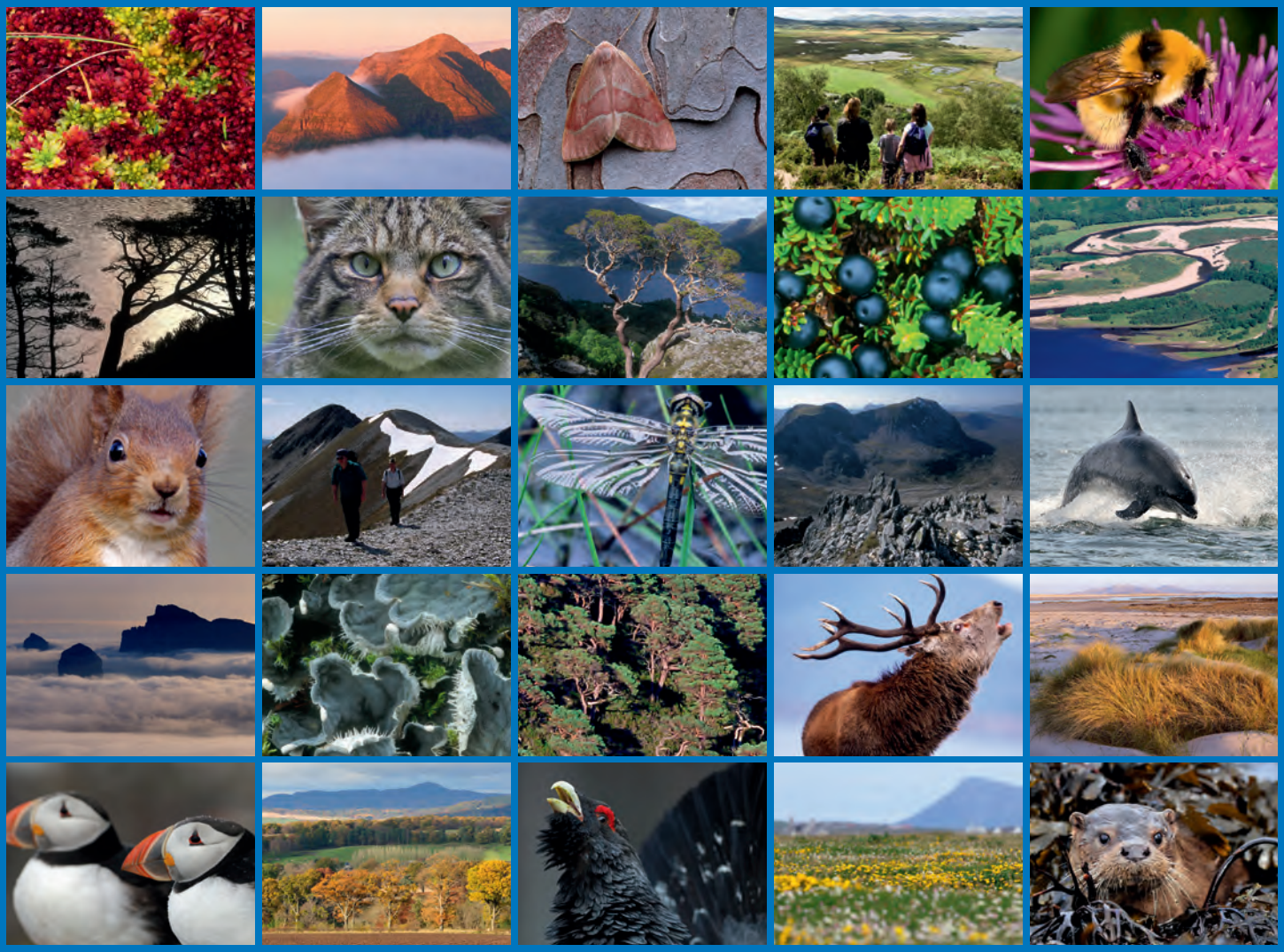
Scottish Natural Heritage
Commissioned Report No. 491

Development of detailed ecological guidance to support the application of the Scottish MPA selection guidelines in Scotland's seas



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COMMISSIONED REPORT

Summary

Development of detailed ecological guidance to support the application of the Scottish MPA selection guidelines in Scotland's seas

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Keywords

Marine protected areas; detailed ecological guidance; search features; functional links; biological diversity; coherence; indicators of damage/naturalness; recovery potential; geographic range.

Background

Provisions to designate Marine Protected Areas (MPAs) within Scotland's seas have been introduced through the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009. To help target nature conservation action SNH and JNCC have generated a prioritised list of habitats and species of importance in Scottish waters - the Priority Marine Features (PMFs). A subset of the PMFs are being used to underpin the selection of Nature Conservation MPAs alongside black guillemot and five large-scale features considered to be of functional significance for the overall health and diversity of Scotland's seas. Collectively these features are known as MPA search features.

In early 2011 Marine Scotland published the Scottish MPA Selection Guidelines[2] which set out a five-stage process for the selection of MPAs and development of an ecologically coherent network in Scotland's seas. This highlighted the need to summarise current understanding of the ecology of the MPA search features to ensure that the information used was up-to-date, and to support consistent decisions being made in the application of the Scottish MPA Selection Guidelines.

Summary

This report describes how detailed ecological guidance on selected marine habitats and species was produced to support application of the Scottish MPA Selection Guidelines. The work consisted of the following stages:

[1] This report was initially submitted in 2011 and therefore contains information applicable at the time of submission.
[2] Marine Protected Areas in the seas around Scotland: Guidelines on the selection of MPAs and development of the MPA network http://www.scotland.gov.uk/Topics/marine/marine-environment/mpanetwork/mpaguidelines

- Clarification of ecological terms used in the Guidelines to focus the collation of information.
- Literature review and collation of information relevant to the selected marine habitats and species.
- Production of draft ecological guidance.
- Internal peer review by specialists within SNH, JNCC and Marine Scotland Science.
- External peer review by the Scottish Association for Marine Science, Envision and SMRU Ltd.
- Production of final detailed ecological guidance.

The detailed ecological guidance focuses on Stages 2, 4 and 5 of the Guidelines although does not cover every guideline in each stage. The ecological terms which form the basis of the detailed ecological guidance were taken from the Guidelines and are:

- functional links;
- biological diversity;
- coherence;
- indicators of damage/naturalness;
- risk;
- recovery potential; and
- geographic variation.

A literature review was initially carried out for all components of features for which MPAs were considered to be an appropriate mechanism. Following the literature review, it became clear that some grouping of features was required. This was to reduce duplication between detailed ecological guidance documents (DEGs) which covered similar features and to make best use of relevant information which for some features was largely recorded at a broader habitat level. Most of the DEGs were produced for MPA search features, however, some were produced to cover other marine habitats and species of relevance to work on MPAs.

Although many DEGs were produced, this report concentrates on those features considered most relevant to the MPA network, i.e. 32 DEGs covering a range of different types of marine habitats and species (see Annex A). Twenty relate to seabed habitat MPA search features, three cover low-mobility species that are MPA search features, seven cover mobile species that are MPA search features, and two cover other marine habitats and species that are of importance to the MPAs. The large-scale features[3], representative sediment communities[4], and black guillemot were not covered by this project.

The literature review undertaken during this project identified significant data gaps for some habitats and species and/or relating to parts of the Guidelines. This was expected because many of the concepts used in the Guidelines are still evolving and consequently have multiple definitions within the literature. Project specific interpretations were therefore agreed for many of these terms. A significant challenge throughout the project was sourcing detailed ecological information specific to Scottish examples of the species and habitats. Evidence relating to similar habitats and species and/or examples from waters outside Scotland were used to address known data gaps. This information was only used for situations when the ecology of the habitats and species was considered comparable to the known ecology in Scotland's seas.

[3] Continental slope, Fronts, Shelf banks and mounds, Seamounts, and Shelf deeps.

[4] Circalittoral sand and coarse sediment communities, Circalittoral and offshore sand and coarse sediment communities, Sublittoral mud and mixed sediment communities, Sublittoral mud and specific mixed sediment communities, Circalittoral muddy sand communities, Circalittoral sand and mud communities, Circalittoral sands and mixed sediment communities.

Despite these information gaps, all objectives of the project were met. The detailed ecological guidance is based on the best available evidence/understanding of the habitats and species and will therefore support the selection of Nature Conservation MPAs in Scottish waters. It is recommended that periodic reviews of the DEGs are undertaken to ensure any new information relevant to the designation of MPAs in Scottish waters is included in the process.

Note that although the DEGs were initially to be incorporated into this report, due to their size they are now provided as supplementary documents.[5]

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[5] These are available at http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/marine-protected-areas-(mpa)/detailed-ecological-guidance/

Table of Contents **Page**

1. INTRODUCTION 1

2. DEVELOPMENT OF THE DETAILED ECOLOGICAL GUIDANCE 3
2.1 Clarification of terms 3
2.2 Literature review and collation of detailed ecological information 4
2.3 Production of draft detailed ecological guidance 4
2.4 Peer review and finalisation of detailed ecological guidance 5

3. CLARIFICATION OF TERMS 8
3.1 Functional links 8
3.2 Biological diversity (habitats only) 9
3.3 Coherence 9
3.4 Indicators of least damaged/more natural 10
3.5 Recovery potential 11
3.6 Geographic variation 11

4. LAYOUT OF THE DETAILED ECOLOGICAL GUIDANCE PRODUCED 13

5. DISCUSSION 15

6. REFERENCES 16

ANNEX A. LIST OF FEATURES FOR WHICH DETAILED ECOLOGICAL GUIDANCE HAS BEEN PRODUCED 18

ANNEX B. SUMMARY OF INFORMATION SOURCES REVIEWED TO OBTAIN RELEVANT ECOLOGICAL INFORMATION 21

ANNEX C. EXAMPLE DETAILED ECOLOGICAL GUIDENCE DOCUMENT 24

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Please Note: This report was initially submitted in 2011 and therefore contains information applicable at the time of submission.

1. INTRODUCTION

Development of the Scottish MPA network

Provisions to designate Nature Conservation Marine Protected Areas (MPAs) within Scotland's seas have been introduced through the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009. Following adoption of the Marine (Scotland) Act, the Scottish MPA Project was established. The Project is led by Marine Scotland and includes Scottish Natural Heritage (SNH), the Joint Nature Conservation Committee (JNCC), Marine Scotland Science, the Scottish Environment Protection Agency, and Historic Scotland. The aim of the Project is to enable Scotland to meet its international commitments to establish an ecologically coherent network of MPAs.

In early 2011 Marine Scotland published the Scottish MPA Selection Guidelines[6] which set out the overall policy context, together with a vision and principles for the network. The Guidelines contain a five-stage process for the selection of MPAs and development of an ecologically coherent network in Scotland's seas. Whilst some of the guidelines are fairly coarse in terms of their application (e.g. Stage 1 is largely concerned with presence of MPA search features), others require a more in-depth knowledge of the ecology of the habitats and species concerned (e.g. levels of associated biodiversity and functional links between different features). This highlighted the need to summarise current understanding of the ecology of the MPA search features to ensure that the information used was up-to-date and suitable to support consistent decisions being made in the application of the Scottish MPA Selection Guidelines.

Priority Marine Features and MPA search features

There are a number of statutory requirements and policy initiatives of relevance to the conservation and management of the Scottish marine environment and its biodiversity. Amongst these statutory and policy drivers are OSPAR[7], the Habitats and Birds Directives[8], the Marine Strategy Framework Directive[9], the Marine and Coastal Access Act 2009 and the Marine (Scotland) Act 2010[10], the Scottish Biodiversity Strategy (SBS)[11] and the Marine Biodiversity Implementation Plan (MBIP)[12]. As this catalogue has grown, so the number of marine species and habitats recognised as being of conservation importance has increased. For practical conservation purposes, SNH and JNCC, on behalf of Scottish Government, embarked on an exercise to identify a subset of those recognised marine habitats and species on which to focus their marine nature conservation work in future. The result is a list of Priority Marine Features (PMF) covering the seas around Scotland i.e. both territorial and offshore waters.

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[6] Marine Protected Areas in the seas around Scotland: Guidelines on the selection of MPAs and development of the MPA network http://www.scotland.gov.uk/Topics/marine/marine-environment/mpanetwork/mpaguidelines

[7] The Ospar Commission for the protection of the marine environment of the Noerth-East Atlantic. More information at: http://www.ospar.org/

[8] The Conservation (Natural Habitats, etc.) Regulations 1994 (as amended, 2004) information at: http://www.legislation.gov.uk/uksi/1994/2716/contents/made

[9] Marine Strategy Framework Directive information at: http://ec.europa.eu/environment/water/marine/index_en.htm

[10] Scottish Marine Act at: http://www.oqps.gov.uk/legislation/acts/acts2010/pdf/asp_20100005_en.pdf UK Marine and Coastal Access Act at: http://www.opsi.gov.uk/acts/acts2009/ukpga_20090023_en_1

[11] Scottish Biodiversity Strategy infromation at: http://www.biodiversityscotland.gov.uk/doing/framework/strategy/

[12] Marine Biodiversity Implementation plan at: http://www.scotland.gov.uk/Publications/2004/05/19412/37942

To support work on MPAs as part of the Scottish MPA Project, the PMF list was reviewed to identify those marine habitats and species which:

a. were considered likely to benefit from the protection afforded by an MPA; and
b. for which sufficient data were likely to be available to support assessment against the MPA Selection Guidelines and development of an MPA proposal.

The result was a list of MPA search features. Some other features not included as PMFs were also considered. This resulted in a number of large-scale features (e.g. shelf banks and mounds, and fronts) and black guillemot being added. The final list contains 42 features comprising 21 habitats, five low or limited mobility species, 10 mobile species and five large-scale features. These features are being used to underpin the selection of Nature Conservation MPAs around Scotland.

Aim & Objectives

The aim of this project was to provide detailed ecological guidance on selected marine habitats and species to support application of the Scottish MPA Selection Guidelines. The focus of the detailed ecological guidance is on the MPA search features but a number of other habitats and species were also covered. This report only considers those features most relevant to the MPAs (see Annex A).

The objectives were:

1. To provide clarification of the ecological terms used in the Scottish MPA Selection Guidelines.
2. Using these terms as a guide, to undertake a literature review and collate relevant information on selected marine habitats and species.
3. Based on the above, to produce detailed ecological guidance for the selected marine habitats and species which provides an interpretation of the available evidence to support application of the Scottish MPA Selection Guidelines.

2. DEVELOPMENT OF THE DETAILED ECOLOGICAL GUIDANCE

The following stages were used in the production of the detailed ecological guidance:

- Clarification of ecological terms used in the Guidelines to focus the collation of information.
- Literature review and collation of information relevant to the selected marine habitats and species.
- Production of draft detailed ecological guidance.
- Internal peer review by specialists within SNH, JNCC and Marine Scotland Science.
- External peer review by the Scottish Association for Marine Science, Envision and SMRU Ltd.
- Production of final detailed ecological guidance.

The detailed ecological guidance focuses on Stages 2, 4 and 5 of the MPA Selection Guidelines although does not cover every guideline in each stage. Detailed ecological guidance was not produced for Stage 1 of the Guidelines because assessment of this stage is concerned with the presence of MPA search features, rather than detailed aspects of their ecology. Equally Stage 3 of the Guidelines is not covered. This is because Stage 3 relates to consideration of the size of the search location as a whole rather than consideration of individual features. Only one part of Stage 5 (geographic variation) is covered by the detailed ecological guidance. The remaining parts are not covered because they relate to broader concepts such as representativity and replication.

The remainder of this section describes the work done to address the above bullets. Note that although the detailed ecological guidance documents (DEGs) were initially to be incorporated into this report, due to their size they are now provided as supplementary documents[13].

2.1 Clarification of terms

Table 2.1 shows the relationship between the individual guidelines and the terms used in the DEGs. The DEGs use the following terms as the major section headings:

- functional links and associations;
- biological diversity;
- coherence;
- indicators of damage/naturalness;
- risk;
- recovery potential; and
- geographic variation.

These terms are often interpreted and defined differently throughout scientific papers and conservation legislation. For this reason a review was undertaken on the definitions of these terms. This is summarised in section 3.

Guidance on risk (Guideline 2e) was carried out in-house by SNH and JNCC. The methods for assessing risk are set out in a separate document (Chaniotis *et al.*, 2014).

[13] These are available at http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/marine-protected-areas-(mpa)/detailed-ecological-guidance/

2.2 Literature review and collation of detailed ecological information

Following the clarification of terms, a list of specific information requirements for each feature was produced. This information was sourced through literature searches and through discussion with recognised experts including consultants, academics and staff from within SNH and JNCC. Given the large volume of information being handled, Entec designed a simple database in MS Access. The database contains technical information on each of the features, along with information regarding the services provided by the features and indications of the reliability of the data. Reference sources for the information are also stored within the database to create a record of the evidence base.

An access database was chosen for a number of reasons:

- It allows easy revision and addition of data and features throughout the project.
- It allows analysis of data as well as reporting (e.g. creating subsets of features which provide the same ecosystem services or identification of information gaps within the evidence base).
- It provides consistency in reporting (e.g. reference citations).
- It allows flexibility in the format of output data via reporting templates.
- It will remain as a lasting resource for future use.

The database allows easy analysis of the patterns within the data, and the output of data for each feature in a consistent tabular or report format. The database allows reporting by individual features or by groups of features, as appropriate. Similar features have been grouped together into logical groups within the database such that where information exists for individual features it has been recorded at feature level, and where information only exists for a larger group it has been recorded at group level. By creating these links within the database, groupings of features can be re-arranged if necessary. Reporting from the database can be done at feature level or group level.

The database has been designed to record information about the species and habitats including coherence, diversity, indicators of damage and potential for recovery, as well as more complex interrelationships such as ecological links between features and geographic range. Fields are also provided to allow for estimates of the confidence or security of the validity of the data, and detailed bibliographic referencing has been included.

2.3 Production of draft detailed ecological guidance

The information in the database was reviewed and tailored to provide specific guidance for each feature to support application of the MPA Selection Guidelines. This was done prior to extraction of the data from the database. The interpreted data were then used to generate output tables for each feature which formed the basis of the DEGs.

Where information could be clearly displayed habitat DEGs were produced at the level of the MPA search feature, however, where deemed appropriate DEGs where separated into single or grouped components. For example, the guidance on horse mussel beds was produced at the level of the MPA search feature and covers all four component biotopes in a single document. Conversely, the guidance for Northern sea fan and sponge communities has been split into three DEGs. The first, Northern sea fan communities, covers two biotopes and one sub-biotope. The second, Deep sponge communities, covers one biotope and one sub-biotope. A final document for this search feature was created for the Northern sea fan species alone.

The order of the terms in the DEGs follows the order in which they appear in the Scottish MPA Selection Guidelines i.e. terms relating to Guideline 2 come before those relating to 4

and 5. Whilst some of the sections might logically have grouped together in a different order, these guidance documents are intended to be used as reference documents to support the application of the Guidelines rather than as documents that will be read from start to finish at any one time. Section 4 provides more detail on the structure and content of the detailed ecological guidance. The DEGs summarise our understanding of the ecology of selected features and therefore provide background information. This will be complemented by detailed site-specific data from surveys to allow assessment of the MPA Selection Guidelines.

A summary of the sources used to obtain ecological information is provided in Annex B. A full reference list has been provided at the end of each document so that information relevant to each feature can be readily accessed.

2.4 Peer review and finalisation of detailed ecological guidance

The draft DEGs were reviewed by SNH and JNCC staff and revised by Entec before being subject to external peer review. David Hughes of the Scottish Association for Marine Science (SAMS) carried out the reviews of the offshore species and habitats. Judy Foster-Smith of Newcastle University and Envision Mapping Ltd carried out the reviews of the species and habitats from territorial waters. Kate Grellier and Claire Lacey of SMRU Ltd. conducted reviews of the marine mammal features. Following these reviews, the comments made by the reviewers were reviewed by Entec, SNH and JNCC. The actions required to complete the DEGs were agreed and then made before being finalised.

Table 2.1 The relationship between the Scottish MPA Selection Guidelines and the detailed ecological guidance

The table below shows the relationship between the Scottish MPA Selection Guidelines and the detailed ecological guidance which has been produced for each feature. The comments in the right hand column provide a summary of the information given in the detailed ecological guidance. The DEGs provide the background ecological information that will be complemented by detailed site-specific data from surveys to allow assessment of the Selection Guidelines (specific parts of the selection guidelines not covered within the DEGs are identified in the comments column).

Stage	Selection guideline	Read across to detailed ecological guidance	Comments
1	1a. Presence of key features.	N/a	Detailed ecological guidance does not apply to Stage 1 selection guidelines
	1b. Presence of features considered to be under threat and/or subject to rapid decline.		
	1c. Functional significance for the overall health and diversity of Scottish seas.		
2	2a. The search location contains combinations of features, rather than single isolated features, especially if those features are functionally linked.	Functional links and associations	Considers links with other search features and with the wider Scottish marine environment. Associations have also been included to reflect potential functional links. This also relates to consideration of linkages under Stage 5 of the selection guidelines (see note overleaf).
	2b. The search location contains example(s) of features with a high natural biological diversity.	Biological diversity	Provides a description of the feature in the seas around Scotland. For habitats, highlights the characterising and key species associated with it. Includes JNCC biotope description(s) where relevant.
	2c. The search location contains coherent examples of features, rather than smaller, potentially more fragmented ones.	Coherence	For most features, considers typicalness (i.e. how that feature is usually present), ecological variation in feature across the seas around Scotland, viability, longevity and fragmentation of the feature. For mobile species, population structure is used in place of typicalness and incorporates elements longevity where relevant.

Stage	Selection guideline	Read across to detailed ecological guidance	Comments
	2d. The search location contains features considered least damaged/ more natural, rather than those heavily modified by human activity.	Indicators of damage and/or naturalness	Based on evidence of sensitivities, or activities that result in damage to features, indicators of damage and naturalness were extracted.
	2e. The search location contains features considered to be at risk of significant damage by human activity.	Risk assessment	A separate report provides an assessment of the degree to which each feature is exposed to activities associated with pressures to which it is sensitive. Provides a qualitative measure of risk for each MPA search feature by MPA region, but not for component habitats and species (Chaniotis *et al.,* 2014).
3	3. The size of the search location should be adapted where necessary to ensure it is suitable for maintaining the integrity of the features for which the MPA is being considered. Account should also be taken where relevant of the need for effective management of relevant activities.	N/a	Detailed ecological guidance does not apply to Stage 3 selection guidelines
4	4. There is a high probability that management measures, and the ability to implement them, will deliver the objectives of the MPA.	Recovery potential	Reviews available evidence on the potential for features to recover in terms of timescales and condition. Guidance only relates to the part of the guideline which refers to recovery and not the part relating to potential for management or implementation of management.
5	5. The potential area contributes significantly to the ecological coherence of the MPA network in Scottish waters.	Geographic variation	Describes distribution with respect to the Scottish MPA regions. Does not relate to any other parts of Stage 5 (replication, representation, resilience and socio-economic considerations). Note for highly mobile species, consideration of linkages (another part of the Stage 5 guideline) will be covered under Functional links.

3. CLARIFICATION OF TERMS

The terms used as major headings within the DEGs are often interpreted and defined differently throughout scientific papers and conservation legislation. The following section provides project specific interpretations of these terms for use in the Scottish MPA project. This also provides a rationale behind the type of information included within each section of the DEGs. The DEGs provide the background ecological information that will be complemented by detailed site-specific data from surveys to allow assessment of the Selection Guidelines. The term 'feature' is used as a short-hand to cover both MPA search features and other habitats and species for which the detailed ecological guidance was produced.

3.1 Functional links

The interdependence of species and habitats based upon the ecosystem functions and the critical services they provide results in a multitude of linkages between them. Therefore, 'a functional link' has been defined as **'a known association between features where one feature is dependent on another to perform a critical service or important ecosystem function'.**

It is therefore also important to clarify the term 'ecosystem function'. In the ecological literature this term has been subject to various and often contradictory interpretations (de Groot *et al*., 2002). Sometimes the concept is used to describe the internal functioning of an ecosystem (e.g. maintenance of energy fluxes, nutrient cycling, food web interactions) and sometimes it relates to the benefits derived by humans from the properties and processes of ecosystems (e.g. food production and waste treatment). For the purposes of providing guidance for the application of the MPA selection guidelines 2-4, it has been decided that information is required relating to the functioning of the ecosystem, rather than the anthropogenic benefits of ecosystem functioning. For this reason the definition adapted from Naeem *et al*. (2004) in Bremner *et al*. (2006) is considered most appropriate: 'Ecosystem functioning are the activities, processes or properties of ecosystems that influence or are influenced by its biota'.

Each species within an ecosystem has an ecological function (or role), many of which are critical to the maintenance of ecosystem functioning (Hiscock *et al*., 2006). The variety of critical processes performed by species and the biological traits by which they are achieved are extensive. They include predation (e.g. this can lead to removal of lower tropic predators, creation of space), food production (either as primary production or as a prey item), structural engineering (e.g. by providing habitats themselves or stabilising substrate), bioturbation (increasing nutrient cycling, gas exchange and oxygenation) and water filtration (thus improving water quality and light penetration).

Certain habitats are also essential for particular species by providing critical services. These can include feeding grounds, breeding grounds, spawning grounds, nursery areas, resting grounds, and areas which are refuges for predator avoidance. Certain habitats may also be critical for the survival of other habitats through some ecological function, e.g. a mussel bed filters the water, leading to better light penetration and allowing a kelp forest to survive in an area where this would not be possible otherwise (Hiscock *et al*., 2006).

For highly mobile species the issue of connectivity was also considered to be a type of functional link[14]. In relation to MPAs connectivity was defined from Palumbi (2003); 'Connectivity is a process dependent on the extent to which populations in different parts of

[14] Connectivity was also identified as being an important functional link for non-mobile habitats and species; however, there was insufficient feature-specific evidence to include within the DEGs.

a species range are linked through the exchange of larvae, recruits, juveniles, or adults'. For highly mobile species, the factors effecting the level of connectivity between populations include hydrology, temperature, movement of key prey species and the range and speed of swimming.

Within the 'Functional Links' section, information has therefore been provided on:

- for features that are habitats, information on the critical services that a habitat provides, the species it supports and any ecological function relevant to other features or the wider ecosystem;

- for features that are species, information on biological traits which are critical to ecosystem functioning, as well as any association with other features or the wider ecosystem;

- for the connectivity of highly mobile species, information on drivers of connectivity between populations and habitats or areas that provide critical services to the species.

3.2 Biological diversity (habitats only)

According to the UN Convention on Biological Diversity (CBD, 1992), "biological diversity" means **the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.** Biological diversity is often used as a measure of the health of biological systems, being applied to both species richness and habitat diversity at a site and is valued positively as it increases (JNCC, 1989). Some marine habitats are naturally low in diversity (e.g. mussel beds on littoral mud), yet are still important to conserve, for example due to the functional links to the wider ecosystem.

Specific information typically required to assess biological diversity includes identifying the range of species present in a habitat; representative species (i.e. those typically present in the habitat) and typical values for diversity indices.

Within the 'Biological diversity' section information has therefore been provided on:

- habitat/biotope descriptions for Scottish waters;
- records of diversity indices across Scotland;
- representative species associated with the habitat.

3.3 Coherence

Coherence is a difficult term to define as in scientific literature it has often been used with varying meanings. The majority of available literature looks at coherence with regards to networks of MPAs, as opposed to individual features such as species or habitats. For the purposes of the MPA guidelines it is necessary to define coherence in relation to individual features.

To define coherence, a draft guidance note published by Defra (2009) was used together with the SSSI description of coherence. This allowed a definition to be produced for application of MPA selection guidance for individual features: **a coherent feature is one that is typical, viable (according to best available evidence) and of sufficient size to support persistence throughout the natural cycles of variation.**

The OSPAR Commission recommend that viability of features should take into account species life-history, population structure, habitat quality, the quality of the surrounding areas and connectivity to other populations (OSPAR 2007). OSPAR (2007) also states that in data-poor areas adequate protection may require more sites, or a site of larger size, than if more data were available. Although information on larval dispersal was not a focus of this section, this information is important in understanding the life histories of the features. As a result, where available, information on larval dispersal was provided in this section.

Overall, within the 'Coherence' section information has therefore been provided on:

- what is a 'typical' or 'common' example of that feature (habitat or species population), based on best knowledge at the time;
- ecological variation of the feature between Scottish MPA regions (see Figure 3.1);
- the adequate size of a habitat/population to maintain the feature over time (in the absence of this specific information being found, information on the size range of the habitat or population was provided);
- longevity of a feature (including both the life-span of a species and the persistence of a feature within a given location);
- typical fragmentation of features (including the spread, density and structure of a feature).

3.4 Indicators of least damaged/more natural

In order to provide guidance on any known indicators of a feature being 'least damaged/more natural' the focus was on evidence of activities that result in damage to features and from these, indicators of damage and naturalness were extracted. For example a paper that describes how sea fans are adversely affected by trawling, could suggest that evidence of broken sea fans in an area would be an indicator of trawling damage (although broken sea fans could arise due to some natural events such as storm damage). Conversely evidence that described the presence of an algal turf on maerl beds under high organic enrichment could be used to infer that the absence of an algal turf is an indicator of naturalness.

Where information was lacking on specific indicators of damage or naturalness, information was sought on the sensitivity of the features. From this, indicators of damage due to a particular activity were identified, e.g. if a feature is vulnerable to abrasion (e.g. *Lophelia* reefs) an indicator of trawl damage could be the presence of coral rubble.
Within the 'Indicators of Least Damaged/More Natural' section information has therefore been provided on:

- indicators of changed or damaged features, in relation to particular activities (from scientific papers);
- information on sensitivity to activities which have the potential to harm the feature (MarLIN, 2010), including:
    - Physical factors: substratum loss; suspended sediment; desiccation; changes in emergence regime; changes in water flow rate; changes in temperature; changes in turbidity; changes in wave exposure; noise disturbance; visual disturbance; physical disturbance and abrasion; displacement.
    - Chemical factors: synthetic compound contamination; heavy metals contamination; hydrocarbon contamination; radionuclide contamination; changes in nutrient levels; changes in salinity; changes in oxygenation.
    - Biological factors: introduction of microbial pathogens / parasites; introduction of non-native species; selective extraction of this species; selective extraction of other species.

3.5 Recovery potential

To provide guidance on ‘the potential for features to recover/be restored’; information was required on the recoverability of features. 'Recoverability' is the ability of a habitat, community, or species to return to a state close to that which existed before the activity or event which caused the change (MarLIN, 2010).

The likelihood of a species or habitat recovering from disturbance or damage is dependent on its ability to regenerate, re-grow, recruit, or recolonize, as well as the extent of the damage incurred to the feature and its intolerance to damage.

The potential for recovery was assessed by looking for evidence that particular features have recovered from particular activities, therefore assessing whether it is likely that they can recover and assigning the timescales that maybe involved. Key information on the feature’s reproductive biology, habitat preferences and distribution was also considered where appropriate. To better understand recovery potential, information will also be required on the current state of a feature and the pressures acting on a given site, however, this is not considered within the DEGs.

Where information was lacking for specific features, information was compiled from MarLIN on the recovery potential of habitats or key species in the habitats in order to provide an informed estimate of the recoverability of the feature.

Within the ‘Recovery Potential’ section information has therefore been provided on:

- evidence of recovery from damage;
- measures of recoverability;
- potential to manage/enhance recovery;
- the time required for regeneration/re-growth (could be linked to life history, reproductive success, recruitment);
- conditions from which features cannot recover or be restored.

3.6 Geographic variation

The DEGs include consideration of how the range of each feature relates to the Scottish MPA regions and the importance of the feature both within and outside Scotland. Therefore the feature’s abundance and distribution outside Scottish waters was needed in order to put Scottish records into context.

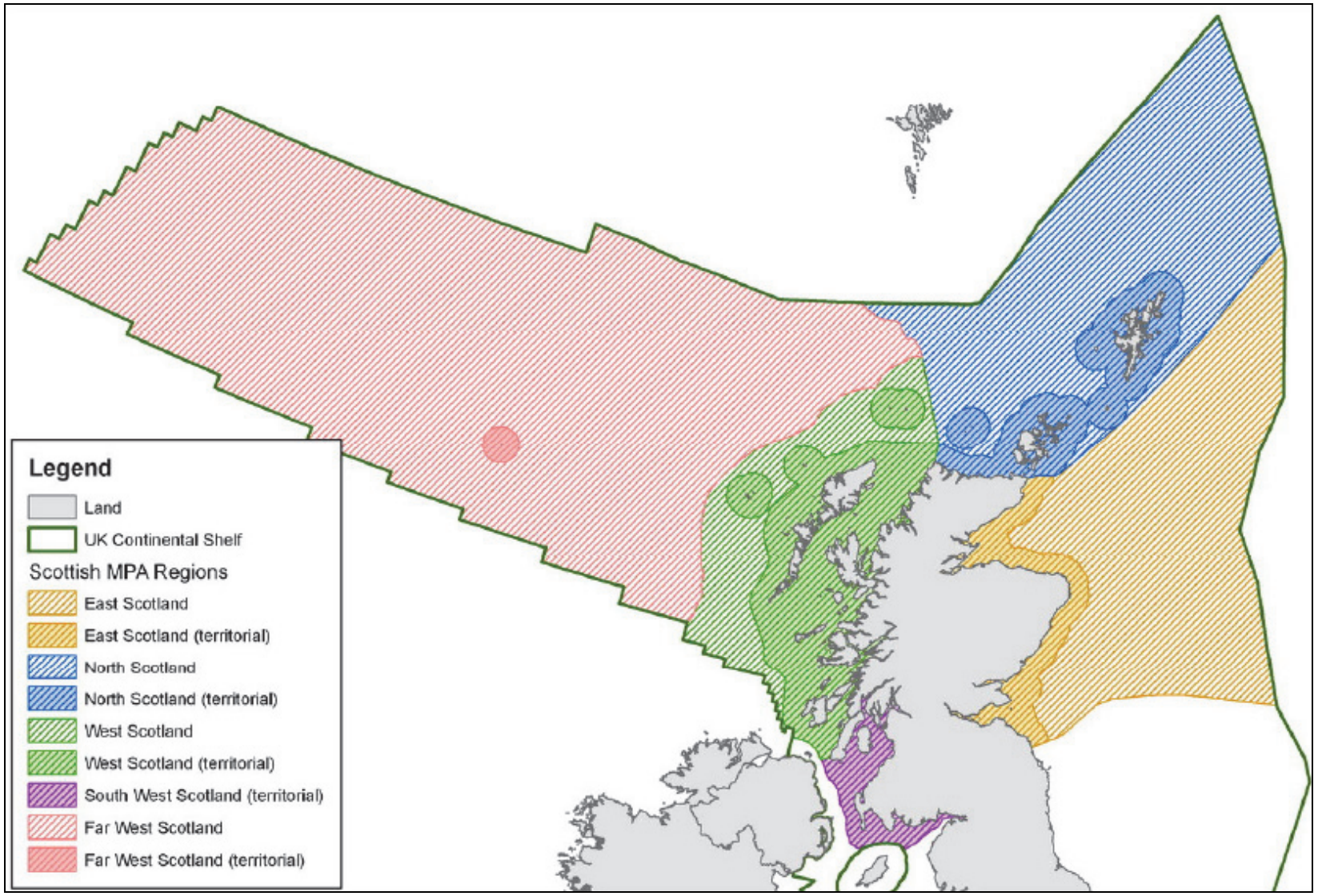

Figure 3.1 Scottish MPA regions

4. LAYOUT OF THE DETAILED ECOLOGICAL GUIDANCE PRODUCED

An example document showing the structure of the DEGs with additional text to explain each section is presented in Figure 4.1. Due to the length of some of the DEGs these have been published separately[15]. The tables in Annex A list the DEGs that have been produced as part of this report. They also highlight for the marine habitats whether the guidance was produced at the level of the MPA search feature or to cover components. As an example of the information produced, the DEG for 'Flame shell beds' is provided in Annex C.

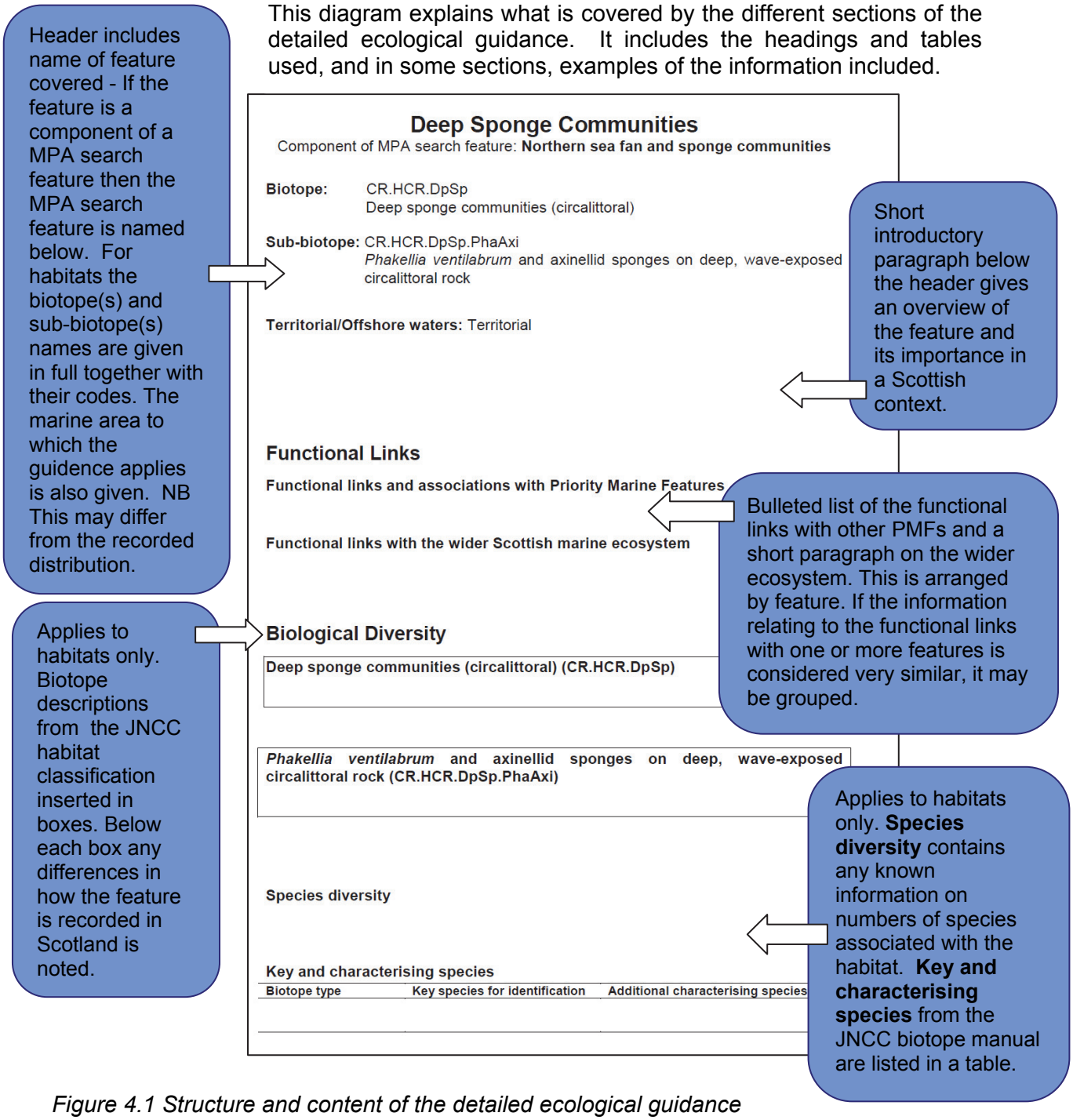

Figure 4.1 Structure and content of the detailed ecological guidance

[15] Available at http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/marine-protected-areas-(mpa)/detailed-ecological-guidance/

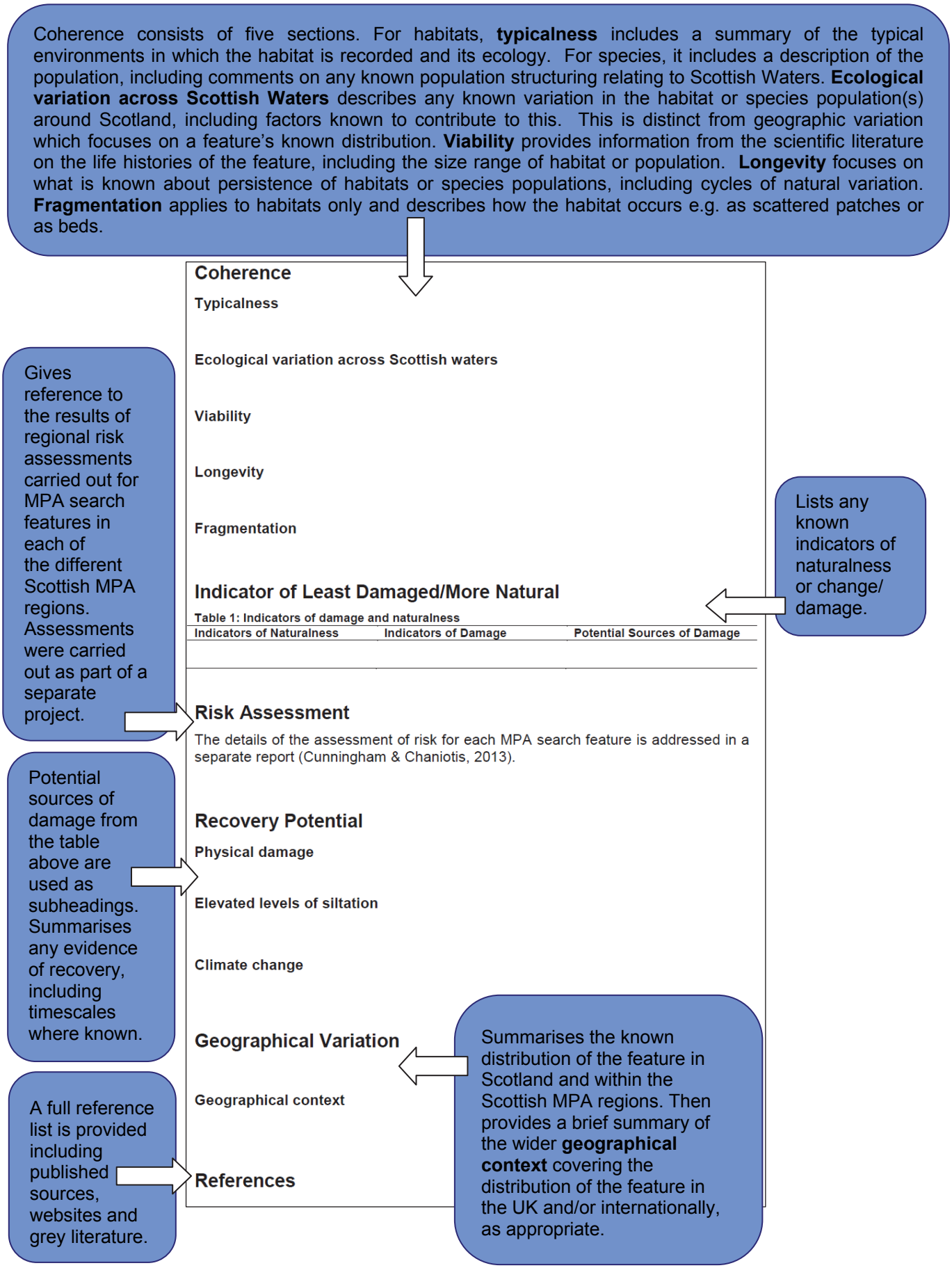

Figure 4.1 Structure and content of the detailed ecological guidance (contd.)

5. DISCUSSION

This project set out to provide supporting ecological guidance for SNH and JNCC on the selection of Nature Conservation Marine Protected Areas in Scotland's seas. Although all of the objectives of this project have been met to date, it is through the application of the MPA Selection Guidelines that this project will be properly tested, and its success measured.

Many of the terms used within the MPA Selection Guidelines are often interpreted and defined differently throughout scientific papers and conservation legislation, This represented the first major information gap found during this piece of work. Clarifying these terms, although only a small part of the overall project, was integral to its success and without doing so it is unlikely that the project would have achieved any of the original objectives.

In terms of producing the guidance, information gaps were often present due to the specific nature of the questions being asked and the detailed information requested on specific Scottish examples of features. Very little work for example has been done on assessing what a coherent example of a habitat might be. This lack of information was often greatest for species, and although surrogate species, or populations from areas outside Scotland were used where possible, this approach was not always appropriate. For example, when providing information on the variation across Scottish waters, detailed data on Scottish examples is required. Information on longevity, however, is likely to be an area where information from populations/habitats outside of Scotland is appropriate. In addition to the difficulties in finding appropriate data sources, some of the species and habitats included are poorly studied, and some are considered rare, in these cases where evidence exists, the evolving concepts considered within the MPA Selection Guidelines have often not been focused upon and as such some questions have had to be left only partially answered.

Despite these difficulties, the general principles for Nature Conservation MPAs in Scottish waters follow that defined by Principle 15 of the Rio Declaration (1992). i.e. that although the best available evidence is to be used in the designation of Nature Conservation MPAs, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Within this principle, the available scientific knowledge has been presented for each feature according to the guideline specified within the MPA Selection Guidelines, and although further research should be a continuing theme of the conservation of Scottish biodiversity, the best scientific knowledge available to date should form the basis of any selection of MPAs in Scotland's seas.

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ANNEX A. LIST OF FEATURES FOR WHICH DETAILED ECOLOGICAL GUIDANCE HAS BEEN PRODUCED

The tables below have been arranged by MPA search feature to enable the grouping of some features to be easily understood. Only those features considered most relevant to the MPA network have been included in this report. Some of the habitats guidance has been produced at the level of the MPA search feature and others at the level of component habitats/species. In Table A1 bold text is used to highlight at what level the guidance has been completed. Throughout the tables those features on the OSPAR Threatened and Declining list are marked [T&D].

Table A1. Detailed ecological guidance relating to seabed habitats that are MPA search features

MPA search feature	Component habitats / species	Marine area
[T&D] Burrowed mud	**Burrowed mud communities** (comprises 2 components: Seapens and burrowing megafauna in circalittoral fine mud & Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud)	Both (Territorial and offshore waters)
	Tall seapen *Funiculina quadrangularis*	Both
	Fireworks anemone *Pachycerianthus multiplicatus*	Territorial waters
[T&D] **Coral gardens**	Coral gardens	Offshore waters
[T&D] **Deep sea sponge aggregations**	Deep sea sponge aggregations	Offshore waters
Flame shell beds	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment	Territorial waters
[T&D] **Horse mussel beds**	*Modiolus modiolus* beds (comprises 3 components: *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata, *Modiolus modiolus* beds on open coast circalittoral mixed sediment, *Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata)	Territorial waters
Kelp and seaweed communities on sublittoral sediment	Kelp and seaweed communities on sublittoral sediment	Territorial waters
[T&D] **Maerl beds**	Maerl beds	Territorial waters
Maerl or coarse shell gravel with burrowing sea cucumbers	*Neopentadactyla mixta* in circalittoral shell gravel or coarse sand	Territorial waters
[T&D] **Native oysters**	Native oyster *Ostrea edulis*	Territorial waters

MPA search feature	Component habitats / species	Marine area
Northern sea fan and sponge communities	**Northern sea fan communities** (comprises 2 components: *Caryophyllia smithii* and *Swiftia pallida* on circalittoral, Mixed turf of hydroids and large ascidians with *Swiftia pallida* and *Caryophyllia smithii* on weakly tide-swept circalittoral rock)	Territorial waters
	Deep sponge communities	Both
	Northern sea fan *Swiftia pallida*	Territorial waters
Offshore deep sea muds	Includes muds on the continental slope, abyssal and bathyal zones and on the continental shelf - *Ampharete falcata* turf with *Parvicardium ovale* on cohesive muddy sediment near margins of deep stratified seas; Polychaetes & *Thyasira* spp. in offshore circalittoral mud and sandy mud (comprises 4 components: Foramiiferans and *Thyasira* sp. in deep circalittoral fine mud, *Levinsenia gracilis* and *Heteromastus filifirmis* in offshore circalitoral mud and sandy mud, *Paramphinome jeffreyseii, Thyasira* spp. and *Amphiura filiformis* in offshore circalittoral sandy mud & *Myrtea spinifera* and polychaetes in offshore circalittoral sandy mud)	Offshore waters
Offshore subtidal sands and gravels	Includes sands and gravels on the continental slope, abyssal and bathyal zones and on the continental shelf - *Glycera lapidum*, *Thyasira* spp. and *Amythasides macroglossus* in offshore gravelly sand; *Hesionura elongata* and *Protodorvillea kefersteini* in offshore coarse sand; Echinoderms, infaunal bivalves and polychaetes in circalittoral fine sand (comprises 3 components: *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand*, Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand & Maldanid polychaetes and *Eudorellopsis deformis* in offshore circalittoral sand or muddy sand; *Owenia fusiformis* and *Amphiura filiformis* in offshore circalittoral sand or muddy sand)	Offshore waters
[T&D] Seagrass beds	**Eelgrass beds**	Territorial waters
	Tasselweed beds	Territorial waters
Seamount communities	Seamount communities	Offshore waters
Tide-swept coarse sands with burrowing bivalves	*Moerella* spp. with venerid bivalves in infralittoral gravelly sand	Territorial waters

Table A2. Detailed ecological guidance covering low-mobility species that are MPA search features

MPA search feature	Species name	Marine area
Fan mussel aggregations	*Atrina fragilis*	Territorial waters
Northern feather star aggregations on mixed substrata	*Leptometra celtica*	Territorial waters
[T&D] Ocean quahog aggregations	*Arctica islandica*	Both

Table A3. Detailed ecological guidance covering mobile species that are MPA search features

MPA search feature	Species name	Marine area
[T&D] Basking shark	*Cetorhinus maximus*	Territorial waters
[T&D] Common skate	*Dipturus batis* complex	Territorial waters
Minke whale	*Balaenoptera acutorostrata*	Territorial waters
[T&D] Orange roughy	*Hoplostethus atlanticus*	Offshore waters
Risso's dolphin	*Grampus griseus*	Territorial waters
Sandeels	*Ammodytes marinus* & *A. tobianus*	Both (*A. tobianus* only territorial)
White-beaked dolphin	*Lagenorhynchus albirostris*	Territorial waters

Table A4. Detailed ecological guidance covering proposed protected features that are not MPA search features

Feature	Component habitats / species	Marine area
Serpulid aggregations	*Serpula vermicularis* reefs on very sheltered circalittoral muddy sand	Territorial waters
White cluster anemone	White cluster anemone *Parazoanthus anguicomus*	Territorial waters

ANNEX B. SUMMARY OF INFORMATION SOURCES REVIEWED TO OBTAIN RELEVANT ECOLOGICAL INFORMATION

This annex gives a summary of where information on each section of the DEGs was found. Full references are given in the reference section.

Functional Links and Connectivity

Functional links both to the other marine features, plus those that constitute important ecological goods or services, have been taken from multiple sources (e.g. Jones *et al.*, 2000; OSPAR, 2008). Links have been identified through JNCC's Marine Habitat Classification Hierarchy (Connor *et al.,* 2004), and scientific literature (see individual feature guidance). In the DEGs, the information researched under this criterion is referred to as '*functional links and associations'* to reflect the additional information presented on biological associations.

Information on connectivity for mobile species has been taken from the many sources detailing the life history characteristics of the species in question. In particular, scientific literature detailing important sites e.g. breeding, feeding areas, has been used as a priority, where available.

Biological Diversity

The information sources for the various sections within the Biological Diversity section are listed below:

- Habitat/Biotope description for Scottish waters – where available this section was populated with the biotope descriptions available from JNCC's Marine Habitats Classification Hierarchy (Connor *et al.,* 2004). For certain features with no biotope code (e.g.coral gardens) a description of the typical biological diversity present was compiled from other habitat listings (e.g. OSPAR, 2008) as well as the scientific literature. Additional information to supplement the biotope description was also provided to give a more detailed account of the feature in Scottish waters or update information in the Marine Habitats Classification Hierarchy which was out of date.
- Key and Characterising Species – This information was taken from JNCC's Marine Habitats Classification Hierarchy (Connor *et al.,* 2004).
- Species Diversity – this section provides information from the scientific literature and site monitoring reports to give an indication of the typical levels of species diversity present, for example through the use of diversity indices.

Coherence

The information sources for the various sections within the Coherence section are listed below:

- Typicalness - For biotopes and species a description of typicalness was taken from information from the MarLIN online database, Encyclopaedia of Marine Life of Britain and Ireland and the British Marine Life Studies website, along with other feature information obtained from appendix 2 of Howson *et al.* (2009). Further data were added from scientific literature where relevant.
- Ecological Variation across Scottish Waters - Information on the variability of the species or habitat both within and between Scottish MPA regions has been sourced from, JNCC's Marine Habitat Classification Hierarchy (Conner *et al.,* 2004), various published reports and surveys from SNH and the peer reviewed literature where available.

- Viability - Viability assessments for many of the features have been undertaken by Hill *et al.* (2010). The evidence, on which an estimate of minimum viable area size was based, was deemed to be insufficient to use in this section. Therefore, information from the scientific literature on the life histories of the feature, such as the size range of the habitat or population, was researched and presented in order to allow those applying the MPA selection guidelines to make an informed judgement.

Indicators of Least Damaged/More Natural

Information on damaging activities and threats was taken from sensitivity and intolerance data from the MarLIN online database. Peer reviewed literature was also used to give additional information regarding any further activities that may impact the feature. Only those activities/factors for which sensitivity or intolerance were high/very high were included.

Information from the UK Marine SACs Project reports for several of the broad habitat classifications (*Zostera* species – Davison, 1998; Intertidal sand and mudflats and subtidal mobile sandbanks - Elliott *et al*., 1998; Seapens and burrowing megafauna – Hughes, 1998; Maerl - Birkett *et al,*. 1998); Intertidal reef biotopes - Hill *et al.,* 1998; Infralittoral reef biotopes with kelp species - Birkett *et al*.,1998); Circalittoral faunal turf biotopes – Hartnoll, 1998; and Biogenic reefs - Holt *et al*.,1998) were also used to add to the MarLIN data, as was the review paper of the UK Marine SAC reports (Jones *et al.,* 2000) and the OSPAR (2008) case reports. The OSPAR reports (2008) provided large amounts of data for the records with no marine habitat classification code.

Risk

Where indicated within the DEGs, the results of regional risk assessments carried out for the feature in each of the different Scottish MPA regions, can be found in a separate report (Chaniotis *et al.,* 2014).

Recoverability Potential

The initial assessment of recoverability for species was taken from MarLIN online database for those activities/factors for which sensitivity or intolerance were high/very high. The confidences assigned to these are those posted on MarLIN and reflect the level of available data upon which they were based. Further information on recovery, particularly for the habitats, was gathered from the MarLIN guidance, the UK Marine SACs Project reports (see section 1.3.4), the Jones *et al.* (2000) review and the OSPAR (2008) case reports. Further data was added from scientific literature, e.g. on the management of recovery (other than through cessation of the damaging activity) or the point where recovery is not possible.

Geographic Variation

Information on the geographic distribution of species data in Scottish waters was taken from Defra datalayers project. This large scale project has collated information on the distribution of species and habitats in the offshore environment to inform the identification and designation of a network of Marine Conservation Zones.

The geographic range of biotopes is published by SNH and JNCC through the Marine Habitat Classification Hierarchy, with records identified as Core, Not core but certain or Uncertain depending on the strength of the data behind each record. Records were assigned as being within 1 of 9 Scottish MPA regions (see *figure 2.1*), defined by JNCC for the project; this was done through the use of visual markers and not via a GIS application.

For those features not classified under the Marine Habitats Classification Hierarchy, or listed in MarLIN's online database, other reports (e.g. OSPAR, 2008; JNCC, 2007) have been

used to specify the location of features in Scottish waters. For those features without whole feature distribution maps the NBN Gateway (http://data.nbn.org.uk/) was used to obtain distribution data for the main biological components of each feature.

ANNEX C. EXAMPLE DETAILED ECOLOGICAL GUIDENCE DOCUMENT

Flame Shell Beds

Biotope: SS.SMx.IMx.Lim
Limaria hians beds in tide-swept sublittoral muddy mixed sediment

Territorial/Offshore waters: Territorial

The keystone species *Limaria hians* (commonly called the flame shell or gaping file shell) secretes and binds byssal threads to surrounding material such as detritus, stones and algae to create a 'nest'. When adjacent nests are bound to one another they produce a continuous byssus 'carpet' over the sea bed. Where dense populations of *L. hians* exist the beds can extend over large areas. The flame shell creates a complex habitat which, by virtue of stabilising the substratum and creating additional living space, increases the biodiversity of a given area. Numerous flora and fauna can attach to the surface of the bed, whilst many animals live within or under the nest material. Recent evidence suggests that *L. hians* beds among the richest and most diverse in UK inshore waters (Trigg *et al.,* 2011).

Functional Links

Functional links and associations with other Priority Marine Features

- *Horse mussel beds: M. modiolus* are sometimes found in the vicinity of flame shell beds (Connor *et al.,* 2004). In Loch Linnhe and Loch Leven there are records of flame shell beds adjacent to horse mussel beds (Moore *et al.*, 2012). Beyond providing a habitat for *L. hians,* the functional significance of this association is not quantified.
- *Maerl beds:* Nests of the flame shell *Limaria hians* are often found in conjunction with maerl (Hall-Spencer *et al.*, 2003). *L. hians* binds maerl together with its byssal threads, helping to stabilise the maerl bed (Birkett *et al.*, 1998). For example, the beds recorded in the Clyde Sea area, e.g. Creag Gobhainn in Loch Fyne, appear to be strongly associated with maerl (Trigg, pers. comm.).
- *Tide-swept algal communities:* Beds of *L. hians* are often found in combination with tide-swept algal communities; the nest providing a stable substratum for the attachment of seaweeds in an otherwise unsuitable location (Minchin, 1995).

Functional links with the wider Scottish marine ecosystem

L. hians beds may act as a refuge for juvenile fish such as cod and saithe (Minchin, 1995; Hall-Spencer & Moore, 2000).

Biological Diversity

Habitat/Biotope description for Scottish waters

There is one biotope described for *Limaria hians* beds that is known to occur in Scotland. The following biotope description has been taken directly from the Marine Habitat Classification Hierarchy (Connor *et al.,* 2004). Below, the description is supplemented with additional information specific to Scotland, from the scientific literature.

Limaria hians **beds in tide-swept sublittoral muddy mixed sediment (SS.SMx.IMx.Lim)**
"Mixed muddy gravel and sand often in tide-swept narrows in the entrances or sills of sealochs with beds or 'nests' of Limaria hians*. The* Limaria *form woven 'nests' or galleries from byssus and fragments of seaweeds so that the animals themselves cannot be seen from above the seabed.* Modiolus modiolus *sometimes occur at the same sites lying over the top of the* Limaria *bed. Other fauna associated with this biotope include echinoderms (*Ophiothrix fragilis, Ophiocomina nigra *and* Asterias rubens*),* Buccinum undatum*, mobile crustaceans (e.g.* Pagurus bernhardus*),* Alcyonium digitatum *and hydroids such as* Plumularia setacea*,* Kirchenpaueria pinnata *and* Nemertesia *spp. Sometimes red seaweeds such as* Phycodrys rubens *occur if the beds are in shallow enough water."* (Connor *et al.,* 2004).

This biotope has been found at a number of locations along the west coast of Scotland. As the beds are often found in shallow water it is typical for there to be a dense canopy of epiflora associated with them. This can include kelp such as *Laminaria hyperborea* and *Saccharina latissima,* and a dense covering of red algae (e.g. *Delesseria sanguinea, Phycodrys rubens* and *Plocamium cartilagineum*) (Minchin, 1995; Hall-Spencer & Moore, 2000; Mercer *et al*., 2007; Trigg *et al*., 2011). *Limaria* beds are often associated with the coralline algae maerl, for example, this is recorded as interwoven with the nests in Loch Fyne (Hall-Spencer & Moore, 2000) and Little Loch Broom (Holt, 1991).

Species diversity

On the west coast of Scotland a quantitative study on the biodiversity of two *L. hians* beds recorded 7275 organisms in *ca* 0.16m² (Trigg *et al*., 2011). These covered 16 phyla (3 algal and 13 faunal) and 306 taxa, about a third of all species in the study being represented by the phylum Annelida. At the *Limaria* bed in Loch Creran, they recorded respective values of 5.02 and 0.88 for Shannon Wiener diversity and Pielou's evenness indices. Although high values for biodiversity were found in this study, the figures are thought to be an underestimation as neither meiofauna or large motile organisms were sampled (Trigg *et al*., 2011). A qualitative study by Hall-Spencer and Moore (2000) recorded more than 280 taxa from six *Limaria* nests equating to an area of *ca* 0.29m².

Key and characterising species

These have been taken from the JNCC biotope classification (Connor *et al.,* 2004).

Biotope type	Key species for Identification	Additional characterising species
SS.SMx.IMx.Lim	*L. hians*	*K. pinnata; Nemertesia antennina; Nemertesia ramosa; A. digitatum; Pomatoceros triqueter; P. bernhardus; Munida rugosa; Hyas araneus; Cancer pagurus; Necora puber; Buccinum undatum; Modiolus modiolus; Pecten maximus; Aequipecten opercularis; A. rubens; O. fragilis; O. nigra; Psammechinus miliaris; Echinus esculentus*

Coherence

Typicalness

In Scotland *L. hians* beds are most frequent in the shallow infralittoral (5-10 m), down to depths of ~30m (e.g. Loch Broom and Loch Sunart; Davies & Connor, 1993; Howson, 1996). They are found in areas of weak to moderately strong tidal currents and areas ranging from reasonably exposed to sheltered from wave action. The presence of *Limaria* in Creagan Narrows, Loch Creran suggests that they can be found in regions exposed to variations in salinity although at this particular site densities of *Limaria* are not sufficient to create a bed. The underlying sediments tend to be mixed muddy gravel and sand, though they may incorporate pebbles and cobbles (e.g. bed off Port Appin in Loch Linnhe) and have even been observed to overlap the edges of bedrock reef in Loch Creran (Moore *et al*., 2012; Moore *et al.,* 2013).

The thickness varies from less than 5cm (in Loch Linnhe) to about 20cm (at parts of the bed within Loch Fyne) (Hall-Spencer & Moore, 2000; Trigg & Moore, 2009) and it appears that where suitable environmental conditions exist the beds can be extensive, covering several hectares in extent (e.g. in Loch Linnhe). Within the beds high densities of *Limaria hians* have been found, with >700 ind. m^{-2} in the Creag Gobhainn area of Loch Fyne (Hall-Spencer & Moore, 2000), up to 400 ind. m^{-2} in Loch Sunart (Bates *et al*., 2004) and around 350 ind. m^{-2} in Loch Linnhe (Trigg & Moore, 2009). A common factor thought to allow large populations to flourish at such high densities is attributed to the existence of strong currents in their locality, helping in the removal of waste products and simultaneously supplying food. However, it would seem a continual expansion of the bed is untenable, even on areas which outwardly appear to have similar physical characteristics, as has been seen in Loch Linnhe and Loch Creran (Moore *et al*., 2012; Moore *et al.,* 2013). Equally there is no immediate cut off point to the *Limaria* nests. These are found in frequent clumps around the perimeter of the bed, gradually dwindling in both size and number as the distance from the bed increases (e.g. the beds in Lochs Creran, Broom, Linnhe and Sunart).

Sessile, sedentary and mobile species are found in large numbers on, within and underneath the bed; and in shallow Scottish waters many species of algae are found including the laminarians which many organisms use for attachment and food. Attached epifauna are largely made up of hydroids, bryozoans and tunicates whilst mobile species on top of the bed consist of large numbers of brittlestars and less abundant but readily visible megafauna such as the starfish *Asterias rubens Marthasterias glacialis,* and the decapods *Cancer pagurus* and *Necora puber*. The polychaete *Flabelligera affinis* and the bivalve *Mysella bidentata* are frequently found inside the galleries of the nest, whilst bivalves such as *Mya truncata, Tapes rhomboides* and *Dosinia* spp. are found in the sediment beneath the bed (Hall-Spencer & Moore, 2000).

Where maerl is present the nodules are bound together by *Limaria* byssus to create a bricolage that has been recorded at several locations in Scotland (e.g. Little Loch Broom, Loch Fyne; Hall-Spencer & Moore, 2000; Moore *et al.,* 2010). *Limaria* is indiscriminate in its binding of materials to the nest (Trigg *et al*., 2011) and in shallow waters the nest has a spongy texture as foliose and filamentous algae is assimilated into the bed (Mercer *et al*., 2007).

Ecological variation across Scottish waters

Within the west and south-west MPA regions the obvious difference in the beds is size. Estimations of the extent of the beds varying from about 40 hectares in Loch Linnhe to 7 hectares in Loch Broom (assuming nest coverage of the sea bed to be at least 50%) (Moore *et al.,* 2011; Moore *et al*., 2012). Furthermore, the beds recorded in the Clyde Sea area (e.g. Creag Gobhainn in Loch Fyne) seem to be strongly associated with maerl, the coralline algae being bound together with byssus. Despite records indicating a similar association and bed in Little Loch Broom, a recent survey found dense maerl with only juvenile *Limaria* living within the algae, and no indication of nest material other than a few byssal threads attached to the maerl (Moore *et al.,* 2011).

Another physical variation seen among the west coast beds is the formation of *Limaria* terraces in both Loch Sunart and Loch Broom, where small clusters/nests are found in 'steps' along the slopes. In Loch Sunart nests have a patchy distribution, precluding them from being designated as a bed, however, those found in Loch Broom are contiguous with a flatter bed and considered dense enough in coverage to constitute a bed (Holt, 1991; Bates *et al*., 2004). The current at these sites is much weaker than found on other beds in Scotland, possibly indicating that slope rather than current speed is important for establishing nests at these sites (Moore, pers. comm.). Beds can also vary substantially in thickness, the bed recorded in Loch Fyne ranged from 10-20 cm compared with 4-6 cm in Loch Linnhe and Loch Creran.

These physical variations undoubtedly contribute towards the different communities seen. For example, 43% of the species found in the Loch Fyne study (Hall-Spencer & Moore, 2000) were recorded on the *Limaria* beds in Lochs Creran and Linnhe (Trigg *et al*., 2011), yet the composition of the benthos found in these studies was quite different. Molluscs and brittlestars dominated the Loch Fyne samples (Hall-Spencer & Moore, 2000), whilst in Lochs Creran and Linnhe almost a third of all organisms were polychaetes; with *Pholoe inornata* being the most prevalent (Trigg *et al., 2011)*. Furthermore, clear variations in the associated communities of these beds are apparent with depth. The shallow water beds having a preponderance of filamentous and foliose algae, whilst outwith the photic zone brittlestars become the most identifiable visual epibiont (Mercer *et al*., 2007).

Even when beds are near one another they may exhibit a number of differences in their community composition. Trigg *et al*. (2011) showed a significant difference in the species richness between *Limaria* beds in Loch Linnhe and Loch Creran. They highlight a number of possible causes for these differences such as the continual assimilation of material and organisms to the bed, the stochastic variability associated with settlement of invertebrates and the damage to beds from natural occurrences. On several occasions they observed patches of the Loch Linnhe bed being torn away by the 'uprooting' of kelp holdfasts attached to the nest (Minchin, 1995). By contrast the Creran bed is more stable, with only very small patches devoid of nest material, mainly as a result of the scarcity of kelp. It is considered that a naturally stable *L. hians* bed may provide a habitat sufficient for the development of a less transient community, possibly resulting in a different assemblage of organisms than from a bed subjected to frequent natural impacts (Trigg, 2009). The constant assimilation of material to a *Limaria* bed means that although the beds are generally considered stable structures, they contain dynamic communities that constantly acquire opportunistic organisms that are themselves attached to material bound to the nest (Trigg, 2009).

Viability

The area required for a minimum viable population (MVP) of *L. hians* individuals is not known (Hill *et al.,* 2010). It is thought *L. hians* larvae can exist in the plankton for up to three weeks (Minchin, 1995; Trigg & Moore, 2009) and therefore dispersal potential is thought to be fairly large (Hill *et al.*, 2010). However, *L. hians* has a restricted distribution, recorded only in certain sea lochs on the west coast. Due to the varying flushing times of these lochs, the larvae are likely to be restricted in certain locations. For this reason consideration should be given to protecting all patches or beds of *L. hians* within an area where larval supply is likely to be restricted i.e. all beds within a specific sea loch. Due to a lack of information a precautionary approach to protection must be taken. The boundary of any MPA should therefore be drawn so as to encompass not only the known distribution of *L. hians*, but also adjacent areas of associated or overlapping biotopes.

Longevity

Although the life-span of a single *L. hians* individual is unknown, when beds are undisturbed they are very stable, and some are thought to have existed for around 100 years (Trigg & Moore, 2009)

Fragmentation

The level of fragmentation with flame shell beds does seem to vary between sites but is not well documented. Flame shell beds are characterised by dense populations of *L. hians* where nests coalesce into a carpet over the sedimentary substratum. These nests can be built of shell, stones, debris and maerl (when present) interlaced by several hundred byssus threads, and lined by mucus, mud and their faeces (Hall-Spencer & Moore, 2000). *L. hians* nests can also occur individually or in small numbers. Small fragmented beds of *L. hians* have been found in a number of including Lochs Sunart and Teacuis (Bates *et al*., 2004).

Indicators of Least Damaged/More Natural

Up to date information on the sensitivity of Flame shell beds to pressures associated with human activities is included in the Feature Activity Sensitivity Tool (FeAST; Marine Scotland, 2013). Below, information on indicators of naturalness and damage are taken from primary literature (were referenced) or from MarLIN sensitivity data (Tyler-Walters, 2008a)(where reference is absent).

Table 1. Indicators of damage and naturalness

Indicators of Naturalness	Indicators of Damage	Potential Sources of Damage
Presence of undisturbed i.e. not 'rolled up' *L. hians* beds	'Rolled up' *L. hians* beds, dredge tracks (Trigg & Moore, 2009)	Physical damage or disturbance due to altered hydrography, erosion/ sedimentation, habitat loss.
Presence of intact, undisturbed *L. hians* beds with no dredge scars or increased sedimentation/scour.	Presence of disturbed/ damaged *L. hians* beds and/or presence of dredge scars and/or sedimentation/ scour.	Physical damage/ disturbance (from scallop dredging Trigg & Moore, 2009) due to changes in sedimentation, hydrography and sedimentation,
Byssal mats present and undamaged, epifaunal community present and undamaged.	Byssal mats damaged and/or absent, epifaunal community damaged and/or absent.	Physical disturbance and/or removal of habitat.
Normal community diversity, absence of excessive algal growth.	Increased incidence of algal blooms and potential for resultant benthic hypoxia.	Over enrichment of nutrients
Normal larval survival and recruitment to the beds.	Decreased larval survival and recruitment to the bed, reducing bed survival.	Chemical pollutants

Risk Assessment

The details of the assessment of risk for each MPA search feature is addressed in a separate report (Chaniotis *et al.*, 2014).

Recovery Potential

Physical disturbance/damage

Many causes of disturbance and damage are due to long term activities, the temporal and spatial extent of which will directly affect recoverability rates. Disturbances that remove vast quantities of bed take far longer to recover from than instances where considerable bed material remains. A 7.5m wide area of removed bed has been predicted to take over 100 years to recover; whereas if nest material remains after disturbance it has been shown that *L. hians* quickly recolonises these areas (Trigg & Moore, 2009). Damage of the epifaunal communities will likely recover rapidly once cessation of the damaging activity occurs. Linear expansion rates of 3.2cm per annum have been predicted for regrowth of *L. hians* over dredge scars (Trigg & Moore, 2009).

Increase incidence of algal blooms/ephemeral algae

Although it is thought that *L. hians* is sensitive to enrichment from both organic waste and fish farms (Diawara *et al*., 2008; Wilding, 2011), strong evidence is lacking.

Contamination

Minchin (1995) found that Tri-Butyl-Tin (TBT) had a negative effect on *L. hians* recruitment to a population in Ireland. This had a detrimental impact on *L hians* beds, resulting in loss of the byssal carpet. However, several years after the cessation of TBT as an antifoulant, the flame shell bed was similar in condition to that recorded prior to the use of TBT (Minchin, 1995).

Geographic Variation

Recent survey evidence suggests that the beds are found at several lochs along the west coast of Scotland, from Loch Broom in the north to Loch Fyne in the south. Thus the beds have a rather restricted distribution around Scotland. However, it is quite likely that the cryptic appearance of the bed and the potential for them to exist beyond normal dive limits (> 30m) has led to them being under recorded.

This search feature is considered scarce in the UK, and therefore the Scottish beds are of national importance. The most extensive and undisturbed examples are found in Loch Sunart and Loch Alsh (Moore *et al.*, 2013). They are also widespread in areas of accelerated tidal streams within Loch Sunart (Howson, 1996; Bates *et al*., 2004; Mercer *et al*., 2007) and a number of other sea lochs on the west coast of Scotland (e.g. Loch Carron, Loch Creran, Little Loch Broom and lower Loch Linnhe).

Geographic context

Outside the UK this species is found from the Lofoten Isles Norway, Iceland, Iberian Peninsula, the Mediterranean, Canary Isles and Azores (Tyler-Walters, 2008b). It is also found within Moross Channel, Mulroy Bay, Ireland (Minchin, 1995).

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