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Marine Rocky Habitat Ecological Groups and their Sensitivity to Pressures Associated with Human Activities

Maher, E. & Alexander, D.

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For further information please contact:

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

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Summary

Seabed habitats are under pressure from numerous and varied anthropogenic activities. Understanding the sensitivity of sublittoral and circalittoral rock habitats is crucial for effective management of the marine environment, and decision makers need to have access to suitable tools for identifying the state of marine biodiversity and habitats.

The sensitivity of ecological groups in marine sedimentary habitats has been previously assessed by Tillin and Tyler-Walters (2013) but as yet, the sensitivity of ecological groups in rocky habitats has not been examined. This project aims to identify ecologically similar groups of species based on trait characteristics within the sublittoral rock habitat. Alexander *et al* (2015) previously developed conceptual ecological models (CEMs) using ecological groups made up of characterising species for sublittoral rock habitats; the scope of this project is to reconsider and supplement the evidence gathered during that project to categorise the species present in the context of assessing sensitivity.

The project scope includes habitats defined as 'sublittoral rock'. This definition includes those habitats that fall into the EUNIS Level 3 classifications A3.1 Atlantic and Mediterranean high energy infralittoral rock, A3.2 Atlantic and Mediterranean moderate energy infralittoral rock, A3.3 Atlantic and Mediterranean low energy infralittoral rock, A4.1 Atlantic and Mediterranean high energy circalittoral rock, A4.2 Atlantic and Mediterranean moderate energy circalittoral rock, and A4.3 Atlantic and Mediterranean low energy circalittoral rock as well as the constituent Level 4 and 5 biotopes that are relevant to UK waters. A species list of characterising fauna to be included within the scope of the models was defined in Alexander *et al* (2015).

Previously, work by Alexander *et al* (2015) defined ecological groupings of sublittoral rock habitat species based on their ecology. These groupings did not consider any traits specifically relating to the sensitivity of species to pressures exerted by anthropogenic activities. A literature review was conducted as part of this project as a continuation of the review completed by Alexander *et al* (2015). Evidence relating to the habitat preference and biological traits (including those influencing sensitivity) of characterising species was gathered following an iterative process and was used to inform the designation of ecological groups.

Habitat preference and biological traits were examined using multivariate analysis to assist with identifying ecologically similar groups of characterising species. Assigning the ecological groups using this method ensured that the groups were not species specific but contained species that were ecologically similar. The inclusion of species characteristics which influence sensitivity ensured that characterising species within the groups will respond to pressures in a similar way, allowing sensitivity scores to be expressed as a single value rather than a range.

Nine ecological groups were proposed to represent the characterising species found in sublittoral rock biotopes. These were largely based upon analyses of biological traits and habitat preferences though expert judgement was also used to group species based upon taxonomic form. These ecological groups will be used in Phase 2 of the project to characterise the responses of sublittoral rock habitats to pressures caused by anthropogenic activities.

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1 Introduction

The Joint Nature Conservation Committee (JNCC) commissioned this project to develop and improve the understanding of the effects that human activities have on sublittoral rock habitats in the UK. This report represents Phase 1 of this project and focuses upon the recommendation and rationale of ecological groups based upon species characteristics previously defined by Tillin and Tyler-Waters (2013) and Alexander *et al* (2015). Phase 2 of the project will follow this and will outline the findings of the sensitivity assessment conducted on the recommended ecological groups. By contributing to our understanding of habitats responses to pressures caused by anthropogenic activities this work will support the management advice of Marine Protected Areas (MPAs), UK marine monitoring and further assessments.

A range of factors determine how species reacts to pressures in the marine environment. These are broadly determined by species characteristics. Biological traits and habitat preferences of a species dictate resistance and resilience and ultimately sensitivity. As such, the crucial aspects of these traits must be understood. The definitions of sensitivity, resistance and resilience can be seen below in Table 1.

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

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

Species features that influence resistance to a particular pressure have been classified as ‘response traits’ (Diaz & Cabido 1997; Tillin & Tyler-Walters 2013). As in Tillin and Tyler-Walters (2013), this project looks to identify ecological groups of species that have similar responses to sensitivity.

In order to achieve this, it is essential that potentially sensitive species are assessed in relation to their broadscale primary habitats. As such, the concept of ecological groups has been developed by JNCC through Tillin and Tyler-Walters (2013) following the previously commissioned work Tillin and Tyler-Walters (2010), which assessed the sensitivities of broadscale sedimentary habitats on the continental shelf and the deep-sea. The assessments within Tillin and Tyler-Walters (2010) were on a scale which resulted in the understanding that habitats have a range of sensitivities in relation to the various pressures applied to them. To assess the impacts of human pressures in terms of the sensitivity of individual species was not deemed practicable by Tillin and Tyler-Walters (2013) due to a lack of available information and the number of assessments that would be required. To reduce the number of assessments needed, species were therefore organised in to ecological groups alongside other species that were probable to respond to pressures in a comparable manner. By grouping species according to shared biological traits, the investigation ensured that the groups were not species specific and that the sensitivity assessment result for each group could be presented as a single score rather than a range. This method allowed for the assessment of human pressures on groups of species which were impacted in a similar manner, though the pathways by which the impacts were delivered may have been variable. The approach of organising characterising species in to ecological groups for sensitivity assessment is adopted in this project for sublittoral rock habitats.

Alexander *et al* (2015) developed a series of conceptual ecological models (CEMs) for sublittoral rock biotopes as a potential management tool to assist with the identification of indicators which may be useful for monitoring purposes. As a result of this work, seven ecological groups were identified within the sublittoral rock habitat. These were:

- Macroalgae
- Temporarily or permanently attached active filter feeders
- Temporarily or permanently attached passive filter feeders
- Bivalves, brachiopods and other encrusting fauna
- Tube building fauna
- Scavengers and predatory fauna
- Non-predatory mobile species

These groups were however determined on the basis of ecological function rather than sensitivity response and as such only defined ecological groups based upon a reduced number of traits that were specifically applicable to the modelling project. This study does not re-examine the previously identified ecological groups in great detail but focuses on proposing ecological groups based upon sensitivity response in order to assess the potential impacts of human pressures. To achieve this, additional traits applicable to sensitivity to pressures are considered.

Sublittoral rock habitats are highly diverse and widespread around the UK. The infralittoral zone typically supports various algal communities that may include kelp species and erect seaweeds with associated understory fauna. Circalittoral rock habitats tend to be dominated by sessile (permanently attached), sedentary (temporarily attached) and mobile fauna with algal crusts. Both biological zones may be subject to varied exposure to wave energy and tidal streams and may comprise topographically complex environments that support a large diversity of marine life (Connor *et al* 2004).

The sublittoral rock habitat covers two biological zones at EUNIS (European Nature Information System) Level 2: infralittoral rock and other hard substrata, defined as those areas between mean low water and the maximum depth at which 1% light attenuation reaches the seabed; and circalittoral rock and other hard substrata, defined as the zone between which 1% light attenuation reaches the seabed and the bottom of the wave base (approximately 50-70m depth) (Cochrane *et al* 2010; McBreen *et al* 2011). The distribution of EUNIS Level 2 biotopes which represent infralittoral and circalittoral rock habitats in the UK is shown in Figure 1.

Two biotopes with very restricted extent have been excluded from the project scope: A3.114 Sparse *Laminaria hyperborea* and dense *Paracentrotus lividus* on exposed infralittoral limestone; and A4.136 *Suberites* spp. with a mixed turf of crisiids (west coast of Ireland) and *Bugula* spp. on heavily silted moderately wave-exposed shallow circalittoral rock (east of the Isle of Anglesey).

A complete list of the 57 Level 5 EUNIS biotopes and their corresponding Level 2, 3 and 4 biotopes included in the scope of this project are presented in Appendix 1.

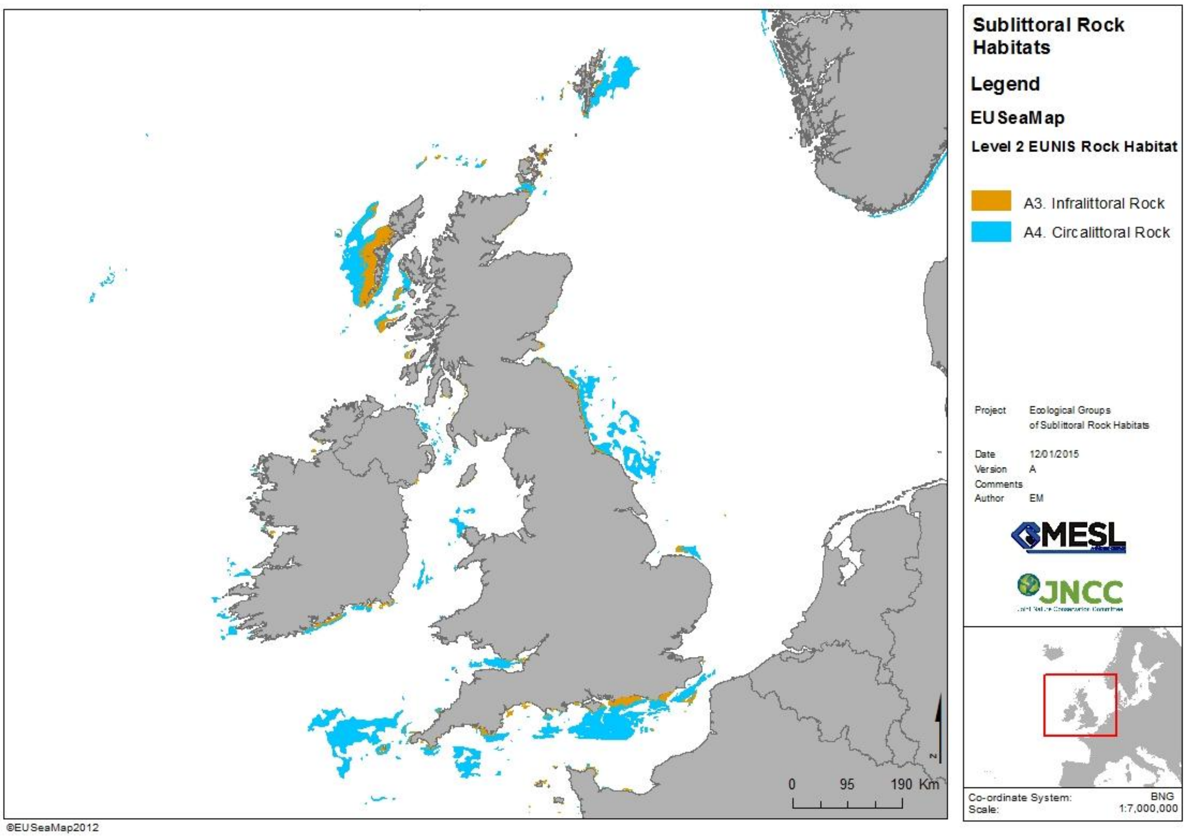

Figure 1. The distribution of sublittoral rock habitats around the UK differentiated by depth zone. Data are taken from the EUSeaMap broad-scale modelled habitat mapping project[1]

1.1 Project Aims

The aim of this project was to identify groups of ecologically similar species from sublittoral rock habitats which were likely to display similar sensitivities to defined pressures based on their species characteristics or biological traits and habitat preferences. The groups were identified using the process of creating ecological groups as described in Tillin and Tyler-Walters (2013), and where possible groups were compatible with those previously suggested in Alexander *et al* (2015). Where groups differ between Alexander *et al* (2015) and this work, or where additional groups were needed based on sensitivities information, sub-groupings were considered.

The specific project objectives are outlined below:

- Undertake a literature review to support the ecological groups and in doing so gather information on species characteristics which influence the sensitivities of species within sublittoral rock habitats. This is then to be used in addition to the study conducted by Alexander *et al* (2015).
- Produce a coded trait matrix based on the evidence collated during the literature review process.
- Determine ecological groups for sublittoral rock habitats using multivariate analysis techniques and where necessary expert judgement.
- Produce detailed descriptions of the ecological groups proposed and draw comparisons where possible with previous work by Alexander *et al* (2015).

[1] http://jncc.defra.gov.uk/page-5020

2 Developing Ecological Groups

2.1 Species Selection

The ecological groups defined in this report are based upon 57 key and characterising Level 5 EUNIS biotopes all of which fall beneath the umbrella of either 'Infralittoral Rock' or 'Circalittoral Rock' biotopes at EUNIS Level 2. The full list of biotopes considered by this project is presented in Appendix 1 and the full species list is in Appendix 2. From the selected biotopes Alexander *et al* (2015) identified 76 characteristic species of sublittoral rock habitat. These species have been used as the basis for this project. The full list of species included in the project scope is presented in Appendix 1.

Characterising species were selected by a set methodology as described in Alexander *et al* (2015). An initial review of all taxa associated with the project biotopes yielded a list of 255 species as described in the biotope descriptions (Connor *et al* 2004); though this was deemed too numerous for assessment within the constraints of the project. In addition, considering all of these species within the scope was not considered suitable as some may not be wholly representative of rock habitats, either occurring across many biotopes including sedimentary types, or conversely being restricted at low abundances to one or two biotopes. As such, species understood not to be fully representative of sublittoral rock habitats were removed from the list.

The number of taxa was then reduced to a manageable figure through the application of an iterative process using information sourced from the initial habitat and biotope review. All taxa named in the biotope titles were automatically included in the project species list, in addition to those listed as important in the biotope descriptions (Connor *et al* 2004). Species which were not identified as characterising within a biotope were not included. The species that remained following this initial iterative process were sorted by considering the energy levels and the depth zone of the habitats they occupied (high, moderate and low energy; infralittoral or circalittoral rock). The functional groups were then refined based on a combination of taxonomic order, growth form and feeding preference. Using this approach ensured that at least one species from each taxonomic group was represented within each energy level and habitat type and therefore eventual assessments of the species would be applicable to a wider range of fauna and macroalgae. Where multiple species from the same functional group existed and inhabited the same depth zone/energy habitat, preference was given to species considered more common (using expert judgement), or the species for which traits information was available via the MarLIN Biological Traits Information Catalogue database[2]. In situations where expert judgement was applied, benthic taxonomists with specialist knowledge of benthic species in British waters were consulted by the project team.

Two Annelida which were recurring within the biotopes and considered representative of key polychaete families during species selection were Harmothoe and Polydora. The biotope classification does not however assign species to these genera in the relevant biotope descriptions for sublittoral rock. As it was deemed important to identify the traits of the characterising Harmothoe and Polydora species to conduct the sensitivity analysis, specific species were assigned by the project team; *Harmothoe impar* and *Polydora ciliata* were chosen as the most representative. Both *H. impar* and *P. ciliata* were known to be distributed across a range of habitats relevant to the project and information on biological and habitat traits was readily available in relevant literature and the MarLIN BIOTIC database. Trait information was sourced for both species and information was duly updated in the faunal and coded trait matrices for the project (included in the literature review and ancillary data pro forma accompanying this document).

[2] http://www.marlin.ac.uk/biotic

2.2 Species Traits

It is acknowledged that species which demonstrate characteristics which respond in a similar fashion to pressures caused by anthropogenic activities can be categorised in distinct ecological groups (Tillin & Tyler-Walters 2013). The species characteristics which have been used to define ecological groups in this project are based upon those determined by Alexander *et al* (2015) and Tillin and Tyler-Walters (2013) but have been reassessed for the range of human pressures relevant to sublittoral rock habitats as detailed below. The traits used in this study have been selected on the basis of influencing biological function, with the eventual purpose of determining the sensitivity of proposed ecological groups. A total of 12 species characteristics have been identified for use in this project, the full list of which is presented in Tables 2 and 3.

Standardised trait categories based on those indicated in the MarLIN BIOTIC database were utilised wherever possible in the literature review. Both in this project and in previous works, species characteristics have been selected according to the relevance of a trait in determining ecological groups based upon sensitivity i.e. would the trait have bearing upon the resistance or resilience of a species to pressures. For example, the biological trait ‘mobility’ has been used as fauna that are mobile are likely to demonstrate higher resilience to pressures due to their potential to relocate in response to an environmental change. Due to the differing nature of this project to previous works, some changes have been made to the traits and trait categories as used by Tillin and Tyler-Walters (2013) and Alexander *et al* (2015). For example, ‘epibenthic’ and ‘epiphytic’ have been added as classes of the trait ‘environmental position’. These newly added variables are common physical descriptions for the environmental positions that macroalgae, bryozoan, hydroid and crustacean species occupy and are regularly listed as standard categories in literature and databases including BIOTIC. These biological assemblages would not have featured as characterising species in sedimentary habitats as they are most commonly found in rocky sublittoral environments. ‘Algae’ was added as a class within ‘substratum preference’ as bryozoan species such as *Membranipora membranacea* use macroalgae for their primary substratum. Many other attached and mobile species from amphipods to cnidarians also utilise algae as well as hard substrates for primary and secondary habitats. It was not likely to have been considered as a key substrate preference in Tillin and Tyler-Walters (2013) as sedimentary habitats are largely devoid of macroalgae which are suitable for establishment.

Table 2. Biological traits used to define Ecological Groups for species associated with sublittoral rock habitats. Full definitions are included in Sublittoral Rock EG Literature Review and Ancillary Information' spreadsheet that accompanies this report, available from JNCC. Traits were identified for inclusion based upon the methodology in Alexander *et al* (2015) and Tillin and Tyler-Walters (2013).

Biological Trait	Information Source	Type of Variable
Mobility	BIOTIC, MarLIN, supplemented with literature review	Permanently attached; temporarily attached; burrower; crawler; swimmer
Resource capture (feeding type)	BIOTIC, MarLIN, supplemented with literature review	Passive suspension feeder; active suspension feeder; surface deposit feeder sub-surface deposit feeder; scavenger; grazer; predator; primary producer
Environmental position	BIOTIC, MarLIN, supplemented with literature review and expert judgement	Infauna; epibenthic; epilithic; epifauna; epiphytic
Habit	BIOTIC, MarLIN, supplemented with literature review and expert judgement	Attached; free-living; burrow-dwelling; tubicolous; erect
Maximum Body Size	BIOTIC, MarLIN supplemented with literature review	Very small (<1cm); small (1-2cm); small-medium (3-10cm); medium (11-20cm) medium-large (21-50cm); large (>50cm)
Lifespan	BIOTIC, supplemented with literature review	<1 year; 1-2 years; 2-3 years; 3-5 years; 6-10 years; 11-20 years; 21+ years
Flexibility	BIOTIC, supplemented with literature review and expert judgement	None; low (0-9°); intermediate (10-45°); high (>45°)
Fragility	BIOTIC, supplemented with literature review and expert judgement	Fragile; intermediate; robust

Table 3. Habitat preferences used to define ecological groups for species associated with sublittoral rock habitats. Full definitions are included in 'Sublittoral Rock EG Literature Review and Ancillary Information' spreadsheet that accompanies this report, available from JNCC. Traits were identified for inclusion based upon the methodology in Alexander *et al* (2015) and Tillin and Tyler-Walters (2013).

Habitat Traits	Information Source	Classes
Substratum preference	BIOTIC supplemented with literature review	Bedrock; cobbles; gravel; sand; mixed; algae
Tidal stream preferences	BIOTIC, MarLIN, supplemented with literature review and expert judgement	Very weak (negligible); weak (<1kn); moderately strong (1-3kn); strong (3-6kn); very strong (>6kn)
Salinity preference	BIOTIC supplemented with literature review and expert judgement	Low (<18psu); reduced (18-30psu); variable (18-40psu); full (30-40psu)
Wave Exposure	BIOTIC supplemented with literature review	Extremely exposed; very exposed; exposed; moderately exposed; sheltered; very sheltered; extremely sheltered; ultra sheltered

2.3 Literature Review and Confidence Assessment

An extensive literature review into the traits of the species identified as part of this project was conducted as part of the Sublittoral Rock CEM project (Alexander *et al* 2015). This project however did not include the full list of species characteristics necessary to define ecological groups on the basis of sensitivity, as per the methodology described in Tillin and Tyler-Walters (2013).

The information gathered in the literature review for the Sublittoral Rock CEM project has therefore been revised and additional information for all the species characteristics deemed relevant to the sensitivity assessment has been included. The full list of traits considered in this project is shown in Tables 2 and 3. The literature review revealed the trait characteristics which had been used in the rock CEM project and were taken from the MarLIN BIOTIC standard definitions were still appropriate for use when considering the characterising species in terms of sensitivity. The additional traits which were used in Tillin and Tyler-Walters (2013) were also judged applicable for rock habitats when literature sources were assessed. Likewise, the variables and class categories which had been selected based upon previous works were still fitting though one class was added to substratum preference and two variables were added in environmental position to reflect the literature. Two additional biological traits and one additional habitat trait which required a revised literature review were:

- Fragility
- Flexibility
- Wave exposure preference

A separate literature review was conducted to gather information on these additional traits and the supplementary variables included in the 'environmental position' trait. The majority of biological trait information was obtained from peer-reviewed and grey literature (such as the MarLIN BIOTIC database) and from taxonomic identification books and keys. Predominantly, the information obtained from journals was research that had been carried out internationally from comparable temperate regions (Spalding *et al* 2007), but in most cases can still be applied to UK species. Standard categories for species traits were used during the literature review according to those described in MarLIN BIOTIC. Where literature could not be found to provide appropriate trait information from BIOTIC or other sources, expert knowledge was applied by experienced benthic taxonomists. This mostly applied to the traits 'fragility' and 'flexibility' for which fewer written sources were available. This knowledge was based upon a structured process that involved examining species with similar fragility and flexibility properties for which information was available, and examining this in the context of the species in question.

The confidence assessment undertaken as part of Alexander *et al* (2015) was also updated with new information gathered as part of the literature review using the methodology where sources were scored based on their quality and applicability. Any new literature sourced for existing traits, classes and variables was also subject to a confidence assessment. Evidence of the source confidence is presented in the 'Sublittoral Rock EG Literature Review and Ancillary Information' available from JNCC.

Predominantly the information sourced was of a medium-high confidence. Several gaps were apparent within the trait information literature and where this was the case expert judgement was applied to infill the gaps and make the ecological group assessment as robust as possible. The literature and knowledge gaps were deemed too numerous for the trait 'lifespan' to be included in the scope of the project and as such it has not been used to assist in the formation of ecological groups. Multivariate analyses conducted both with and without the limited 'lifespan' data gathered demonstrated minimal variation. Had sufficient data been available for the species included in the scope of the project, lifespan may have been a more influential factor and been used when grouping species according to trait. Literature and knowledge gaps have been captured in the faunal traits summary which summarises for which species trait information could not be sourced and in which cases expert opinion has been exerted. This is included in the 'Sublittoral Rock EG Literature Review and Ancillary Information' spreadsheet that accompanies this report, available from JNCC.

2.4 Trait analysis

Information gathered during the literature review and from the work of Alexander *et al* (2015) was used to populate a trait-species matrix. Following the methodology outlined in Tillin and Tyler-Walters (2013), the biological trait information for each species was assigned a numerical value so that the species-trait matrix could be interrogated statistically using multivariate analysis tools and PRIMER V6 software. Where a species expressed one specific variable or class within a characteristic, a score of 1 was assigned to the relevant field. Where a species could express several trait categories, the score of 1 was split equally between all relevant fields. For example, when considering the biological characteristic 'Resource Capture'; the bryozoan *Electra pilosa* is recorded as an active filter feeder only and thus receives a score of 1 within this field; the barnacle *Balanus crenatus* is recorded as both an active and a passive filter feeder, so receives a score of 0.5 in each relevant field and the polychaete *Harmothoe impar* is recorded as a scavenger, a grazer and a predator and thus receives a score of 0.33 in each relevant field. This process was repeated for all species and for all traits until the matrix was completed. Empty fields in the coded trait matrix where a field was left blank if it was not relevant to a species were assigned a score of zero as the analytical software does not allow missing variables. The coded trait matrix is available in the ‘Sublittoral Rock EG Literature Review and Ancillary Information’ spreadsheet that accompanies this report, available from JNCC.

2.5 Data Analysis

The fully scored species-trait matrix was imported to PRIMER v6 statistical software (Clarke & Warwick 2001) for analysis. A Bray-Curtis similarity matrix was created based on the values for each trait. The trait data were already considered to be standardised as the sum of the contribution to each trait category equalled 1 and no further data transformations were deemed necessary. Patterns and similarities within the species traits were explored using both non-metric multidimensional scaling (nMDS) plots and cluster analysis (based on group averaging). Combinations of the traits were plotted in PRIMER using a variety of factors to best determine how the groups should be formed.

Following the methods of Tillin and Tyler-Walters (2013), multiple trait scenarios were trialled in attempt to explore the best method of defining the ecological groups and to ensure that the eventual ecological groups were formed based upon the most appropriate traits. This was structured using the questions outlined below:

- Can ecological groups be defined based upon habitat preferences alone? This question will look to ascertain whether distinct groups of species are associated with particular habitat types (substratum preference, tidal stream preferences, salinity preferences and wave exposure).

- Can ecological groups be defined based upon biological factors alone? This question will investigate how life history and ecological traits (mobility, resource capture (feeding type), environmental position, habit, maximum body size, lifespan, flexibility and fragility) can affect the formation of ecological groups according to similarity.

- Can ecological groups be defined in terms of key biological life history traits in combination with habitat preferences? This question addresses the traits in questions 1 and 2 together.

These three questions are addressed in turn below.

2.5.1 Can ecological groups be defined on the basis of habitat preferences?

Using the habitat preference data, a number of ordinations were performed to determine if habitat traits alone were suitable for determining ecological groups. The habitat ordination in Figure 2 was conducted using all of the habitat preference data from each class (Table 3). An ordination was also conducted without the inclusion of salinity as salinity was considered to be less relevant to structuring infralittoral and circalittoral rock habitats, following the approach outlined in Tillin and Tyler-Walters (2013). There was however little difference in the resulting plot to the one shown in Figure 2 when salinity data were excluded; salinity was therefore included in the final plot as it was deemed better to include all available habitat data. The ordination indicates that habitat preference traits alone do not result in the grouping of similar species. A lack of clustering based upon substratum, tidal stream, salinity and wave exposure has resulted in overlapping of species which suggests that habitat preferences alone cannot be used as a mechanism for developing ecological groups. The biological trait ‘habit’ was used as a factor because the nature of habit is likely to exert a large influence over species which are grouped according to where they live in relativity to the substratum.

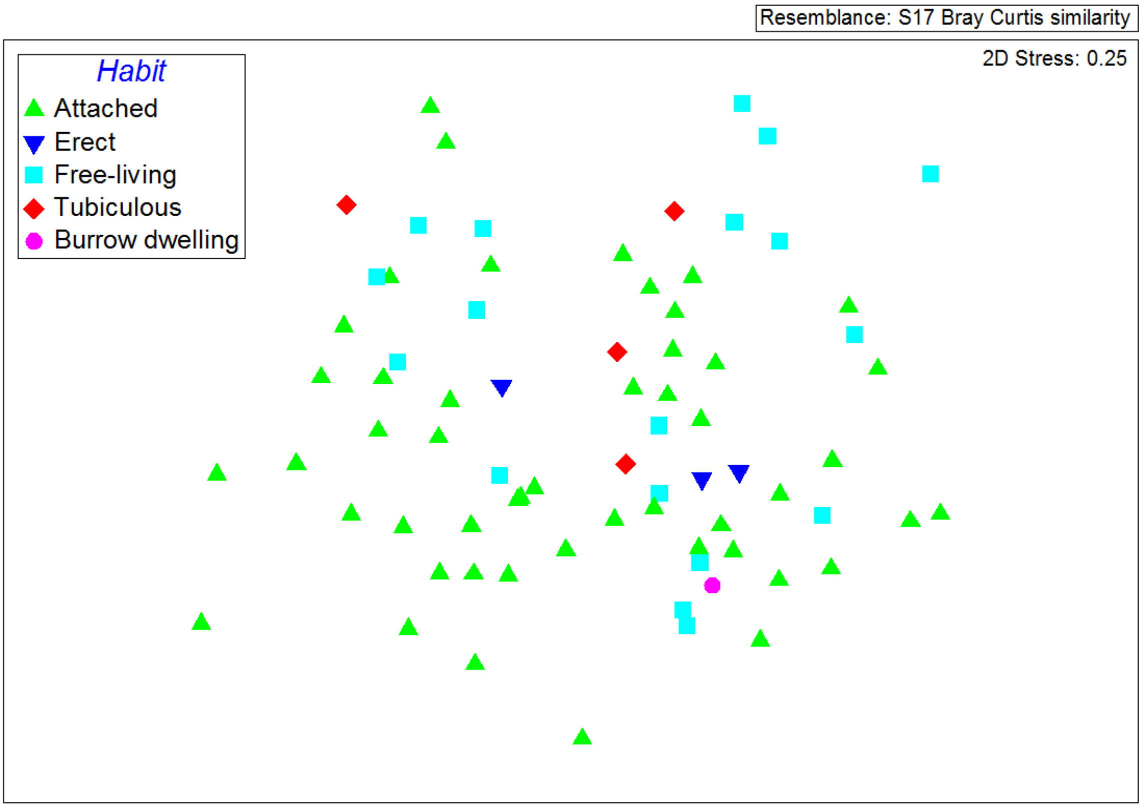

Figure 2. Preliminary nMDS ordination of habitat preferences based upon all habitat class information coloured according to habit. Each point represents a characterising species.

2.5.2 Can ecological groups be defined on the basis of biological factors?

Biological trait data were explored to determine whether or not biological life history and ecological traits alone were suitable for allocating ecological groups. All of the biological traits summarised in Table 2 (mobility, resource capture (feeding type), environmental position, habit, maximum body size, lifespan, flexibility and fragility) were included for the exploratory ordinations to answer the above question as all were judged as important when regarding the ecological structure of rock habitats. The resulting ordination plot is displayed using resource capture (feeding type) as a factor in Figure 3. Resource capture (feeding method) was selected because of the importance it plays in habitat arrangement and life history of species.

The ordination in figure 3 demonstrates that primary producers and suspension feeders form fairly distinct groups. This indicates that suspension feeders and primary producers (macroalgae) tend to be dissimilar in terms of biological traits compared to the other characterising species. Exploration of the species traits further revealed that habit and mobility were connected to the resource capture which impacted on the clustering of the species. For example, all macroalgae and suspension feeders are permanently attached as are many of the suspension feeders whereas many of the predators and scavengers are crawlers. An examination of the nMDS plot with species names displayed (not shown) also revealed that taxonomically related species were spatially grouped according to similarity of life history traits. This enforces the importance of ecological structure when assessing the potential designation of ecological groups. Using biological trait data produced an nMDS plot with more apparent clustering than was observed in the ordination containing just habitat preference data suggesting that similarity between species is more rooted in biological variables than habitat traits.

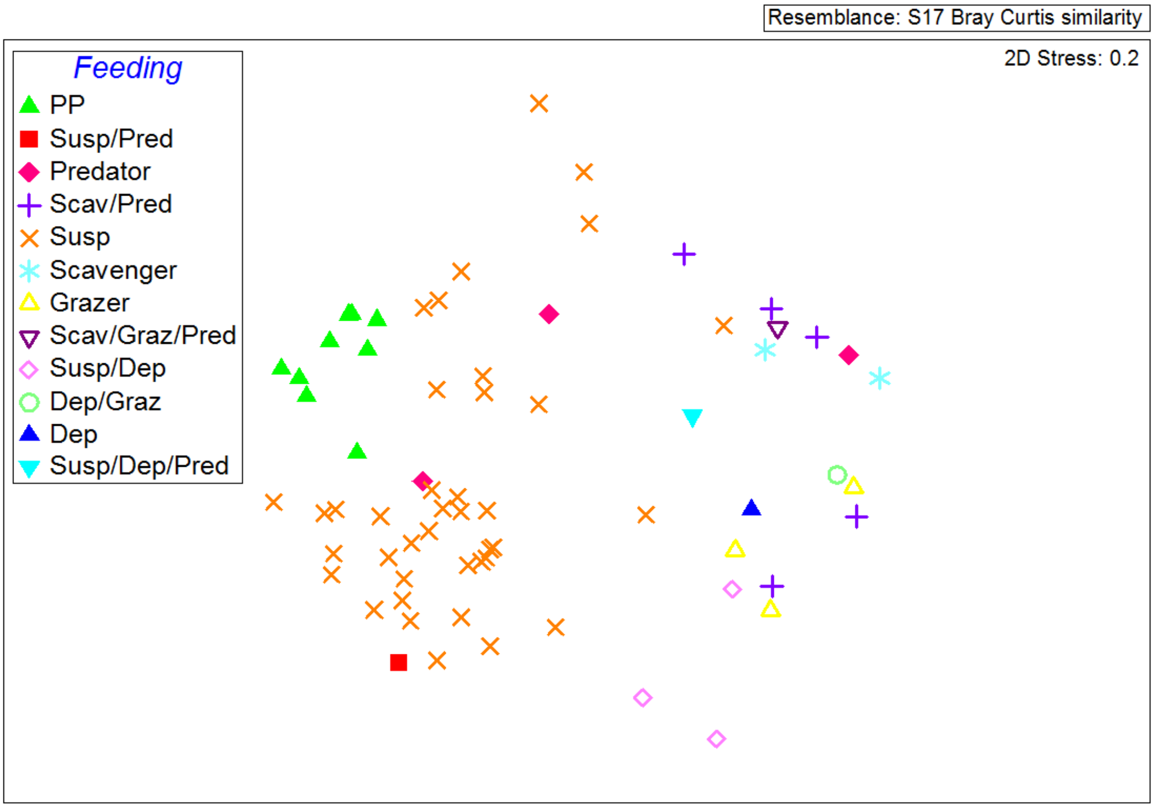

Figure 3. Preliminary nMDS ordination of biological traits coloured according to resource capture (feeding type). Each point represents a characterising species.

2.5.3 Can ecological groups be defined in terms of key ecological and life history traits in combination with habitat preferences together?

The nMDS ordination was re-run using biological and habitat preference traits combined. The resulting plot is shown in Figure 4. This approach investigated whether biological life history traits are interrelated with habitat preferences and whether ecological groups of species can be determined by examining both sets of traits.

As can be seen in Figure 4, the combination of the data from both biological and habitat preference traits results in a plot where some clustering is evident though there are still areas of overlap between species. It is also apparent that the ordinance of species in the combined habitat and biology traits nMDS somewhat resembles the plot that resulted from examining the biological traits alone, enforcing the importance of biological traits when examining habitat structure. The clustering of species based upon biological life history and habitat preference is apparent, though there is still some ambiguity surrounding solid groupings for some. For this reason, expert judgement was consequently applied by experienced taxonomists following the examination of the three questions outlined above to discern clear ecological groups.

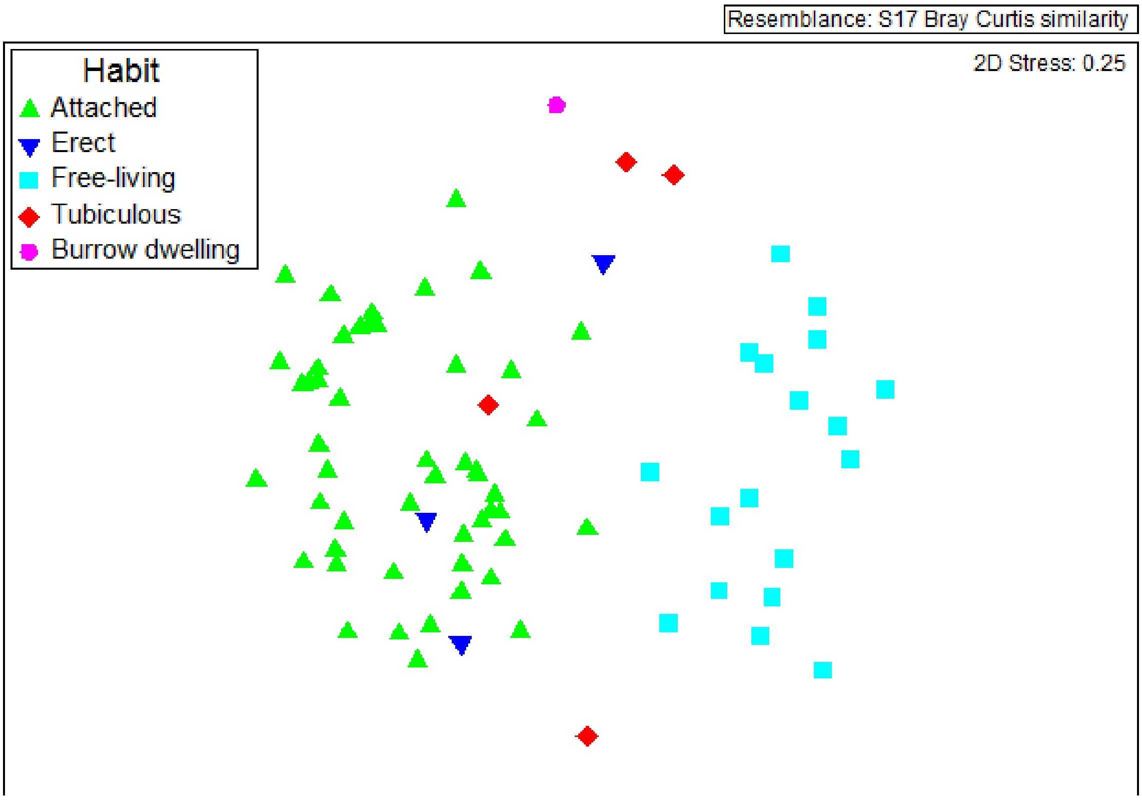

Figure 4. Preliminary nMDS ordination of habitat preferences and biological traits based upon trait information coloured according to Habit. Each point represents a characterising species.

2.6 Determining ecological groups using biological and habitat preference traits

Based on the results of the analyses presented above it was apparent that the multivariate techniques applied did not indicate a full complement of ecological groups. Where clusters were dispersed and no ecological groups were readily apparent on the nMDS plot, expert judgement was applied to identify linkages between species based upon traits associated with sensitivity. Predominantly, these traits included mobility, resource capture (feeding method), habitat and environmental position as these were deemed to be the most crucial traits when considering the structure of the habitats and the potential sensitivities of the groups to pressures. All of the species which did not assemble in to clear clusters shared life history or biological traits that became evident upon examination of the coded trait matrix, labelled dendrogram (Appendix 3) and a labelled nMDS ordination (Appendix 4). Primarily trait information was consulted when determining ecological groups although taxonomic form was also considered where necessary to pull together small groups based upon anatomical similarities or to separate large groups which could not represent all species efficiently in terms of sensitivity.

Many of the species loosely clustered together in the analyses were fauna that shared the mobility trait category of 'permanently or temporarily attached'. It was possible to define this 'attached' group into four sub-groups based on traits for fragility and nature of attachment as these were considered important traits for influencing sensitivity. Largely, standardised trait categories (Tables 2 and 3) were adhered to, though expert judgement was used to assign some groups such as the 'Attached – encrusting' group. 'Encrusting' was not a standard trait category used in the coded trait matrix but it was the most unifying and appropriate feature of overlapping species assigned to the 'attached' group. All species within this subcategory were distinct from those in the other subcategories belonging to the 'attached' group largely due to their encrusting forms which were considered to be very pertinent from a sensitivity perspective. Another instance in which expert judgement was applied was in the designation of the 'Bivalves and brachiopods' group. Though biological and habitat preference trait data did not cluster the species in this group very tightly on the nMDS, the species are biologically similar and are likely to be subject and reactive to similar pressures based upon their life history and ecology.

Figure 5 below shows the final ecological groups designated on the basis of biological and habitat preference traits. Each species has been colour coded according to its ecological group. The stress value of the nMDS plot shown in Figure 5 is moderate (0.25) and increased re-runs of the trait matrix data in PRIMER did not alter this. However, when viewed in 3D, the plot differs very little from the 2D representation, suggesting that the clusters displayed are a meaningful representation of the data. Similar stress values (0.24) were also recorded in Tillin and Tyler-Walters (2013). The dendrogram (Appendix 3) was also used to assist the ecological grouping which added further validity to the process.

It should be noted that the interpretation of the plots in PRIMER is subjective and based on the relative distances which are representative to dissimilarity between data points (in this case the species). Species that are plotted closer together in the ordination plots are more similar in terms of the selected traits than species that are further apart. The nMDS plot shown in Figure 2 indicates several distinct groups of species.

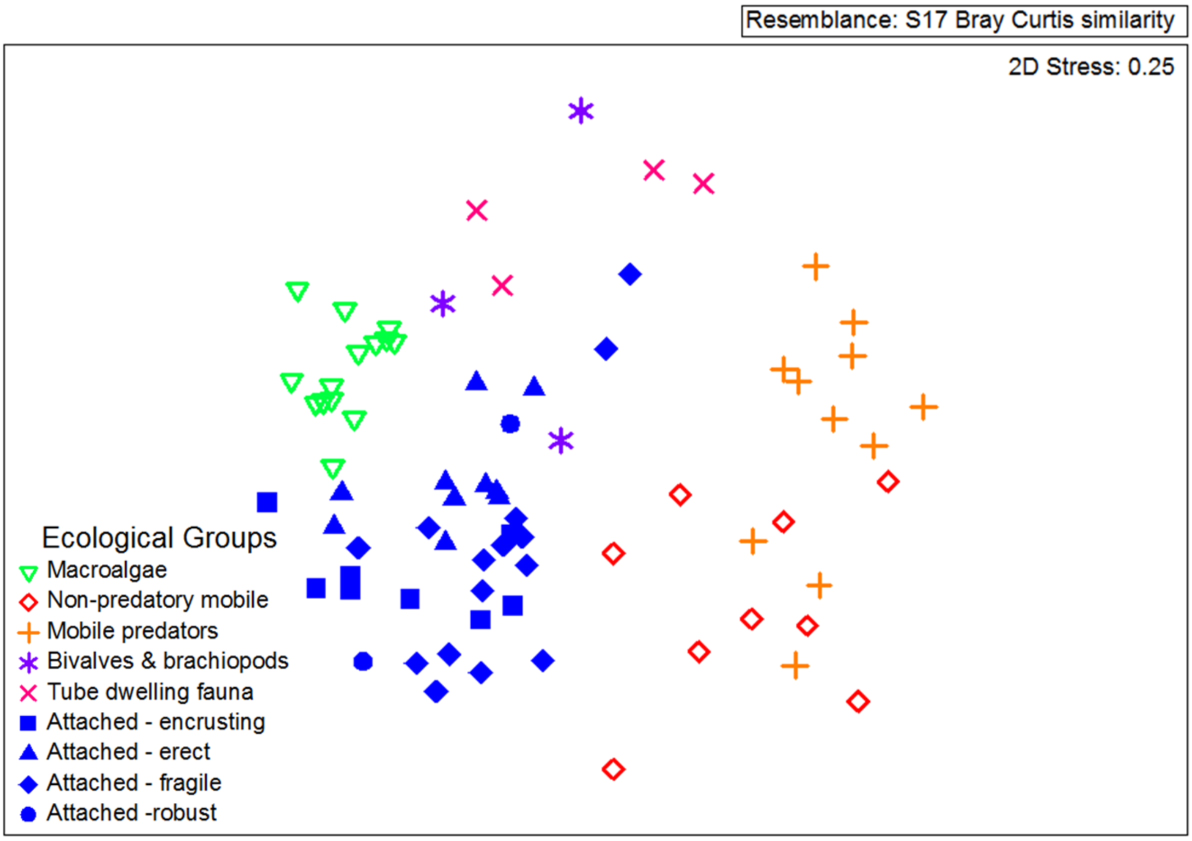

Figure 5. Non-metric multidimensional scaling ordination, shown in 2D format, based on Bray-Curtis similarity of coded traits for the selected project species. Colours show proposed ecological groupings defined using the outputs of the cluster analysis.

It should be noted that the data labels indicating group membership were added following the ordination, rather than representing *a priori* defined groups. The ecological groups are described in full in Section 4.

SIMPROF analysis was used to assist with the determining of ecological groups but resulted in a high number of outputs which were not useful for the purposes of the investigation.

2.7 Results summary

By examining the biological and habitat preference traits in combination it was possible to discern ecological groups which are appropriate for sensitivity assessment. Some ecological groups were readily apparent, while others were more difficult to assign. The ordinations demonstrated that there is a lot of overlap in similarity between species, especially where habitat preferences were concerned. Much of the overlap observed for species in terms of biological and habitat traits can be attributed to the mixed preferences for trait categories that they display. Similarity may have been more evident between species which demonstrate only a single preference for resource capture method for example. However, many species demonstrated multiple feeding methods or substrate preferences which created a higher possibility for variation between individual spices within a single habitat.

Visual analysis of the nMDS plots and dendrograms assisted with the identification of ecological groupings within the species. Some species appeared as outliers and could only be assigned to an ecological group with very careful consideration of the traits and potential sensitivities, involving a degree of expert judgement applied by experienced taxonomists and ecologists. This resulted in the creation of smaller, subgroups within some of the ecological groupings which reflected finer-scale similarities in sensitivity-related traits and ecology, between species.

3 Proposed Ecological Groups

Based on the trait matrix analyses conducted and the pragmatic expert judgement described above, the nine following ecological groups are proposed to form the basis of the sensitivity assessment in Phase 2 of the project. A full breakdown of the biotopes and species that are included in each group are presented in Appendix 1 and 2.

3.1 Ecological Group 1: Macroalgae

This group is entirely composed of macroalgal species which represent the primary producers in the sublittoral rock habitat. No faunal species are represented in this ecological group. Along with other primary producers, macroalgae form the basis of the food web and as such are a crucial group within the sublittoral rock habitat. They most commonly occupy the infralittoral region and attach to a range of substratum types (Connor *et al* 2004) though relatively clear water and suitable conditions for holdfasts to survive are prerequisite.

Though there is variation within the macroalgae represented in this project, most algal species are subject to similar environmental pressures and as such are likely to demonstrate comparable sensitivities to human pressures. Red, green and brown algal species are all represented within this group and this is likely to account for some of the variation between species.

3.2 Ecological Group 2: Non-predatory mobile species

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

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

The feather star species *Antedon bifida* and *Antedon petasus* are closely clustered yet are dispersed slightly from the main cluster of echinoderms in Group 2. This is most likely due to their similar environmental preferences and suspension feeding habits which differ from other echinoderms. The brittle star *Ophiothrix fragilis* is more closely grouped to *Echinus esculentus* than the feather stars which may be due to similar mobility methods (crawling) and the epifanual nature of both species.

Polychaetes
Polydora ciliata is the only polychaete and the only burrower in Group 2. It has been grouped according to its feeding habits as a suspension and deposit feeder, similar to several of the echinoderms also allocated to this group. The other polychaetes included as characterising species for the rock habitats are either predatory or form encrusting tubes and are therefore likely to respond differently to some pressures.

Gastropods
There are two grazing gastropod species within this group: the pearly top shell, *Margarites helicinus* and the grey top shell *Gibbula cineraria* which is widely distributed throughout the British coastline (Pizzolla 2002). Both species are physically fragile and possess similar feeding preferences, grazing on algae on the lower rocky shore. As grazers, the gastropods show similar feeding preferences to multiple echinoderms allocated within the group and like most of the echinoderm species their environmental position is also epifaunal/epilithic.

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

3.3 Ecological Group 3: Mobile predators and scavengers

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

Crustaceans
With the exception of *P. montaguii*, all of the characterising crustaceans for rocky habitats are allocated to this group. The crab and lobster species are tightly clustered in the multivariate analyses and are grouped with the amphipods *Dexamine spinosa* and *Dyopedos porrectos* which are most ecologically similar due to their free-living and crawling/swimming natures. The velvet crab *Necora puber* is more dispersed from the main cluster of mobile predators, nearer to the non-predatory mobile species group which is most likely because it occasionally demonstrates omnivorous dietary habits by feeding on brown algae (MaRLIN 2006). All of the crustaceans allocated to this group are epifaunal

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

Gastropods

A single species of gastropod, *Nucella lapillus* is grouped in 'Mobile predatory' fauna. *N. lapillus* is widely distributed and although found in the sublittoral is mostly found on rocky shores across the UK. It is acknowledged to avoid low salinities and excessive algal cover but is tolerant of a wide range of exposures (MarLIN 2006). Like most of the other species in this group, *N. lapillus* is also an epifaunal crawler.

Nudibranchs

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

3.4 Ecological Group 4: Bivalves and brachiopods

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

All of the species in this group are permanently attached to a hard substrate (with the exception of *M. edulis* which is temporarily attached for a part of its life) and demonstrate low mobility which makes the species within this group likely to react to pressures in a similar manner.

3.5 Ecological Group 5: Tube-Dwelling Fauna

Tube-dwelling fauna are represented by Ecological Group 5. The group consists of four species: the polychaetes *Protula tubularia*, *Sabella pavonina* and *Lanice conchilega*, and the anemone *Cerianthus lloydii*. All of the species included in this group construct and maintain a protective tube structure around their bodies made from either calcareous secretions (*Protula tubularia*) or mud or sand particles held together with mucus secretions (*Lanice conchilega*, *Sabella pavonina, Cerianthus lloydii*). The tube structures make the species comparatively robust compared to other ecological groups. The group is relatively scarce in the infralittoral zone and within lower energy environments, more typically found within high energy circalittoral habitats. The species included in the group share a number of similar species traits, and are all likely to show similar levels of sensitivity to pressures in the marine environment.

3.6 Ecological Group 6: Temporarily or Permanently Attached Epifauna

Permanently or temporarily attached epifauna form a wide and diverse group of species which are attached to the seabed for part or all of their life history. The species present represent several different growth forms which influence their potential sensitivity to pressures in the environment. The group has therefore been split into three sub-groups as follows:

Group 6 (a): Attached soft-bodied Species
The attached soft-bodied species groups includes species from several Phyla which are all either permanently or temporarily attached to the seabed, and can be characterised as having soft or flexible-bodied taxa which are not encrusting and do not rise to a great height above the seabed.

Species of ascidians, sponges, anemones, cnidarians and soft corals are included in this group, which are all likely to have similar sensitivities to pressures given their physical characteristics, habitat e and feeding method. All species in this group are filter feeders that strain food particles from the water column. The group is found in both the infralittoral and circalittoral zones in a range of environmental conditions.

Group 6 (b): Attached Encrusting Species
This group comprises those epifaunal species which form crusts on the seabed, or are characterised as epilithic species that form crusts on other living species. This group includes exclusively sponge and bryozoan species with highly similar traits, all likely to display a similar level of sensitivity to pressures in the marine environment. The group is typically found in medium-high energy environments in both the infralittoral and circalittoral zones.

Group 6 (c): Attached Erect Species
Attached erect species are those which rise above the plane of the seabed and are typically flexible and mainly not soft-bodied (with exceptions). Erect bryozoans, hydroids soft corals and sponges typify this group, which is most frequently found in high-moderate energy circalittoral biotopes. The species represented within this group are likely to display similar sensitivities to pressures based on the larger body size of these species, their growth form and other similar traits.

Group 6 (d): Attached Robust Fauna
The ‘attached robust fauna’ group comprises two widespread species: the calcareous tube-forming polychaete *Spirobranchus triqueter* and the acorn barnacle *Balanus crenatus.* These two species are likely to have similar sensitivities to pressures based upon their small body size and robust, encrusting nature amongst other similar biological traits such as resource capture method. *Spirobranchus triqueter* has not been grouped with other polychaetes in the tube-dwelling fauna group due to its encrusting nature. Unlike the sabellid and terebellid worms included in the project, *S. triqueter* does not project up from the seafloor, making it more robust and similar to *B. crenatus* when considering sensitivity response.

4 Conclusions

This project has proposed a series six of ecological groups of similar species found in sublittoral rock habits based upon the trait characteristics. Species within these groups are likely to exhibit similar sensitivities to pressures in the marine environment. Four subgroups have been proposed for the sixth ecological group, bringing the total number of groups proposed to nine. The groups proposed include ‘macroalgae’, ‘non-predatory mobile species’, ‘mobile predators and scavengers’, ‘bivalves and brachiopods, ‘tube-dwelling fauna’ and ‘temporarily or permanently attached epifauna: attached soft-bodied species, attached encrusting species, attached erect species and attached robust fauna’. These groups are based on 76 characterising taxa from the relevant sublittoral rock biotopes.

The information previously collated by Alexander *et al* (2015) has been revised and updated to include a wider range of traits which are likely to be useful in terms of sensitivity assessments. The ecological groups proposed also take into account the previously suggested ecological groups which formed the basis of the Sublittoral Rock CEM project. A comparison of the groups from the current project and the CEM project can be seen below.

Table 3. Comparison of ecological groups proposed in the conceptual ecological modelling (CEM) of sublittoral rock habitats project (Alexander *et al* 2015) and the sensitivity assessment project for rock habitats.

CEM Ecological Groups – based on ecological function	Sensitivity assessment Ecological Groups – based upon sensitivity response
1. Macroalgae	1. Macroalgae
2. Non-predatory mobile fauna	2. Non-predatory mobile species
3. Scavengers and predatory fauna	3. Mobile predators and scavengers
4. Bivalves, brachiopods and other encrusting fauna	4. Bivalves and brachiopods
5. Tube building fauna	5. Tube-Dwelling Fauna
6. Temporarily or permanently attached active filter feeders	6. Temporarily or permanently attached epifauna
7. Temporarily or permanently attached passive filter feeders	6a. Attached soft-bodied Species
	6b. Attached Encrusting Species
	6c. Attached Erect Species
	6d. Attached Robust Fauna

The proposed ecological groups were identified using species trait information and associated multivariate analyses, in combination with expert judgement. All of the factors which enabled the establishment of the ecological groups were considered in relation to the sensitivity of the species within it. Feeding method, mobility, environmental position and habitat above all other traits assisted with the determination of ecological groups. Lifespan was considered as a trait to be used to aid grouping but was revealed to have little impact on the final outputs of the cluster analysis.

The groups proposed are grouped in such a way that species biological traits are taken into consideration. Multivariate analyses were used to identify patterns of similar species in terms of their traits, ensuring that those species grouped together are likely to display similar levels of sensitivity to human pressures. It is proposed that the sensitivities of each group to a list of pre-defined pressures are assessed in Phase 2 of this project.

Understanding the sensitivity of the ecological groups determined in Phase 1 may in the future support ecosystem level assessment and management which are of increasing concern in the marine environment due to high levels of human pressures. In Phase 2 of this project, the sensitivity of each of the groups to a range of biological, chemical and physical anthropogenic pressures will be assessed by applying the sensitivity assessment methods developed by Tillin *et al* (2010) to the ecological groups defined in this phase.

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6 Glossary

The following terms and definitions are those used within this project to describe biological traits and habitats (MarLIN 2006). A breakdown of the categories for each trait is shown in the ‘Sublittoral Rock EG Literature Review and Ancillary Information’ spreadsheet that accompanies this report, available from JNCC.

6.1 Species Trait Definitions

Species Trait Definitions	
Mobility/Movement	The organisms ability and method of locomotion through its environment
Resource capture	The processes by which organisms consume their food
Environmental Position	The position within a habitat the organism occupies in relation to the seabed
Habitat	How the organism exists within the environment
Size	Average total length of an adult. In the case of worms this is the length from the prostomium to the pygidium, in crabs this is carapace length and in anemones this is the diameter of the disc
Substratum Preference	The sediment type that the organisms are likely to favour
Salinity preference	The salinity the organism favours
Tidal Stream Preference	Favoured location in relation to tidal currents
Lifespan	The length of time the organism is likely to live naturally
Flexibility	The extent to which a species may flex or is rigid
Fragility	The resistance of a species to physical impact
Wave Exposure Preference	Favoured degree of wave action

7 Appendices

Appendix 1. List of EUNIS Level 5 habitats in the scope of this project based on the Marine Habitat Classification for Britain and Ireland

Appendix 2. Project species list for sublittoral rock habitats

Appendix 3. Annotated ecological group cluster dendrogram for the sublittoral rock habitat ecological groups

Appendix 4. Annotated ecological group nMDS for the sublittoral rock habitat ecological groups

Appendix 1

List of EUNIS Level 5 habitats in the scope of this project based on the Marine Habitat Classification for Britain and Ireland (Conner *et al* 2004).

Level 2	Level 3	Level 4	Level 5 biotope code and description
A3 Infralittoral rock and other hard substrata	A3.1 : Atlantic and Mediterranean high energy infralittoral rock	A3.11 : Kelp with cushion fauna and/or foliose red seaweeds	A3.111 : *Alaria esculenta* on exposed sublittoral fringe bedrock
			A3.112 : *Alaria esculenta* forest with dense anemones and crustose sponges on extremely exposed infralittoral bedrock
			A3.113 : *Laminaria hyperborea* forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed infralittoral rock
			A3.114 : Sparse *Laminaria hyperborea* and dense *Paracentrotus lividus* on exposed infralittoral limestone
			A3.115 : *Laminaria hyperborea* with dense foliose red seaweeds on exposed infralittoral rock
			A3.116 : Foliose red seaweeds on exposed lower infralittoral rock
			A3.117 : *Laminaria hyperborea* and red seaweeds on exposed vertical rock
		A3.12 : Sediment-affected or disturbed kelp and seaweed communities	A3.121 : *Saccorhiza polyschides* and other opportunistic kelps on disturbed upper infralittoral rock
			A3.122 : *Laminaria saccharina* and/or *Saccorhiza polyschides* on exposed infralittoral rock
			A3.123 : *Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders and cobbles
			A3.124 : Dense *Desmarestia* spp. with filamentous red seaweeds on exposed infralittoral cobbles, pebbles and bedrock
			A3.125 : Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock
			A3.126 : *Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment
			A3.127 : *Polyides rotundus*, *Ahnfeltia plicata* and *Chondrus crispus* on sand-covered infralittoral rock
	A3.2 : Atlantic and Mediterranean moderate energy	A3.21 : Kelp and red seaweeds (moderate energy	A3.211 : *Laminaria digitata* on moderately exposed sublittoral fringe rock

	infralittoral rock	infralittoral rock)	A3.212 : *Laminaria hyperborea* on tide-swept, infralittoral rock
			A3.213 : *Laminaria hyperborea* on tide-swept infralittoral mixed substrata
			A3.214 : *Laminaria hyperborea* and foliose red seaweeds on moderately exposed infralittoral rock
			A3.215 : Dense foliose red seaweeds on silty moderately exposed infralittoral rock
			A3.216 : *Laminaria hyperborea* on moderately exposed vertical rock
			A3.217 : *Hiatella arctica* and seaweeds on vertical limestone / chalk
		A3.22 : Kelp and seaweed communities in tide-swept sheltered conditions	A3.221 : *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock
			A3.222 : Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
			A3.223 : Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids
			A3.224 : *Laminaria saccharina* with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock
			A3.225 : Filamentous red seaweeds, sponges and *Balanus crenatus* on tide-swept variable-salinity infralittoral rock
	A3.3 : Atlantic and Mediterranean low energy infralittoral rock	A3.31 : Silted kelp on low energy infralittoral rock with full salinity	A3.311 : Mixed *Laminaria hyperborea* and *Laminaria ochroleuca* forest on moderately exposed or sheltered infralittoral rock
			A3.312 : Mixed *Laminaria hyperborea* and *Laminaria saccharina* on sheltered infralittoral rock
			A3.313 : *Laminaria saccharin*a on very sheltered infralittoral rock
			A3.314 : Silted cape-form *Laminaria hyperbore*a on very sheltered infralittoral rock
			A3.315 : Sargassum muticum on shallow slightly tide-swept infralittoral mixed substrata
A4 Circalittoral rock and other hard substrata	A4.1 : Atlantic and Mediterranean high energy circalittoral rock	A4.11 : Very tide-swept faunal communities on circalittoral rock	A4.111 : *Balanus crenatus* and *Tubularia indivisa* on extremely tide-swept circalittoral rock
			A4.112 : *Tubularia indivisa* on tide-swept circalittoral rock
		A4.12 : Sponge communities on	A4.121 : *Phakellia ventilabrum* and axinellid sponges on deep, wave-

		deep circalittoral rock	exposed circalittoral rock
		A4.13 : Mixed faunal turf communities on circalittoral rock	A4.131 : Bryozoan turf and erect sponges on tide-swept circalittoral rock
			A4.132 : *Corynactis viridis* and a mixed turf of crisiids, *Bugula*, *Scrupocellaria*, and *Cellaria* on moderately tide-swept exposed circalittoral rock
			A4.133 : Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tide-swept circalittoral rock
			A4.134 : *Flustra foliacea* and colonial ascidians on tide-swept moderately wave-exposed circalittoral rock
			A4.135 : Sparse sponges, *Nemertesia* spp., and *Alcyonidium diaphanum* on circalittoral mixed substrata
			A4.136 : *Suberites* spp. with a mixed turf of crisiids and *Bugula* spp. on heavily silted moderately wave-exposed shallow circalittoral rock
			A4.137 : *Flustra foliacea* and *Haliclona oculata* with a rich faunal turf on tide-swept circalittoral mixed substrata
			A4.138 : *Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock
			A4.139 : Sponges and anemones on vertical circalittoral bedrock
	A4.2 : Atlantic and Mediterranean moderate energy circalittoral rock	A4.21 : Echinoderms and crustose communities on circalittoral rock	A4.211 : *Caryophyllia smithii* and *Swiftia pallida* on circalittoral rock
			A4.212 : *Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock
			A4.213 : *Urticina felina* and sand-tolerant fauna on sand-scoured or covered circalittoral rock
			A4.214 : Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock
			A4.215 : *Alcyonium digitatum* and faunal crust communities on vertical circalittoral bedrock
		A4.23 : Communities on soft circalittoral rock	A4.231 : Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay
			A4.232 : *Polydora* sp. tubes on moderately exposed sublittoral soft rock
			A4.233 : *Hiatella*-bored vertical sublittoral limestone rock

		A4.24 : Mussel beds on circalittoral rock	A4.241 : *Mytilus edulis* beds with hydroids and ascidians on tide-swept exposed to moderately wave-exposed circalittoral rock
			A4.242 : *Musculus discors* beds on moderately exposed circalittoral rock
	A4.3 : Atlantic and Mediterranean low energy circalittoral rock	A4.31 : Brachiopod and ascidian communities on circalittoral rock	A4.311 : Solitary ascidians, including *Ascidia mentula* and *Ciona intestinalis*, on wave-sheltered circalittoral rock
			A4.312 : Large solitary ascidians and erect sponges on wave-sheltered circalittoral rock
			A4.313 : *Antedon* spp., solitary ascidians and fine hydroids on sheltered circalittoral rock
			A4.314 : *Neocrania anomala* and *Protanthea simplex* on sheltered circalittoral rock

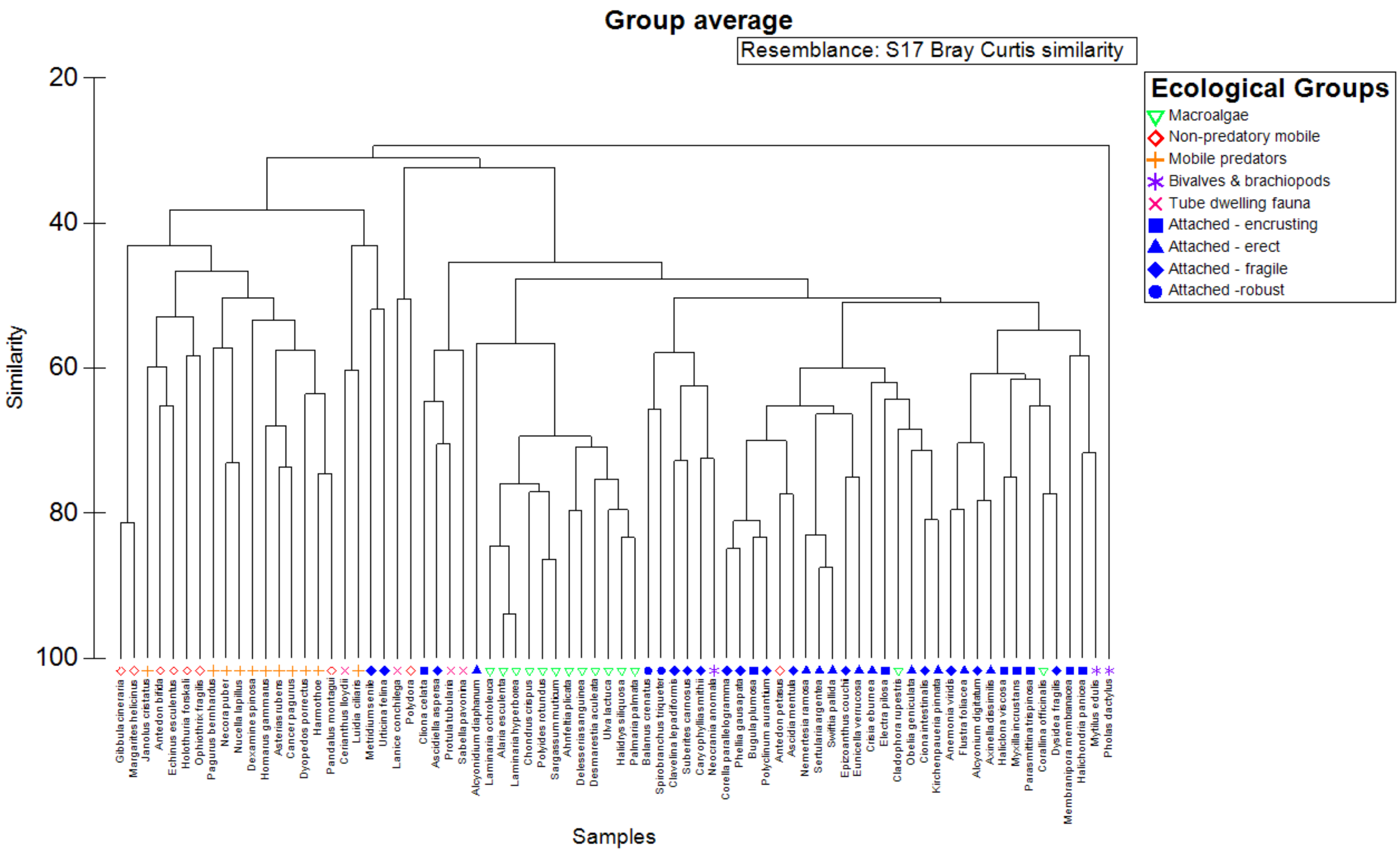
Appendix 2

Project species list for sublittoral rock habitats

Project Species:
Ahnfeltia plicata
Alaria esculenta
Alcyonidium diaphanum
Alcyonium digitatum
Anemonia viridis
Antedon bifida
Antedon petasus
Ascidia mentula
Ascidiella aspersa
Asterias rubens
Axinella dissimilis
Balanus crenatus
Bugula plumosa
Cancer pagurus
Caryophyllia smithii
Cerianthus lloydii
Chondrus crispus
Ciona intestinalis
Cladophora rupestris
Clavelina lepadiformis
Cliona celata
Corallina officinalis
Corella parallelogramma
Crisia eburnea
Delesseria sanguinea
Desmarestia aculeata
Dexamine spinosa
Dyopedos porrectus
Dysidea fragilis
Echinus esculentus
Electra pilosa
Epizoanthus couchii
Eunicella verrucosa
Flustra folicea
Gibbula cineraria
Halichondria panicea
Haliclona viscosa
Halidrys siliquosa
Harmothoe impar
Holothuria forskali
Homarus gammarus
Janolus cristatus
Kirchenpaueria pinnata
Laminaria hyperborea
Laminaria ochroleuca
Lanice conchilega
Luidia ciliaris
Margarites helicinus
Membranipora membranacea
Metridium senile
Mytilus edulis
Myxilla incrustans
Necora puber
Nemertesia ramosa
Neocrania anomala
Nucella lapillus
Obelia geniculata
Ophiothrix fragilis
Pagurus bernhardus
Palmaria palmata
Pandalus montagui
Parasmittina trispinosa
Phellia gausapata
Pholas dactylus
Polyclinum aurantium
Polydora ciliata
Polyides rotundus
Protula tubularia
Sabella pavonina
Sargassum muticum
Sertularia argentea
Spirobranchus triqueter
Suberites carnosus
Swiftia pallida
Ulva lactuca
Urticina felina

Appendix 3

Annotated ecological group cluster dendrogram for the sublittoral rock habitat ecological groups



Appendix 4

Annotated ecological group nMDS for the sublittoral rock habitat ecological groups