* seedlings tolerated burial of <7 cm, while moderate burial stimulated the growth of surviving seedlings. In the case of the small-sized seagrass *Z. noltii,* both erosion (−2 cm) and burial (2 cm) decreased shoot density in natural meadows, while the burial threshold for the shoot dying out was found to be between 4 and 8 cm (Cabaco and Santos, 2007). Moreover, under laboratory experimental conditions, individual shoots of *Z. noltii* did not survive >2 wk under complete burial (Cabaco and Santos, 2007). Nacken and Reise (2000) found that where sediment was allowed to accumulate in parts of a sheltered upper intertidal *Z. noltii* bed from which wildfowl (and hence their eroding effects on leaves, shoots, rhizomes and roots) were excluded, the seagrass did not grow as profusely compared to areas in which the wildfowl actively fed. It was noted that this seemed to be due to a self-inhibition of dense overwintering seagrass by mud accretion. Although many studies have shown sedimentation to result in negative impacts (Moore et al. 1993) found that *Z. marina* seeds that were S buried 15-25 mm below the surface had a significantly higher germination rate (63%) than seeds buried at 5 mm. The authors suggest that postponed germination could be an adaptation to allow for bioturbation, stimulating burial deeper in the sediment to permit the development of an effective root-anchoring system, enhancing seedling establishment. *Previous Sensitivity Assessments* Information from MarLIN assessment of seagrass beds (EUNIS A2.611 and A5.533) to smothering by sediment up to a depth of 5cm (Tyler-Walters and Wilding, 2008a; 2008b and references therein). Seagrasses are intolerant of smothering. The shoots, leaves and flowering structures of seagrasses

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						can be buried by sedimentation associated with the disturbance of the seabed (e.g. by trawling, dredging or boat propellers). Shoots and leaves bend under the re-settling sediment becoming buried with as little as approximately 4cm of settled material (Fonseca, 1992). Once buried the leaves can no longer function, reducing the plant's ability to grow and reproduce. If completely buried by sediment of between 4-8cm for two weeks, shoots of *Zostera noltii* will not survive (Cabaço and Santos, 2007). The rhizome of Mediterranean *Zostera noltii* was, however, able to grow upward, through 2 cm of substratum in 4 months (Vermaat et al. 1996). In Z. noltii beds, surface dwelling epifauna such as the gastropod Littorina littorea is highly intolerant of smothering, although Hydrobia ulvae is less so (Tyler-Walters and Wilding, 2008a). Infaunal species within the community are unlikely to be intolerant to siltation. For example, burrowing deposit feeding polychaetes are probably not sensitive to siltation by up to 5 cm of sediment (Tyler-Walters and Wilding, 2008a). However, the community will probably be intolerant to the loss of the source of primary production (i.e. the loss of seagrass and associated epiphytes and macroalgae; Tillin et al. 2010). The common cockle Cerastoderma edule will experience some mortality due to siltation by 5cm of sediment (Tyler-Walters and Wilding, 2008a). Recoverability of *Zostera noltii* to smothering will depend on recruitment from other populations. Although *Zostera* species seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt et al. (1997) suggested that recovery would take between 5-10 years, but in many cases longer. *Zostera noltii* populations are considered to be in decline (Philippart, 1994b; Jones et al. 2000). Therefore recoverability is assessed as low, and sensitivity is high. Polychaetes such as *Arenicola marina* may recolonise the sediment relatively quickly from the surrounding area or from planktonic larvae. Gastropods such as *Hydrobia ulvae* and *Littorina littorea* are common and mobile with planktonic larvae and also likely to recover quickly. However, recruitment in the bivalve macrofauna is sporadic e.g. *Cerastoderma edule* and may take longer to recover (1 -5 years). It should be noted that rapid recolonisation by Arenicola marina before *Zostera noltii* may inhibit recolonisation by the seagrass (Philippart, 1994a). Loss of *Zostera noltii* would result in loss of the biotope. Although the above impacts refer to *Z. noltii* beds, the effects would be similar in subtidal *Zostera*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						habitats and their associated communities (see Tyler-Walters and Wilding, 2008b). Both *Zostera* biotopes were assigned a high intolerance to smothering by up to 5cm of silt and a low (A2.611) and a very low (A5.533) recovery to this pressure. In a review of the effects of marine fish farm discharges on UK BAP habitats, Wilding and Hughes (2010) concluded from the MarLIN seagrass bed sensitivity assessments that seagrass beds directly beneath or in close proximity to fish cages (most relevant to subtidal *Z. marina* beds) will be seriously impacted by the deposition of solid organic waste. Beds of *Z. noltii* in the intertidal or very shallow infralittoral environments are less likely to be in close proximity to fish cages. Expert workshops convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having 'medium' resistance (loss of <25%) to changes in siltation rates (low- assessed as 5cm of fine material added to the seabed in a single event.) and 'medium-high' resilience (full recovery within 2 years to 2-10 years) so that sensitivity was assessed as 'low-medium' (Tillin et al. 2010). Expert workshops convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having 'no' resistance (loss of >25%) to changes in siltation rates (high- assessed as 30 cm of fine material added to the seabed in a single event.) and 'low- medium' resilience (full recovery within 2-10 years to 10-25 years) so that sensitivity was assessed as 'low-medium' (Tillin et al. 2010). Based on the evidence above resistance to siltation is assessed as 'None', recovery is assessed as 'Low' (greater than 6 years) as recovery where beds are significantly affected is likely to be very slow. Overall sensitivity is therefore categorised as 'High'. The effects of siltation arising from shellfish cultivation on soft sediment habitats not characterised by *Zostera* species but with similar associated biological communities (e.g. littoral muddy sand and sublittoral fine sand and muddy sand) are covered in the relevant accompanying assessments. Siltation may be coupled with additive/synergistic effects through organic enrichment, decreased oxygen levels, increased sediment sulfides and turbidity (see relevant pressures).
	Smothering	Physical effects	N (*)	L (***)	VH (***)	The addition of a layer of coarse materials to the sediment surface would be expected to lead to

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
	(addition of materials biological or non-biological to the surface)	resulting from addition of coarse materials				physical damage of plants and the prevention of photosynthesis through shading where the plant leaves were covered. Few examples of this interaction were found in the literature. Static fishing gears such as pots or traps can cause a 'smothering' type of impact (i.e. causing the bending and burial of leaves), especially if left in place for an extended period of time (ASMFC, 2000). Natural smothering has occurred in the northern Wadden Sea, where the expansion of sandy bedforms due to increased hydrodynamics has led to the displacement of seagrass beds (mainly *Z. noltii*). Bedform expansion usually takes place due to winter storms when the seagrass plants have died back and are present as sub-surface rhizomes. This smothering prevents spring growth (Dolchand Reise, 2010). No evidence relating to the addition of coarse materials as a result of aquaculture activities in seagrass beds was found. However given the species' intolerance to siltation and shading (see also relevant interaction sections), resistance was assessed as 'None', to the addition of coarse, smothering materials, and recovery was assessed as 'Low', so that sensitivity was assessed as 'High'. Recovery would be dependent on habitat rehabilitation.
	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 addressed under physical disturbance pathways.
Disturbance	Underwater Noise				NS	Not sensitive.
	Visual - Boat/ vehicle movements				NS	Not sensitive.
	Visual - Foot/ traffic				NS	Not sensitive.
	Changes to sediment composition-increased	Coarse sediment fraction increases	M (*)	M (*)	M (*)	No evidence relating to the impacts of increased sediment coarseness arising from fishing or aquaculture activities on this feature was found. Thom et al. (2001) cultivated *Z. marina* for 13 weeks in sediment types typically occupied by this

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
	coarseness					species in the Pacific Northwest, as well as coarse, organic-poor sand and gravel, which typically are not inhabited by *Z. marina* (Phillips, 1984). The greatest growth was observed in the finer grained sediments containing organic matter, and lowest growth was measured in the gravel substratum. Coarse-grained sand and a sand/gravel mixture produced intermediate growth rates. These experimental results may be confounded by differences in nutrient availability or mineralogy (cited in Nelson et al. 2009 references therein). The smothering interaction describes how the movement of sandy sediments has led to the displacement of seagrass beds (see above). Expert workshops convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having low resistance (loss of 25-75%) to physical change to another seabed type (assessed as a change in 1 folk class for 2 years) and medium recovery (within 2-10 years) ,so that sensitivity was assessed as 'medium' (Tillin et al. 2010). Seagrass beds are found in clean sands so a reduction in silt content or an increase in sand content would not lead to the removal of the bed although the process by which this happens may be damaging, see siltation and smothering pressures and changes in water flow above. Resistance is assessed as 'Medium' as some reduction in habitat suitability may occur with increased sand fraction due to decreases in organic matter availability. Recovery was assessed as 'Medium', so that sensitivity was assessed as 'Medium'. In some cases where high silt and clay contents are limiting (see changes in fine sediment proportion, and oxygenation and organic enrichment interactions) an increase in sand or sand and gravel content may be beneficial and may allow population expansion (where water flows are not, in turn, limiting).
Change in Habitat Quality	Changes in sediment composition – Increased fine sediment proportion	Fine sediment fraction increases	M (***)	H (***)	M (***)	Increased silt contents in sediments has been associated with the deterioration of seagrass meadows (*Zostera marina*), which may be due to reduced pore-water exchange with the overlying water column , de-oxygenation and the build-up of sulphide levels which are toxic to the plants (Tamaki et al. 2002 and references therein). As well as changes in sediment chemistry, physical changes may also decrease habitat suitability. Wicks et al. (1990) found that soft-sediments provide poor anchorage for eelgrass shoots with increased displacement, the effects were mediated by local hydrodynamics, in areas exposed to currents and waves more displacement would be expected although in these locations

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						deposition may be reduced. Fine sediments are also prone to resuspension, which will affect light penetration and negatively impact production. Statistical models developed from a Danish seagrass dataset found that seagrass were negatively impacted (depth limit decreased) by increased silt-clay content of sediments, the response was non-linear and a threshold response was observed at 13% silt-clay content (Krause-Jensen et al. 2011). However, Koch (2001) has observed healthy seagrass populations in areas with up to 56% silt-clay contents. Nacken and Reise (2000) found that where sediment was allowed to accumulate in parts of a sheltered upper intertidal *Zostera noltii* bed from which wildfowl (and hence their eroding effects on leaves, shoots, rhizomes and roots) were excluded, the seagrass did not grow as profusely compared to areas in which the wildfowl actively fed. It was noted that this seemed to be due to a self-inhibition of dense overwintering seagrass by mud accretion. Based on the above evidence and the habitat preferences of *Zostera*, resistance to increased fine sediment fraction was assessed as 'Medium', as increased fine sediments led to decreased productivity rather than high levels of mortality (although siltation pathways may lead to significant mortalities, see siltation pressure above). Recovery was assessed as 'High', so that sensitivity is categorised as 'Low'. Increased fine sediments may be coupled with additive/synergistic effects through siltation, organic enrichment, decreased oxygen levels, increased sediment sulphides and turbidity (see relevant pressures).
	Changes to water flow	Changes to water flow resulting from permanent/ semi permanent structures placed in the water column	M (***)	M (*)	M (*)	Aquaculture installations may lead to changes in water flow that can lead to erosion of sediments around structures or can reduce local water currents through drag effects. Strong currents and erosion are detrimental when excessive drag dislodges the plant. Fast currents can increase sediment resuspension reducing light availability (see Increase in turbidity interaction). Increased current velocity and/or wave action can also physically affect the ability of macrophytes to colonize or survive in a certain area (Biggs, 1996, Madsen et al. 2001) whereas stagnant flow conditions can limit photosynthesis of seagrasses (Koch, 1994; Van Keulen, 1997). A decrease in water velocity does not only change sedimentation and resuspension rates, altering indirectly the sediment composition, but also decreases self-shading, resulting in lower drag, so that photosynthesis is increased Because rooted macrophytes obtain most of their needed phosphorus and nitrogen from the sediments,

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						current velocity, through its effect on sediment particle size and organic content have the potential to constrain macrophyte growth (see Madsen et al. 2001 and references therein). A decrease in water velocity does not only change sedimentation and resuspension rates, altering indirectly the sediment composition, but also decreases self-shading, resulting in lower drag, so that photosynthesis is increased (De Boer, 2007). A review of seagrass sediment interactions (De Boer, all references therein) found that *Zostera marina* beds can tolerate current velocities up to 120–150 cm/s (Fonseca et al. 1983). While Koch (2001) reported minimum current velocities of 0.04–16 cm/s, and maximum velocities between 7 and 180 cm/s tolerated by seagrass, depending upon species, with intermediate velocities of 5-100 cm/s for optimal development. Where water flow rates are below 8cm s^{-1}, sediment deposition on leaves was observed that negatively affected production and plant survival (Tamaki et al. 2002). Deposition rates of 2.27 mg cm^{-2} over 5 days seemed to be enough to inhibit photosynthesis (see siltation pressure and increased fine sediment for indirect effects of decreases in water flow). *Experimental Studies* In field experiments undertaken to assess the impacts of commercial oyster cultivation on *Z. marina*, Everett et al. (1995) showed that both stake and rack methods of oyster culture resulted in significant decreases in the abundance of *Z. marina* compared to undisturbed areas. *Z. marina* cover was less than 25% of that in undisturbed reference sites after one year of culture. Heavy erosion was observed around the oyster racks resulting in a complex surface topography with pronounced trenches (about 15cm deep) on sides of the racks. Through comparison of sediment surface topography, the authors concluded that the loss of *Z. marina* under and adjacent to oyster racks appeared to be a direct result of the high erosional environment created by the rack structures, although they noted that other mechanisms, such as shading may have contributed to the decline. It was not clear from the results whether the erosional scour effects were coincident with the loss of *Z. marina* or followed as a consequence of the loss of the sediment stabilising seagrass. Few studies have considered erosion effects on the survival of seagrass plants (Han et al. 2012). In a

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						study of simulated erosion Han et al. (2012) found that during erosion events, plants subjected to continuous erosion were unable to bury into the sediment until disturbance ceased and the time needed by plants to reach the preferential depth was directly related to erosion intensity. The greater the erosion, the longer the period plants remained uncovered and, therefore, the higher the risk of plants being uprooted by waves, currents, or animal activities. The high mortality of individual propagules that were initially placed on the sediment surface, could be easily explained by plants washed away by hydrodynamic forces (Han et al. 2012). Therefore changes in water flow that exposed rhizomes through sediment removal would be expected to lead to high mortality rates. *Previous Sensitivity Assessments* The following evidence was taken from MarLIN sensitivity of intertidal and subtidal *Zostera* biotopes (EUNIS A2.611; Tyler-Walters and Wilding, 2008a and EUNIS A5.533; Tyler-Walters and Wilding, 2008b). Seagrasses require sheltered environments, with gentle long shore currents and tidal flux. Where populations are found in moderately strong currents they are smaller, patchy and vulnerable to storm damage and blow outs (creation of seagrass free depressions within seagrass beds) (Tyler-Walters and Wildling, 2008a; 2008b). Coastal developments which alter hydrology have been implicated in the disappearance of seagrass beds (Van der Heide et al. 2007). Increased water flow rates may destabilize the bed and increase the risk of 'blow outs' within the seagrass beds, deposit coarser sediments and erode fine sediments resulting in loss of suitable substrata for the species within this biotope. Epifauna may be removed or 'washed' to unsuitable substrata at high water flow rates (Tyler-Walters and Wildling, 2008a). Seagrass beds slow water flow and trap fine sediment particles and organic matter- these conditions may lead to a decrease in habitat suitability for the plant due tiosiltation and organic enrichment (see these interactions for more information). Removal of sediments in winter may be important to maintain habitat condition. Davison and Hughes (1998) have pointed out that *Zostera* beds probably exist in areas with defined rates of summer accretion and winter erosion, with too much sediment deposition

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						resulting in smothering. Installations that alter hydrodynamics and interfere with the seasonal cycle could lead to the removal of seagrass beds. A negative feedback cycle with increases in summer flow through the absence of the bed may prevent reestablishment. It should be noted that current attenuation in water flows may occur in tide dominated communities but not wave dominated communities (Koch and Gust, 1999). At expert workshops to assess the sensitivity of MCZ features, intertidal and subtidal seagrass beds were assessed, by expert judgement, as having high-medium resistance (loss of <25%) and high to medium resilience (within 2 years although possibly taking as long as 10 years to recover) to 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 year. So that sensitivity was assessed as 'not sensitive to medium' (Tillin et al. 2010). Seagrass are assessed as sensitive to changes in water flow (increases and decreases) through erosion and deposition and other associated changes in the sedimentary habitat. Sensitivity will be site and scale specific. Resistance was assessed as 'Medium' and recovery as 'Medium' so that sensitivity is categorised as 'Medium'. Decreased water flow may be coupled with additive/synergistic effects through siltation, organic enrichment, decreased oxygen levels, increased sediment sulphides and turbidity (see relevant pressures).
	Changes in turbidity/ suspended sediment - Increased suspended sediment/turbidity	Increase in particulate matter (inorganic and organic)	L (***)	L (***)	H (***)	Seagrasses depend on available penetrating light for photosynthesis. Irradiance normally decreases exponentially with increasing depth, and the suspended sediment concentration has a direct linear effect on light attenuation (van Duin et al. 2001). Increased suspended sediment will reduce the light available for photosynthesis and therefore the growth of seagrasses. Turbidity is therefore an important factor controlling production and ultimately survival and recruitment of seagrasses. It has been estimated that seagrasses need more than 10% of the surface irradiance (Duarte 1991), i.e. >200 µmol photons m^{-2} s^{-1} during cloudless middays, in order to survive (while most algae need only 1% of the surface light), Bjork et al. 2008. Thus, the depth limit for seagrass growth is largely determined by light penetration through the water By increasing sediment deposition and reducing re-suspension seagrasses may exert some control over turbidity levels, Total suspended material varied between 18 mg/l near seagrass beds to 150 mg/l in unvegetated areas in Laguna Madre, Texas (De Boer, 2007 and references therein). Teeter et al. (2001) assumed that seagrasses can still occur when 20% of the light

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						reaches the meadows, and that the water column extinction coefficient can, even at low levels of resuspension, limit the depth range of seagrasses (see De Boer, 2007, references therein). Tolerance to changes in turbidity varies seasonally; in summer and in clearer waters seagrass beds may tolerate sporadic (month long) high turbidity (Moore et al. 1997). However where seagrass beds are already exposed to low light conditions, late in season or high turbidity environments, then losses may result from even short-term events (Williams 1988; cited in Newell and Koch, 2004). *Activity Specific Information* Dayton et al. (1995) state that *Zostera marina* is indirectly impacted by increased turbidity from fishing activities and in areas of chronic disturbance is replaced by deposit feeding polychaetes. Community composition shifts such as these may resist the recovery of suspension feeding species (Dayton et al. 1995; cited in Sewell and Hiscock, 2005). *Natural Disturbance* Catastrophic losses of seagrass in Australia have occurred in deep water (at least 10 m depth) apparently as a result of light deprivation caused by a persistent plume of turbid water that resulted from floods and the resuspension of sediments caused by a cyclone (Preen et al. 1995). In contrast, the passage of hurricane Andrew over south Florida in 1992 increased turbidity and nutrient loading, yet the seagrasses in the region suffered little (Tilman et al. 1994; Dawes et al. 1995). The difference in macrophyte response during and after these two events is likely related to the duration of the turbid conditions. When submersed macrophytes are growing under extremely low light levels (late in the season when days become shorter, in deep waters or high turbidity environments), a short-term high turbidity event can result in the loss of the macrophyte population. The disappearance of seagrasses at 20 m depth but not in shallower waters following a late season storm (Williams, 1988) is an example of the interdependence of light availability and sediment resuspension events (cited from Madsen et al. 2001). *Previous Sensitivity Assessments*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						Evidence from MarLIN *Zostera noltii* can store and mobilize carbohydrates and has been reported to be able to tolerate acute light reductions (below 2% of surface irradiance for two weeks) (Peralta et al. 2002). However, *Z. noltii* are likely to be more intolerant to chronic increases in turbidity. Also, permanently submerged brackish water populations may be more vulnerable to increased turbidity. Most other species in the biotope, e.g. infauna and epifauna will probably not be adversely affected by changes in turbidity (Tyler-Walters and Wilding, 2008a). Light attenuation limits the depth to which subtidal *Z. marina* beds can grow as light is a requirement for photosynthesis. Growth of both *Z. marina* and its associated epiphytes is reduced by increased shading due to turbidity (Moore and Wetzel, 2000). Turbidity resulting from dredging and eutrophication caused a massive decline of *Zostera* populations in the Wadden Sea (Giesen et al. 1990; Davison and Hughes, 1998). Seagrass populations are likely to survive short term increases in turbidity; however, a prolonged increase in light attenuation, especially at the lower depths of its distribution, will probably result in loss or damage of the population. When loss of seagrass beds is due to increased turbidity related to suspended sediment, recovery may be impossible, probably because seagrass beds are required to initially stabilise the sediment and reduce turbidity levels (Van der Heide et al. 2007). A high turbidity state appears to be a highly resilient alternative stable state, hence return to the seagrass biotope is unlikely. Seagrass beds should be considered intolerant of any activity that changes the sediment regime where the change is greater than expected due to natural events. Expert workshops convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as low-medium resistance to water clarity changes (assessed as a change in one rank, e.g. from clear to turbid for one year) and low-medium recovery (within 2-10 years and 10-25 years) so that sensitivity was assessed as 'low to medium' (Tillin et al. 2010). The effects of settling out of suspended sediment are addressed in the 'Siltation' section. Resistance to increased turbidity is assessed as 'Low' as seagrass are restricted to shallow areas and recovery is assessed as 'Low' so that sensitivity is categorised as 'High'. Increases in turbidity may be coupled with

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						additive/synergistic effects through siltation, organic enrichment, decreased oxygen levels, increased sediment sulphides and turbidity (see relevant pressures).
	Changes in turbidity/ suspended sediment - Decreased suspended sediment/turbidity	Decrease in particulate matter (inorganic and organic)	H (*)	VH (*)	NS (*)	This feature is found in sheltered areas – a decrease in turbidity would have no effect on the main structural component (*Zostera* species) or the associated biological community and potentially this would be a beneficial effect where it allowed greater production or range expansion into previously unsuitable, turbid areas, so *Zostera* are categorised as 'Not Sensitive'. Resistance is therefore considered to be 'High' and recovery as 'Very High'.
	Organic enrichment - Water column	Eutrophication of water column	L (***)	L (***)	H (***)	In some cases, local increases in nutrient levels appear to have favourable consequences for *Zostera* beds. This is likely to occur in situations where *Zostera* growth is limited by available nitrate (Fonseca et al. 1987; Kenworthy and Fonseca, 1992). However, eutrophication (excessive proliferation of planktonic or benthic algae which can be caused by increased nutrient inputs originating from sewage, agricultural runoff or aquaculture) is more often cited as a major cause of the decline, or the lack of recovery of, *Zostera* beds (Davison and Hughes, 1998). Typically eutrophication leads to the replacement of seagrass by green and brown macroalgae (and, where severe, replacement of macroalgae by phytoplankton may occur due to water column shading (Schmidt et al. 2012). Indirect effects of nutrient enrichment can accelerate seagrass disappearance, including sediment re-suspension from seagrass loss (see increased turbidity), increased system respiration and resulting oxygen stress, (see de-oxygenation pressures) depressed advective water exchange from thick macroalgal growth (see changes in water flow), biogeochemical alterations such as sediment anoxia with increased hydrogen sulfide concentrations (see de-oxygenation) and internal nutrient loading via enhanced nutrient fluxes from sediments to the overlying water. Indirect effects on trophic structure can also be important, for example, Evidence suggests that natural seagrass population shifts are disrupted, slowed or indefinitely blocked by cultural eutrophication, and there are relatively few known examples of seagrass meadow recovery following nutrient reductions (cited from Burkholder et al. 2007-see for review). Eutrophication may lead to the following adverse effects (see Dumbauld et al. 2009 and references therein):

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						▪ Inhibition of cell growth; ▪ Stimulation of the growth of epiphtyes reducing seagrass production by shading the leaves. (see De Boer and references therein). Research in the Mediterranean has shown that nutrient enrichment of the water column can lead to the proliferation of epiphytic algae which reduce the photosynthetic ability of the seagrasses (Cancemi et al. 2003, study of *Posidonia oceanica* beds in Corsica; cited in Wilding and Hughes, 2010). In general, seagrasses tend to be negatively affected by both epiphytic algal growth and macroalgal blooms (Hauxwell et al. 2001; McGlathery, 2001; Hauxwell et al. 2003; cited in Dumbauld et al. 2009); ▪ Increased turbidity through phytoplankton blooms in the water column (see increased turbidity interaction). Crane et al. (2006) in a review of environmental quality standards in relation to finfish farming found ‘considerable uncertainty’ regarding the levels of nitrate that may lead to detrimental effects on seagrasses. Continuous accumulation of organic matter may lead to the death of macrophytes. Koch (2000) showed that more than 5% organic matter in the sediment may lead to the loss of marine macrophytes,- from Madsen *Natural Disturbance* Resuspension of sediment from within or outside submersed macrophyte beds has the potential to release nutrients into the water column (Wainright, 1990). This mechanism can provide up to 94% of the N and 83% of the P required by phytoplankton (Cowan et al. 1996). According to Fanning et al. (1982), if a storm resuspends as little as 1 mm of sediment, the local productivity could be augmented by as much as 200%. Therefore, resuspension of sediment will not only contribute to light attenuation by the increased particles, but also by increased phytoplankton growth due to enhanced nutrients in the water column (cited from Madsen et al. (2001), references therein). Fisheries which use gear that contacts the sediment may re-suspend material to greater depths but at smaller spatial scales. *Previous Sensitivity Assessments*

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						The following evidence was taken from MarLIN sensitivity of intertidal and subtidal *Zostera* biotopes (EUNIS A2.611; Tyler-Walters and Wilding, 2008a and EUNIS A5.533; Tyler-Walters and Wilding, 2008b, references therein). Increased nutrient concentrations (nitrates and phosphates) have been implicated in the continued decline of seagrass beds world-wide, either directly or due to eutrophication (Phillips and Menez, 1988; Philippart, 1994b; Vermaat et al. 1996; Philippart, 1995a; 1995b; Davison and Hughes, 1998; Asmus and Asmus, 2000a; 2000b). The following effects on *Zostera* sp. have been attributed to nutrients and eutrophication. Burkholder et al. (1992) demonstrated that nitrate enrichment could cause decline of *Z. marina* in poorly flushed areas. This effect was exacerbated by increasing/high temperatures associated with spring. Growth and survival were significantly reduced by nutrient enrichment levels of between 3.5 and 35µM nitrate/day with the most rapid decline (weeks) at high nitrate levels. The adverse effect of nitrate has been shown to be dependent on salinity and vary between *Z. marina* populations. Van Katwijk et al. (1999) noted that estuarine *Z. marina* plants were negatively affected by high nitrate loads at salinities of 26 and 30 psu but benefitted from nitrate enrichment (0-4 to 6.3 µM nitrate per day) at 23 psu. Marine *Z. marina* plants were negatively affected by a high nitrate load 30 psu but benefitted from nitrate enrichment at 23 and 26 psu. Sediment and water-column NH4+ were high relative to levels typically found in seagrass habitats, with die-off occurring at 3–220 µM NH4+N in the water column, and at 500–1600 µM NH4+N in the sediment pore water. Z. marina plants growing in sandy sediments were more susceptible than plants grown in organic sediments (van Katwijk et al. 1997). Nutrients and eutrophication have also been shown to increase the growth of epiphytes or blanketing algae. Philippart (1995b) reported that shading by periphyton (algae, cyanobacteria, heterotrophic microbes and detritus) reduced incident light reaching the leaves of *Z. noltii* by 10-90%, reducing the period of time that net photosynthesis could occur by 2-80% depending on location. Philippart (1995b) suggested that the decline of *Z. noltii* in the Wadden Sea in the 1970s was in part due to increased

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						periphyton growth as a result of eutrophication, and a simultaneous decline of the mud-snail (*Hydrobia ulvae*) which they estimated removed 25-100% of the periphyton and microphytobenthos. Den Hartog (1994) reported the growth of a dense blanket of *Ulva radiata* in Langstone Harbour in 1991 which resulted in the loss of 10ha of *Z. marina* and *Z. noltii* and the complete loss of both *Zostera* species by summer 1992. Levels of disease resistant (phenolic) compounds in *Zostera* species are reduced under nutrient enrichment and hence may increase susceptibility to infection by wasting disease (Buchsbaum et al. 1990; Burkholder et al. 1992). In contrast, elevated levels of nutrients and increases in epiphytes and blanketing algae may benefit deposit feeding polychaetes such as *Arenicola marina* and grazing gastropods in *Z. noltii* beds. However, loss or reduction of the *Zostera* bed will result in loss or reduction of the biotope itself (Tyler-Walters and Wilding, 2008a). Slight increases in nutrients may be beneficial to *Zostera* sp. However, the evidence above suggests that eutrophication is detrimental, either directly or indirectly. Resistance to this pressure is therefore assessed as ‘Low’, (decline of 25-75% of extent) with resilience assessed as ‘Low’. Sensitivity is therefore assessed as ‘High’. The smothering of the seagrass beds by epiphytes and ephemeral (short-lived) algae arising from eutrophication may indirectly result in anoxic conditions as the algae die and decompose. The impacts of this pressure are addressed in the ‘Decrease in oxygen levels – water column’ section.
	Organic enrichment of sediments - Sedimentation	Increased organic matter input to sediments	L-M (***)	M (***)	L-M (***)	Sedimentation of organic sediments is determined by the differential settling velocity of the particles. Organic matter is a food resource for a wide variety of benthic species and can be used as a nutrient pool by the seagrasses (De Boer, 2007). *Zostera marina* blades have no method to regulate nitrogen uptake, whereas roots are able to regulate nitrogen uptake from the sediment by controlling the number of root hairs (Tennant, 2006). This suggests Z. marina beds are particularly susceptible to damage from excessive nutrient loading of the water column but are better able to tolerate elevated nitrogen concentrations in the sediment. (Dale et al. 2007). Both field and laboratory results indicate that *Zostera* marina and other seagrass species are most

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						abundant or productive in fine or muddy sand containing substantial organic matter. This type of sediment can contain elevated pore water concentrations of substances such as NH4+ or dissolved sulfides. Whether or not these constituents act as nutrients or toxins to eelgrass plants may depend upon the pore water concentrations, other characteristics of the sediment, and the physiology of the exposed plants. Thus, although grain size of the substratum does appear to influence the distribution and health of *Zostera* marina, relatively little is known of the specific processes involved in such effects. The percent organic matter in sediments is related to the sulfate reduction potential, and hence to the sulfide concentrations in the sediment. The ability of seagrass to protect itself from high levels of sulfide in the root zone will be directly dependent on availability of light to drive photosynthesis, and may be indirectly dependent on irrigating infaunal associates or to the presence of Fe or Mn minerals that detoxify the sulfides in seagrass sediments (cited in Nelson et al. 2009) In *Z. marina*, moderate sulfide levels (N400 μM) were related to depressed maximum rates of photosynthesis (Pmax), increased requirements for light, and decreased slope of the photosynthesis versus irradiance curve, which led to a 55% decrease in shoot-to-root ratios from shoot senescence/mortality within 6 days of exposure (Goodman et al. 1995; Holmer and Bondgaard, 2001). The authors reported that eutrophication effects through reduced light and increased sediment sulfide on Pmax were additive, and suggested that elevated sulfide could contribute to *Z. marina* loss under low-light stress (Burkholder et al. 2007, references therein). Aquaculture has the potential to stimulate competitors with seagrass, for instance providing attachment sites for epiphytic macroalgae and enriching nutrients used by algae (review by Dumbauld et al. 2009). For example, Vinther and Holmer (2008) undertook experimental studies of the effects of biodeposition and ammonium excretion from blue mussels (*Mytilus edulis*) on *Zostera marina*, two species which co-exist in many locations. The results showed that high loads of mussel biodeposits altered the sediment biogeochemical conditions as the mussel deposits enhanced sulphate reduction rates and increased sulphide concentrations in the porewater. The high deposit load had a negative effect on *Z. marina*, reducing leaf numbers and biomass and resulting in accumulation of elemental sulphur in the rhizomes. The authors also studied the effect of mussel excretion, particularly ammonium, on *Z. marina* and its associated epiphytes. A thick cover of epiphytes developed on the *Z. marina* growing together with mussels, and *Z. marina* growth rate was reduced by 20% compared to control plots without mussels.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						These experiments supported a field study by the authors (Vinther et al. 2008) which had indicated that the effects of *M. edulis* in seagrass beds was primarily negative. Mesocosm experiments have found that *Z. marina* exhibited a 'remarkable tolerance' to high sediment fertilisations. Plants were positively stimulated by porewater N concentrations 1000 higher (30 µM) than those considered inhibitory in the water column (>35 µM ammonium, van Katwijk et al. 1997, >10 mM nitrate, Burkholder et al. 1992). The tolerance of Z. marina to high N porewater availability could be explained by suitable conditions for a high ammonium assimilation in roots which might prevent photosynthetic inhibition, which is considered to be the main mechanism of ammonium toxicity for seagrasses (van Katwijk et al. 1997). The high availability of phosphorus in the sediment may also have helped to increase the tolerance to porewater nitrogen because P is needed for nitrogen assimilation. In addition the long photoperiods used in the experiment could have supported nitrogen assimilation by *Z. marina*. Although with high tolerance, plant inhibitory effects (i.e. reduction in plant weight, leaf growth and leaf turnover rate) were detected in part of the high fertilised sediments (HF, 0.5 mg N g^{-1} DW, 2 mg P g^{-1} DW). The threshold of *Z. marina* tolerance to sediment fertilisation was detected at N porewater concentration of 30 mM. (Peralta et al. 2003). The interaction between seagrass production and organic matter in the sediment is highly variable, and there are studies showing that healthy seagrass can occur in highly enriched organic sediments (Koch 2001). *Activity Specific Information* In the Mediterranean, research has indicated that organic waste deposition has severe impacts on seagrass beds. For example, studies have shown that *Posidonia oceanica* disappears directly beneath fish cages and surrounding beds are significantly degraded (Delgado et al. 1997; Ruiz et al. 2001). Deterioration of seagrass beds may continue even after salmon farming activity ceases (Delgado et al. 1999). The literature indicates that the critical factor causing impacts appeared to be solid waste deposition and the consequent high organic loading and deoxygenation of sediments (see decrease in oxygen levels – sediment) (Wilding and Hughes, 2010). In addition, changes in epiphytic density and/or enhancement of grazing pressure (Ruiz et al. 2001) in response to nutrient enrichment derived from fish

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						farm activities may also enhance seagrass loss (cited in Huntingdon et al. 2006). *Previous Sensitivity Assessments* Expert workshops convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having high-medium resistance (loss of <25% to no significant effects) to organic enrichment of sediments (assessed as the addition of 100gC/m²/yr) and high-medium recovery (within 2 years or 2-10 years) so that sensitivity was assessed as 'not-sensitive to medium' (Tillin et al. 2010). Slight increases in nutrients may be beneficial to *Zostera* sp. However, the evidence above (also see organic enrichment-water column) suggests that organic enrichment can be detrimental either directly or indirectly through increased sediment sulfides and increased turbidity. Resistance to this pressure is assessed as 'Low-Medium' (decline of <25% of extent) to loss of 25-75%) to take into consideration the high level of resistance to nitrate in experiments with resilience assessed as 'Medium'. Sensitivity is therefore assessed as 'Low-Medium'. Resistance to organic enrichment is likely to be lower when coupled with decreased oxygen levels, increased sediment sulfides, turbidity and siltation pressures.
	Increased removal of primary production - Phytoplankton	Removal of primary production above background rates by filter feeding bivalves	H (*)	VH (*)	NS (*)	This feature is a primary producer and would not be impacted by a reduction in water column primary production. An associated reduction in turbidity may be beneficial to seagrasses, hence the 'Not Sensitive' assessment. Resistance is therefore assessed as 'High' and recovery as 'Very High'.
	Decrease in oxygen levels - Sediment	Hypoxia/anoxia of sediment	N-L (***)	L (*)	H-VH (*)	Most sediments are naturally hypoxic, and seagrasses have the ability to transfer oxygen from the shoots to the roots and, so, counteract the otherwise negative effects of hypoxia. Jones et al. (2000) have noted that *Zostera* beds can be associated with markedly anoxic sediments but this may only be possible where light levels/turbidity allow high levels of photosynthesis to counteract this (through transfer of oxygen to roots). Where light penetration is reduced the corresponding reduction in photosynthesis will mean that the seagrass leaves will form less oxygen for transport towards the root system (Bjork et al. 2008). Sulfide produced in marine sediments by sulfate reduction is toxic for several macrophytes, and high sediment sulfide concentrations have been associated with seagrass die-off events. Sulfide concentrations of approximately 1000 µM could be considered an upper threshold limit

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						for the survival of *Zostera marina* in the coastal lagoons of Baja California (Mexico) in a recent study (Korhonen et al. 2012). Respiration was not inhibited by sulfide concentrations up to 1000 µM during 48-h incubations, while photosynthetic performance was reduced by short exposure to sulfide concentrations of 25 µM but also by long exposure to concentrations as low as 50 µM (Korhonen et al. 2012). Seagrass loss can also occur indirectly through the loss of herbivores that promote seagrass survival by controlling algal overgrowth (see review by Burkholder et al. 2007) A week long anoxic episode on the Mediterranean coast of France resulted in complete mortality of *Z. marina* beds (Plus et al. 2003). *Activity Specific Information* Studies of the impact of salmon farming on subtidal *Posidonia oceanica* seagrass beds in the Mediterranean confirm that organic waste deposition and subsequent organic loading and deoxygenation of the sediments has severe impacts on seagrass beds (reviewed by Pergent-Martini, 2006). For example, studies have shown that *P. oceanica* disappears directly beneath fish cages and surrounding beds are significantly degraded (Delgado et al. 1997; Ruiz et al. 2001). Deterioration of seagrass beds may continue even after salmon farming activity ceases (Delgado et al. 1999). *Posidonia* plants growing near fish cages display growth abnormalities and carbon budget imbalances indicative of physiological stress (Cancemi et al. 2003; Marba et al. 2006; cited in Wilding and Hughes, 2010). *Previous Sensitivity Assessments* Information from MarLIN *Zostera marina* sensitivity assessment (Tyler-Walters, 2008) The presence of air spaces (lacunae) in the leaves of *Zostera* species suggests that seagrass may be tolerant of low oxygen levels in the short term, however, prolonged deoxygenation, especially if combined with low light penetration and hence reduced photosynthesis may have an effect (Tyler-Walters and Wilding, 2008a). Long-term anoxic conditions in the water column and sediment (for

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						example that arise from organic enrichment) influence the metabolism of *Zostera* plants resulting in poor energy availability and production of toxic metabolites, both of which may negatively affect growth and survival of the plants (cited in Huntingdon et al. 2006). Subtidal seagrass beds are considered to have low resistance to sediment anoxia/hypoxia, where these conditions occur for longer than a week it is likely that resistance will be 'Low to None' (decline of 25-75% or more severe decline), resistance may be decreased by high turbidity levels and low light conditions. Recovery will be scale dependent and is assessed as 'Low' (6+ years). Sensitivity is therefore categorised as 'High-Very High'. Intertidal seagrass beds are considered to be less exposed to sediment decreases due to periods of emmersion supplying the sediment with oxygen (and the plants with light for photosynthesis for root transfer of oxygen).
	Decrease in oxygen levels - Water column	Hypoxia/anoxia water column	N-L (*)	L (*)	H-VH (*)	Studies of the environmental impacts of cage aquaculture on the water column have shown an increase in the levels of suspended solids and nutrients, and a decrease in dissolved oxygen levels around cages (Hargrave et al. 1993; Islam, 2005; cited in OSPAR, 2009). Measurements of oxygen within and close to salmon cages show reductions of up to 2.0 mg/l compared to control sites (AQUAFACT International, unpublished reports; cited in OSPAR, 2009). *Previous Sensitivity Assessments* Smothering of the seagrass beds by epiphytes and ephemeral algae (see Organic Enrichment section) may indirectly result in anoxic conditions as the algae die and decompose. Therefore, given the potential intolerance of *Zostera noltii* to deoxygenation, MarLIN assigned an overall intolerance of intermediate to exposure to dissolved oxygen concentrations of 2mg/l for 1 week. On return to normal conditions recovery is likely to be quick, provided the seagrass itself is not damaged. Therefore recoverability is deemed to be high, resulting in a sensitivity assessment of low (Tyler-Walters and Wilding, 2008a). The following evidence was taken from the MarLIN sensitivity assessment of *Zostera marina/angustifolia* beds in lower shore/infralittoral clean or muddy sand (Tyler-Walters and Wilding, 2008b). Loss of grazers due to low oxygen levels will result in unchecked growth of epiphytes and other algae which may smother *Zostera marina*. Therefore intolerance is classed as intermediate to exposure

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						to dissolved oxygen concentrations of 2mg/l for 1 week. On return to normal conditions, recovery is likely to be rapid, so is assessed as high, resulting in a low sensitivity value. Prolonged deoxygenation is likely to damage the seagrass itself (Jones et al. 2000). Living in sheltered microhabitats with little water exchange, some individuals of the grazing gastropod *Lacuna vincta* may die as a result of lowered oxygen concentrations. However, the annual life cycle, high fecundity and long planktonic larval stage means that successful recruitment from other populations is likely (Tyler-Walters and Wilding, 2008b). Subtidal seagrass beds are considered to have low resistance to water column anoxia/hypoxia due to the lack of oxygen for respiration, where these conditions occur for longer than a week it is likely that resistance will be 'Low to None' (decline of 25-75% or more severe decline). Recovery will be scale dependent and is assessed as 'Low' (6+ years). Sensitivity is therefore categorised as 'High-Very High'. Intertidal seagrass beds are considered to be less exposed to sediment decreases due to periods of emmersion supplying the plants with oxygen (and the plants with light for photosynthesis for root transfer of oxygen).
Geological 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	Presence of the interaction pathway e.g. cultivation of a non-native species and potential for introduction of non-natives in translocated stock.	L (**)	L (***)	H (**)	There are 8 known invasive species in Irish Seas (Invasive Species Ireland management toolkit http://invasivespeciesireland.com/toolkit). The brown seaweed *Sargassum muticum* is of relevance to this feature (species either occurs in this feature and/or can be spread by aquaculture activities and boat movements). 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

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						prevent accidental transport. *Sargassum muticum* has been recorded at several locations around the coast of Ireland. The 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 *Zostera marina* (eel grass) beds, where the vegetation provides surfaces for colonisation (Tweedley, 2008; cited in Tyler-Walters and Wilding, 2008a and b). 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 (Eno et al. 1997; IUCN, 2007). 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 *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. *S. muticum* may prevent recolonisation of areas of seagrass beds left open by disturbance (Davison and Hughes, 1998). Prevention of spread should be covered by licensing requirements through keeping boats and marine equipment free of fouling. Common cord grass Spartina anglica Smooth 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. maritime*. *Spartina anglica* is widespread on sheltered muds at tide level around the coast of Ireland. The primary habitat of this species is just below the regular salt marsh communities and in the areas occupied by intertidal *Zostera*. 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. *Previous Sensitivity Assessments* The following evidence was taken from MarLIN sensitivity of intertidal and subtidal *Zostera* biotopes (EUNIS A2.611, Tyler-Walters and Wilding, 2008a and EUNIS A5.533, Tyler-Walters and Wilding 2008b respectively, references therein).

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						Spartina anglica (a cord grass) is an invasive pioneer species, a hybrid of introduced and native cord grass species, which colonises the upper parts of mud flats. Its rapid growth consolidates sediment, raises mudflats and reduces sediment availability elsewhere. It has been implicated in the reduction of *Zostera* sp. cover in Lindisfarne, Northumberland due to encroachment and changes in sediment dynamics (Davison and Hughes, 1998). Japanese weed (*Sargassum muticum*) invades open substratum subtidally and may prevent recolonisation of areas of seagrass beds left open by disturbance (Davison and Hughes, 1998). *Zostera marina* and *Sargassum muticum* may compete for space in the lower shore lagoons of the Solent. *Sargassum muticum* is able to colonise soft sediments by attachment to embedded fragments of rock or shell (Strong et al. 2006). Further, it has been suggested by Tweedley et al. (2008) that the presence of *Zostera marina* beds may facilitate the attachment of *Sargassum muticum*. However, evidence for competition is conflicting and requires further research, hence an assessment of intermediate intolerance. If the invasive species prevent recolonisation then the recoverability from other factors will be reduced. Therefore recoverability is low, and sensitivity is assessed as high. MarLIN assessed the intolerance of both the *Z. noltii* and *Z. marina* biotopes to the effects of the introduction of alien or non-native species (not specifically arising from aquaculture) as intermediate, the recoverability as low, and overall sensitivity as high. An expert workshop and external review convened to assess the sensitivity of marine features to support MCZ planning assessed intertidal and subtidal seagrass beds as having 'low to medium' (loss of <25% to 25-75%) resistance to introduction of non-indigenous species (invasive macroalgae) and 'very low-medium' resilience (recovery within 2-10 years to >25 years) so that sensitivity was assessed as 'medium-high' (Tillin et al. 2010). Due to the potential for habitat change resulting from colonisation by *S. muticum* and the aggressive growth rates of this species, *Zostera* beds are assessed as having 'Low' resistance to this pressure and 'Low' recoverability (as eradication is not considered likely), sensitivity is therefore assessed as 'High'. *S. anglica* is not included in this assessment as it is not considered to be introduced via aquaculture or fishing activities.

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
	Introduction of parasites/ pathogens				NE	Not Exposed. This feature is not farmed or translocated.
	Removal of Target Species		H (*)	VH (*)	NS (*)	Commercially exploited species associated with seagrass include cockle (*Cerastoderma edule*), hard-shell clam (*Mercenaria mercenaria*) and cuttlefish (*Sepia officinalis*). The effects of removal of these species are likely to be constrained to physical damage interactions which are 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. Resistance is therefore considered to be 'High' and recovery is '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 process of removing non-target species is considered above in the physical disturbance theme. *Zostera* species are not functionally dependent on any species which are likely to be removed as by-catch by commercial fishing activities and hence are not considered to be sensitive to this pressure. Resistance is therefore considered to be 'High' and recovery 'Very High'.
	Ecosystem Services-Loss of biomass				NA	Not relevant to SAC habitat features.
Chemical Pressure	Introduction of Medicines	Introduction of medicines associated with aquaculture.			NEv	No evidence relating to the effects of medicines specifically on *Zostera* beds was found. In general (i.e. not specifically in seagrass beds) residues can often be detected in the sediments below farms that have treated fish with antibiotics but it is highly unlikely that this form of discharge will have any effect on benthic animal or plant life (Wilding and Hughes, 2010).
	Introduction of hydrocarbons	Introduction of hydrocarbons	H (***)	VH (***)	NS (***)	The following evidence was taken from the MarLIN sensitivity assessment of the *Zostera noltii* beds on mid to upper shore muddy sands biotope (EUNIS A2.611) (Tyler-Walters and Wilding, 2008a and references therein). Intertidal seagrass beds are likely to be more vulnerable to direct oil contamination and the sheltered conditions in which they occur suggests that any oil will weather slowly (Davison and Hughes, 1998; Jones et al. 2000). However, several studies on seagrass beds after oil spills and in the vicinity of long term, low level hydrocarbon effluents, suggest that *Zostera* species are little affected by

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						hydrocarbon contamination (Jacobs, 1980; Hiscock, 1987; Davison and Hughes, 1998; Jones et al. 2000). On the other hand, pre-mixed oil and dispersant were found to cause rapid death and significant reduction in cover of *Zostera noltii*, and led to the recommendation that dispersants should be avoided (Holden and Baker, 1980; Howard et al. 1989; Davison and Hughes, 1998). The removal of oil intolerant grazers, e.g. gastropods and amphipods, however, is likely to indirectly affect the seagrass bed, resulting in unchecked growth of periphyton, epiphytes and ephemeral algae and smothering of the seagrass (see organic enrichment). Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general in soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected. For example, evidence from oil spills suggested that gastropods such as *Hydrobia ulvae* and especially *Littorina littorea* were intolerant of oil spills (Jacobs, 1980). Large numbers of dead or moribund *Cerastoderma edule* were washed ashore after the Sea Empress oil spill. Similarly, the abundance of *Arenicola marina* populations were adversely affected by oil or oil/dispersant mixtures, and seawater oil concentrations of 5 mg/l caused the lugworms to leave the sediment (Levell, 1976; Prouse and Gordon, 1976). Therefore, hydrocarbon contamination is likely to adversely affect epifaunal and infaunal species within the biotope, and although *Zostera noltii* may not be adversely affected directly, the loss of grazers is likely to result in smothering and potential loss of areas of seagrass bed. MarLIN assigned the biotope intolerance to this pressure as intermediate, recoverability as moderate, and an overall sensitivity rating of moderate. The following evidence was taken from the MarLIN sensitivity assessment of the *Zostera marina* beds in lower shore or infralittoral clean or muddy sand mid to upper shore muddy sands biotope (EUNIS A5.533) (Tyler-Walters and Wilding, 2008b and references therein). *Zostera marina* may be partially protected from direct contact by oil due to its subtidal position (Tyler-Walters and Wilding, 2008b). The Amoco Cadiz oil spill off Roscoff caused *Zostera marina* leaves to blacken for 1-2 weeks but had little effect on growth, production or reproduction after the leaves were covered in oil for six hours (Jacobs, 1980). The same spill resulted in the virtual disappearance of Amphipods, Tanaidacea and Echinodermata from *Zostera* marina beds in Roscoff and a decrease in numbers of Gastropoda, sedentary Polychaeta and Bivalvia. The numbers of most groups returned to normal within a year except Echinoderms which recovered slowly and Amphipods which had not recovered after one year (Jacobs, 1980). As noted for the intertidal *Zostera* biotope above, removal of oil intolerant gastropod

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						grazers may result in smothering of seagrasses by epiphytes. Jacobs (1980) noted a larger algal bloom than in previous years after the Amoco Cadiz spill in Roscoff, probably as a result of increased nutrients (from dead organisms and breakdown of oil) and the reduction of algal grazers. However, in his study the herbivores recolonised and the situation returned to 'normal' within a few months. Due to the importance of grazers in maintaining the seagrass community and due to the differing sensitivity between seagrass and grazers to hydrocarbons both components were assessed. *Z. marina* was assessed as having 'High' resistance to hydrocarbon contamination and, due to the lack of impact, 'High' recovery, so they are categorised as 'Not Sensitive'. The grazer community is assessed as having no resistance to the same pressure and high recovery (within 2 years) so that sensitivity is assessed as 'Medium'.
	Introduction of antifoulants	Introduction of antifoulants			NEv	In a review of environmental impacts of aquaculture on sensitive areas, including seagrass beds, Huntingdon et al. (2006) stated that pollution arising from man-made chemicals, such as anti fouling agents, may in certain areas constitute a substantial problem to seagrass performance and survival (although no specific evidence was cited). In their sensitivity assessment of sublittoral seagrass beds on sediments, these authors rated the tolerance to chemical use related to aquaculture as low, recoverability as low and overall sensitivity as high. *Zostera marina* is known to accumulate Tributyltin (TBT) and heavy metals but no direct harmful effects have been recorded (Wilding and Hughes, 2010). TBT contamination is likely to adversely affect grazing gastropods resulting in increased algal growth, reduced primary productivity and potential smothering of the biotope (Tyler-Walters and Wilding, 2008b). However, the use of TBT has not been permitted on aquaculture installations for over 20 years in Ireland (Marine Institute, 2007). Antifoulants are not always used in aquaculture and mechanical cleaning of nets/equipment is often preferred (Marine Institute, 2007). Where antifoulants are used to prevent fouling of cages they are usually, copper based. Zinc may also be an active ingredient in some products. Laboratory experiments have shown that *Z. marina* accumulate and biomagnify heavy metals and that these can lead to significant impacts on growth (Brix and Lyngby, 1984) The uptake of Cd, Cr(III), Cu, Hg, Pb and Zn in different parts of seagrass *Zostera marina* L. and their effect on growth were studied in laboratory experiments. Seagrass plants were

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						incubated up to 19 d in 0.1, 0.5, 5.0 and 50 µM-seawater solutions of the respective metals. In all experiments a rapid increase in tissue concentrations of the metals was recorded. In the 0.1 and 0.5 µM-experiments the uptake of Cd and Zn was greatest in the stem+leaves, whereas the uptake of Cu, Hg and Pb was greatest in the roots. The concentrations of the metals in the plant tissue were up to 1850 times the initial concentrations in the water. The uptake capacity by the stem + leaves and rhizomes for the respective metals decreased in the order: Zn ≥ Cu > Cd > Hg ≥ Pb. In the roots a greater absorption capacity of Hg was recorded. The growth of seagrass was significantly inhibited by Cd, Cu, Hg and Zn and the toxicity of the metals decreased in the order: Hg ≥ Cu > Cd ≥ Zn > Cr (III), Pb. In the copper and mercury experiments release of organic compounds to the water was recorded. However it should be noted that no negative effects on productivity could be shown in areas of high *in situ* levels of zinc, lead and cadmium (Hoven et al. 1999, Marie-Guirao et al. 2005, cited from Bjork et al. 2008). Some members of the invertebrate communities associated with seagrass beds may be more adversely affected by heavy metal contamination (Wilding and Hughes, 2010). Herbicides are commonly incorporated into antifouling paints to boost the efficacy of the compound towards algae. Previous investigations have identified environmental concentrations of these herbicides as being a threat to seagrasses. The toxicity of Irgarol 1051 (2-(tert-butylamino)-4-cyclopropylamino)-6-(methylthio)-1,3,5-triazine) and Diuron (3-(3',4'-dichlorophenyl)-1,1-dimethylurea) has been assessed singly and in-combination on *Zostera marina* growth. Plants exposed to Irgarol 1051 and Diuron showed a significant reduction in growth at concentrations of 1.0 and 5.0 µg/l, respectively. When *Z. marina* was exposed to mixtures, the herbicides commonly interacted additively or antagonistically, and no significant further reduction in photosynthetic efficiency was found at any concentration when compared to plants exposed to the individual herbicides. However, on addition of the Diuron EC20 to varying Irgarol 1051 concentrations and the Irgarol 1051 EC20 to varying Diuron concentrations, significant reductions in Fv:Fm were noted at an earlier stage. The growth of plants exposed to Diuron plus the Irgarol 1051 EC20 were significantly reduced when compared to plants exposed to Diuron alone, but only at the lower concentrations. Growth of plants exposed to Irgarol 1051 and the Diuron EC20 showed no significant reduction when compared to the growth of plants exposed to Irgarol 1051

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						alone. Despite the addition of the EC20 not eliciting a further significant reduction when compared to the herbicides acting alone for most of the mixtures, the lowest observable significant effect concentration for growth and photosynthetic efficiency decreased to 0.5 µg/l for both herbicides. Irgarol 1051 and Diuron have been shown to occur together in concentrations above 0.5 µg/l, suggesting that seagrasses may be experiencing reduced photosynthetic efficiency and growth as a result (Chesworth et al. 2004). No evidence is available to assess the response of *Zostera* to copper and zinc contamination at the benchmark level and therefore a score on 'No Evidence' is provided in the sensitivity matrix.
Physical pressures	Introduction of litter				NA	Not assessed. No benchmark available for this pressure.
	Prevention of light reaching seabed/features	Shading from aquaculture structures, cages, trestles, longlines	N (**)	L-M (**)	H-VH (**)	Light attenuation is a major factor controlling the depth limits of seagrasses (Duarte, 1991) the section above regarding turbidity effects contains more information relevant to this interaction. Light availability is not only influenced by shading, depth, and turbidity, but also by seagrass shoot density and the reflectance of the sediment, which is higher for sand than for muddy sediments (Zimmerman and Mobley, 1997). Shading by farm structures could reduce the amount of light reaching the seafloor, with implications for the growth, productivity, survival and depth distribution of ecologically important primary producers such as seagrasses (Forrest et al. 2009). In a review of the impacts of oyster cultivation in estuaries, these authors highlighted the discrepancy in the evidence relating to the effect of shading on seagrass beds beneath oyster farms. For example, from studies that reported negligible effects on seagrass beds beneath oyster farms (e.g. studies by Crawford, 2003 in Australia; Ward et al. 2003 in Mexico), they inferred that shading effects in such cases were of little significance. However, other studies have described adverse effects on seagrass beneath oyster racks and suggested shading as a possible cause (e.g. Everett et al. 1995, study in USA). Despite the absence of clear evidence for adverse effects from shading, Hewitt et al. (2006) demonstrated that a small reduction in cover of New Zealand seagrass (*Zostera muelleri*) was theoretically possible because of shading from planned long-line oyster cultures. Burke et al. (1996) reported that experimental shading of *Z. marina* for only 3 weeks in the spring

Pressure		Benchmark	Resistance (Confidence)	Resilience (Confidence)	Sensitivity (Confidence)	Evidence/Justification
						growing season reduced non-structural carbohydrate concentrations in the leaves, rhizomes and roots by 40–51%, and reduced stored potential non-structural carbohydrate reserves by 66%. Forrest et al. (2009) stated that shading effects are conceivably important where oyster farms are placed across seagrass habitats in environments of relatively high water clarity, and in locations (e.g. well-flushed systems) where other ecological effects (especially those from sedimentation and biodeposition) are minimal. The incremental reduction in incident light by shading may be, however, also more important in turbid systems where the depth distribution of macrophytes is already light limited (Dumbauld et al. 2009 cited in Forrest et al. 2009). Clear evidence on the quantitative impact of shading on seagrass is not available and some of the available studies have taken place in areas where levels of light irradiance would be likely to be higher than in Irish waters. Given the requirement of light for photosynthesis long-term shading is considered to lead to the death of plants within the footprint of this effect. Resistance is assessed as ‘None’. Recovery is assessed as ‘Low to Medium’ and will be modified by the spatial scale of the impact, recovery is likely to be more rapid where the impact area is small and recovery takes place by vegetative growth. Sensitivity is categorised as ‘High- Very High’.
	Barrier to species movement					Not relevant to SAC habitat features.

Table VIII.10 Confidence Levels

Pressure	Quality of Information Source	Applicability of Evidence	Degree of Concordance
Surface Disturbance	*** (>5)	**	**
Shallow Disturbance	*** (>5)	**	***
Deep Disturbance	*** (>5)	***	***
Trampling - Access by foot	***(4)	**	***
Trampling - Access by vehicle	***	***	***
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	***(>5)	N/A	N/A
Changes to water flow			
Changes in turbidity/suspended sediment - Increased	***(>5)	***	***
Changes in turbidity/suspended sediment - Decreased	*	N/A	N/A
Organic enrichment - Water column	*** (>5)	**	**
Organic enrichment of sediments	*** (>5)	**	**
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	** (1)	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		
Introduction of hydrocarbons	***(4)	**	***
Introduction of antifoulants	No Evidence		
Introduction of litter			
Prevention of light reaching seabed/features	** (8)	**	**
Barrier to species movement	Not Exposed		

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