Wild Seaweed Harvesting

Strategic Environmental Assessment
Environmental Report

November 2016

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Non-Technical Summary

What is the role of this Strategic Environmental Assessment?

The Environmental Assessment (Scotland) Act 2005 requires the assessment of certain plans, programmes and strategies (including policies) that may have significant effects on the environment. Strategic Environmental Assessment (SEA) is the process used to fulfil this requirement, and includes consultation with the public and the Consultation Authorities.

A screening exercise was carried out by Marine Scotland and this found that wild seaweed and seagrass harvesting has the potential to give rise to significant environmental effects unless it is undertaken in a sustainable manner. It was concluded that an SEA should be prepared. A scoping exercise was carried out and a Scoping Report was prepared and issued to the Consultation Authorities in November 2015. This document set out the approach to and scope of the SEA.

Marine Scotland commissioned ABP Marine Environmental Research Ltd. (ABPmer) to provide technical support to the SEA and this Environmental Report. The purpose of this report is to document the findings of the SEA.

How was the Strategic Environmental Assessment undertaken?

Schedule 3 of the Environmental Assessment (Scotland) Act 2005 sets out the environmental factors or topics that may be subject to SEA. The scoping exercise identified that the following SEA topics should be scoped into the SEA and assessed:

- Biodiversity, flora and fauna;
- Climatic factors; and
- Cultural heritage.

The potential environmental effects of harvesting on each of these SEA topics have been assessed using the set of Key Questions that were developed at the scoping stage. These questions are based on a consideration of the ecological functions and ecosystem services provided by wild seaweed and seagrass, a review of the existing environment, the potential effects of wild harvesting and relevant environmental protection objectives. They also take account of the comments received from the Consultation Authorities.

The assessment is structured in a narrative style, centred on exploring the issues that the Key Questions raise. This narrative approach provides explanatory text to support the findings of the assessment, and record the evidence used in reaching its conclusions and recommendations.

This SEA has built on and updated existing information collected through the SEA for seaweed cultivation that was published for consultation in August 2013 alongside a draft Seaweed Policy Statement. Information from other sources including but not limited to the National Marine Plan have also informed this SEA. The SEA has also taken into account information provided by respondents to consultations.

Why are seaweeds and seagrasses important?

Seaweeds and seagrasses play a key role in marine and coastal ecosystems. Some are able to modify the environment (i.e. “ecosystem engineers”) and support high levels of marine and coastal biodiversity. As primary producers, they are also critical for supporting food webs which in turn contribute to fish and shellfish productivity. The importance of seaweeds and seagrasses in ecological functioning is recognised by the fact that they are used as indicators for assessing the ecological status of Water Framework Directive (WFD) water bodies and are included in a number of nature conservation designations.

Seaweeds and seagrasses also provide a number of ecosystem services, including natural hazard protection and climate regulation. Kelp forests and seagrasses are known for their capacity to weaken waves and reduce currents. Beach-cast seaweeds provide nutrients to dune habitats which in turn stabilise local sediments and contribute to coastal protection. In terms of climate regulation, seaweeds and seagrass habitats are important carbon stores and some may act as carbon sinks.

What is the current state of the environment?

A wide range of physical conditions are experienced along the coastline and inshore waters of Scotland from exposed areas characterised by rock to sheltered sandy bays, mudflats, sandflats and sea lochs. Water quality in Scotland as a whole is generally very good. However, there are some localised areas of concern, such as the Firth of Forth and Moray Firth.

Scotland’s seas are among the most biologically diverse and productive in the world. Scotland’s marine biodiversity is protected by a range of European, UK and Scottish-level designations. Key habitat types include estuaries; lagoons; large shallow inlets and bays; mudflats and sandflats not covered by seawater at low tide; reefs; sandbanks which are slightly covered by seawater all the time; submarine structures made by leaking gases; and submerged or partially submerged sea caves. Key animal species include cetaceans (whales, dolphins and porpoises), seals, seabirds, fish (including sharks, skates and rays) and turtles.

Climate change is predicted to lead to an increase in water temperature and acidity, a rise in sea levels, changes in wave heights and changes to coastlines. Climate change is already having an impact on weather patterns. Changes in temperature, levels and timing of rainfall, and more extreme weather events are all expected to occur, affecting other aspects of the environment.

Scotland’s seas and coasts support a wide range of historic and archaeological sites. These are found on the coast, the foreshore and the seabed, ranging from the remains of ships and aircraft lost at sea to harbours, lighthouses and other structures along the coast

What are the potential environmental effects of wild harvesting?

The SEA has identified that the sustainable extraction of maerl is not possible and that harvesting of maerl should be prohibited. Although the evidence indicates that the sustainable harvesting of seagrass might be possible, the seagrass beds found in Scotland are typically small and unlikely to support wild harvesting activities. The commercial harvesting of seagrass should therefore also be prohibited.

Current small scale (i.e. artisanal) hand cutting or picking of wild seaweed in Scotland is unlikely to result in significant adverse environmental impacts. It is therefore considered that these small scale activities can continue to be undertaken sustainably through existing practices (i.e. landowner permissions) and consultation with Scottish Natural Heritage. There is a risk that small seaweeds (namely green and red seaweeds) could be completely cleared from an area by these small scale harvesting activities. However, there is no information available on what would be considered a significant volume of removal for these small seaweeds and therefore at this stage in the absence of evidence it is not possible to propose a threshold for triggering a marine licence requirement for these activities.

The SEA has confirmed that significant adverse effects can occur as a result of large scale (i.e. industrial) mechanised harvesting of seaweeds (namely kelps and wracks). These primarily relate to impacts on the ecological function of these important habitats (namely ecological interactions, food web dynamics and production) as well as on the ecosystem services that they provide (including coastal protection and carbon sequestration), and that these impacts may be further exacerbated in the future with the predicted effects of climate change. Harvesting also has the potential to affect cultural heritage (namely underwater heritage assets and the collection of beach-cast seaweeds by crofters).

Key issues include but are not limited to:

- Loss of habitat and/or shelter for a range of plants and animals, alongside loss of direct and indirect food sources. This has consequences for detrital grazers and suspension feeders, as well as higher trophic levels, e.g. mammals, birds and fish;
- Loss of nursery grounds for juvenile invertebrates and fish, with consequences for higher trophic levels and commercial fish stocks;
- Loss of the physical modification effects of seaweed, e.g. wave damping, which may result in increases in coastal erosion and/or flooding events;
- Loss of carbon stores and sinks provided by some seaweed species; and
- Loss or damage to cultural heritage assets and reduction in resource available to crofters.

Many of these effects are likely to be site specific and will depend on a range of factors, including the species to be harvested, the harvesting method, the amount taken, the timing (season) of harvest, the harvesting location and its environmental context, and the time allowed for regeneration prior to harvesting again. Harvesting practices, most notably the extent and scale of harvesting (i.e. frequency of harvesting, the proportion of a seaweed community harvested, and the proportion of an individual plant harvested) and the species harvested have been identified as key factors in ensuring plant regeneration and recovery of harvest areas, and ensuring the sustainability of the resource and the biodiversity it supports.

How can significant effects be mitigated?

The specific mitigation that is appropriate will depend on the extent and scale of extraction which will only be known at the project level. In particular, it is important that any monitoring requirements reflect the scale, scope and complexity of the harvesting, as well as the level of risk (and confidence limits) of an ecological or environmental impact. The cost should also not be excessive compared to the estimate of income due from the harvesting activity.

A range of potential mitigation measures have been identified that developers will need to consider at the project level where relevant and necessary. These are based on relevant Codes of Conduct for seaweed harvesting and also recommended sustainable practices. The measures will include consideration of areas around the Scottish coast that are particularly sensitive to harvesting and where industrial scale harvesting may be restricted or unacceptable, including:

- Coastal areas that are wave exposed, prone to erosion and where kelps dissipate wave energy (e.g. Uists);
- Designated sites that could potentially support kelps or wracks (i.e. SACs, PMFs and MPAs);
- Seal haul out sites;
- Charted archaeological features (wrecks) and Historic Marine Protected Areas (HMPAs);
- Areas where beach cast seaweed is used by crofters.

What are the likely cumulative effects of a new licensing mechanism with other plans?

The focus of licensing wild harvesting is to ensure it is only undertaken where sustainable. The principles of sustainable development and protection of Scotland's marine environment are also key threads of wider Scottish policy (e.g. the National Marine Plan, Scottish Biodiversity Strategy). The licensing of wild harvesting activities therefore provides a means to manage negative environmental impacts.

Licensing also helps industry in developing a better understanding of expectations for future applications in relation to wild harvesting. Furthermore, by ensuring that wild harvesting activities do not result in significant negative environmental impacts, the licensing complies with environmental protection objectives, such as the WFD.

What are the outcomes of the Strategic Environmental Assessment?

On the whole, this SEA and the consideration of potential cumulative and synergistic effects demonstrate how the nature and extent of any potential impacts, depends on the method and scale of harvesting, and the composition and sensitivity of the corresponding marine ecosystems. It also demonstrates the interdependence of licensing, the seaweed industry and its stakeholders, the processes currently in place, and the combined role that they will need to play to ensure the sustainable growth of wild harvesting industries into the future.

The SEA has confirmed that significant adverse effects can occur as a result of large scale (i.e. industrial) mechanised harvesting of seaweeds (namely kelps and wracks).

Although there is no evidence that small scale artisanal hand cutting or gathering of living and beach-cast seaweeds at discrete locations has significant environmental effects, there is the potential for significant cumulative effects as a result of multiple harvesting activities. However, we do not know what the cumulative effects of a large number of small-scale activities being undertaken within the same geographic location or the cumulative effects of potential small scale harvesting operations in conjunction with large scale industrial operations would be. These would need to be considered in the cumulative assessments of individual licence applications.

Following on from this SEA, Marine Scotland intends to prepare a guidance note for regulators and applicants. This will include information on key issues associated with wild harvesting that have been identified in the SEA. It will also include information on issues that fall outside the scope of the assessment but will need to be considered at the project-level by industry. The guidance note will also present mitigation measures that might be required to ensure future wild harvesting activities do not result in any significant adverse effects and are undertaken sustainably.

GIS data layers that have been created as part of this SEA, namely the distribution of the current seaweed and seagrass resource and will be included on Marine Scotland's National Marine Plan interactive (NMPi) site.

How do I respond to the consultation?

A consultation on this Environmental Report will follow. Public views and opinions on this Environmental Report are invited.

Reponses need not be confined to the consultation questions, and more general comments on the Environmental Report and the Consultation Document are also invited.

What happens next?

Following the consultation period, the responses received will be analysed and reported. Key messages from the various stakeholder groups will be highlighted, and the findings of the analysis will be taken into account.

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1. Introduction

1.1. Wild Seaweed and Seagrass Harvesting

1.1.1. Seaweed and seagrass play an important role in marine and coastal ecosystems and also provide a significant number of ecosystem services. Seaweed and seagrass harvesting is undertaken in many countries for a range of end uses, including by the pharmaceutical and foodstuffs industries.

1.1.2. Until recently the wild seaweed sector in Scotland was small, however the sector is looking to grow with existing companies expanding and new proposals coming forward to harvest at a larger scale. A Strategic Environmental Assessment (SEA) has been undertaken to ensure that such harvesting of wild seaweed in Scotland is sustainable[1], to assist decision making and to inform future policy.

1.2. Strategic Environmental Assessment

1.2.1. The Environmental Assessment (Scotland) Act 2005 ("the Act") requires the assessment of certain plans, programmes and strategies (including policies) that may have significant effects on the environment. Strategic Environmental Assessment (SEA) is the process used to fulfil this requirement.

1.2.2. A screening exercise was carried out by Marine Scotland and this found that wild seaweed harvesting has the potential to give rise to significant environmental effects unless it is undertaken in a sustainable manner. It was concluded that an SEA should be undertaken.

1.3. Report Purpose and Structure

1.3.1. The purpose of this Environmental Report is to document the findings of the SEA. The remainder of this report is structured as follows:

- Following this introductory section,
- **Section 2** sets out the approach to the SEA, including the scope of the harvesting activity, the scope of the assessment, the reasonable alternatives and the methods used.
- **Section 3** provides background information about seaweed species and distribution and discusses their use as a natural resource.
- **Section 4** gives a general description of the physical environment and water quality in Scottish coastal ecosystems, then discusses some of the diverse marine species.
- **Section 5** describes ecological functions, habitats and shelter provided by seaweed and seagrasses and discusses their contributions to primary and secondary production.

[1] The working definition of sustainable harvesting in this document is the harvesting of a resource at specified time intervals (e.g. every year) and over a specific period after it has recovered to a sufficient degree to be harvestable again.

- **Section 6** The potential effects of wild seaweed and seagrass harvesting on the ecological function of seaweeds and seagrasses are reviewed and discussed in this section.
- **Section 7** investigates the climatic factors that affect seaweed and may be impacted by seaweed harvesting.
- **Section 8** discusses impacts on cultural heritage.
- **Section 9** introduces a risk matrix based on current evidence and mitigation
- **Section 10** presents an assessment of reasonable alternatives.
- **Section 11** discusses the potential for cumulative effects.
- **Section 12** provides a summary of the assessment findings.
- References and supporting information are provided in **Section 13** and the appendices, respectively.
- Appendices include background information to mapping methods, environmental objectives, seaweed and seagrasses, protected sites and the evidence base.

2. Approach to SEA

2.1. Background

2.1.1. A screening exercise was carried out by Marine Scotland to ascertain whether wild seaweed harvesting would be likely to result in significant environmental effects. Based on the evaluation against the screening criteria (Schedule 2 of the Act), Marine Scotland concluded that wild seaweed harvesting activities are likely to give rise to such effects unless they are undertaken in a sustainable manner. The screening report was submitted to the Consultation Authorities[2] in October 2015. All three agreed with Marine Scotland's view. Marine Scotland therefore concluded that SEA is required to ensure that such harvesting of wild seaweed in Scotland is sustainable, to assist decision making and to inform future policy.

2.1.2. The next step was to undertake a scoping exercise. The resulting Scoping Report, setting out the proposed approach to and scope of the SEA, was submitted to the Consultation Authorities in November 2015. All three provided helpful comments on the proposed scope and level of detail of the SEA, and the majority of these were taken into account in progressing the assessment.

2.1.3. Marine Scotland commissioned ABP Marine Environmental Research Ltd. (ABPmer) to provide technical support to the SEA and to assist in the preparation of this Environmental Report.

2.1.4. Marine Scotland and ABPmer were assisted in the SEA by a Project Advisory Group, and we would like to thank the representatives of the following organisations for their participation and helpful contributions:

- Scottish Natural Heritage;
- Scottish Environment Protection Agency;
- The Crown Estate;
- Marine Scotland Science;
- Marine Scotland Licensing Operations Team;
- The Scottish Seaweed Industry Association;
- Marine Alliance for Science and Technology for Scotland;
- Scottish Environment Link;
- Scottish Fishermen's Federation;
- Comhairle nan Eilean Siar;
- Scottish Coastal Forum; and
- Natural History Museum, Department of Botany.

[2] Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), and Historic Environment Scotland (HES)

2.2. Scope of Harvesting Activities

Definition of Wild Harvesting

2.2.1. Wild seaweed and seagrass harvesting is defined as the picking, cutting, removal or gathering of seaweed or seagrass, either by hand or mechanically, and where there is a commercial reward and a sustained harvest. It is this activity that is included in the scope of this SEA. The traditional gathering of beach-cast seaweed by crofters is also included. The collection of seaweed/seagrass for personal use and the clearance of a single beach for environmental health reasons have been scoped out.

Geographic Scope

2.2.2. Wild harvesting activities are undertaken in Scottish territorial waters (0-12 nautical miles), including the intertidal zone and the coastal fringe of adjacent land, and it is not anticipated that future harvesting would be carried out beyond 12 nautical miles. Together these set the context for the geographic scope of the SEA.

Target Species

2.2.3. Maerl and seagrasses are not currently harvested in Scotland but have been included in the scope of the SEA for completeness, following the screening consultation, an information review and discussion.

2.3. Scope of the Assessment

2.3.1. The SEA focuses on the environmental effects of commercially harvesting wild seaweed and seagrass. One of the scoping responses included a request for the SEA to include an assessment of the effects of the end use(s) of harvested seaweed and seagrass. These concerns related to human health, i.e. through consumption of contaminated seaweed, and to the use of biofuel. However, widening the scope of the SEA in this way is not considered to be a proportionate approach. Such an approach would make the SEA more of a lifecycle analysis and would not be aligned with other marine SEAs. For example, the SEA of offshore wind, wave and tidal energy did not consider the end uses of the electricity that would be generated.

2.3.2. Schedule 3 of the Act sets out the environmental factors or topics that may be subject to SEA. The scoping exercise identified that the wild harvesting of seaweed and seagrass could affect the following:

- Biodiversity, flora and fauna;
- Climatic factors; and
- Cultural heritage.

2.3.3. These topics have therefore been scoped into the SEA, with the remaining topics scoped out. The rationale for this approach is provided in **Table** 1**.**

Table 1: Scoping In / Out of SEA Topics

SEA Topic	In/out	Reasons for inclusion / exclusion
Biodiversity, flora and fauna	In	Wild harvesting may affect biodiversity, including but not limited to: loss of habitat and/or shelter for a range of plants and animals, alongside loss of direct and indirect food sources. As well as detrital grazers and suspension feeders, this has consequences for higher trophic levels, e.g. mammals, birds and fish. This topic is scoped into the SEA. There may also be disturbance of protected and other species (seals, otters, cetaceans, birds etc.) from harvesting and/or gathering activities in intertidal waters or on the shore, or from infrastructure construction such as buildings, access tracks, etc. Unless there are significant locational issues, these potential effects will be included in a guidance note for decision-makers and applicants.
Population	Out	Wild harvesting activities would not result in e.g. significant increases and/or decreases in human population numbers, changes to in- or out-migration, etc. These topics are scoped out of the SEA.
Human health	Out	Wild seaweed harvesting activities have health and safety implications for harvesters using certain harvesting methods, but these are issues for the sector under the appropriate health and safety at work legislation. Harvesting activities would not result in significant changes to air, noise, water quality, or land quality (contamination). Human health issues around the human consumption of seaweed have been scoped out of the SEA (see Section 2.3.1 for the rationale).
Soil, geology and hydrodynamic processes	In	Potential impacts on coastal geodiversity interests include sediment processes; changes to sedimentation rates and patterns, changes to water movement and changes in coastal accretion. These impacts are scoped into the SEA and reported under “climatic factors”..
	Out	Wild seaweed harvesting activities would be unlikely to result in levels of detritus higher than those that would occur naturally as part of seaweed growth cycles, and would therefore not result in increased detritus on the seabed (which would have potential for smothering and changes in benthic chemistry). These topics are scoped out of the SEA
Water quality, resources, ecological status	In	Activities are likely to affect the ecological status of water bodies, through their effects on biodiversity, and ecological status is therefore scoped into the SEA. This topic has been assessed and reported under “biodiversity, flora and fauna”, in the interests of proportionality.
	Out	Wild seaweed harvesting activities would not result in increased discharges to the aquatic environment, or require significant increases in water consumption. Water quality is scoped out of the SEA.

SEA Topic	In/out	Reasons for inclusion / exclusion
Air	Out	Wild harvesting activities would be unlikely to result in emissions to air, other than those from vessels used for gathering and/or harvesting activities. It is unlikely that such vessels would make a significant contribution to existing vessel emissions. We therefore consider that wild seaweed harvesting activities would not result in significant changes to atmospheric emissions, and have scoped air quality out of the SEA.
Climatic factors	In	Wild harvesting activities would not result in increased/ decreased emissions of greenhouse gases and these are scoped out of the SEA. The role of seaweed/seagrass in carbon cycling, providing carbon sinks and providing coastal/flood defence is scoped into the SEA.
Material assets	In	The role of kelp beds as spawning and nursery areas for (commercial) fish and invertebrates is scoped into the SEA and reported under “biodiversity, flora and fauna”. The role of seaweed in providing coastal defences (e.g. through wave energy absorption), carbon sinks and carbon cycling is scoped into the SEA and reported under “climatic factors”. The traditional gathering of beach-cast seaweed, e.g. by crofters is scoped into the SEA and reported under “cultural heritage”.
Cultural heritage	In	Wild harvesting activities, particularly those using dredging methods, have the potential to affect underwater marine archaeological features. This topic is scoped into the SEA. Gathering beach-cast *Laminaria* and other species is a traditional activity by crofters and others, and could be affected by commercial harvesting. Such harvesting may also affect the ability of cast seaweed to provide coastal erosion protection and, therefore, protection of historic environment features vulnerable to such erosion.
Landscape/ seascape	Out	The construction and/or operation of supporting infrastructure may have local effects on landscape and/or seascape. However, these issues are likely to arise at all sites, at the local level, and will be considered accordingly. These issues are therefore scoped out of the SEA.

2.3.4. The activity of harvesting of wild seaweed and seagrass also has the potential to give rise to contamination (e.g. spills from vessels), disturbance of coastal and intertidal species (e.g. by the construction of infrastructure such as access tracks), and effects on landscape from such infrastructure. There may also be disturbance of protected and other species (e.g. seals, otters, cetaceans etc.). There are also concerns about the potential introduction and/or spread of invasive non-native species during hand or mechanical harvesting, through the discharge of ballast water or use of equipment where such species are inadvertently present.

2.3.5. These issues could arise at most sites around the coast. Marine Scotland considers that, although these issues are important at project and/or activity level, there are well-known measures for the control and/or management of such issues. They have therefore been scoped out of the SEA with the agreement of the Consultation Authorities. However, these issues will be included in a guidance note for decision-makers and applicants, along with the necessary mitigation measures (see **Section 9**).

2.3.6. An SEA of seaweed aquaculture was undertaken and an Environmental Report published for consultation in August 2013 alongside a draft Seaweed Policy Statement[3] . The scope of this SEA therefore does not include the environmental effects of seaweed aquaculture, given that the previous work is relatively recent and that, as yet, no monitoring results are available from pilot seaweed farms.

2.4. Reasonable Alternatives

2.4.1. The Act requires the assessment of reasonable alternatives. The reasonable alternatives that have been identified are:

- Do nothing, i.e. continue with the existing licensing/leasing arrangements for all future commercial harvesting activities;
- All commercial wild harvesting activities to require a marine licence;
- Using a combination of existing arrangements and marine licensing depending on the scale of the harvesting activity;
- Stop all commercial harvesting activities.

2.4.2. The implications of these alternatives are discussed in **Section 10.**

2.5. Assessment Methodology and Reporting

2.5.1. The potential environmental effects of harvesting have been assessed using the key questions set out in **Table 2.** These were developed at the scoping stage and are based on consideration of the ecological functions and ecosystem services provided by wild seaweed and seagrass (**Section 4.4)**; a review of the existing environment (**Section 5**); the potential effects of wild harvesting (**Section 6**) and the environmental protection objectives (**Appendix B**). They also take account of the comments received from the Consultation Authorities.

[3] both are available at http://www.gov.scot/Publications/2013/08/6786

2.5.2. The key questions enable the assessment to focus not only on environmental topics, but also on the interactions and inter-relationships between them. They also enable the identification of measures for mitigation and/or enhancement and requirements for monitoring.

2.5.3. The results of the assessment are structured in a narrative style, centred on exploring the issues that the key questions raise. This approach provides explanatory text to support the findings of the assessment, and records the evidence used in reaching its conclusions and recommendations.

	Table 2 Key Questions	Section(s) of Environmental Report (ER)
1	Which species are most likely to be exploited by wild harvesting activities?	Table 4: Page 39
2	What is the nature of the resource, based on existing information? i.e.: What are the target species? Identify living, beach-cast, calcified seaweeds and seagrass What amount/biomass is available for harvesting?	Appendix C: Page 177
3	Where around the Scottish coast is it located?	Section 3.2 Page 21
4	What ecological functions and ecosystem services do these seaweeds/seagrasses provide? How do these vary with location? The relative importance of locations should be considered in this context.	Section 3.10: Page 34; Section 4.4: Page 61; Section 5: Page 77
5	Would wild harvesting activities affect these ecological functions, both those of coastal margins and marine ecosystems, including but not limited to: Would loss of habitat and/or shelter for other species be permanent? How would the scale and duration of habitat loss relate to the sensitivity (resistance and resilience) of any impacted species? How would loss of feeding grounds affect higher trophic levels? How would loss of direct and indirect food sources affect suspension feeders and others? Would this be related to season? Can adverse effects be mitigated?	6.2,0
6	Would wild harvesting activities affect these ecosystem services, both those of coastal margins and marine ecosystems, including but not limited to: Adverse effects on coastal defences? Adverse effects on fish spawning and nursery grounds? Seaweed's role in the carbon cycle, including its function as a carbon sink? Loss of physical modification, e.g. wave damping? An increase in wave scour?	6.2, 7.5
7	Would wild harvesting/gathering activities affect historic environment assets?	Section 8
8	Can wild harvesting activities be undertaken in a sustainable manner?	Section 12
9	Are there any geographic areas/locations of particular environmental/ecosystem service sensitivity? (Please note that this includes ecological services for the coastal margins as well as marine ecosystems.)	9.2
10	Could the harvesting of wild seaweed be undertaken in such a way as to maintain the environmental quality and resources which support material assets such as fish nursery grounds/ coastal defences?	Section12

11	Are there potential cumulative environmental effects from wild harvesting, including but not limited to aquaculture, renewables, coastal defence works, coastal realignment, etc.?	Section 11

2.6. Building on Previous Assessments

2.6.1. An SEA of seaweed cultivation was undertaken and an Environmental Report published for consultation in August 2013, alongside a draft Seaweed Policy Statement (http://www.gov.scot/Publications/2013/08/6786). The SEA included a high-level assessment of the potential environmental effects of wild seaweed harvesting, but was not detailed enough to inform decision making and the information is also out-of-date.

2.6.2. The current SEA has built on, and updated, existing information collected through the SEA for seaweed cultivation. Information from other sources including, but not limited to, the National Marine Plan for Scotland and the SEAs of the Marine Protected Areas has also been used to inform this SEA. Information provided by respondents to previous consultations was also taken into account.

2.7. Identifying Monitoring Proposals

2.7.1. Proposals for monitoring will be provided in the Post Adoption Statement. These will focus on the significant environmental effects identified in **Sections 6, 7 and 8** of this report. Where possible, existing data sources and indicators will be linked with relevant indicators, to minimise resourcing requirements for additional data collection.

3. Wild Seaweed and Seagrass Harvesting

3.1. Seaweed and Seagrass

3.1.1. The term seaweed is the collective name for a number of different groups of macroscopic, multicellular, marine algae (macroalgae). **Seaweeds** in Scotland's coastal waters fall into the following five broad categories:

- **Wracks (rockweeds):** large brown seaweeds of the taxonomic order Fucales. Species include *Ascophyllum nodosum* (Egg wrack)[4] , *Pelvetia canaliculata*, *Fucus vesiculosus*, *F. spiralis*, *F. serratus* and *Himanthalia elongata*.
- **Kelps**: large brown seaweeds of the taxonomic order Laminariales. Scotland's kelp forests mainly comprise *Laminaria hyperborea*, but also include *Laminaria digitata*, *Alaria esculenta*, *Saccharina latissima* (formerly *Laminaria saccharina*) and *Saccorhiza polyschides*.
- **Green seaweeds**: smaller, simpler in structure and shorter-lived than wracks and kelps; generally, range from a few centimetres to a metre in length. Key species in Scotland include *Ulva intestinalis* and *U. lactuca*.
- **Red seaweeds**: smaller than wracks and kelps with a similar size range to the green seaweeds. In Scotland, this group includes perennial species (e.g. *Chondrus crispus*, *Mastocarpus stellatus* and *Palmaria palmata*) and annual species (e.g. *Porphyra umbilicalis*).
- **Calcified seaweeds** (namely maerl): a calcium-carbonate encrusted red alga which produces calcareous prolongations. These accumulate subtidally as dense beds of calcareous material, both living and dead. The two species of maerl found in Scotland are *Lithothamnion glaciale* and *Phymatolithon calcareum*.

3.1.2. Examples of seaweed species in Scotland are provided in **Figure 1**.

3.1.3. **Seagrasses** are grass-like flowering plants with dark green, long, narrow, ribbon-shaped leaves. They are unique in being the only truly marine flowering plants or angiosperms (Heminga and Duarte, 2008). Seagrass species in Scotland comprise *Zostera marina*[5], *Z. noltii*, and *Ruppia maritima*[6] . The closely related and morphologically very similar *R. cirrhosa* is not widespread in Scotland.

[4] There is another form of *Ascophyllum* known as *A. nodosum* f. mackayi. This is a free-living unattached form that lives on gravel, sand and mud beds in very sheltered sea lochs. It takes the form of dense, tangled masses of fronds, usually finer than attached fronds. In Britain it is known only from the west coast of Scotland and is regarded as being of conservation value.

[5] What was formerly considered to be a third species, *Z. angustifolia*, is now generally considered to be an intertidal variant of *Z. marina*. For WFD monitoring purposes it has been retained as an entity.

[6] d'Avack et al (2014) note that R. maritima is not a true seagrass, but is considered to be a freshwater species able to tolerate salinity. However, *R. maritima* will be included in seagrasses for the purposes of this SEA.

Figure 1: Examples of seaweed

3.2. Location of the Seaweed and Seagrass Resource

3.2.1. The known (recorded) and potential distribution of each of the broad groups of seaweeds and seagrasses in Scottish waters has been mapped (**Figure 2** and **Figure 3** [7]). Information on the mapping process is provided in **Appendix A.**

3.2.2. An overview of the distribution of each broad group and key corresponding EUNIS habitats is provided in**Table 3**. Further information on the specific EUNIS habitats that represent each of the broad seaweed and seagrass groups in the distribution maps and the spatial data layers used is included in **Appendix C**(**Table C2**).

[7] These maps only present the distributions of seaweeds that are available from existing GIS layers. In reality, seaweeds (except perhaps maerl) are more prolific and present around much of the Scottish coast.

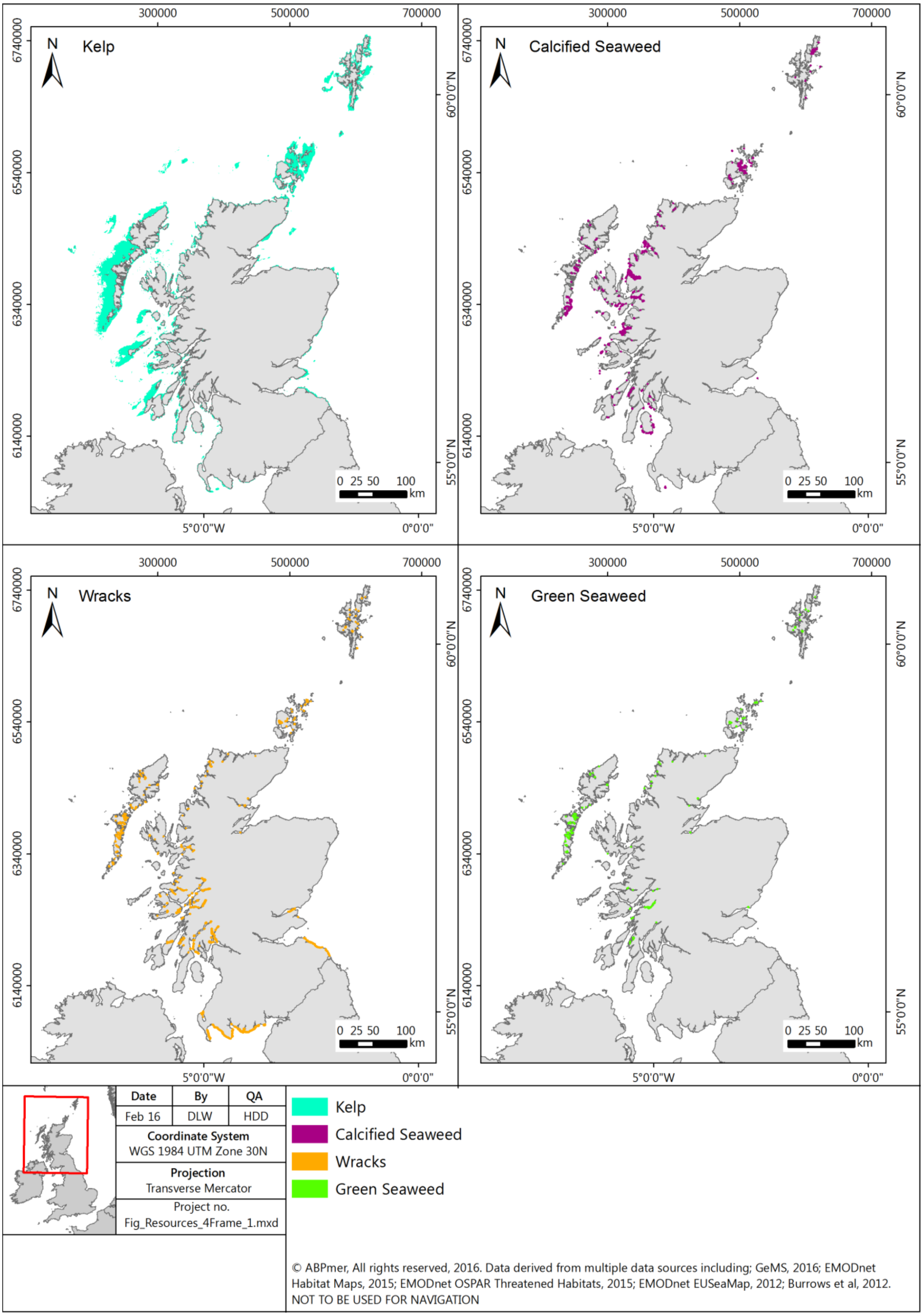


Figure 2: Available spatial information on the distribution of kelps, maerl, wracks and green seaweeds

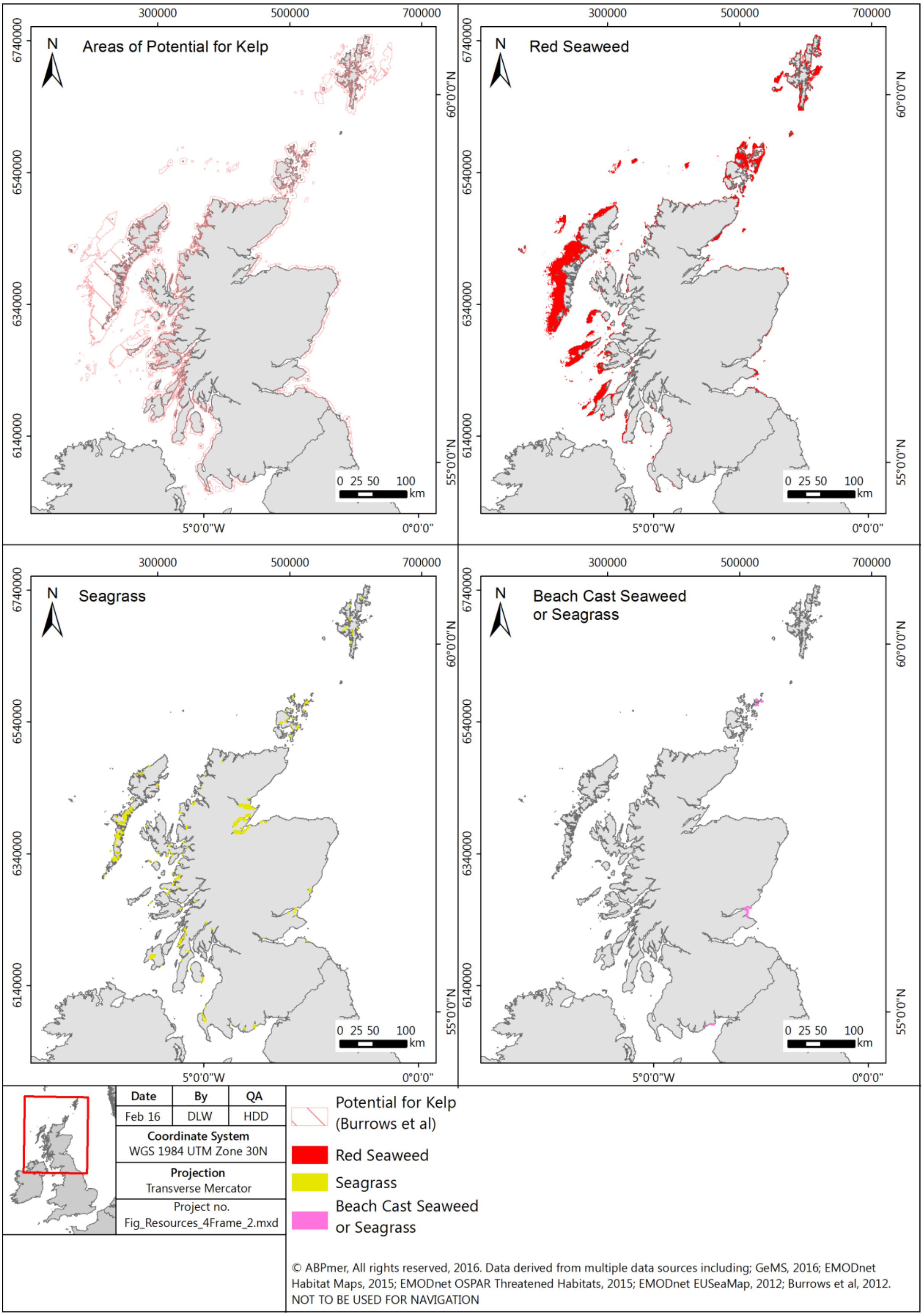


Figure 3: Available spatial information on the distribution of potential areas for kelps, and the distribution of red seaweeds, seagrasses and beach-cast seaweeds or seagrasses

3.2.3. Spatial coverage is also provided in **Table 3.** The table includes an estimate for each of the broad groups of living seaweeds and seagrasses and beach-cast seaweeds and seagrasses in Scottish waters, based on available data. These area estimates do not account for the quality of the resource (in terms of biomass and density) and whether it is suitable for harvesting. Furthermore, there is a large area of Scotland's foreshore and intertidal zone with no data available but which may also provide additional biological resource.

Table 3: Summary of distribution and potential coverage of each of the broad groups of seaweed and seagrass in Scotland

Broad group	Key EUNIS Habitat Codes (Level 3)	Approximate Area (km^2)	Distribution
Wracks	A1.15 Fucoids in tide-swept conditions A1.21 Barnacles and fucoids on moderately exposed shores A1.31 Fucoids on sheltered marine shores A1.32 Fucoids in variable salinity A3.22 Kelp and seaweed communities in tide-swept sheltered conditions A3.34 Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	62	Wracks primarily grow on intertidal rocky shores and also on sheltered, mud, sand or gravel shores. They are recorded along much of the coast of Scotland but appear to be most abundant in Western Scotland, the Inner and Outer Hebrides, Orkney and Shetland (Figure 2). Smaller areas of wracks are also located along the southeast coast of Scotland. In terms of biomass, the majority of *Ascophyllum nodosum* around the Outer Hebrides is primarily located around Lewis, North Uist and South Uist and Harris (Burrows et al., 2010).
Kelps	A3.32 Kelp in variable or reduced salinity A5.52 Kelp and seaweed communities on sublittoral sediment	10,004 (15,042)	Kelps are mainly found on suitable rocky areas all around the Scottish coastline, most extensively around Skye and the west coast mainland, as well as along the coast of the Inner and Outer Hebrides (e.g. Norton & Powell, 1979; Brodie & Wilbraham, 2012) and around Orkney and Shetland (Figure 2, Lancaster *et al.*, 2011; Wilkinson, 1995). There are fewer records of kelps on the east coast of Scotland, where much of the seabed is composed of sand (SNH, undated), although some significant patches of kelps do occur, particularly along the northeast and southeast Scottish coast.

Broad group	**Key EUNIS Habitat Codes (Level 3)**	**Approximate Area (km^2)**	**Distribution**
Green seaweeds	A3.34 Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	3	The majority of green seaweeds that have been digitally mapped are in the Outer Hebrides, in patches along the Western coast of the mainland, and also in Shetland and Orkney (Figure 2). The distribution of this group is likely to have been highly underestimated as it is a less conspicuous intertidal species that does not regularly form a dominant feature/biotope in the available spatial data layers. For example, there is known to be an abundance of *Ulva* sp. in some estuaries (e.g. in Ythan and Montrose Basin) which has not been captured in the available spatial data layers (Raffaelli et al., 1989; JNCC, 1995).
Red seaweeds	A3.11 Kelp with cushion fauna and/or foliose red seaweeds A3.21 Kelp and red seaweeds (moderate energy infralittoral rock) A3.33 Mediterranean submerged fucoids, green or red seaweeds on full salinity infralittoral rock A3.34 Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	8,695	The majority of red seaweeds are located along the west coast of Scotland, the Inner Hebrides, the west coast of the Outer Hebrides and around Orkney and Shetland. Some smaller patches of red seaweeds are also found on the north and east coasts of Scotland (Figure 3).

Broad group	Key EUNIS Habitat Codes (Level 3)	Approximate Area (km^2)	Distribution
Maerl	A5.51 Maerl beds	42	Maerl is usually restricted to places such as the sills of fjords and fjards (sea lochs in Scotland), together with the shores to the leeward of headlands and island archipelagos (Lancaster *et al*., 2014a). Maerl is found along the west coast of Scotland, in the Western Isles, Orkney, Shetland and the north coast, but is absent from the east coast (Figure 2). In the west region maerl is found within sea lochs and inlets on the mainland such as the Sound of Arisaig and Loch Laxford and areas such as Loch nam Madadh and the Sound of Barra in the Outer Hebrides. In the north region, there are widespread records of maerl beds in tide-swept areas, especially in Orkney and Shetland and Loch Eriboll on the north coast of the Scottish mainland.
Seagrasses	A2.61 Seagrass beds on littoral sediments A5.53 Sublittoral seagrass beds	112	The largest seagrass beds are found in Cromarty Firth, Moray Firth and Dornoch Firth (Figure 3). Other seagrass beds found in Scotland are typically small. There are some beds in the Outer Hebrides, including Loch Maddy and Loch Bi, and in Islay. Other smaller beds are found along the West coast of Scotland, such as in Loch Ryan, Loch Sunart, in the Montrose Basin and in the Forth and Tay Estuaries (JNCC, 1995; SNH, undated).

Broad group	Key EUNIS Habitat Codes (Level 3)	Approximate Area (km^2)	Distribution
Beach-cast seaweeds/ seagrasses	A2.21 Strandline	<1	There is very limited information on the distribution of strandline habitat which might include beach-cast seaweeds/seagrasses from the available spatial data layers (Figure 3). The only strandline habitat that has been recorded is in outer Tay Estuary and north coast of Orkney. However, it is considered likely that this habitat will occur wherever there is a beach located close to kelp habitat for example along the beaches on the southwest coast of the Outer Hebrides, parts of the Inner Hebrides (e.g. Tiree), in Orkney and Shetland and the west coast of the Scottish mainland.
Approximate area covered by potential for kelps (Burrows *et al*., 2014) is provided in the table in brackets.			

3.3. General Distribution

3.3.1. Many environmental factors affect the distribution of seaweed and seagrasses. These can be abiotic (physical or chemical features) or biotic factors, such as biological competition. The major abiotic factors influencing seaweed and seagrass growth are light, temperature, salinity, water motion, wave exposure, nutrient availability and exposure to air (desiccation) (Lobban & Harrison, 1994; Smale et al., 2016). Living seaweeds and seagrasses are present in the intertidal zone and in subtidal coastal areas where sunlight reaches the seabed (i.e. the infralittoral zone). Beach-cast seaweeds (mainly kelps) and (potentially) seagrasses may occur on the shoreline in drift lines, as a result of wave action during storms.

3.4. Seaweeds

3.4.1. Each seaweed species' tolerance of environmental conditions determines where it will occur and it abundance within its distribution range. Two abiotic factors are key in determining distributions on rocky shores; the vertical position on the shore in relation to the tides and the degree of wave action.

3.4.2. Positions higher up the shore in the intertidal or littoral zone are more stressful because the organisms, which are marine, have to withstand increased periods out of seawater, exposed to the drying effect of air, and the salinity shock of fresh rainwater. Below the low water mark, increasing depth results in a very rapid decrease in light intensity so that sublittoral (subtidal) species are restricted to a depth range near the surface, known as the photic zone, where light is sufficient for growth. Within the photic zone species may also be zoned based on their light requirements or their tolerance to damaging wave action around the low water mark.

3.4.3. The effects of wave action occur in both the littoral and sublittoral zones of rocky shores: in general, species can be recognised as characteristic of shelter or characteristic of wave exposure. The two dominant groups of large seaweeds on the shore, wracks and kelps, generally have different habitat preferences. The wracks are almost entirely intertidal, while the kelps dominate the subtidal, forming the kelp forest, but also extend into the lowest intertidal just above the low water mark.

3.4.4. **Figure 4** to **Figure 7** illustrate zonation of seaweed species, based on these tolerances. Although **Figure 4** and **Figure 5** present a schematic of a generalised sheltered shore and exposed shore respectively, these are extremes. There are many shores of intermediate exposure with some features of both diagrams, depending on the exposure of the shore..

3.5. Sheltered Shores

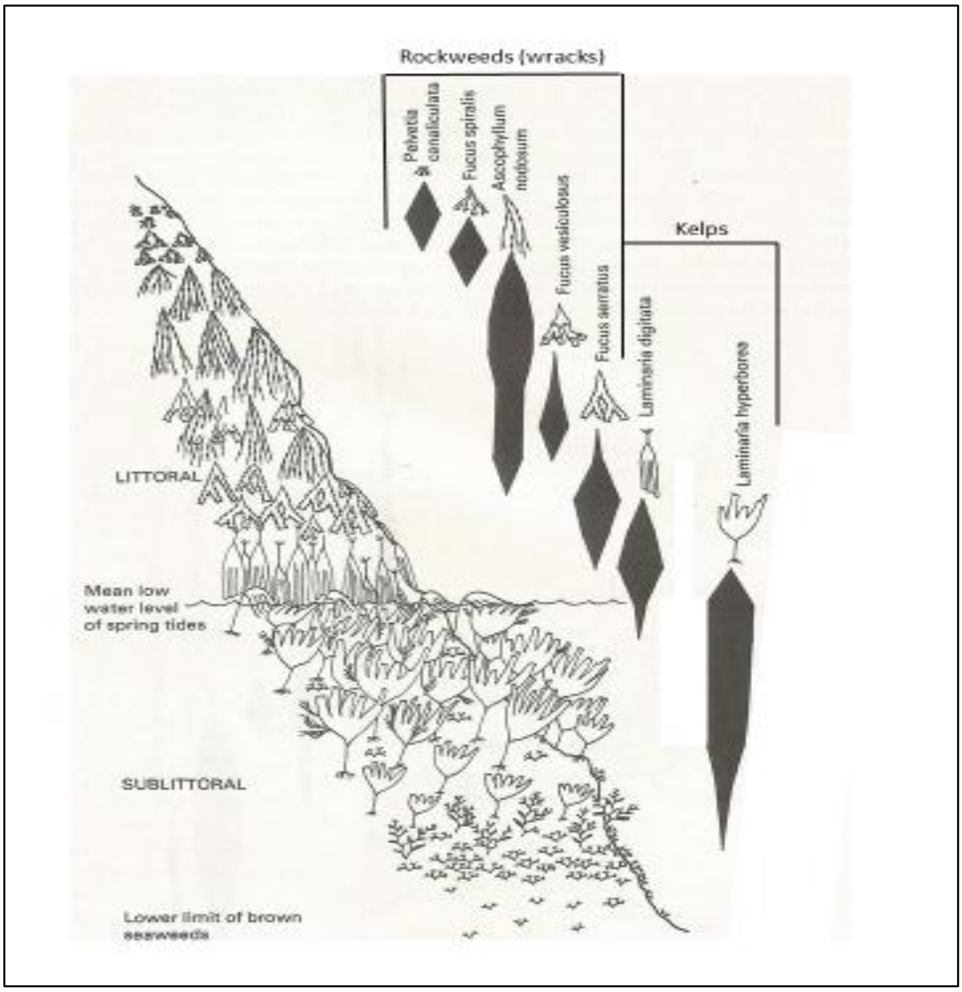


Figure 4: Generalised littoral and sublittoral zonation of wracks and kelps on a sheltered shore (adapted from Hiscock (1979))

3.5.1. The black kites on Figure 4 indicate the vertical range of each species; the width of the kite indicates approximate abundance at any height or depth. Note that the great abundance of *Ascophyllum nodosum* would only apply on the most sheltered shores, e.g. those found on the west coast and in Hebridean sealochs. With a slight increase in exposure *A. nodosum* is replaced by a greater abundance of *Fucus vesiculosus*. It is not possible to show a numerical depth limit in the sublittoral as this depends on water clarity and varies geographically. On sheltered shores there are often dense stands, in potentially harvestable amounts, of intertidal wracks. With a little increase in wave action, other possible communities can be present in a mosaic with the wracks so that continuous dense wracks cover does not occur.

3.6. Exposed Shores

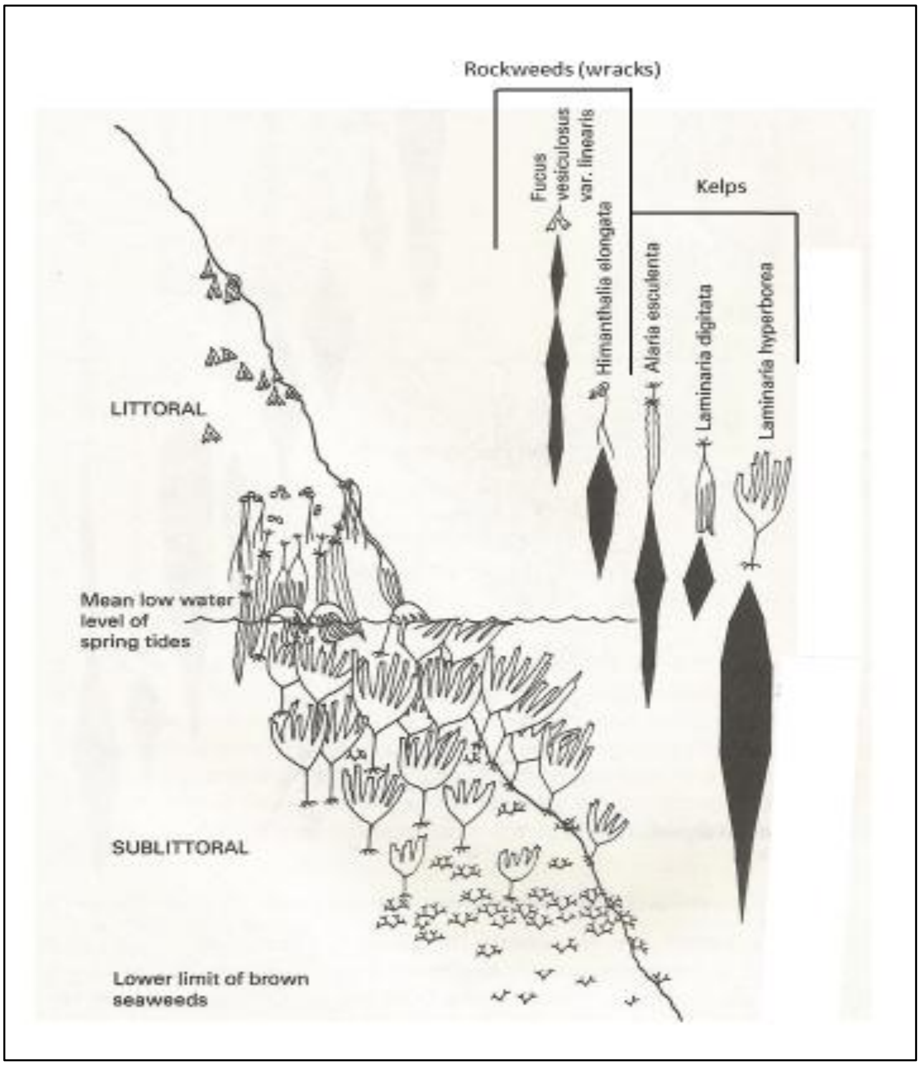


Figure 5: Generalised littoral and sublittoral zonation of wracks and kelps on an exposed shore (adapted from Hiscock (1979)).

3.6.1. The black kites on Figure 5 indicate the vertical range of occurrence of each species; the width of the kite indicates approximate abundance at any height or depth. Again, it is not possible to show a numerical depth limit in the sublittoral as this depends on water clarity and varies geographically. Most of the intertidal wrack cover is reduced. *Fucus vesiculosus* is represented by the variety "*linearis*", which lacks bladders and is of reduced size. *Pelvetia canaliculata* and *F. spiralis* are absent. *F. serratus* has been replaced by the thong weed *Himanthalia elongata*. A kelp characteristic of strong wave action, *Alaria esculenta*, occurs around the low water mark and in the shallow sublittoral.

3.7. Pebble and Gravel Shores

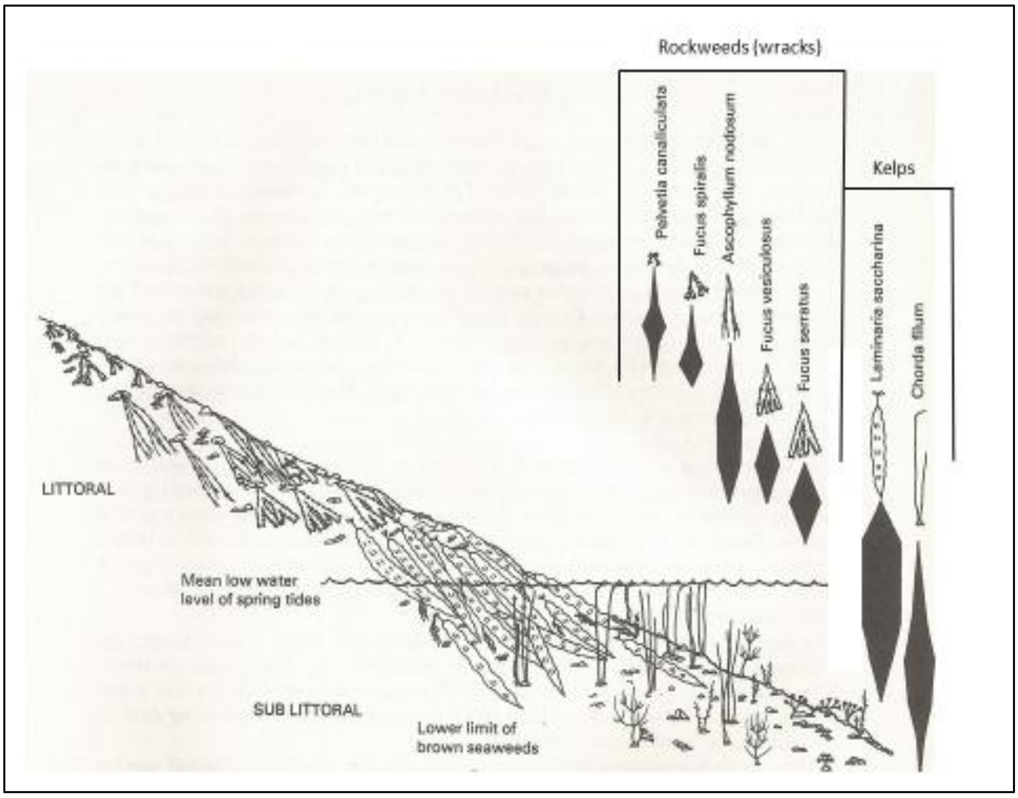


Figure 6: Generalised littoral and sublittoral zonation of wracks and kelps on a shore with a substratum of pebbles and gravel (adapted from Hiscock (1979))

3.7.1. Pebble and gravel shores that can support large seaweeds will be very sheltered and so will have wracks and kelps characteristic of strong shelter. The black kites in Figure 6: Generalised littoral and sublittoral zonation of wracks and kelps on a shore with a substratum of pebbles and gravel (adapted from Hiscock (1979))indicate the vertical range of occurrence of each species with very approximate abundance at any height or depth indicated by the width of the kite. The kelp *Laminaria saccharina* (now known as *Saccharina latissima*), occurs on many types of shore, but in this situation it can be dominant around the low water mark and in the shallow sublittoral. The larger *Laminaria* spp. and *Alaria esculenta* of solid bedrock shores do not occur here. *Chorda filum*, the bootlace weed, is a narrow but long string-like kelp restricted to this situation.

3.8. Stratification in Response to Exposure

3.8.1. **Figure 7** illustrates two features:

- increased depth penetration of kelps, going from less clear inshore waters to very clear open oceanic waters, and
- change in the dominant, forest-forming kelp species, going from extreme shelter at the head of sealochs through slightly greater wave exposure in the outer parts of sealochs to more wave exposed coastal sites, and finally extremely wave-exposed open oceanic sites.

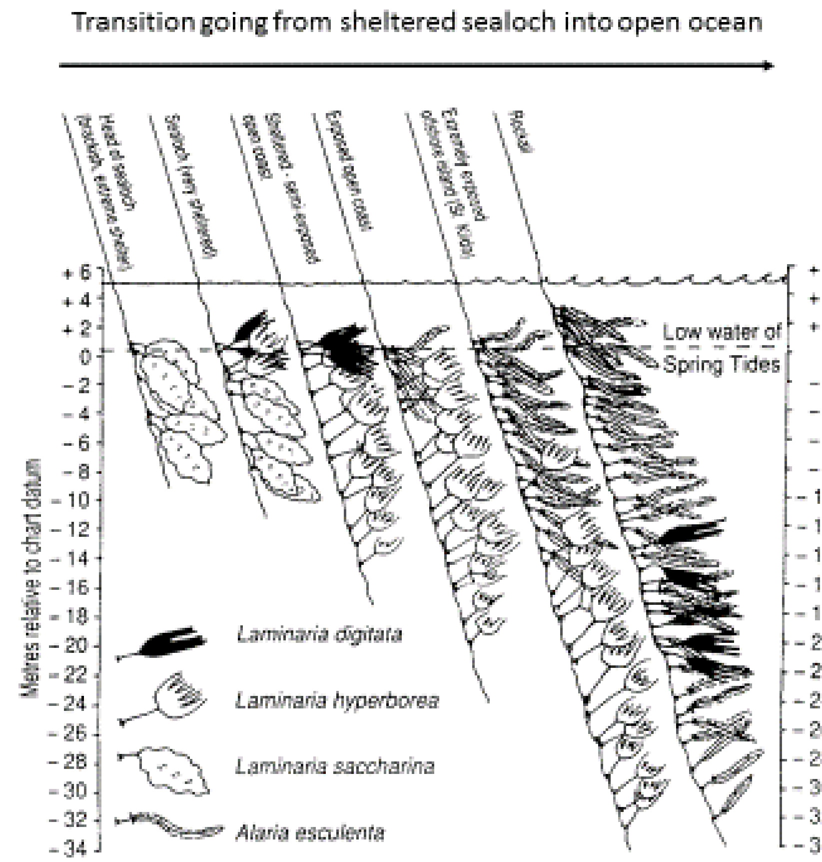


Figure 7: Depth transition of kelps from sheltered to exposed shores (adapted from Scott (1993).

3.8.2. Below the low water mark, increasing depth results in a very rapid decrease in light intensity so that sublittoral (subtidal) species are restricted to a depth range near the surface, known as the photic zone, where light is sufficient for growth. Within the photic zone species may also be zoned based on their light requirements or their tolerance to damaging wave action around the low water mark.

3.8.3. The effects of wave action occur in both the littoral and sublittoral zones of rocky shores: in general, species can be recognised as characteristic of shelter or characteristic of wave exposure[8]. The two

[8] Some species change their form with degree of wave action. For example, *Ascophyllum nodosum* can grow in a very long stranded form up to 2 m long in strong shelter where it forms very dense,

dominant groups of large seaweeds on the shore, wracks and kelps, generally have different habitat preferences. The wracks are almost entirely intertidal, while the kelps dominate the subtidal, forming the kelp forest, but also extend into the lowest intertidal just above the low water mark.

3.9. Seagrasses

3.9.1. In Scotland seagrasses grow in sheltered waters such as inlets, bays, estuaries and saltwater lagoons; in more exposed areas beds tend to be smaller and patchier (Davison & Hughes, 1998). Common eelgrass (*Zostera marina*) is the only species that occurs below low water mark, forming dense underwater lawns. The dwarf eelgrass (Z. noltii) grows on sheltered seashores in the intertidal zone and never below low water mark (Davison, 1998 cited in Wilkinson & Wood, 2003). *Ruppia maritima* (beaked tasselweed) grows in sheltered coastal brackish waters and inland saltwater habitats (lagoons) on soft sediments.

3.10. Long Term Variability

3.10.1. There is considerable diversity in form and life-style amongst seaweeds (Wilkinson, 2001 and 2002). The wracks and kelps are physically large organisms which often dominate particular zones on the shores where they occur. Often these dominant species appear to be stable features of the shore. Ecologists may call them climax species or late successional species because they can be the culmination of a process in which the seaweeds that colonise a bare area of shore go through a progression of different species starting from smaller, simpler ones. The early colonising species are often called opportunist species, and these include *Ulva* spp. (green seaweeds) and some *Porphyra* spp. (red seaweeds). Opportunists are generally smaller, have simple form, short life-span, fast growth rate, a relatively wide tolerance to environmental conditions, and are reproductive for most or all of the year so that they can rapidly and opportunistically colonise spaces that occur in habitats. In contrast, late successional or climax species are generally complex in form, may be larger, may have a life-span running into years, with specific reproductive seasons. Although they may be tough they are likely to be well-adapted to a specific set of conditions where they form the climax communities (and therefore may be vulnerable to change in these conditions).

3.10.2. Opportunists are normal members of all communities. A frequent mistake by those concerned with shore monitoring is to interpret their presence as indicating “bad conditions”. However, there can be an exceptional abundance of them when there is physical disturbance or considerable nutrient enrichment. In some naturally disturbed habitats, e.g. shores abraded by coarse sand in strong wave action, they may be naturally abundant.

3.10.3. Apparently stable climax communities may change in response to changes in environmental conditions. An example is the replacement

harvestable stands. But with even slight exposure to wave action this species adopts a very small form, close to the rock surface, which is not harvestable.

of *Laminaria* communities in Nova Scotia by sea urchins after excessive kelp removal by harvesting (see **Section 6.2**). In Scotland, very abundant and dense seaweed climax communities at Joppa in the Firth of Forth have been replaced by a stable mussel-barnacle community, owing to effects of Edinburgh's sewage discharge (Wilkinson, 2002; Wilkinson et al., 1987).

3.10.4. The growth of seaweeds and seagrasses, their distribution, and ultimately their effectiveness in providing ecological functions and ecosystem services is a result of several climatic and environmental factors which can vary both spatially and temporally. Alterations to temperature, pH and sea levels along with several other factors may result in community shifts which have the potential to affect the ecological functions and ecosystem services currently provided by seaweeds (Jackson et al., 2012).

3.10.5. Rapid warming could impact kelp forests in Scotland, although this is likely to take a long time as *L. hyperborea* is in the centre of its north-south distribution in Scotland (Brodie et al., 2014). Ocean acidification is likely to result in the loss of maerl habitat (Brodie et al., 2014). Conversely, seagrasses are predicted to proliferate if they are adequately protected from other anthropogenic pressures (Brodie et al., 2014). However, it is possible that increased sea temperature could be a threat to *Zostera* beds as it will result in an increase in respiration and decrease in photosynthesis (Wilkinson & Wood, 2003).

3.10.6. Combined impacts of seawater warming, ocean acidification, and increased storminess may replace structurally diverse seaweed canopies, with associated calcified and non-calcified flora, with simple habitats dominated by non-calcified, turf-forming seaweeds. In addition, invasive species may dominate in niches liberated by loss of native species (Brodie et al., 2014).

3.11. Uses of Seaweed and Seagrass

3.11.1. Human beings have used seaweed for a wide range of purposes for centuries. Today seaweed continues to be used in a variety of products. The main interest is in:

- horticultural and agricultural applications, e.g. organic fertilisers and animal feed;
- alginates, used in foods, textiles and pharmaceuticals, including as a gelling and thickening agent,
- cosmetics; and
- food products that are marketed as providing health and medical benefits. It is also a human food in its own right.

3.11.2. Seaweed also plays a beneficial role in integrated multi-trophic aquaculture systems, where the by-products from one species are recycled to become inputs for another.

3.11.3. The renewable energy industry is interested in using seaweed in biofuel production. Initial indications are, that in early stages of development, seaweed for biofuel may be a mix of cultivated and wild harvested seaweed.

3.11.4. Seagrass has been used in the past, for example, as a material to thatch roofs, to stuff mattresses and for bandages (Reynolds, no date). Its high nutrient content has also resulted in its being harvested for agricultural uses; however, this has mainly been focused overseas and activity levels have reduced in recent years, partly in response to bans on harvesting in some countries (CCEES & ABPmer, 2010). The main use of seagrass today appears to be as a craft material (d'Avack et al, 2014), for the manufacture of furniture.

3.12. Current and Future Harvesting Activity

3.12.1. Scotland has a small-scale wild seaweed industry, harvesting a range of brown, red and green seaweeds. The two main types harvested are *Ascophyllum nodosum* (egg wrack/ knotted wrack) and kelp, usually *Laminaria hyperborea*, and these comprise the largest volumes harvested. However, other species are also harvested, in smaller volumes, including (but not limited to) saw wrack (*Fucus serratus*), carragheens (i.e. *Mastocarpus stellatus* and *Chondrus crispus*), the channel wrack (*Pelvetia canaliculata*), dulse (*Palmaria palmata*), pepper dulse (*Osmundea* spp.) and laver (*Porphyra* spp.) (Angus, 2012). Current seaweed harvesting activity mainly takes place in Orkney, the Western Isles, Fife, Ardnamurchan, Loch Sunart, Bute, and Caithness (**Figure 8**). Small-scale harvesting took place in Shetland until relatively recently (circa 2010).

3.12.2. Beach-cast seaweed is 'gathered' from the shore in many of Scotland's island communities, for use as a soil conditioner or fertiliser. In the Western Isles, for example, beach-cast *Laminaria* spp. (and other species mixed with it) are traditionally gathered to spread on machair land (Angus, 2009), which is also important for the biodiversity of the machair (Comhairle Nan Eilean Siar, 2013). Little information is available about the extent or volumes of such gathering.

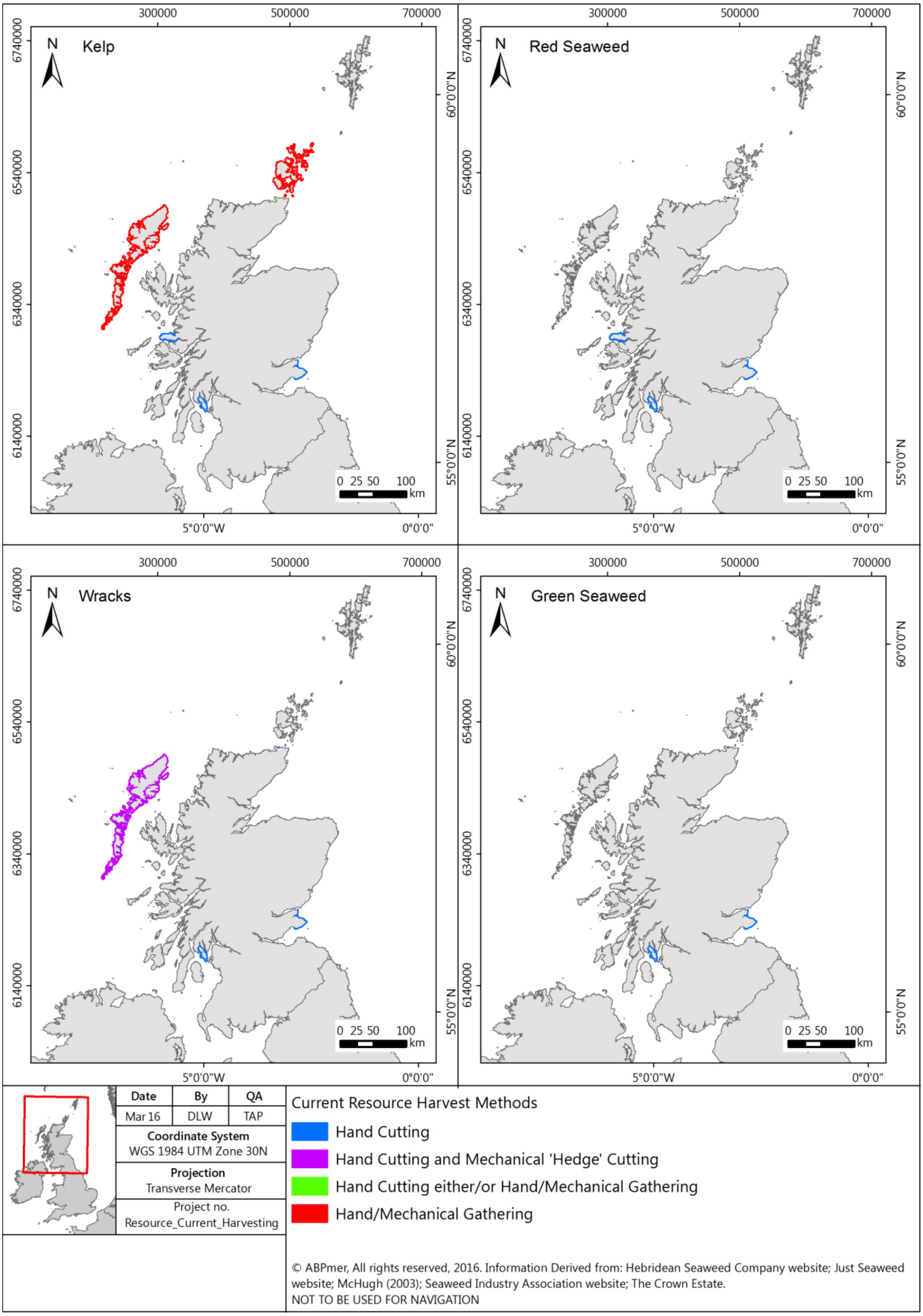


Figure 8: Location of current commercial harvesting activities in Scotland

3.13.1. Commercial extraction of maerl does not currently take place in Scotland[9] (SNH, 2015b). However, the resource is harvested elsewhere in Europe using dredges and grabs (Grall & Hall-Spencer, 2003; Blunden et al., 1975), e.g. in Ireland and Iceland (Celtic Sea Minerals, no date). In England commercial-scale extraction of maerl took place in the River Fal between 1975 and 1991, as much as 30,000 tonnes annually (UK Marine Special Areas of Conservation webpage[10]).

3.13.2. No evidence of current seagrass harvesting in Scottish waters has been found[11].

3.13.3. **Table 4** identifies the main seaweed and seagrass species that are either harvested at present or could be harvested in the future. Illustrations of some of these are provided in **Figure 1**. Further information on these target seaweed and seagrass species is included in **Appendix C** (Table C1), including their general distribution on the shore, growth cycles, and. the nature of the resource (i.e. living and/or beach-cast).

[9] Although extraction has been undertaken or proposed in Orkney in the past (SNH, pers. comm.)
[10] http://www.ukmarinesac.org.uk/communities/maerl/m1_1.htm
[11] Maerl and seagrass, although not currently harvested in Scotland, have been included in the scope of the SEA for completeness, following the screening and scoping exercises, information review and discussion (see Section 2).

Table 4: Target seaweed and seagrass species for harvesting

Seaweeds:	
Brown: wracks	
Ascophyllum nodosum	*F. vesiculosus*
Fucus serratus	*Himanthalia elongata*
F. spiralis	*Pelvetia canaliculata*
Brown: kelps	
Alaria esculenta	*L. digitata*
Laminaria hyperborea	*Saccharina latissima*
Green	
Ulva intestinalis	*U. lactuca*
Red	
Chondrus crispus	*Palmaria palmata*
Mastocarpus stellatus	*Porphyra umbilicalis*
Osmundea pinnatifida	*P. purpurea*
Maerl:	
Lithothamnion glaciale	*Phymatolithon calcareum*
Seagrasses:	
Ruppia spp.	*Z.noltii*
Zostera marina	

3.13.4. In Scotland, hand cutting has been the most common method of harvesting in the wild (Burrows et al., 2010; Scottish Executive, 2001). Mechanical harvesting has also been used in the past where the seaweed and harvest area were amenable to such methods (Wilkinson, 1995).

3.13.5. The range of methods that are currently used to commercially harvest wild seaweeds, and that could potentially be used to harvest seagrasses, can be classified into five broad groups (**Table 5**). These cover methods used in Scotland and in other countries.

Table 5: Classification of commercial wild harvesting methods

Method	**Description**
Hand cutting or picking	This method involves harvesting living species by hand at low tide using tools such as serrated sickles or scythes.
Trawling/Sledging/Dredging	In the case of kelps, this involves a device which tears living plants larger than a certain size from the substrate and leaves smaller plants for re-growth (i.e. generally only mature plants are harvested). Existing devices include the Norwegian kelp dredge designed to harvest *Laminaria hyperborea* and the Scoubidou which is designed to harvest *L. digitata*. These devices operate in areas of rocky substrate and therefore differ from other forms of dredging (e.g. scallop dredging) that physically disturb the underlying substrate. There may, however, be some potential for physical disturbance of the substrate by other devices (e.g. dredgers used in maerl extraction).
Mechanical ‘hedge’ cutting	Specialised vessels called mechanical seaweed harvesters that work close to the shore and cut the living seaweed as the stalks float above the seabed. These vessels include the Norwegian suction/cutter harvester which is designed to harvest *Ascophyllum nodosum*.
Hand gathering	This method involves the collection of beach-cast species from the strandline by hand.
Mechanical gathering	This method involves the collection of beach-cast species from the strandline using tractors or JCBs.

3.13.6. A summary of known seaweed harvesting is provided in **Figure 8** and **Table 6** including the general location, methods and (where known/appropriate) season of harvesting.

Table 6: Summary of harvesting activities in Scotland

Species	**Known Harvesting Locations**	**Generic Methods of Harvesting**
BROWN SEAWEEDS: Wracks or rockweeds		
Ascophyllum nodosum	Outer Hebrides (specifically Lewis, Harris, North Uist, South Uist) Caithness (Ham to Scarfskerry)	Intertidal. Harvesting takes place all year. In Caithness, *Ascophyllum* sp is cut by hand. In the Outer Hebrides cutting is done manually (sickle) or mechanically (seaweed harvesting boat). Manual seaweed harvesters first encircle the cutting area with a rope or net and cut within this area. Seaweed is cut about 12 inches from the base; the stump that is left will regenerate in 3 to 4 years. When the tide comes back in the seaweed floats to form a large circular bale which is then towed by small boat to a sheltered area for loading onto a lorry. Individual cutters handle their own cutting areas and rotate them to ensure sustainability. A mechanical seaweed harvester may also be used. This vessel works close to the shore and cuts the seaweed as the stalks float above the seabed. The seaweed is then filled into sacks and towed by a small boat to a sheltered area for loading onto a lorry.
Pelvetia canaliculata	Fife; Caithness (Ham to Scarfskerry); Bute	Intertidal. Harvested by hand.
Fucus vesiculosus	Fife; Caithness (Ham to Scarfskerry); Loch Sunart (Salen to Glenmore Bay); Ardnamurchan; Bute	Intertidal. Typically hand harvested at low tide with small knives or scissors. Recommendation is to cut at a height of 15 to 25 cm above the holdfast.
Fucus serratus	Fife; Caithness (Ham to Scarfskerry); Bute	Intertidal. Harvested by hand at low tide. Recommendation is to cut at a height of 15 to 25 cm above the holdfast.
Fucus spiralis	Fife; Caithness (Ham to Scarfskerry); Bute	Intertidal. Harvested by hand at low tide; fronds above the stipe should only be harvested in mature plants.

Species	Known Harvesting Locations	Generic Methods of Harvesting
Himanthalia elongata	Fife; Caithness (Ham to Scarfskerry)	Intertidal. Gathered by hand during May and June. The fronds are cut at least 10 cm from the mushroom-like base.
BROWN SEAWEEDS: Kelps		
Saccharina latissima	Fife; Caithness (Ham to Scarfskerry)	Subtidal. Usually harvested in late spring and summer, from boats or by hand at low spring tides. Blades are cut from existing plants, leaving the stipe and lower blade intact and able to keep growing. Juvenile plants are avoided and no plant is removed in its entirety.
Laminaria hyperborea	Outer Hebrides; Orkney; Caithness (Ham to Scarfskerry)	Subtidal. In Scotland, *L. hyperborea* is harvested at present for small scale applications. In other countries, it is harvested by specially designed seaweed trawlers that use a dredge. Multiple boats operating along the Norwegian and Icelandic coasts can carry dozens of tons each. Depending on the dredge design, juvenile plants can be avoided.
Laminaria digitata	Fife; Caithness (Ham to Scarfskerry); Loch Sunart (Salen to Glenmore Bay); Ardnamurchan; Bute	Inter/subtidal. In Scotland, manual harvesting only is undertaken, using a small boat at low tide, usually by stepping out of the boat to cut the seaweed with a knife. In locations with higher tidal range, it may be possible to harvest without a boat. Juvenile plants are avoided. Mechanical methods may be used in other countries. *L. digitata* beds in Scotland are narrow and therefore mechanical harvesting is unlikely to be viable.
Alaria esculenta	Fife; Caithness (Ham to Scarfskerry)	Inter/subtidal. In some areas, harvest is during a narrow window in early summer, after plants have put on reasonable growth but before breaking waves shred the thin leaves. Harvesting is often done by hand and knife at low tide. Juvenile plants are avoided.
GREEN SEAWEEDS		
Ulva intestinalis	Caithness (Ham to Scarfskerry); Bute	Intertidal. Scissors or a small knife can be used to cut the blade from the holdfast. If the holdfast is accidentally pulled off from the substrate, it can be cut from the frond before processing.

Species	**Known Harvesting Locations**	**Generic Methods of Harvesting**
Ulva lactuca	Fife; Caithness (Ham to Scarfskerry)	Intertidal. *Ulva lactuca* often does not grow in large patches, so harvesting can be a labour intensive effort which only yields small amounts. Scissors or a small knife can be used to cut the blade from the holdfast.
RED SEAWEEDS		
Chondrus crispus	Fife; Caithness (Ham to Scarfskerry); Loch Sunart (Salen to Glenmore Bay); Ardnamurchan; Bute	Intertidal. The bushy top half of the frond is pulled off, leaving the base and holdfast behind.
Mastocarpus stellatus	Caithness (Ham to Scarfskerry)	Intertidal. Harvesting is done by hand cutting or raking, usually in late summer. Care must be taken to keep the holdfast and part of the stipe intact so that plants re-grow for subsequent harvest.
Palmaria palmata	Fife; Loch Sunart (Salen to Glenmore Bay); Ardnamurchan; Bute	Intertidal. It is often harvested from June through September. It is picked by hand at low water.
Osmundea pinnatifida	Fife; Caithness (Ham to Scarfskerry); Bute	Intertidal. Harvested by hand with scissors or a blade at low tide.
Porphyra umbilicalis	Fife; Caithness (Ham to Scarfskerry); Bute	Intertidal. Scissor/ small knife used to carefully cut the blade from the holdfast. If the holdfast is accidentally pulled off from the substrate, the holdfast is cut from the frond before processing.

Sources: Hebridean Seaweed Company website; Just Seaweed website; McHugh (2003); Seaweed Industry Association website; The Crown Estate.

3.13.7. Information on potential future harvesting activity that may be undertaken, in addition to current activity, has been provided by industry. Only two harvesters were able to respond to queries within the timescale of this SEA and therefore this information is not comprehensive. This is shown in **Table 7** and **Figure 9**.

3.13.8. The current and potential distribution of each of the seaweed and seagrass groups shown in **Figures 2** and **3**, together with the known existing wild harvesting locations shown in **Figure 9** provides an indication of the future locations that are likely to be exploited.

Table 7: Summary of potential future harvesting activities in Scotland

Targeted Species	Timing*	Proposed Locations	Proposed Methods of Harvesting
Himanthalia elongata	Feb to Jul	Islands of the southern Firth of Lorn in Argyll (Garvellachs, Scarba, Luing, Easdale, Seil, Insh Lunga, Fladda, Eilean dubh mor, Eilean dubh beag, Mull (near Loch Buie), north shore of Jura)	Light harvesting working around the coast throughout the year. Harvesting of each species would be annual as each species grows rapidly each year. Harvesting method would involve removing 2/3 of the blade/thallus trying to leave the holdfast and meristem. Where plants are removed accidentally then every other plant is either cut or removed in a patch. All harvesting would be by hand though access to shoreline will be by boat.
Saccharina latissima			
Laminaria digitata	Jan to Jul		
Alaria esculenta	(Feb) May to Aug		
Ulva spp.	(All year round) mainly Apr to Sep		
Chondrus crispus	Feb to Aug		
Mastocarpus stellatus	Jan to Aug		
Palmaria palmata	May to Oct		
Osmundea pinnatifida	Oct to Apr		
Porphyra sp.	Apr to Oct		
Laminaria hyperborea	All year round	Multiple locations in the Inner Hebrides	Harvest mature whole plants using mechanical equipment (a comb-like trawl) similar to that used in Norway and Iceland over the last 50 and 30 years respectively, but with a different harvesting regime (namely strips rather than clear felling).
* Macroalgae communities have different composition at different times of year and therefore the timings could change as the demand changes.			

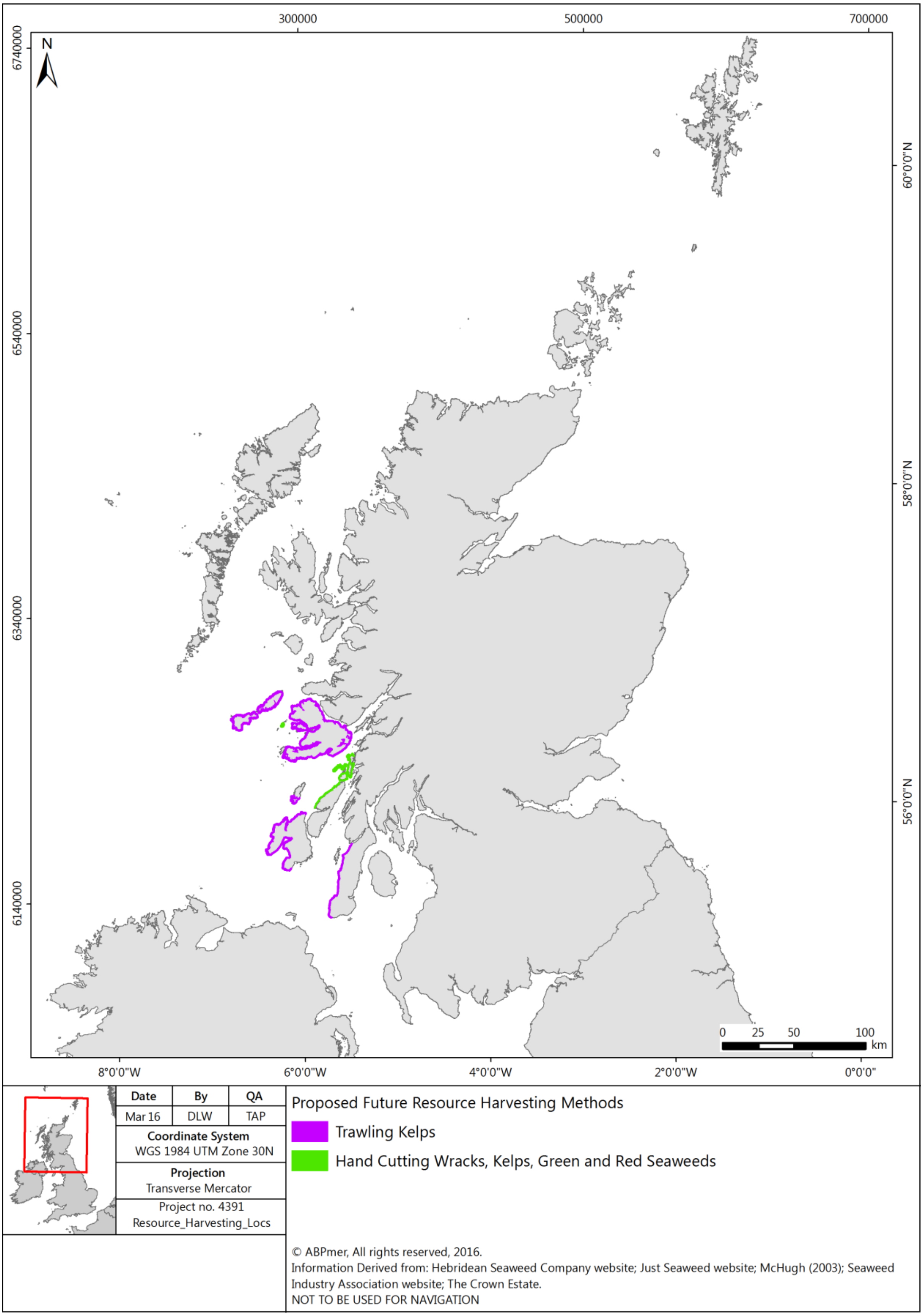


Figure 9: Location of potential additional future commercial harvesting activities in Scotland

3.14. Current Regulation of Wild Harvesting

Marine Licensing

3.14.1. The marine licensing regime - provided under section 21(1) (item 6) of the Marine (Scotland) Act 2010 - may regulate the removal of seaweed in those cases where a vehicle, vessel, aircraft, marine structure or floating container is used to remove the seaweed from the seabed.

3.14.2. It is our assessment that a “one size fits all” approach is not appropriate in regulating the removal of seaweed and so an appropriate and proportionate approach to licensing, dependent upon the circumstances and scale of the proposed removals, will be applied.

3.14.3. Any application for a marine licence must be considered against the need to protect the environment, human health and legitimate use of the sea. Therefore any applicant must provide assessment of the effects of their proposed activity in support of their application. This may involve the collection of ‘baseline’ data and studies to assess the effects.

3.14.4. After an assessment has been completed it may be appropriate for an ‘EIA-type’ process, of Screening, Scoping and Environmental Statement stages to be applied. This will allow for the best targeted Environmental Assessment to be undertaken, reducing both likelihood of unnecessary assessments being conducted by the applicant and the risk of future challenge to licensing decisions. Small scale projects would be ‘screened out’ of such requirements, if appropriate, following consultation. They would still require a lease from The Crown Estate.

3.14.5. The harvest of seaweed under other circumstances does not require a marine licence, however landowner permission may still be required.

3.14.6. General guidance on Marine Licensing can be found online at: http://www.gov.scot/Topics/marine/Licensing

3.14.7. Further guidance on the information required to support an application for a marine licence will be issued by Marine Scotland on completion of the consultation on this Environmental Report.

Landowner Consent

3.14.8. Operations involving the harvesting of living or beach-cast seaweed in the wild, with some exceptions, require the permission of the relevant landowner. These arrangements can range from verbal agreements to formal contracts and specified periods of ‘tenure’. Restrictions also apply in some conservation sites, such as Sites of Special Scientific Interest (SSSIs), and a Habitats Regulations Appraisal (HRA) would need to be undertaken for any harvesting activities that have the potential to affect designated or proposed European/Ramsar sites and associated features.

3.14.9. The traditional gathering of beach-cast seaweed by crofters does not require landowner permission. The Crofters (Scotland) Act 1993 (as amended) gives crofters access to reasonable use of seaweed under Common Grazings regulations and these rights are attached to particular tenancies.

3.14.10. In cases where The Crown Estate is the landowner, a lease for wild harvesting operations will be issued to operators who collect seaweed for commercial reward. Collection or foraging of seaweed in small quantities for personal use is considered to be akin to "blackberrying" and does not require a lease. The Crown Estate recommend that anyone doing so takes account of environmental sensitivity in collecting anything from the wild.

3.14.11. The Crown Estate applies a proportionate approach to the leasing of wild harvesting activities **(Figure 10**). The information that is required from the applicant depends on the proposed scale of the proposed harvesting activity, and can include the following:

- A stock biomass assessment to predict sustainably available annual volumes for each species proposed to be harvested (as an acceptable percentage of standing stock);
- A sustainable harvesting strategy setting out harvesting methods, the proportion of individual plants or plant populations to be harvested, the frequency of removal, wildlife and habitat disturbance considerations, rotational fallowing etc.; and
- A monitoring strategy that sets out the data and records to be collected and maintained to inform the sustainability of the activity undertaken and support the harvesting strategy.

3.14.12. The Crown Estate will grant and levy a fee for the rights to harvest on the condition that SNH can confirm, based on the information supplied by the developer, that they are satisfied that the proposed harvesting activity is sustainable. A lease tends to be for a three year period at the end of which a report must be submitted to inform a review of the sustainability of the harvesting practice, approval of which will allow the lease to be renewed.

3.14.13. Although the lease issued by The Crown Estate delineates the boundaries where harvesting is to take place, it does not grant exclusivity to the seaweed resource in these areas.

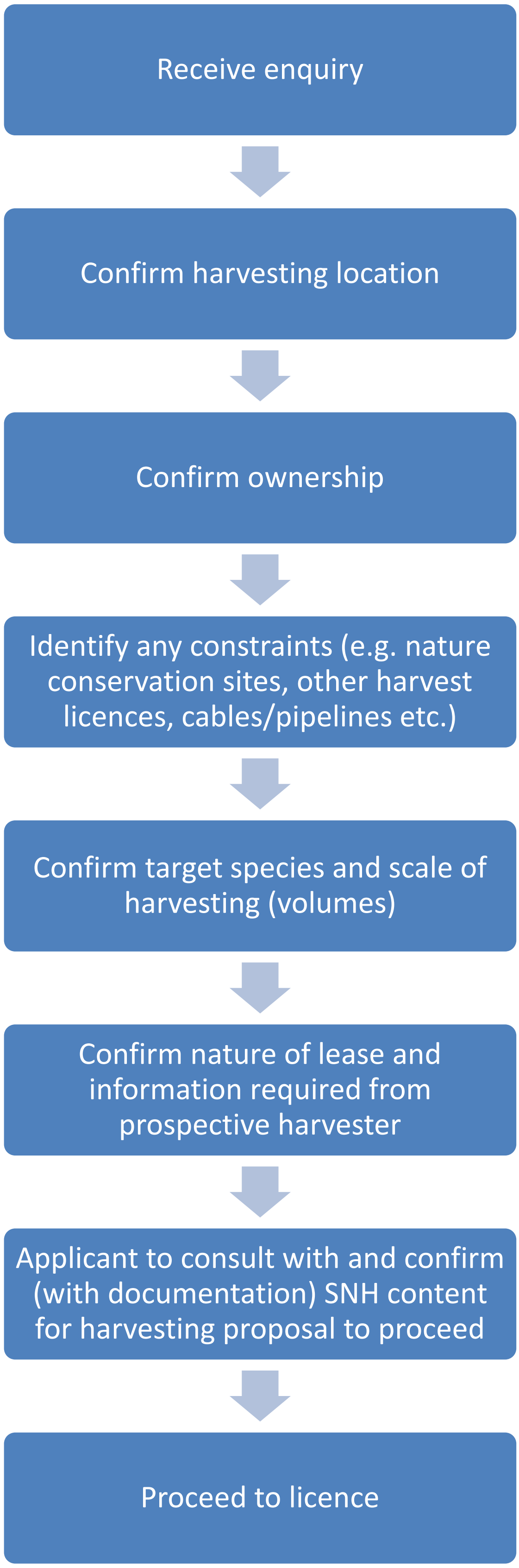


Figure 10: The Crown Estate's process for wild harvesting activities

3.15. Current Scottish Policy Framework

3.15.1. The existing legislative and policy context for the licensing of wild harvesting activities is set out in **Figure 11**. The relevant environmental protection objectives, at the international, European or national level[12], are summarised below and described in **Appendix B**.

General Marine

3.15.2. Higher level objectives which direct environmental protection and sustainable development and use are set out in international conventions, European Directives, and UK and Scottish strategy and law, in particular the National Marine Plan. The key messages relate to the need to balance competing interests and objectives in the marine environment with a strong protective framework, whilst facilitating sustainable economic growth.

3.15.3. The Scottish Government's vision is for 'clean, healthy, safe, productive, biologically diverse marine and coastal environments, which are managed to meet the long-term needs of people and nature'.

Biodiversity, Flora and Fauna

3.15.4. These objectives range from broad commitments to protection and enhancement of key species and habitats, to objectives that focus specifically on conserving marine ecosystems. In relation to the marine and coastal environment this includes the protection of migratory species, including birds and fish stocks, protection of marine and coastal habitats, and management of non-native invasive species. Marine mammals, including cetaceans and seals, are also highlighted as requiring specific protection from a range of marine activities. There is strong emphasis on an ecosystems approach to managing and restoring marine and coastal environments. This includes objectives to ensure the proper consideration of ecosystem services in all relevant sectors of policy and decision-making and to halt their loss. Building resilience to climate change is also a cross-cutting theme.

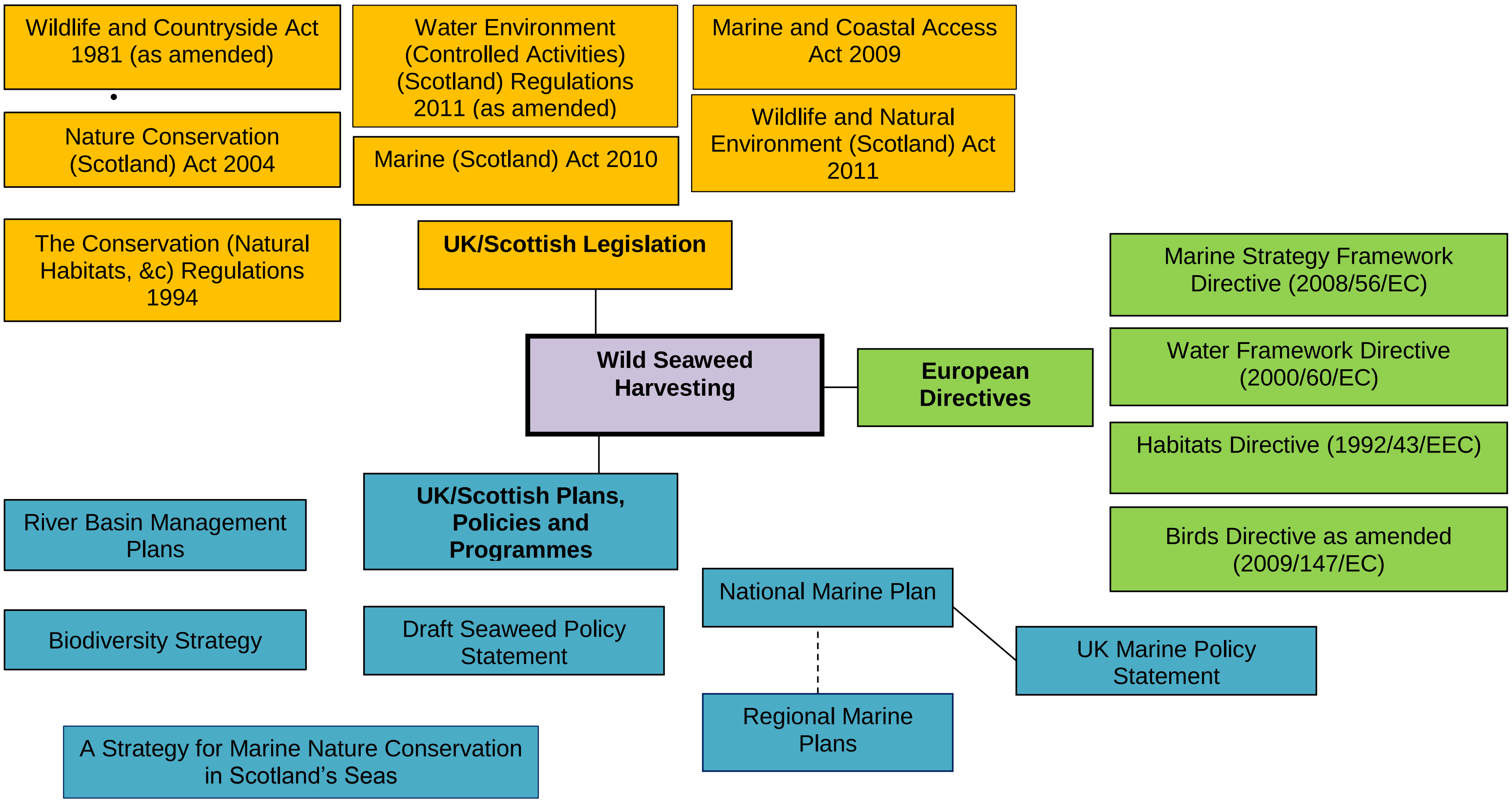
Climatic Factors

3.15.5. These objectives set targets for greenhouse gas (GHG) emissions at the international and national levels. There are also objectives to increase ecosystem resilience and adaptation to climate change as well as to recognise the importance of ecosystem services in this regard. The policy framework for this topic also explores the actions required to understand the necessary adaptation responses within the marine environment.

Cultural Heritage

3.15.6. These objectives include commitments to protecting the historic environment whilst increasing understanding and awareness of its value. Key objectives relate to coastal and offshore designated and undesignated buildings, archaeology and wrecks.

[12] as required by Schedule 3 of the Act



: Legislation and Policy Context for Wild Seaweed Harvesting

Figure 11

3.16. Ecosystem Services

3.16.1. Ecosystem services are the outputs of ecosystems from which people and society derive benefits. The Millenium Ecosystem Assessment recognised four types of services: provisioning; regulating; supporting; and cultural (MEA, 2005). Supporting and regulating services also assist in maintaining the biophysical environment that underpins all services. The UK National Ecosystem Assessment (NEA) Conceptual Framework (2011) identifies intermediate and final ecosystem services and goods/benefits (**Figure 12**).

3.16.2. Seaweeds and seagrasses have a role in supporting food webs which contribute to fish and shellfish productivity, as well as several ecosystem services that have both direct and indirect benefits for human beings (CCEES & ABPmer, 2010), in particular:

- **Fish and shellfish** – supporting local fish populations and in turn commercial fisheries through their high biodiversity and use as spawning and nursery grounds;
- **Algae and seaweed** –direct benefit to human beings (see Section 2.4);
- **Natural hazard protection** – provision of a natural coastal defence through wave dampening and preventing or alleviating coastal erosion;
- **Climate regulation** – provision in regulating the climate through their important role in the carbon cycle in terms of capturing, storing and exporting carbon; and
- **Clean water and sediments** – provision in improving the quality of water through their role in nutrient cycling.

3.16.3. The ecosystem services that have been scoped into this SEA are described in more detail in the relevant sections of this Environmental Report.

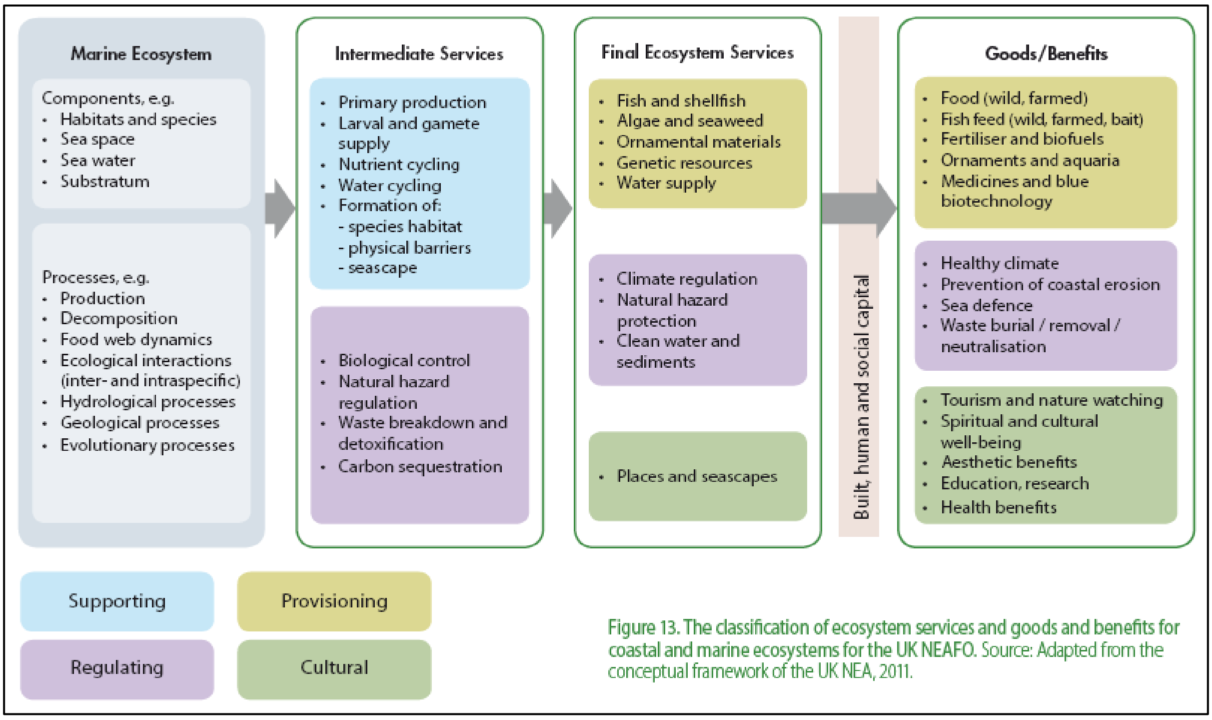


Figure 12: The classification of ecosystem services and goods and benefits

4. Biodiversity

4.1. Physical conditions

Wave Exposure and Sediment Types

4.1.1. Physical conditions vary widely around Scotland's coastline and inshore waters. The western coast of the Western Isles is very exposed to wave action (**Figure 13**) from the Atlantic Ocean and is therefore predominantly characterised by rock (**Figure 14** and **Figure 15**), with some sandy bays in more sheltered areas (Baxter et al., 2011). Sheltered fjordic sea lochs are common along the west coast of the Scottish mainland, while fjardic[13] sea lochs with complex basins, lagoons and tidal rapids are characteristic of many locations on the eastern coasts of the Western Isles. The main sediment types between the Scottish mainland and the Western Isles are coarse sands, gravels and rock. Sandy bays are widespread while very sheltered areas are characterised by muddy sediment (Baxter et al., 2011).

4.1.2. Similar conditions are experienced along the northern coast of the Scottish mainland, western Shetland, Fair Isle and Orkney, which are all exposed to the full force of the Atlantic. These areas are thus also characterised by rocky habitats with sheltered areas supporting intertidal sands. Fine sediments are restricted to very sheltered areas such as Scapa Flow in Orkney (Baxter et al., 2011).

4.1.3. The northern section of the east coast is characterised by small inshore firths, often with sandbanks, mudflats and sandy beaches. The rest of the east coast lacks the complexity of the west coast but includes major firths, sea cliffs and stretches of rocky coastline interspersed with long sandy beaches. Extensive mud and sand flats systems are present in the Forth and Tay estuaries (Baxter et al., 2011).

[13] Fjardic sea lochs are much shallower than fjordic sea lochs. They often possess a maze of islands and shallow basins connected by rapids, which are usually less than five metres deep and often intertidal (JNCC, 2008).

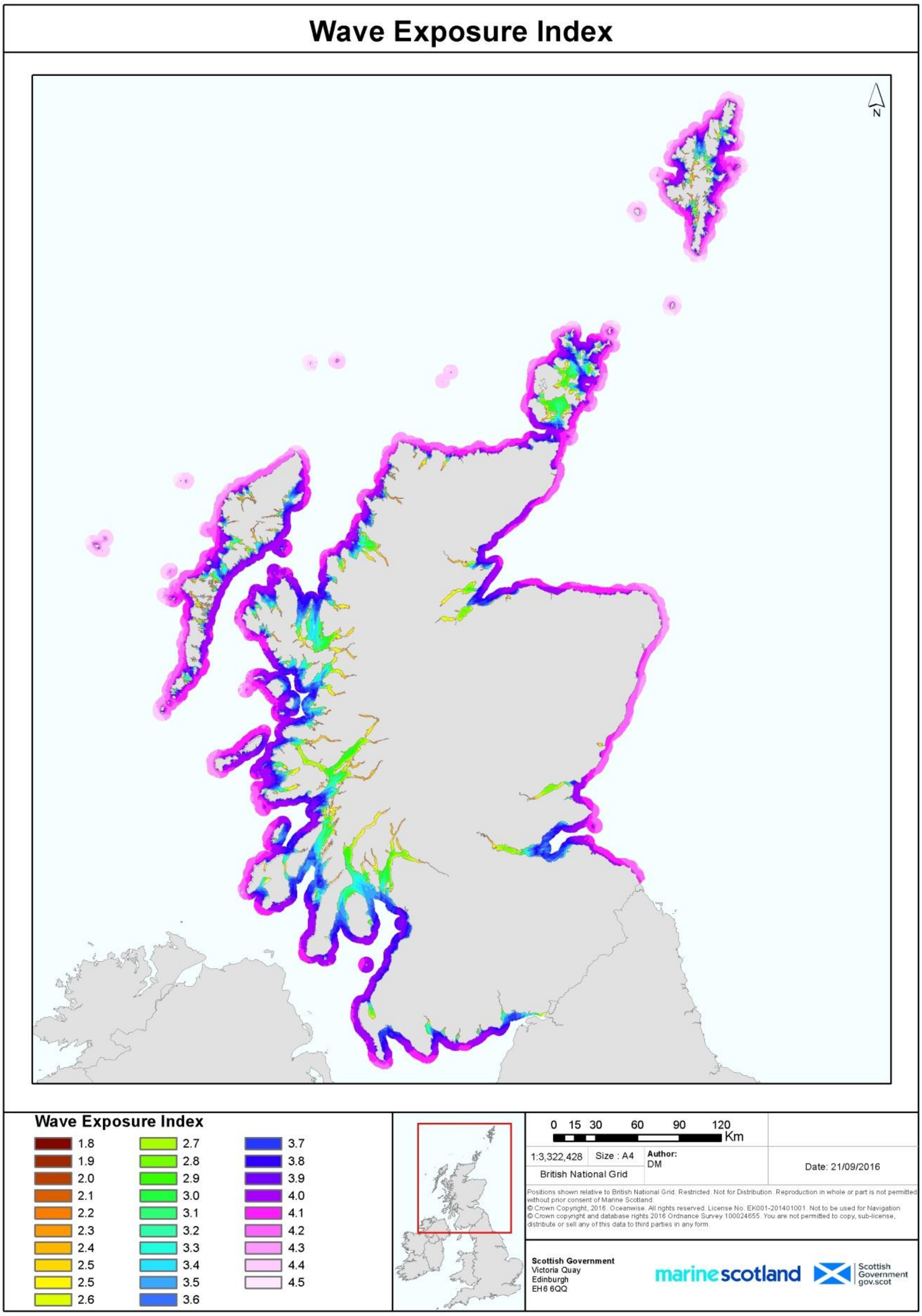


Figure 13: Wave Exposure Index[14]

[14] https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=780

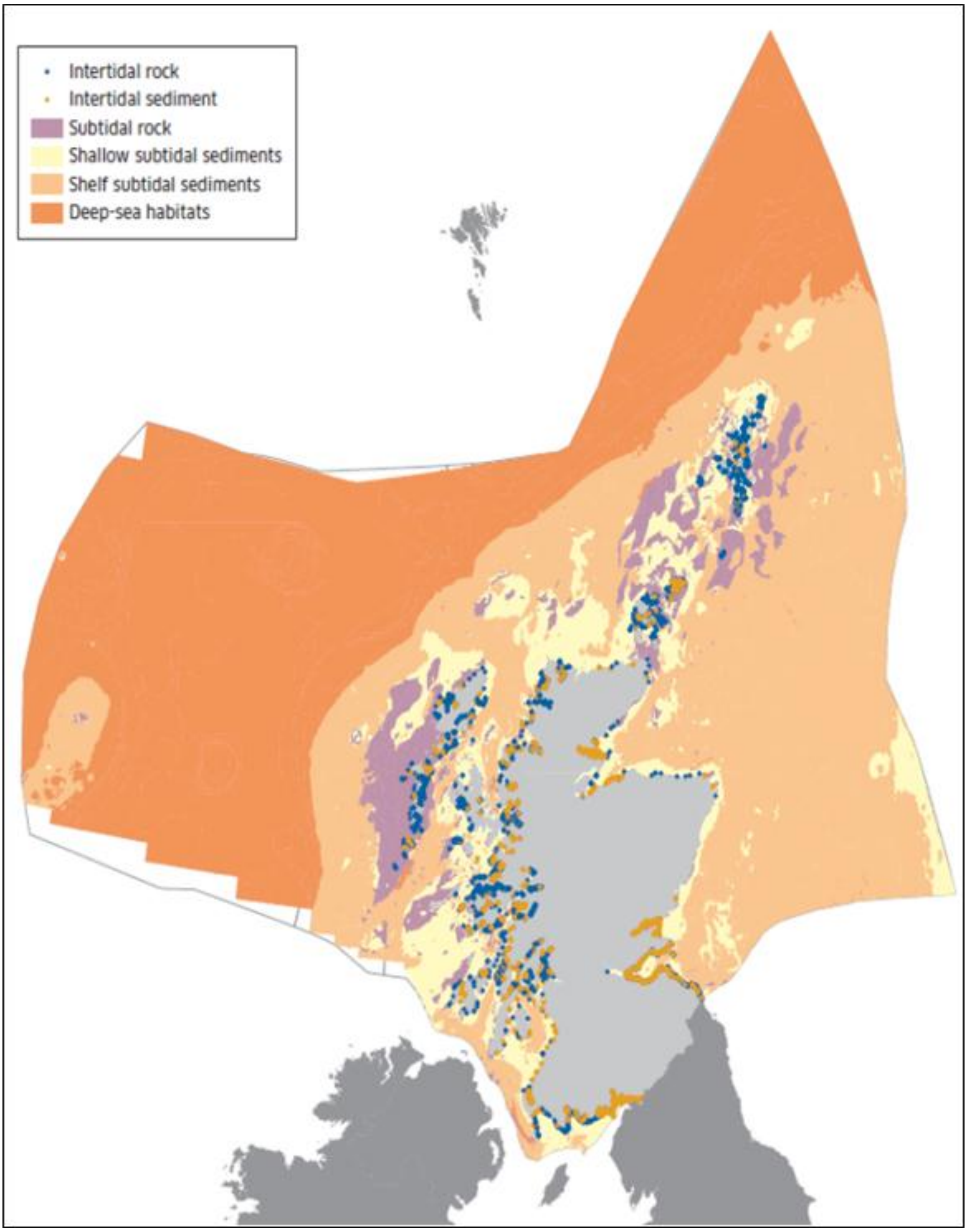


Figure 14: Modelled distribution of broad habitats in Scotland's marine environment[15]

[15] Scotland's Marine Atlas. p. 71: http://www.gov.scot/Publications/2011/03/16182005/43

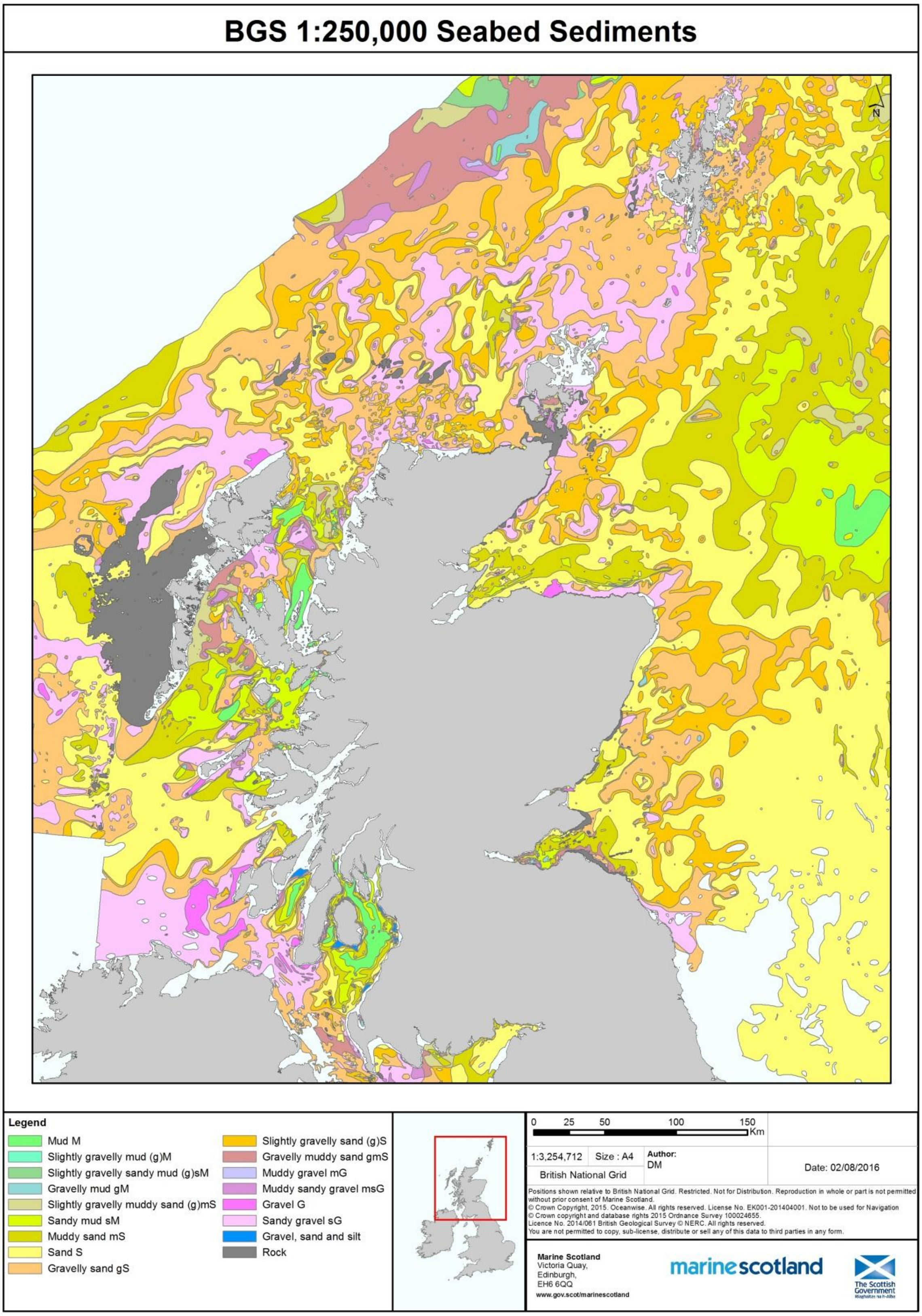


Figure 15: Seabed Sediments in Scottish Coastal and Inshore Waters

4.2. Ecological Status

4.2.1. The current overall status of Scottish coastal and transitional water bodies is shown in **Figure 16**. Overall, the majority of coastal and transitional water bodies have “good” or “high” status (and “good ecological potential”). A few are classified as “moderate” or “poor” (**Table** 8).

Table 8. Moderate/Poor Ecological Status/Potential in Scottish Coastal Waters

Location	**Element(s)**	**Detail**
Outer Tay Estuary	chemical quality	dissolved inorganic nitrogen
Loch Linnhe	biological quality	benthic invertebrates
Firth of Clyde	biological quality hydromorphological quality chemical quality	benthic invertebrates physical condition, barriers and morphology oxygen levels and dissolved oxygen
Solway Firth	biological quality chemical quality	phytoplankton and fish dissolved inorganic nitrogen, nutrient levels
Firth of Forth	hydromorphological quality	physical condition, barriers and morphology

4.2.2. The status of the macroalgal indicators (**Figure 16**) is good or high, apart from the Montrose Basin (moderate due to macroalgal blooming). This in turn may affect seagrass through smothering and reduced light levels. The status of the marine angiosperms indicator has not been reported for coastal and transitional Water Framework Directive (WFD) water-bodies.

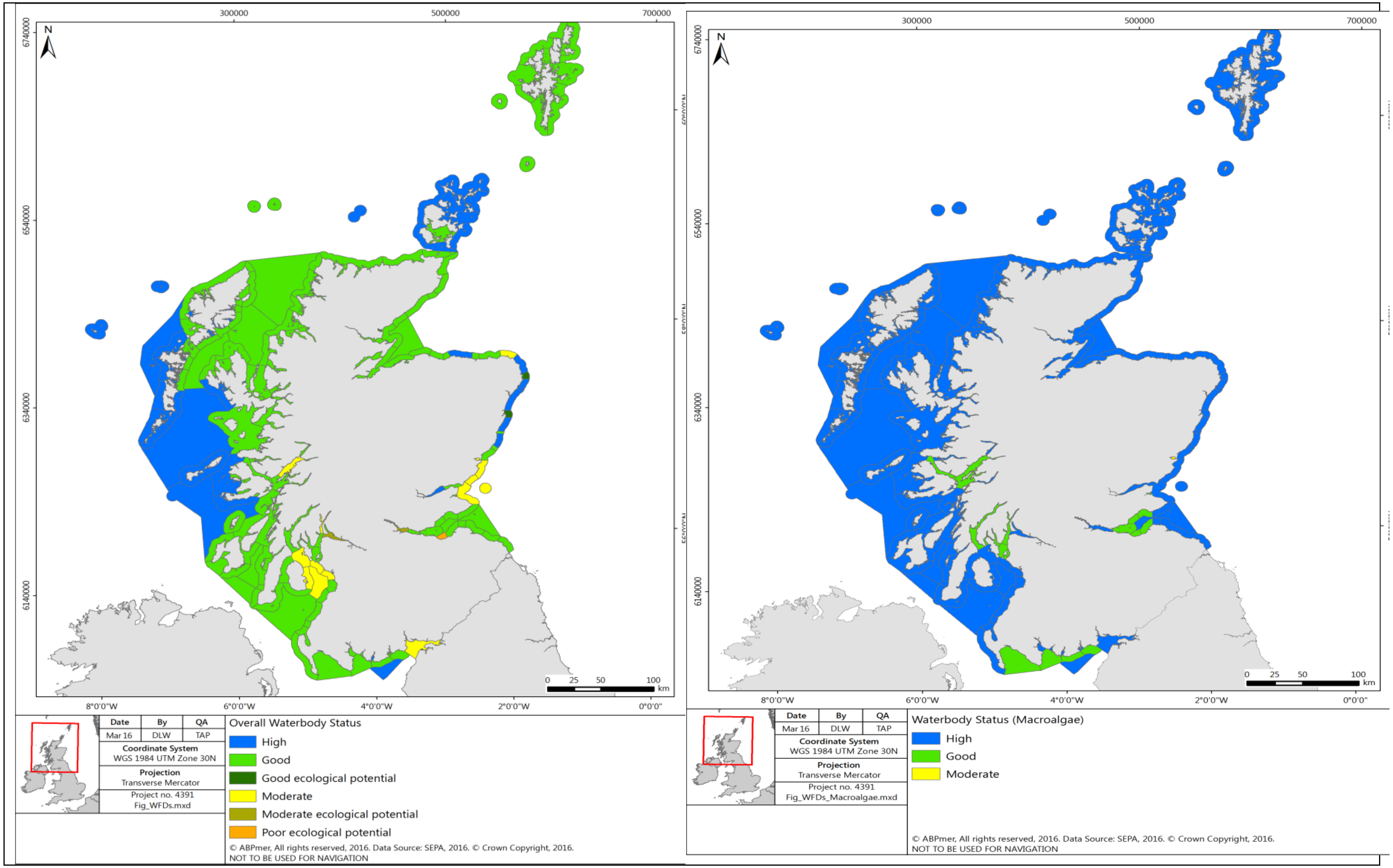


Figure 16: Water body status: overall and macroalgae in Scotland

4.3. Seaweeds and Seagrasses as WFD Biological Quality Elements

4.3.1. The WFD establishes a framework for the management and protection of Europe's water resources, transposed. This became law in Scotland as through the Water Environment and Water Services (Scotland) Act 2003 (WEWS Act). It is implemented in Scotland through The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (more commonly known as CAR) which provide the regulatory controls over activities which may affect Scotland's water environment.

4.3.2. The WFD aims to achieve 'good ecological and good chemical status' in all inland and coastal waters by 2021 (or 2027), apart from in heavily modified in water bodies, where it may be impossible to get to a near natural condition because they have been substantially modified for reasons such as flood protection or to allow navigation. The aim in such waters is to achieve an alternative objective of 'good ecological potential'.

4.3.3. The WFD considers the ecological status of indicator species to reflect the quality, structure and functioning of aquatic ecosystems (Wallenstein et al., 2013). These biological indicators include primary producers and benthic fauna, e.g. benthic invertebrates, phytoplankton and macroalgae. Both seaweeds and seagrasses are WFD indicators because they are important contributors to many coastal ecosystems including rocky shores, soft bottom intertidal and subtidal zones, reefs and saltmarshes (Orfanidis et al., 2001). These species are sessile and respond directly to abiotic and biotic pressures. For example, if eutrophication occurs, perennial seaweeds such as *Fucus* spp. may be replaced by opportunistic seaweeds like *Ulva* spp. (Orfanidis et al., 2001 and references therein).

4.3.4. The ecological quality of water bodies is assessed by comparing the status of biological indicators against the reference conditions expected of a pristine water body (Wilkinson et al., 2007). For macroalgae, assessment considers composition, macroalgal cover and abundance (WFD-UKTAG, 2014). There are, however, uncertainties associated with using macroalgae as ecological indicators. For example, it is not always known which species are sensitive to which pressures (natural or anthropogenic) and also species composition can vary naturally regardless of anthropogenic pressures (Wilkinson and Wood, 2003). As such, different methods have evolved in different countries as to the best way to use seaweeds as an ecological indicator (e.g. Orfanidis et al., 2001; Wells et al., 2007a; Juanes et al., 2008). In the UK, species richness has been found to provide a consistent response to anthropogenic impacts that does not appear to be significantly affected by natural variation (Wells et al., 2007b) and can therefore be used, along with other measures, to assess variations in the ecological quality of a water body.

4.4. Seaweeds and Seagrasses

4.4.1. Seaweeds and seagrasses play a key role in marine and coastal ecosystems. Their importance in ecological functioning is recognised by the fact that they are used as indicators for assessing the ecological status of WFD water bodies (see Section 4.4). They are included as features within a number of designated sites (Marine Scotland, 2015). Five Nature Conservation Marine Protected Areas (MPA) directly support protected features that include seaweed (Marine Scotland, 2015) (**Table** 9 and **Figure 17).** Seaweeds and seagrasses are also included in the list of Scottish Priority Marine Features (PMFs) (**Table 10**). Some Special Areas of Conservation (SAC) contain Annex 1 habitat interest features that potentially support seaweeds and seagrasses (**Table 11** and **Figure 17**).

4.4.2. In addition, 15 sites in Scotland have been nominated as Important Plant Areas[16] (IPAs) for marine seaweeds (Brodie et al., 2007). IPAs that are not already designated as a SAC or MPA include Isle of Cumbrae, Tiree (Argyll), Sound of Islay (Inner Hebrides), Sound of Harris (Outer Hebrides), Loch Eriboll (Sutherland), St. Andrews (Fife) and Pettico Wick (Scottish Borders).

4.4.3. SNH has advised that, for Sites of Special Scientific Interest (SSSIs), marine notified habitats include eelgrass beds, mudflats, rocky shore, saline lagoon, sandflats and sea caves (in addition to those with relevant bird features shown on **Figure 20**. Species features include brackish water cockle (*Cerastoderma glaucum*), egg wrack (*Ascophyllum nodosum* f. mackayi), grey seal, foxtail stonewort (*Lamprothamnium papulosum*) and vascular plant assemblage (which cover eelgrass communities in some sites).

Table 9. Nature Conservation MPAs directly supporting seaweed features

MPA	Protected Seaweed Feature
Fetlar to Haroldswick	kelp and seaweed communities on sublittoral sediment; maerl beds
Loch Sween	maerl beds
South Arran	kelp and seaweed communities on sublittoral sediments; maerl beds; maerl or coarse shell gravel with burrowing sea cucumbers
Wester Ross	kelp and seaweed communities on sublittoral sediment; maerl beds; maerl or coarse shell gravel with burrowing sea cucumbers
Wyre and Rousay Sounds	kelp and seaweed communities on sublittoral sediment; maerl beds

[16]Important Plant Areas have been identied by Plantlife (an environmental NGO) as areas supporting internationally important wild plant populations. See http://www.plantlife.org.uk/wild_plants/ipa_holder/ipas

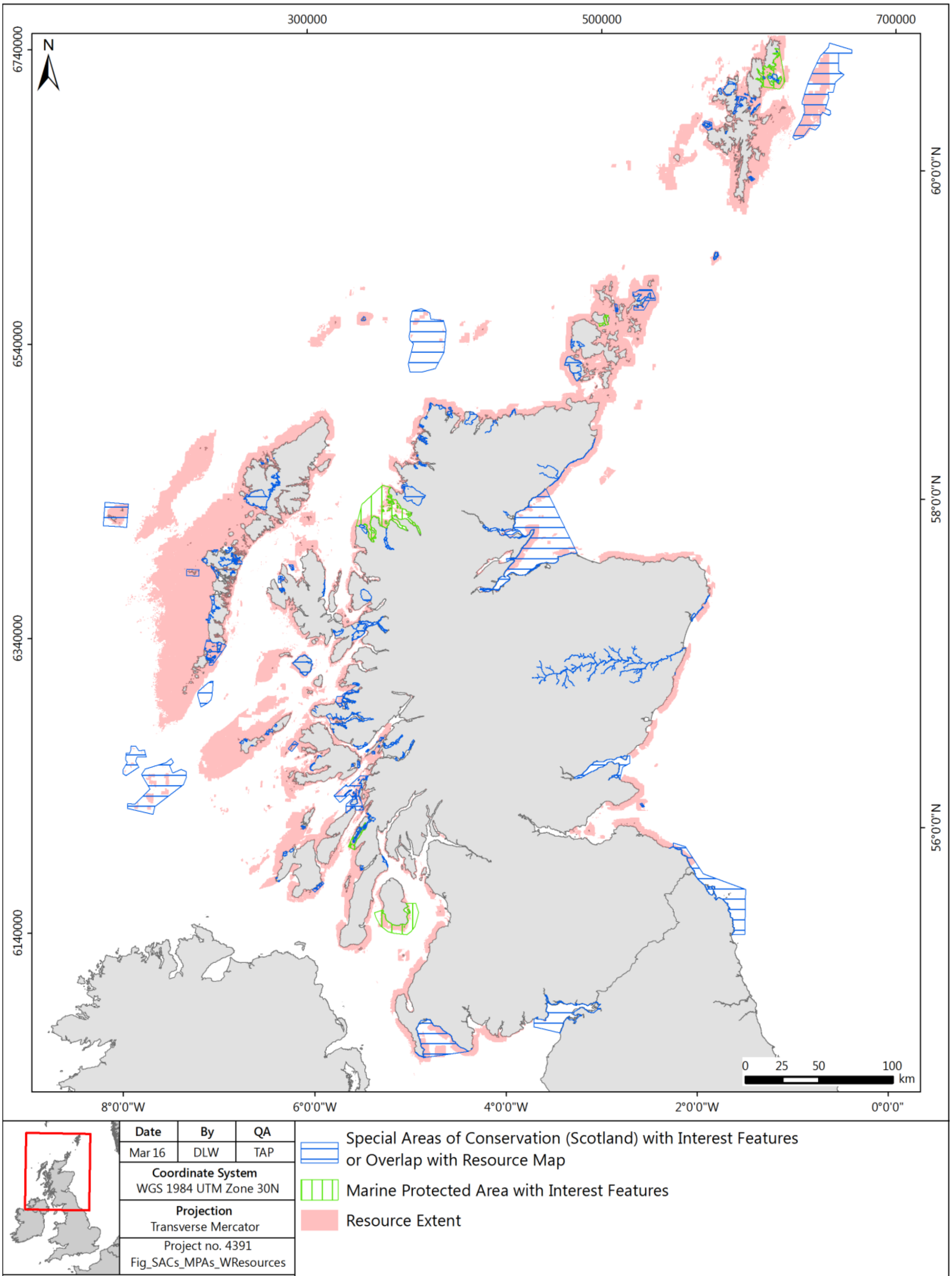


Figure 17: SACs/SCI[17]s and MPAs with seaweed or seagrass interest features

[17] Site of Community Interest (SCI)

Table 10: Priority marine features: seaweeds and seagrasses[18]

Priority marine feature	Component biotopes / species (biotope / common name)
Horse mussel beds	*Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
Kelp and seaweed communities on sublittoral sediment	Kelp and seaweed communities on sublittoral sediment
Kelp beds	*Laminaria hyperborea* forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed upper infralittoral rock
	Laminaria hyperborea with dense foliose red seaweeds on exposed infralittoral rock
	Laminaria hyperborea on tide-swept, infralittoral rock
	Laminaria hyperborea on tide-swept infralittoral mixed substrata [19]
	Laminaria hyperborea and foliose red seaweeds on moderately exposed infralittoral rock
Low or variable salinity habitats	Kelp in variable or reduced salinity
	Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)
	Bird’s nest stonewort *Tolypella nidifica*
	Baltic stonewort *Chara baltica*
	Foxtail stonewort *Lamprothamnium papulosum*
Maerl beds	Maerl beds
Maerl or coarse shell gravel with burrowing sea cucumbers	*Neopentadactyla mixta* in circalittoral shell gravel or coarse sand
Sea loch egg wrack beds	*Ascophyllum nodosum* ecad *mackaii* beds on extremely sheltered mid eulittoral mixed substrata
Tide-swept algal communities	Fucoids in tide-swept conditions
	Halidrys siliquosa and mixed kelps on tide-swept infralittoral rock with coarse sediment
	Kelp and seaweed communities in tide-swept sheltered conditions
	Laminaria hyperborea on tide-swept infralittoral mixed substrata [20]
Seagrass beds	*Zostera noltii* beds in littoral muddy sand
	Zostera marina/angustifolia beds on lower shore or infralittoral clean or muddy sand
	Ruppia maritima in reduced salinity infralittoral muddy sand

[18] Some biotopes are excluded from this list. See http://www.snh.gov.uk/protecting-scotlands-nature/priority-marine-features/priority-marine-features/
[19] This biotope is also a component of the ‘Tide-swept algal communities’ PMF
[20] This biotope is also a component of the ‘Kelp beds’ PMF

Table 11: Annex 1 marine habitats supporting seaweeds and seagrasses (Source: JNCC website http://jncc.defra.gov.uk/page-4166)

Annex 1 Marine Habitats	Special Area of Conservation	
Coastal lagoons (except where landwards of MHWS and not directly connected to the sea) sites where this is a qualifying feature but not a primary reason for site selection:	• Loch nam Madadh, Western Isles • Loch Stenness, Orkney Islands • Loch Roag Lagoons, Western Isles • South Uist Machair, Western Isles	• Sullom Voe, Shetland Islands • Obain Loch Euphoirt (Loch Eport), Western Isles • The Vadills, Brindister Voe, Shetland
Estuaries (Where rock occurs, there may be characteristic communities consisting of green algae, sparse fucoid seaweeds)	• Dornoch Firth and Morrich More, Highland • Firth of Tay & Eden Estuary; Angus; City of Dundee; Fife; Perth & Kinross • Solway Firth; Cumbria; Dumfries and Galloway	
Large shallow inlets and bays	• Loch Laxford, Highland • Loch nam Madadh, Western Isles • Luce Bay and Sands, Dumfries and Galloway	• Sullom Voe, Shetland Islands • Berwickshire and North Northumberland Coast
Reefs Sites where this is a qualifying feature but not a primary reason for site selection:	• East Mingulay, Outer Hebrides • Firth of Lorn, Argyll & Bute • Loch Creran, Argyll & Bute • Lochs Duich, Alsh & Long, Highland • Papa Stour, Shetland Islands • Sanday, Orkney Islands • Sound of Barra, Western Isles • St Kilda, Western Isles • Dornoch Firth and Morrich More, Highland • Isle of May, Fife	• Loch Laxford, Highland • Luce Bay and Sands, Dumfries and Galloway • Mousa, Shetland Islands • North Rona, Western Isles • Solway Firth, Dumfries and Galloway • Sunart, Highland • Treshnish Isles, Argyll & Bute • Berwickshire and North Northumberland Coast • Loch nam Madadh (Loch Maddy), Western Isles • Sullom Voe, Shetland Islands

Sandbanks which are slightly covered by seawater all the time: sites supporting maerl and/or seagrasses	• Sound of Arisaig (Loch Ailort to Loch Ceann Traigh), Highland • Sound of Barra, Western Isles • Dornoch Firth and Morrich More, Highland • Firth of Tay & Eden Estuary; Angus; City of Dundee; Fife; Perth & Kinross • Loch nam Madadh, Western Isles • Sanday, Orkney
Submerged or partially submerged sea caves (Caves may support shade-tolerant seaweeds near their entrances)[21]	• Papa Stour, Shetland Islands • St Kilda, Western Isles • Mousa, Shetland Islands • North Rona, Western Isles • Berwickshire and North Northumberland Coast

[21] It is very unlikely that any harvesting would take place at these locations.

4.5. Marine Mammals

4.5.1. Marine mammals in Scotland's coastal and marine waters include cetaceans, seals and otters.

Cetaceans

4.5.2. Over 25 species of cetacean have been recorded off the coast of Scotland. However, only seven species are considered resident or regular seasonal visitors (harbour porpoise *Phocoena phocoena*, Risso's dolphin *Grampus griseus*, shortbeaked common dolphin *Delphinus delphis*, bottlenose dolphin *Tursiops truncates*, orca *Orcinus orca*, minke whale *Balaenoptera acutorostrata* and white-beaked dolphins *Lagenorhynchus albirostris*). Cetaceans regularly recorded offshore from north west Scotland (particularly along the shelf edge in deeper waters) include Atlantic white-sided dolphins *Lagenorhynchus acutus*, long-finned pilot whales *Globicephala melas*, fin whales *Balaenoptera physalus*, sperm whales *Physeter macrocephalus* and beaked whales (Reid et al., 2003; Clark et al., 2010; Baines and Evans, 2012; CODA, 2009).

4.5.3. There is one Special Area of Conservation for bottlenose dolphin, in the Moray Firth, and one Special Area of Conservation for harbour porpoise in the Inner Hebrides and the Minches (**Figure 18**).

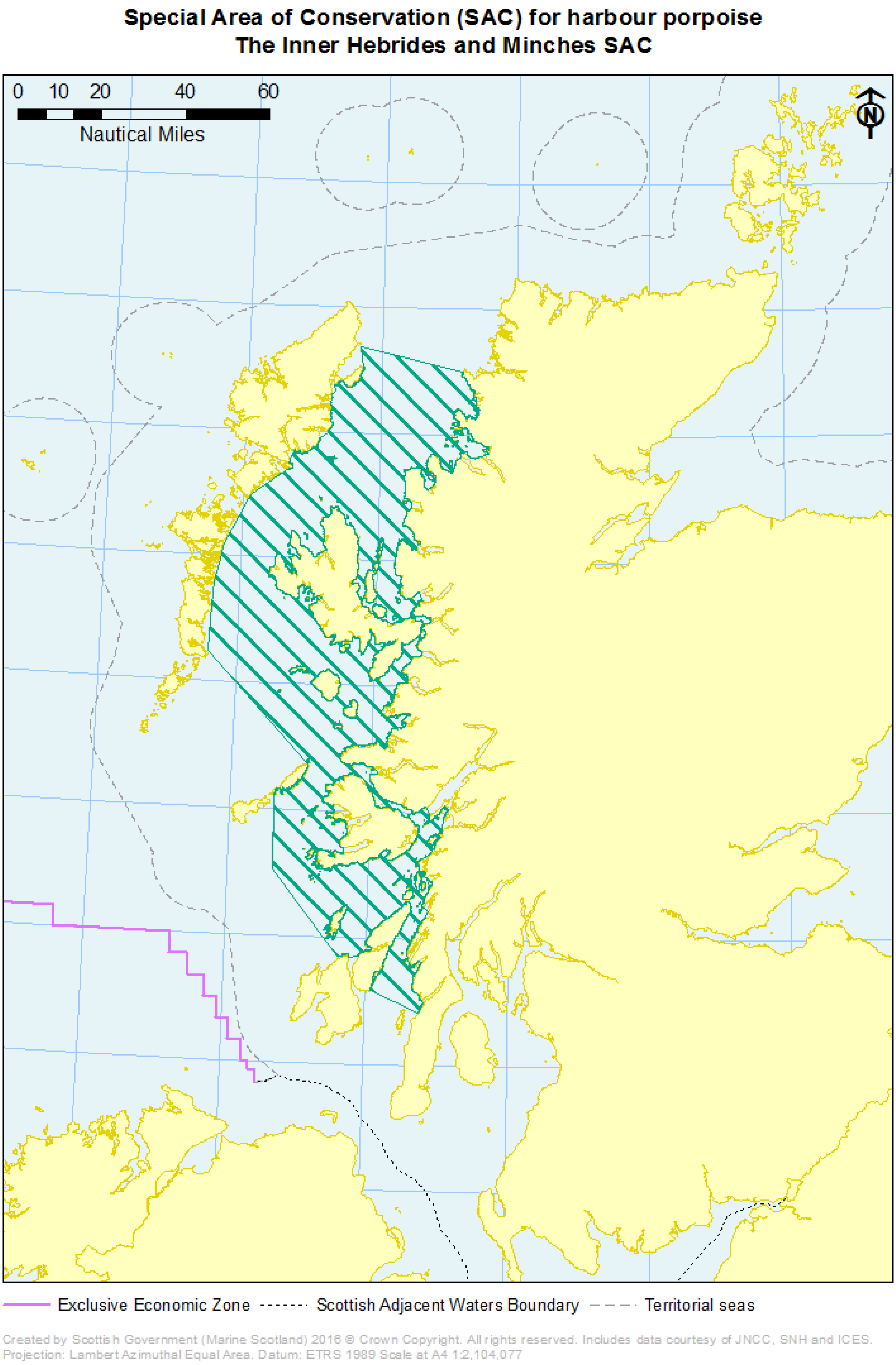


Figure 18: SAC for harbour porpoise

Seals

4.5.4. Two species of seal are present in Scottish waters, grey seal *Halichoerus grypus* and the common seal *Phoca vitulina.* The coast of Scotland hosts important breeding and foraging grounds for both of these species (SCOS, 2013). There are eight SACs designated for harbour seal, and five for grey seal (**Appendix D, Table D6**). SNH recommend using species-specific foraging distances in order to establish the potential for connectivity between seal SAC populations and seaweed or seagrass beds.

4.5.5. Seal haul-out sites are locations on land where seals come ashore to rest, moult or breed. The Scottish Government has designated 194 specific seal haul-out sites to provide additional protection for seals from intentional or reckless harassment (**Figure 19**), and recently consulted on a proposal to designate an additional site in the Ythan Estuary.

4.5.6. Grey seal SACs are principally breeding sites. Grey seals congregate for pupping and mating and then disperse. Grey seals are at the breeding sites for a relatively short period of the year, do not tend to make long foraging trips while there and then disperse very widely and do not necessarily have any focus on that SAC site for the rest of the year. There is growing evidence that some grey seals can disperse widely, spending a considerable amount of the rest of the year well away from their breeding sites. SNH therefore recommend that a foraging distance of 20 km from SACs is appropriate when considering connectivity during the breeding season for grey seals.

4.5.7. Harbour seals are relatively loyal to a SAC site and often remain local to a relatively discrete area, including outside the breeding season, so connectivity with the SAC is stronger for this species all year round than is indicated for grey seals. SNH therefore recommends a foraging distance of 50 km from SACs is appropriate when considering connectivity for harbour seals. This distance applies all year.

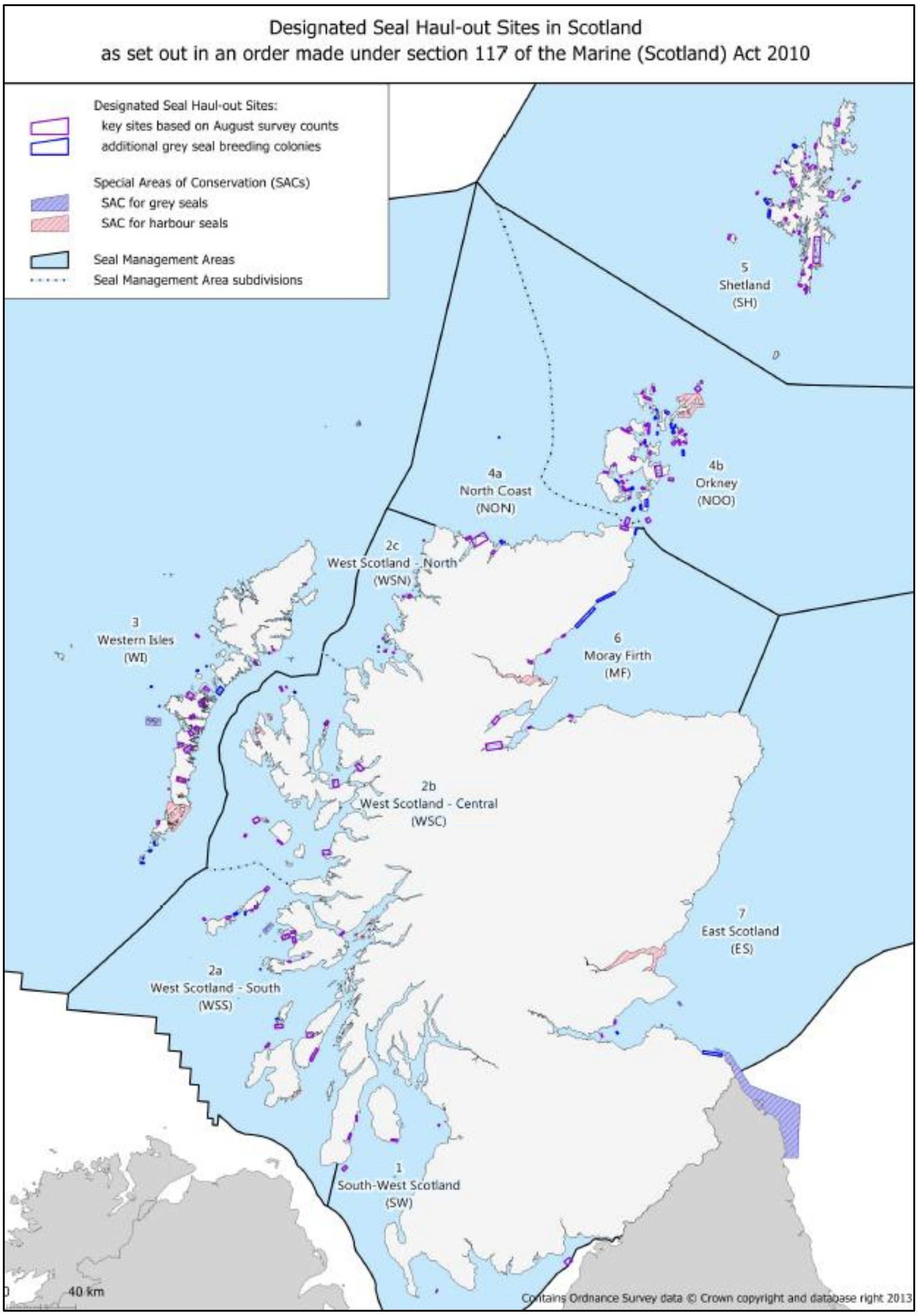


Figure 19: Location of designated seal haul-out sites.

Otters

4.5.8. Otters (*Lutra lutra*) are found in coastal areas in Scotland, as well as inland fresh waters. On the coast they tend to utilise shallow, inshore marine areas for feeding (JNCC, 2016) . The foraging range of otters is considered to be 4 to 5 km (SNH, 2015a). Most otters forage within a 10 m depth.

4.5.9. There are twelve SACs in Scotland designated for otters, and another 32 where otters are a qualifying feature but not the primary reason for site selection. Of these, six have been identified as being sensitive to seaweed harvesting activities (**Appendix D, Table D6)**

4.6. Seabirds

4.6.1. A wide variety of seabirds is found around the coast of Scotland. St Kilda, the Shiant Isles, Handa, North Rona and Sula Sgeir, Rum, Mingulay and Berneray and Sule Skerry and Sule Stack are all breeding colonies that support in excess of 100,000 breeding seabirds each year. Other important breeding colonies regularly supporting over 20,000 species include East Caithness Cliffs, Inner Moray Firth, Firth of Tay and Eden Estuary, and Firth of Forth (DECC, 2004). The species breeding in these colonies include, but are not limited to, Leach's Storm Petrel, Shag, Gannet, Great Skua, Puffin, Razorbill, Fulmar, Manx Shearwater, Kittiwake, and Guillemot. The largest breeding colony in Scotland is at St Kilda, located approximately 65 km off the west coast of the Outer Hebrides, where approximately 600,000 seabirds breed on an annual basis (Stroud et al., 2001).

4.6.2. SNH has advised on bird species that are features of designated and proposed nature conservation sites and use coastal waters that could potentially overlap with living seaweed resources. Sites supporting these species (which comprise SPAs, draft SPAs (dSPAs)[22], Nature Conservation MPAs and Sites of Special Scientific Interest (SSSIs)) are included in **Figure 20.** A list of these sites and associated bird features are included in **Appendix D Tables D1 t**o **D4**.

4.6.3. Some designated sites also support shorebirds that are dependent on living and/or beach cast seaweeds and seagrasses. Sites that have wintering or breeding wader species that are known to either use cast seaweed on the shoreline and/or feed on organisms living in seaweed beds in the intertidal zone as previously advised by SNH are included in **Appendix D (Table D5)** and shown on **Figure 20**.

4.6.4. Black Guillemots have been associated with kelp forests. Although there is no evidence that other seabirds, such as Common Guillemots or Razorbills, forage in kelp forests, there is potential for indirect effects due to impacts on prey populations.

[22] It is probable that dSPAs will soon be subject to public consultation and then will become pSPAs, being afforded the same protection as designated SPAs

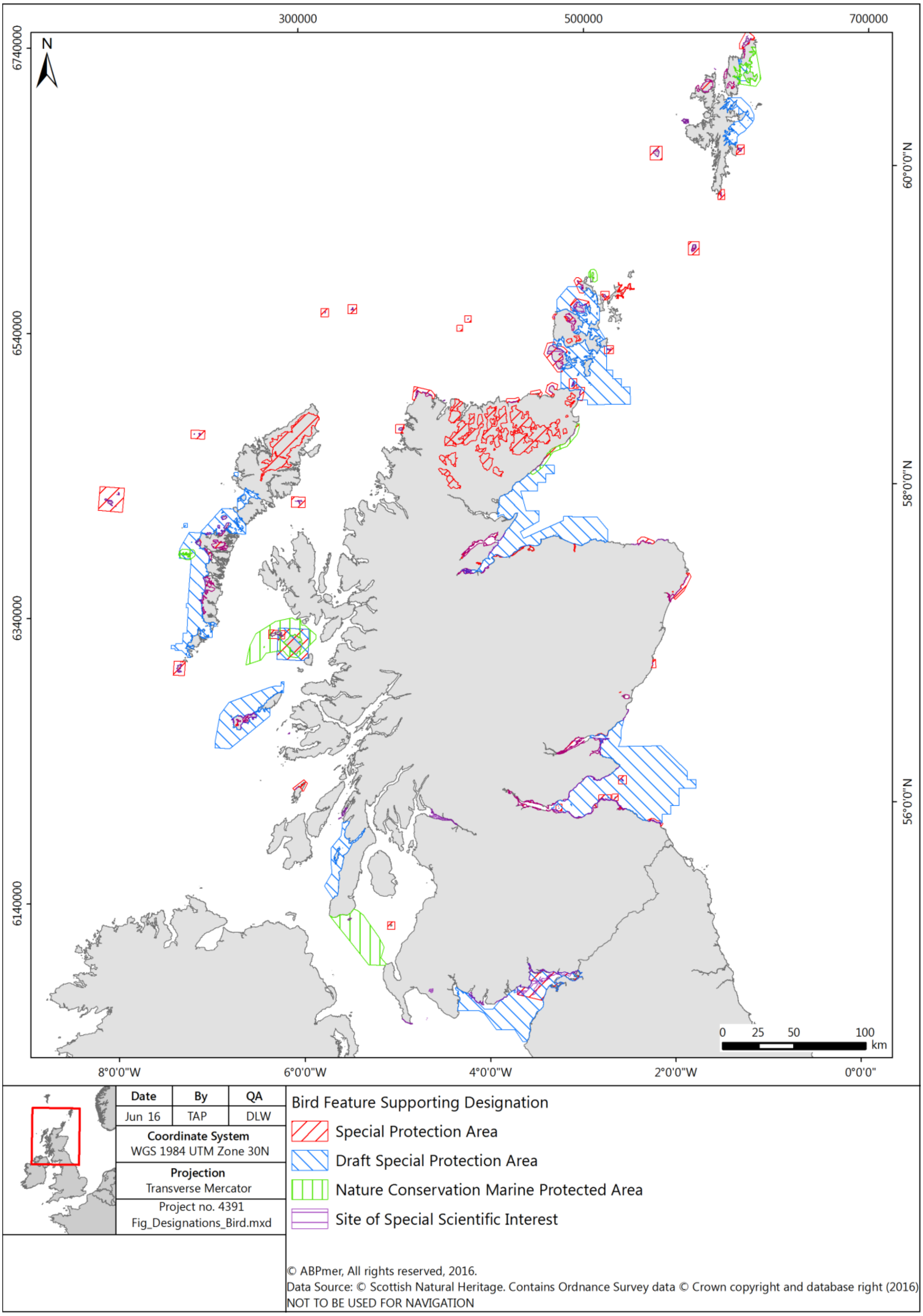


Figure 20: Designated and proposed sites supporting bird features that use coastal waters and could potentially overlap with living seaweed and birds that are dependent on beach-cast seaweed and/or intertidal seaweed beds

4.7. Fish and Shellfish

4.7.1. A large number of fish species inhabit Scottish waters. Some of these are of conservation importance. Atlantic salmon, sea, brook and river lamprey, and shad are species protected by Special Areas of Conservation. Other species, such as eel, skate, and commercial species of fish, are Priority Marine Features. These commercial species include (but are not limited to) cod, ling, horse mackerel and sandeel.

4.7.2. Scottish waters are used as a nursery ground by several species, including spurdog, tope *Galeorhinus galeus*, skate, thornback ray *Raja clavata*, spotted ray *Raja maculata*, herring *Clupea harengus*, cod Gadus morhua, whiting, blue *whiting Micromesistius poutassou*, ling *Molva molva*, hake *Merluccius merluccius*, angler fish *Lophius piscatorius*, sandeel *Ammodytes* spp., mackerel *Scomber scombrus* and plaice *Pleuronectes platessa*. Two species (sandeel and mackerel) are also thought to spawn at several locations in Scottish waters (Ellis et al., 2012).

4.7.3. The main commercial species landed from within the ICES region VIa (the region encompassing the west coast of Scotland) are mackerel, blue whiting, herring, horse mackerel, hake, saithe, haddock, ling, nephrops, crab and scallops. Across the east coast, in areas classed as the northern and central North Sea (ICES region IVb), fisheries tend to focus on cod, haddock, whiting, monkfish, nephrops, herring and mackerel (DECC, 2004). Cod, haddock and whiting are also important fisheries off the north coast of Scotland (ICES region IVa), along with saithe, Greenland halibut, *Nephrops*, scallops, herring, mackerel, sandeel, blue whiting and Norway pout (Gordon, 2003).

4.7.4. A diverse range of shellfish species can also be found off the coast of Scotland. Species include nephrops Nephrops norvegicus, European lobster *Homarus gammarus*, brown crab *Cancer pagurus*, velvet swimming crab *Necora puber* and scallops *Pecten maximus*. Shellfish distribution is highly dependent on sediment type, and therefore distribution tends to be patchy and discrete due to the complex distribution of habitats and sediment types (Marine Scotland, 2013).

4.7.5. Adult European lobsters are reported to show a preference for rocky crevice habitat with gravel and cobble as nursery habitat (Seitz et al., 2014) though it is noted that there is little information on juvenile phases. There is some information to suggest that juvenile lobsters may prefer coarse substrate with suitable crevices, or burrow in mud (Howard and Bennet, 1979). There is evidence that some crab species actively settle in mussel beds, rocky shores, seagrass beds *Zostera marina* and macroalgae (Moksnes, 2002) and that nursery habitats may vary depending on local abiotic and biotic factors (Heraghty, 2013).

4.8. Nursery and Spawning Grounds

4.8.1. Seaweeds and seagrasses provide a niche habitat during various life stages to a number of species. These include migratory and reproductive areas for fish and invertebrates, including nursery and spawning grounds. The distribution of nursery and spawning grounds in Scottish waters for key demersal and pelagic fish species in relation to the known and potential distribution of seaweed and seagrass habitat is shown in **Figure 21.** These maps show broad indicative areas for potential spawning and nursery grounds only. The use or importance of such grounds is not necessarily spatially consistent and may vary between and within years.

4.8.2. The data used to inform the spawning and nursery areas in Figure 21 are based on survey work that does not overlap with areas of kelp bed distribution. However, fish sensitivity maps are available that serve as an update of the existing fish nursery maps (**Figure 22**). These fish sensitivity layers have been generated to identify the probability of the presence of high abundances of 0-group fish (fish in the first year of their life) in Scottish waters as a broad indicator of the distribution of nursery areas. The main limitation of these maps is that there are information gaps for the inshore areas on the west coast of Scotland. Therefore, whilst they give a more considered distribution of 0-group fish, they can only do so where the data is available.

4.8.3. Seagrass rhizomes provide a more stable habitat that can be used as a nursery area by a number of species (Wilkinson & Wood, 2003). It is well documented that the provision of suitable nursery and spawning grounds by seaweed and seagrass habitats is of great importance to many species, including species of commercial and recreational value (Jackson et al., 2008; Unsworth and Cullen-Unsworth, 2015). For example, juvenile cod shelter in kelp forests and seagrass beds (Seitz et al., 2013) and cuttlefish (*Sepia officinalis*) are known to attach eggs directly onto the blades of *Zostera* marina (Blanc & Daguzan, 1998 in Jackson et al., 2001). Herring (*Clupea harengus*) in the North East Atlantic and North Sea appear to spawn on vegetation (Haegele and Schweigart, 1985). Recognised spawning grounds on the west coast of Scotland are shown in **Figure 23.** Juanes (2007) found that the mortality risk of cod is lower in more complex habitat structures provided by kelp forests and seagrass beds than in simple ones. It appears that the complexity of the habitat become less important to individual survival in older life stages (Seitz et al., 2013). Maerl beds can also act as reproductive reservoirs for future generations of commercially important species, e.g. cod, edible crabs and scallops (Lancaster et al., 2014a).

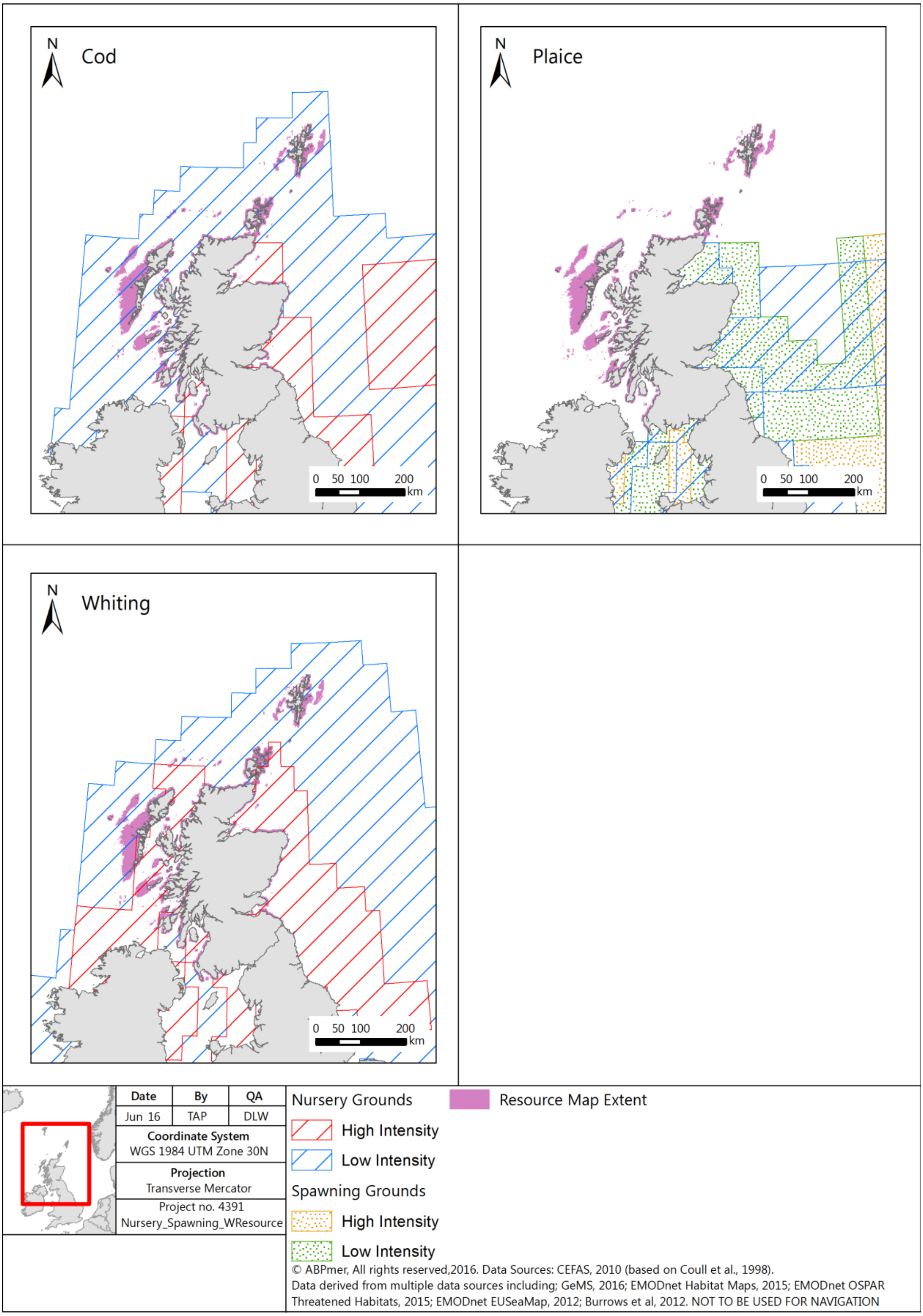


Figure 21: Nursery and spawning grounds for key fish species

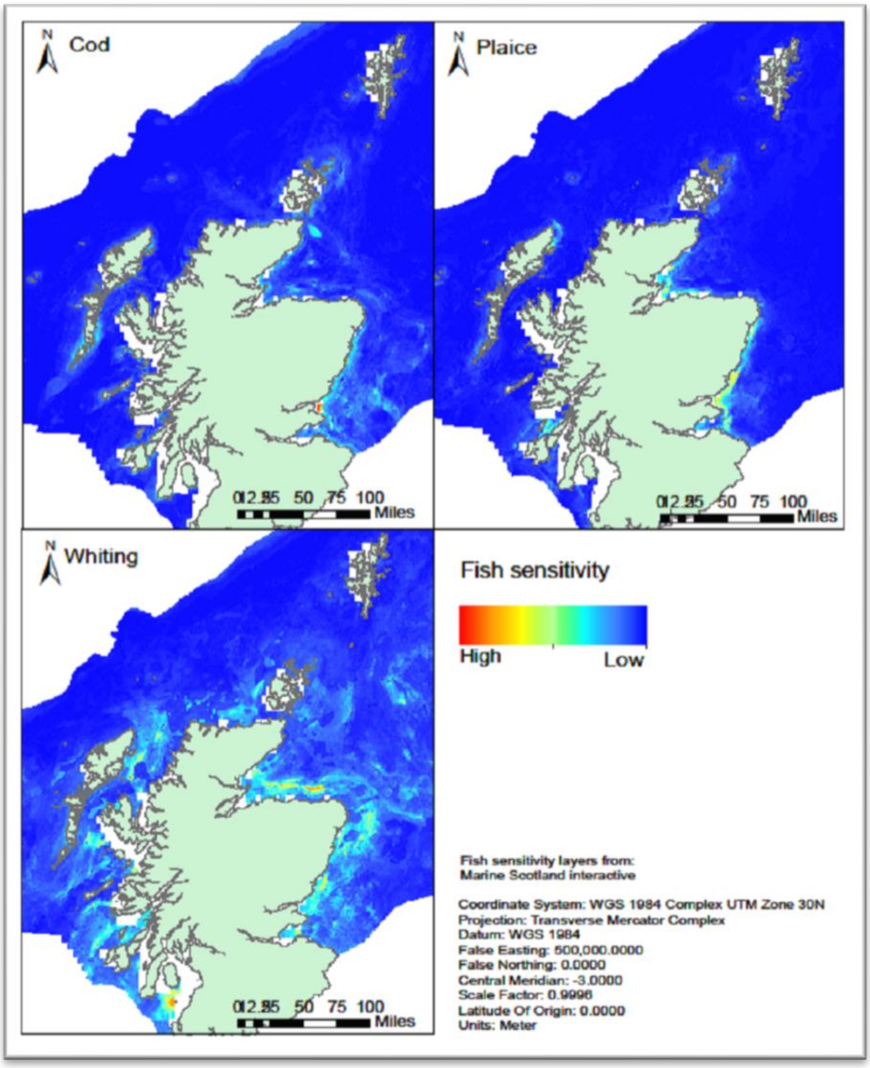


Figure 22: Fish sensitivity maps for 0-group fish species

4.8.4. Drifting seaweed provides juvenile fish with shelter from predators such as larger fish and birds (Orr, 2013). Beaches on the west coast of Scotland are used as nursery grounds by a number of commercially important benthic fish species, such as European plaice *Pleuronectes platessa* and dab *Limanda limanda* (Gibson et al., 1993 cited in Orr, 2013). The abundance of juvenile fish in the surf-zone in western Australian beaches was positively related to the volume of drifting macroalgae (Orr, 2013 and references therein). Therefore, the greater abundances of prey and enhanced habitat complexity provided by drifting macroalgae may increase the survival of juvenile fish in nursery areas in Scotland (Orr, 2013).

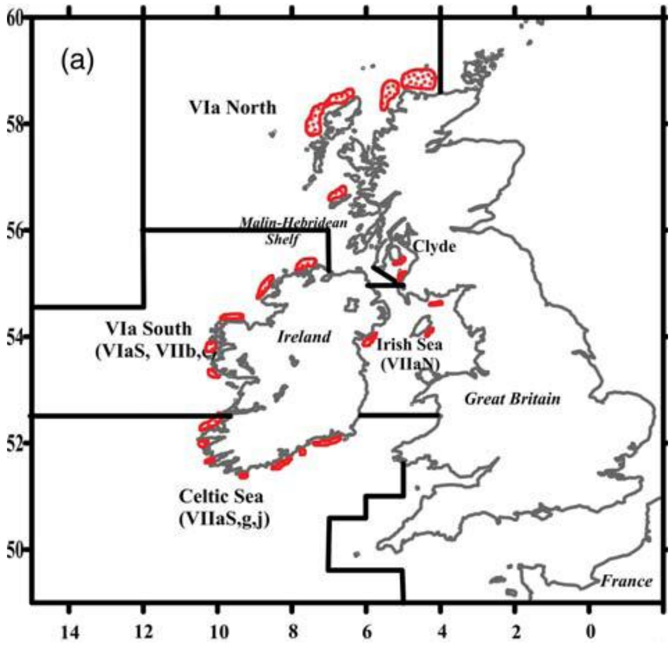


Figure 23: ICES management areas and the known spawning grounds for herring are shown in red (Source: Geffen *et al.*, 2011).

5. Seaweed and Seagrass: Ecological Functions

5.1. Introduction

5.1.1. One of the reasons for the importance of seaweeds and seagrasses is their ecological function within ecosystems. These include:

- the ability of some species (kelp and seagrass in particular) to modify their local environment (so-called “ecosystem engineers”) by altering sedimentation rates, modifying water flow and wave energy and changing light levels;
- providing habitat and shelter to other species of seaweed, and marine plants and animals, e.g. epiphytes, invertebrates, and fish;
- their role in primary production, which is critical for the productivity and survival of the ecosystem;
- providing a food source, both directly, for grazing species such as sea urchins and indirectly by releasing organic matter into coastal waters; and
- providing spawning grounds and nursery grounds for juveniles, e.g. invertebrates and fish. The latter can include commercial fish species.

5.2. Habitat and Shelter

5.2.1. Seaweeds and seagrasses provide a complex habitat structure for many species of marine algae, plants and animals (Bodkin, 1988; Duggins et al., 1989; Jackson et al., 2001). For example, epiphytic and epizoic organisms may colonise seagrass blades (Nybakken, 2001) and various marine fauna occupy areas on the holdfast, stipe and fronds of seaweeds (Jones et al., 2000). In addition, by altering environmental factors, such as light and water movement, they are able to provide indirect habitat for understorey organisms in the sheltered water column and the rock surface between holdfasts (Sjøtun et al., 2006 in Smale et al., 2016; Wilkinson, 1995), and for infaunal species found within the sediment (Unsworth and Cullen-Unsworth, 2015). Maerl beds, including dead maerl, have a complex open structure formed by interlocking maerl thalli allowing water to circulate, providing suitable habitat for a diverse community of organisms (Lancaster et al., 2014a).

5.2.2. Seaweeds and seagrasses also provide shelter from predation for a number of species (Jackson et al., 2001; Seitz et al., 2013; Kelly et al., 2001; Lancaster et al., 2014b). The level of protection varies, depending on the structural functioning and diversity of the habitat. For example, it has been found that the more diverse a habitat is, the better it is for hiding from predators, whilst maximising foraging opportunities (Jackson et al., 2001).

5.2.3. In addition, seaweed and seagrass provide shelter to marine invertebrates and fish species (see **Section 4.7**), as well as foraging habitat to these species and species of marine mammals (see **Section 4.5**).

5.3. Kelps

5.3.1. The holdfast of larger kelp species is capable of supporting a very large number of species and a diverse range of species assemblages (Edwards, 1980; Christie et al., 2003; Blight & Thompson, 2008; Burrows et al., 2014a). For example, in Norway it was found that, on average, a single kelp plant supports approximately 40 macroinvertebrate species represented by almost 8,000 individuals (Christie, et al., 2003; Burrows et al., 2014a); with increased age, the holdfast habitat volume and diversity increases (Wilkinson, 1995; Christie, et al., 2003). The majority of these fauna include invertebrates such as gastropods, crustaceans and echinoderms (Burrows et al., 2014a).

5.3.2. Different kelp species have different morphologies and life histories and, as such, provide structurally varying habitats. For example, the stipe of *Laminaria digitata* is shorter and less rigid than that of *L. hyperborea*. In consequence, the substrate near to *L. digitata* plants experiences greater physical abrasion by the kelp blades and so fewer species can inhabit the understorey in comparison to *L. hyperborea* (Kain, 1979). The understorey assemblages associated with *L. digitata* are thus distinct from those beneath *L. hyperborea*. Certain species that would otherwise be outcompeted by understorey algae are facilitated by the ‘sweeping’ by *L. digitata*, e.g. the limpet *Patella ulyssiponensis* and the sponge *Halichondria panicea*. Similarly, subtle differences in morphology (e.g. holdfast volume and complexity, stipe roughness and susceptibility to epiphyte growth) can have a strong influence on the structure and richness of associated assemblages (e.g. Blight & Thompson 2008).

5.3.3. Physical factors, such as wave exposure, substrate (e.g. unstable boulders, solid bedrock) and location on the infralittoral fringe, influence not only the distribution of different kelp species (**Section 3.3**) but also their associated understorey assemblages (Wilkinson & Wood, 2003). The nature of inter-specific and regional-scale variability in kelps as habitat formers in the UK (and the wider implications for biodiversity) is poorly understood and remains an important knowledge gap in the field of kelp bed ecology.

5.4. Maerl

5.4.1. Maerl provides an attachment site for animals such as feather stars, hydroids and bryozoans (Lancaster et al., 2014a). The loose structure provides shelter for small gastropods, crustaceans, bivalves and juvenile fish, and the fauna that live within the substrate (infauna) include many bivalves such as *Mya truncata* and *Dosinia exoleta*. Fauna that live on the surface (epifauna) include small crustacea. Red seaweeds, sea firs and scallops may also colonise the surface of maerl. Many species have a high specificity to maerl beds, including certain polychaetes (e.g. *Glycera lapidum*, *Sphaerodorum gracilis* and *Polygordius lacteus*) and amphipods (e.g. *Parametaphoxus fultoni*, *Atylus vedlomensis* and *Animoceradocus semiserratus*). Several species of algae are almost entirely restricted to calcareous habitats and are characteristically found in maerl beds (e.g. *Halymenia latifolia*, *Scinaia turgida* and *Gelidiella calcicola*).

5.5. Seagrasses

5.5.1. Seagrasses provide a stable, sheltered and permanent habitat for many fish and invertebrate species (Jackson et al., 2001). The structural habitat of seagrasses reduces flow velocities (Bos et al., 2007), which in turn alters the surrounding environment, leading to increased sedimentation and a reduction in sediment grain size (Bos et al., 2007, van Katwijk et al., 2010). Seagrasses also provide protection from predators and support a wide range of species during different life – history stages (Jackson et al., 2001).

5.6. Beach-casts

5.6.1. Particularly during the autumn and winter months, various kelps can be washed up on the shores as a result of wave action during storms (Kelly, 2005; Orr, 2013). Beach-cast kelps are sometimes referred to as drift weed. Before the drift weed is washed ashore, it acts as a floating shelter for many organisms such as crustaceans and juvenile fish (Kelly, 2005). As the drift weed rots on the shore, it provides shelter for invertebrates, including amphipods, polychaetes, coleoptera and diptera larvae (Kelly, 2005; Orr, 2013). Large accumulations of beach-cast seaweed in the intertidal and supralittoral zones also benefit fauna because they maintain relatively stable micro-climatic conditions, and therefore shelter macroinvertebrates from extreme temperatures and protect them from desiccation when the tide recedes (Orr, 2013). Fauna may also be attracted to drifting seaweed in the surf/swash zone because it partially protects them from rapidly moving water by reducing local current velocities (Orr, 2013).

5.7. Primary and Secondary Production

Primary Production[23]

5.7.1. Seaweeds and seagrasses contribute considerably to the total production of inshore waters. Kelp primary production per unit area is amongst the highest known in aquatic ecosystems (Birkett et al., 1998 cited in Kelly, 2005). Mann (1973) reports productivity levels in kelp forests ranging from 800 g C/m^2 (in California) to as much as 2,000 g C/m^2 in the Indian Ocean. In Scottish waters it has been estimated that an area of 2,900 km^2 has a typical production rate of 1,300 g C/m^2/yr (Dayton, 1985; Burrows et al., 2014b). However, production rates have been found to vary widely between kelp species and depth, with *Laminaria* spp. achieving 1225 g C/m^2/yr at its most favourable depth in south-west England (Bellamy et al., 1968) and 1750 g C/m^2/yr at the Canadian Atlantic coast (Mann, 1972). Low production values have been recorded in *Saccharina latissima* in

[23] Primary productivity is the rate at which energy is converted into organic substances by photosynthetic and chemosynthetic organisms (https://www.britannica.com/science/marine-ecosystem/Patterns-and-processes-influencing-the-structure-of-marine-assemblages#ref588556).

Scotland at only 120 g C/m^2/yr (Johnston et al., 1977), which was attributed to nutrient limitation in a low flow site (Mann, 1982).

5.7.2. Intertidal fucoids have been estimated as having slightly lower, although still high, levels of primary production (Kelly, 2005). Seagrass beds are densely populated with plants and also have high rates of productivity. A study by McRoy & McMillan (1977), for example, estimated that temperate seagrass beds have a productivity rate of 500 to 1,000 g C/$m^{2/}$yr.

5.7.3. In addition to the seaweeds and seagrasses themselves, primary production is provided by the microbial and macroalgal communities living on the fronds and leaves of the individual plants (Wilkinson & Wood, 2003).

Growth of Kelps – contribution to primary production

5.7.4. As well as being very productive, kelps have very fast growth rates (North, 1971; Nybakken, 2001). Irradiation intensity and temperature are the primary factors influencing growth rate and the maximum biomass of both *Laminaria digitata* and *L. hyperborea* (Werner & Kraan, 2004) has been recorded in early autumn (Kelly, 2005).

5.7.5. The main growing point of kelps is the meristem at the junction of the stipe and frond. As new tissue is formed at the base of the frond, old tissue is lost at the distal end by decay and damage, so that the production rate is much greater than that indicated by change in frond size (Wilkinson, 1995).

5.7.6. *L. hyperborea* are perennial; each year this kelp species renews its entire blade or lamina and the stipe increases in size (Kelly, 2005). The blade or lamina primarily sheds in the late spring and early summer; although this can occur at any time of the year and older plants can also be completely removed during winter storms. Regeneration time varies depending upon the time of the year the removal occurs. If the blade is removed prior to the growth peak then regeneration can be 5 months (Kelly, 2005). However, if it occurs at the beginning of or during the low growth phase, then regeneration can take 10 months. The time taken to recover is also a function of the age of the plant.

5.7.7. Other kelp species retain the frond but keep adding to it from the base while the older parts at the distal tip erode. After a few years the distal loss and the new growth balance so that the frond has an approximately fixed size but it is still very productive in terms of inputting detritus and dissolved organic matter (DOM) into the ecosystem (see following section on Secondary Production).

Secondary Production[24]

5.7.8. Seaweeds and seagrasses contribute to secondary production in the ecosystem in two ways. The first is by being grazed directly, which is

[24] Secondary productivity is the rate at which consumers convert the chemical energy of their food into their own biomass (https://www.britannica.com/science/biosphere/Efficiency-of-solar-energy-utilization#ref589414).

discussed in more detail in Section 5.4. The second is through their entry into the food chain in the form of detritus and/or dissolved organic matter (DOM) (Wilkinson, 1995). Detritus and dissolved organic matter may be processed through the microbial loop or consumed by a wide range of detritivores before entering the food web (Krumhansl & Scheibling, 2012 cited in Smale et al., 2016).

5.7.9. Detritus ranges in size from small fragments to whole plants (see Growth of Kelps above, for examples) (Nybakken, 2001). Davison (1998 cited in Wilkinson & Wood, 2003) suggests that *Zostera* beds produce approximately 1 tonne of detrital material per km^2.

5.7.10. Dissolved organic matter from kelp supports infaunal communities beyond the kelp bed itself (Stamp & Hiscock, 2015) by increasing levels of dissolved organic matter within the sediment (Stamp & Hiscock, 2015); this provides valuable nutrition to potentially low productive habitats (Smale et al., 2013). Seagrasses also contribute to secondary production by providing an important source of dissolved organic matter for surrounding coastal habitats (Lancaster et al., 2014b).

5.7.11. In addition Chapman (1984) reports that one *L. digitata* plant may produce 6 thousand million spores per year (Kelly, 2005). These spores only last a few days and are very transient, but it is possible that they are an important food source for species within the immediate area of the kelp (Kelly, 2005).

5.7.12. Beach-cast seaweed and associated particulate organic matter play a central role in sandy beach food webs (Orr, 2013). As beach-cast seaweed rots on the shore, it provides food in the form of organic matter for invertebrates, including amphipods, hypoxic/anoxic-tolerant infaunal opportunistic polychaetes such as *Malacoceros* sp. and *Capitella* spp., and coleoptera and diptera larvae (Kelly, 2005; Orr, 2013). These invertebrates are subsequently a food resource for various arthropods and birds (see Section 5.4). Drifting seaweed will break down into finer particles which is then consumed by suspension feeders (e.g. mysids and bivalves) and deposit feeders (e.g. polychaetes and benthic amphipods) in the inshore beach environment (Orr, 2013).

5.7.13. Large accumulations of beach-cast seaweeds and seagrasses can occur along the coastline creating a source of recycled nutrients and detrital material, which is of great benefit to the local ecology of nearshore habitats (Kirkman & Kendrick, 1997). In addition, kelps have the potential to provide a rich food source to assemblages many kilometres from its source (Vanderklift & Wernberg, 2008) as well as enriching offshore deep sediments at depths of 900 m or more (Vetter & Dayton, 1998). This is highly dependent on the site specific hydrodynamics of an area, and typically kelps are consumed and decomposed near to where they grow.

5.7.14. The decomposition of leaves and stems of the seagrass *Ruppia* spp. has also been found to support benthic communities and be a source of primary production to deeper water and drift line communities

(Verhoeven & van Vierssen, 1978; Zieman et al., 1984; Kantrud, 1991 cited in Wilkinson & Wood, 2003).

Food Web Dynamics

5.7.15. There are a few species which feed directly on seaweeds, primarily grazers such as sea urchins. It has been observed by Jones and Kain (1967), for example, that sea urchins such as *Echinus esculentus* graze on *L. hyperborea* and remove sporelings and juveniles. Although the level of grazing by urchins is not high, it has been found to control the depth of distribution of *L. hyperborea* and reduce the understorey community abundance and diversity (Stamp & Hiscock, 2015).

5.7.16. Seagrasses have high rates of primary production which support a range of diverse fauna (Wilkinson & Wood, 2003). They provide a food source for many fish and invertebrate species (Jackson et al., 2001). Some bird species feed directly on seagrass, and seagrass beds (including Ruppia spp.) are thus an important food source for them. *Zostera* beds are heavily grazed by overwintering wildfowl and, in particular, are an important food source for Brent Geese and Canada Geese (Lancaster et al., 2014b). Canada Geese favour intertidal and shallow subtidal Z. marina (Tyler-Walters & Wilding, 2008b), while Mute and Whooper Swans favour intertidal *Z. noltii* (Nacken & Reise, 2000). The importance of seagrass habitats to these species has been highlighted in Tubbs & Tubbs (1983 cited in Wilkinson & Wood, 2003) who report that Brent Geese grazing reduced *Zostera* cover from 60 - 100% in September to 5 -10% between mid-October and mid-January.

5.7.17. Seaweed and seagrass habitats also provide a food resource and foraging habitat for higher trophic levels such as fish, birds and marine mammals. Diving seabirds and sea ducks, which typically eat large invertebrates, shellfish, fish eggs or fish, are known to feed within kelp forests due to the high biomass and biodiversity associated with kelp and the subsequent food availability (Kelly, 2005). For example, a study in Norway found that Common Eiders selected kelp forest as foraging grounds throughout the winter months. Black Guillemots also feed on fish (e.g. butterfish) in kelp habitats (SNH, pers. comm.). The infralittoral fringe of kelp forests is also an important area for feeding birds, in particular wading birds, as prey items such as crustaceans, bivalves and amphipods are exposed as the tide ebbs (Kelly, 2005).

5.7.18. Seals and otters will also forage in kelp forests and seagrass beds due to the high biomass and diversity supported by the habitat. Seals feed on fish species, such as wrasse, that occur in kelp forests (Tollit et al., 1998; Wilkinson & Wood, 2003). Coastal otters are also likely to utilise the productive inshore waters where seaweed and seagrass habitats are present, as they support high levels of fish and crustacean prey species (SNH, 2015a). Further information on the foraging ranges of seals and otters is provided in **Section 4.4**.

5.7.19. The inshore fauna around drifting fragments of seaweed are consumed by fish and predatory crustaceans such as shrimp (Orr, 2013).

Migratory shorebirds stop over in the Outer Hebrides and feed prolifically on invertebrates within beach-cast seaweed, as do breeding waders in the summer, and hence the seaweed is a rich feeding ground for birds at various stages of their life cycle (Orr, 2013).

6. Effects of Harvesting on Ecological Function

6.1. Introduction

6.1.1. The potential effects of wild seaweed and seagrass harvesting on the ecological function of seaweeds and seagrasses are reviewed and discussed in this section. Mitigation measures that need to be considered to ensure that wild harvesting activities are sustainable are presented in **Section 9**.

6.1.2. Wild harvesting activities have implications for the population structure, community dynamics and wider functioning of marine ecosystems (Smale et al, 2013). They may also affect ecosystem services. Potential issues include but are not limited to:

- loss of habitat and/or shelter for a range of plants and animals, alongside loss of direct and indirect food sources. As well as detrital grazers, suspension feeders et al, this has consequences for higher trophic levels, e.g. mammals, birds and piscivorous fish.
- loss of nursery grounds for juvenile invertebrates and fish, with consequences for higher trophic levels and commercial fish stocks.

6.1.3. These effects depend on a range of factors, including but not limited to:

- the species to be harvested,
- the harvesting method,
- the amount taken,
- the harvesting location and its environmental context,
- the time allowed for regeneration prior to harvesting again, and.
- the timing (season) of harvest.

6.2. Effects of Harvesting

6.2.1. The resistance (tolerance) and resilience (recovery) of seaweed and seagrass species to harvesting and the subsequent effect this activity has on the wider ecological community has been subject to many studies in the UK and abroad. The following sections review the potential ecological effects of wild harvesting on each of the broad groups of seaweeds and seagrasses. The effects of harvesting on the target seaweed or seagrass resource itself (i.e. the biotope) is initially reviewed followed by a review on other ecological functions (i.e. ecological interactions, food web dynamics and production) where information is available.

6.2.2. Effects on seaweeds and seagrasses depend on the harvesting methods used and the habitat requirements of the particular species.

Wracks

6.2.3. *Ascophyllum nodosum* has a long life span; individual fronds can survive for 10 to 15 years and assemblages originating from a common holdfast are thought to be capable of living for decades (Holt et al., 1997 and references therein). The evidence on recovery rates from natural disturbance or harvesting does not agree.

6.2.4. Recovery of very sheltered shores dominated by *Ascophyllum* spp. from natural disturbance may take decades (Hill and White, 2008). Early studies on *Ascophyllum* showed a failure of this species to fully recolonise harvested or experimentally manipulated areas up to eleven years later (Knight & Parke, 1950; Boney, 1965; cited in Jenkins et al., 2004). Jenkins et al. (2004) investigated the effect of experimental *Ascophyllum* canopy removal over a twelve-year period. The Ascophyllum canopy was slow to recover, with no recovery after 6 years and 46% coverage after 12 years (compared to 80-100% cover in uncleared plots). Removal of the canopy led to short term changes in the community composition (namely reduced cover of red algal species and increased area grazed by limpets) which were still apparent 12 years later. After 12 years the affected areas were dominated by other wrack species, namely *Fucus serratus* and *Fucus vesiculosus.*

6.2.5. Harvesting of *A. nodosum* is commonly carried out in most areas of its distribution. For example, in the Western Isles it is reported that *Ascophyllum* is hand cut using a sickle and cutting occurs all year round (The Minch Project website). Mechanical harvesting using a seaweed harvesting boat also occurs in Scotland and is currently restricted to the Outer Hebrides (**Table 6)**.

6.2.6. Harvesting of *Ascophyllum nodosum* involving the removal of the entire plant would severely affect the population given the species' slow growth rate and poor recruitment (e.g. Holt et al., 1997). However, a study in Ireland reported that if stumps 10-20 cm high are left, the plants can re-sprout and re-harvesting is possible after 3 to 6 years (Guiry, 1997; cited in McLaughlin et al., 2006).

6.2.7. Seaweed harvesting boats can only operate when there is a safe depth of water underneath and therefore mechanical hedge cutting is likely to remove less of the plant than hand cutting methods (Walter Speirs, Scottish Seaweed Industry Association, pers. comm.). However, the scale of removal by mechanical means is likely to be greater than by hand harvesting alone.

6.2.8. In an area of Strangford Lough where harvesting of *Ascophyllum* was carried out on a small scale, ecological effects were found up to 3 years after the harvesting ceased (Boaden & Dring, 1980; cited in Hill, 2008 and McLaughlin et al., 2006). In the cut area, the growth rate of *A. nodosum* increased but shore coverage was reduced. The cover of green algae and *F. vesiculosus* increased as did the density of grazers, namely limpets (*Patella* sp.). Microalgal cover of boulders had also increased and had significantly more crustacean meiofauna. It was concluded that harvesting *Ascophyllum* even at a small scale has a significant and persistent effect on shore ecology (Boaden and Dring, 1980).

6.2.9. Another study was undertaken on the impact of hand and mechanical harvesting of *A. nodosum* at two sites on the West coast of Ireland.

Hand harvesting involved cutting floating fronds by hand (from a boat) leaving about 30% cover and 20 cm length of each plant. In both the hand and mechanically harvested areas, most plants were harvested. Kelly et al. (2001) reported that there was no overall impact on the biodiversity of the harvested sites and the percentage cover of *Ascophyllum* was nearing recovery after 11 to 17 months. Although the proportion of *F. vesiculosus* cover increased at the harvested sites, there was no effect on other species of macroalgae, fish populations or other large epifaunal species. These findings correlate with studies in Nova Scotia which found that the impact of harvesting 95% of the A. nodosum standing stock resulted in no decrease in fish abundance or diversity (Tyler, 1994).

6.2.10. After harvesting, fucoid species such as *Fucus spiralis* and *F. vesiculosus* both rapidly recruit cleared areas (Holt et al., 1997; cited in White, 2008b; 2008c), with full recovery of *F. vesiculosus* taking 1 to 3 years (Holt et al., 1997; cited in White, 2008c). *Fucus* spp. can regenerate from the remaining stem provided that it is not removed entirely (White, 2008c). The spores of *F. serratus* are broadcast into the water column allowing a potentially large dispersal distance. Recruitment occurs through reproduction of the remaining population or from other populations. It was concluded by Jackson (2008) that if some of the *Fucus* population remains it is unlikely that other species will come to dominate; however, if the entire population is removed, other species may establish and dominate. Re-establishment may depend on the ability to out-compete other species and this in turn may be dependent on suitable environmental conditions. Recovery from disturbance (such as abrasion, physical disturbance and hydrocarbon contamination), where some of the population remains, is likely to occur after a year (Jackson, 2008).

6.2.11. Another study in Spain noted the benefits of shading effects on the survival of fucoids. An increased physiological resilience to low tide stressors (namely desiccation and irradiation) was found in covered *F. serratus* and *F. spiralis* plants compared to uncovered plants (Fernández et al., 2015). Therefore, the harvesting of fucoids or other seaweeds would remove these protective shading effects.

6.2.12. Recovery rates of *Pelvetia canaliculata* after harvesting may be variable (White, 2008a). Subrahmanyan (1960; cited in White, 2008a), for example, observed that this species readily recruits cleared areas of the shore with full recovery of the community taking place within 5 years. However, in Shetland *P. canaliculata* did not recolonise shores that had been bulldozed until 7 to 8 years after the event. Overall therefore, wracks are reported as having moderate recoverability following extraction (White, 2008a).

Kelps

6.2.13. Each species of kelp has a different growth rate, growth season and life-span (see Appendix C, Table C1). Different populations of the same species may also behave differently. *Laminaria hyperborea* plants can live up to 25 years in Iceland (Gunnarsson, 1991 cited in Wilkinson,

1995) and up to 10 to 15 years in Norway (Sjøtun et al., 1993 cited in Wilkinson, 1995; Steen et al., 2015). The lifespan of this species in Scottish waters is generally 5 to 7 years, with occasional 12 to 15 year old plants also having been reported (D. A. Macinnes, Marine Biopolymers, pers. comm.).

6.2.14. Most of the upper part of the frond or blade of a kelp plant can be removed and the blade will slowly re-grow, but if the growth area of the blade (the meristem at the junction of the stipe and frond) is damaged or removed, the stipe and holdfast degenerate and the whole plant dies as regrowth cannot occur (Birkett et al., 1998). In the case of hand harvesting where the plant is cut below the meristem and the stipe is left in place after cutting, toxic compounds are excreted as the stipe decays which in turn hinders spore germination and plantlet growth (Kelly, 2005). In addition to the decaying compounds, another problem associated with leaving the stipes is that a calcareous film forms on the surface of the substrata. Although this provides a surface for kelp plantlets to settle and grow, this surface is not robust enough to support larger plants which are then ripped away during a storm event or strong currents (Kelly, 2005).

Kelp regeneration

6.2.15. Recovery from damage and/or removal and the rate of kelp regeneration will depend on a number of factors including the life history characteristics of the species affected, the area of the plant cut, nutrient availability, irradiance levels, the level of wave exposure and the presence of grazers (CDFG E.I.R., 2001; Kelly, 2005; Sjøtun et al., 2000). For example, studies in Norway have found that the growth rates of L. hyperborea are higher in wave exposed locations (Sjøtun et al., 2000). Therefore, harvested kelp can recover more rapidly in wave exposed locations than in sheltered locations.

6.2.16. In an assessment of benthic species' sensitivity to fishing disturbance, MacDonald et al. (1996) classified the kelp species *L. hyperborea* (mature) as having 'moderate' recovery potential. Using a similar methodology, McMath et al. (2000) scored the recruitment ability of kelps as 1-20 (on a scale of 1-100, where '1' represents the maximum recruitment success and 100 represents no recruitment ability) based on life history characteristics (rapid growth rates of 1 to 5 cm/week, sexual maturity at 1 to 2 years and frequent reproduction). The regenerative ability of kelps was 'scored' as 20 to 30 (out of a scale of 1-100, where '1' represents the maximum regeneration ability and 100 represents no regeneration ability) as rapid re-growth of kelp blades can occur following damage and/or removal, providing the meristem remains intact (ABPmer, 2013).

6.2.17. Information on the recovery of *Laminaria* from disturbance and removal is provided both by experimental kelp removal studies and from observations at harvested grounds.

6.2.18. Experimental canopy removal and clearance experiments conducted in Scotland and the Isle of Man showed that 3 years after canopy removal, some semblance of a kelp forest, in terms of macroalgal biomass and subsidiary algal species, was regained (Birkett et al., 1998). However, the size of the kelp plants and age structure of the population was different from uncleared kelp forests. These experimental clearing experiments, however, do not directly mimic the effect of mechanical harvesting by which the kelp stipes would be removed.

6.2.19. On the Isle of Man, studies by Hawkins & Harkin (1985) and Smith (1985) observed the effects of the removal of *L. digitata* and *L. hyperborea*. It was found that *L. digitata* re-grew whereas *L. hyperborea* did not (Kelly, 2005). Kain (1975) examined the successional recolonisation of seaweed in areas of *L. hyperborea* forest that had been cleared. After 2.5 years L. hyperborea was again the dominant species with red algae also present, resembling a very similar seaweed composition to that present prior to the clearing (Kain, 1975).

6.2.20. Experimental work in Nova Scotia where *Laminaria longicruris* and *L. digitata* are harvested has shown that if kelp beds are destroyed and/or partially destroyed, grazing sea urchins may prevent regeneration and recruitment of climax kelp communities. It is thought that kelp harvesting removes the cover and protection of urchin predators (e.g. lobsters, crabs and fish) and this consequent reduction in predator pressure enables increases in urchin populations which then graze destructively on *Laminaria*, resulting in areas devoid of kelps (Bernstein et al., 1981; reviewed in Birkett et al., 1998). In Scotland, urchins do not tend to eat adult kelps but hinder re-establishment on cleared areas by grazing sporelings (Wilkinson, 1995). In addition, following harvesting in areas where there is an established population of urchins, the urchins can function as detritus feeders and remain at a sufficient level to inhibit kelp regeneration (Warner, 1984 cited in Wilkinson, 1995).

6.2.21. A large number of studies have been undertaken in Norway to monitor the effect of kelp harvesting (e.g. Birkett et al., 1998 and references therein; 2014a; 2014b; Steen et al., 2015). These indicate that harvested forests of *L. hyperborea* recovered kelp biomass within 2 to 4 years but that individual kelp plant sizes were still below pre-harvesting levels 4 years later. In addition, significant differences in the understorey density, epiphyte community, epifaunal species, holdfast fauna and benthic macrofauna and flora persisted 4 years after harvesting. The recovery of the kelp in terms of size of the kelp plant and number of epiphytes was more rapid in wave exposed areas.

6.3. The kelp forest habitat

6.3.1. A study by Christie et al. (1998) looking at the effects of kelp harvesting on epifaunal communities in Norway concluded that recolonisation by fauna depends upon the recovery time of the kelps and of the fauna. Overall, it took 6 years following the harvest for faunal abundances to stabilise (Christie et al., 1998).

6.3.2. A comparison of kelp harvesting methods reveals that certain types of trawling devices, that involve the entire removal of larger mature plants, result in a predominance of younger plants. Trawling is considered to open the area up to high levels of recruitment as a result of increased levels of light availability (Christie et al., 1998; Kelly, 2005). This recruitment ensures the persistence of a kelp forest and does not give space for other opportunistic species (Christie et al., 1998); little degradation of the habitat therefore occurs. In addition, younger plants have a higher percentage of alginic acid and are of a better end-use quality than older kelps. Although this is preferable when considering maximum yield, from an ecological point of view this will result in homogenous populations of younger plants growing on regularly disturbed substratum. If mechanical harvesting occurs over a number of years it is conceivable that only the dominant, fast growing species will be present (Kelly, 2005). This could result in a reduction in habitat complexity, biomass and diversity of an area which in turn reduces the seaweed capability as a habitat, shelter and food source for a number of species.

6.3.3. The ability of a kelp forest to provide a habitat, shelter and food source for a wide range of species will be hampered by the kelps being harvested. The removal of kelps would affect many marine fauna and flora that use this habitat as feeding and nursery grounds. Some short term studies have reported that the harvesting of kelps may negatively affect fish recruitment. The number of juvenile gadoids was significantly reduced or not present in newly harvested areas and continued to be reduced for at least 1 year following harvest (Steneck et al., 2002; Sjøtun & Lorentsen, 2000). Also, a recent study in Norway found a significant reduction of small cod and an increase in wrasse two years after kelp harvesting (Bodvin et al., 2014a). Conversely, a number of other studies in Norway found no significant effects of kelp harvesting on fish or crab catches (Steen, 2010; Steen et al., 2013; Bodvin et al., 2014b; Steen et al., 2014; Steen et al., 2015). Such effects may however be disguised by large variations in the data sets, for example seasonal variations in fish and crab abundance (Bodvin et al., 2014b). Furthermore, no long term studies have been carried out and therefore the period for full recovery is not known. Although no direct evidence of this impact has been reported, the harvesting of kelp habitat would also remove the availability of food to higher trophic levels including seabirds (Steneck et al., 2002).

6.3.4. It is important to ensure that harvesting of climax seaweeds does not tip the community to alternative, less ecologically valuable climax communities or to opportunist communities (see **Section 3.3**). Part of the mechanism by which climax communities can maintain themselves is for the dominant species to be able to replace dying older plants with younger ones of the same species. In *Laminaria* forests this can occur because the young plants may be kept at a stage of arrested development in the shade cast by the canopy of the older plants (Wilkinson, 1995). Removal of the canopy, which could be due to natural death or due to harvesting, enables the younger plants to grow to replace the older ones. Advantage can be taken of such processes in designing harvesting strategies in order to preserve the resource.

6.4. Kelp harvesting methods

6.4.1. Mechanical cutting removes all kelps, irrespective of size (Vea & Ask, 2011). The removal of juvenile plants may allow opportunistic species to move into the habitat. These species can inhibit the regrowth of kelps (Scheibling & Gagnon, 2006) and may cause a decrease in species richness (Wells et al., 2007) ultimately resulting in long term habitat degradation.

6.4.2. There are a number of other ways in which the harvesting methods can be modified to maximise recovery rates and recruitment. A system of rotation of harvested areas was introduced in Norway to ensure that each area of kelp forest was harvested only once in 4 years to allow the kelp to regrow. It has since been recommended that this timescale be extended to 7-10 years to allow for the partial recovery of populations of non-kelp species (Birkett et al., 1998).

6.4.3. Recruitment success is also found to be enhanced if harvesting of kelps is carried out in patchy patterns, allowing for recruitment from the surrounding, non-harvested areas (Norderhaug et al., 2003; Waage-Nielsen et al., 2003). *L. hyperborea* spores, for example, can disperse over 200 m and therefore recruitment success reduces in harvested areas that span more than this distance (Frederiksen et al., 1995). Algal spores remain viable in the laboratory for 4 to 11 days (Hoffmann & Camus, 1989), which is sufficient to allow them to drift a considerable distance. In the sea, if not eaten, propagules may last even longer, as they are able to photosynthesise (Kain, 1964; McLachlan & Bidwell, 1978; Amsler & Neushul, 1991, Norton, 1992). Within the laboratory undeveloped gametophytes *of L. hyperborea, L. digitata, Saccharina latissima* and *Saccorhiza polyschides* have all been recorded as being able to survive in the dark for at least 80 days (Kain & Jones, 1969).

Red Seaweeds

6.4.4. Red seaweed species such as *Chondrus crispus* and *Mastocarpus stellatus* regenerate at the holdfasts, from the surface and edges of the severed fronds, and also by recolonisation of sporelings (The Minch Project website). Depending on the method of harvesting, recovery for these plants can be as rapid as 6 months for raking and 18 months for a closer crop (The Minch Project website). When cut by hand and the holdfasts left intact, the red seaweed *Porphyra* spp. has been recorded as having complete biomass recovery within 60 days. However, if the holdfast is removed, biomass recovery is very limited (The Minch Project website). Anecdotal evidence indicates that *Porphyra* spp. and *Palmaria palmata* have been completely harvested from certain areas by hand (Juliet Brodie, Natural History Museum, pers. comm.)

6.4.5. In addition, the timing of the harvest can affect reproduction and recoverability of seaweeds. For example, it was found in New Hampshire if *M. stellatus* was harvested in August and the holdfasts were not damaged, plant biomass could be re-established by the following July (The Minch Project website).

6.4.6. Therefore it is concluded that, although recovery times will vary between species, on the whole recovery of red seaweeds is generally quick, taking place within 18 months. In order to maximise recovery rate, the holdfast needs to be left. The holdfast provides an area for spores to settle and recolonise which will also increase recovery rates. In addition, the holdfast of red seaweeds provides a habitat and shelter for supporting species and so disturbance to the wider community would be minimised.

Maerl

6.4.7. Maerl is one of the world's slowest growing plants (Birkett et al., 1998). Studies have measured growth rates from tenths of millimetres to one millimetre per year (Adey & McKibbin, 1970; Bosence & Wilson, 2003). The life span of individual plants of *Lithothamnion glaciale* has been estimated as 10-50 years (Adey & McKibbin, 1970). Spores can potentially disperse long distances although distances would be extremely limited if vegetative propagation was the key dispersal mechanism (OSPAR, 2010).

6.4.8. Given the slow growth rates of maerl, individual plants and beds are slow to recover from damaging impacts. Their recovery potential has been characterised by OSPAR as 'poor' meaning that only partial recovery is likely within 10 years and full recovery may take up to 25 years (IMPACT, 1998). Maerl beds may never recover from severe damage such as bed removal, for example through dredging (OSPAR, 2010, Hiscock et al., 2005).

6.4.9. Steller et al. (2003) found that the morphology of the maerl strongly influences the diversity of the species present. Any damage or removal of the maerl thalli would alter the complexity of the surface matrix thus reducing the interstitial space and complexity, and in turn the maerl's ability to provide habitat and shelter to various species.

Seagrasses

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

6.5. Seagrass regeneration

6.5.1. Recovery time of seagrasses after disturbance varies with seagrass species (ABPmer, 2013). The slow recovery of *Zostera* populations since the 1920s to 30s outbreak of wasting disease suggests that, once lost, seagrass beds take considerable time to re-establish, if at all (Tillin et al., 2010). However, Phillips & Menez (1988) reported that displacement rhizomes and shoots can root and re-establish themselves if they settle on sediment long enough (cited in Huntington et al., 2006).

6.5.2. *Zostera noltii,* which is intertidal, can fill in gaps in seagrass meadows of 0.13 m^2 in 1 month (Han et al., 2012 and preceding references therein). Disturbance size, disturbance intensity, sediment characteristics and seasonal time of disturbance are also likely to be influencing factors. Seagrasses can recover via lateral rhizome spread or via sexual reproduction and seed dispersal depending on location and species. The dispersal range of seagrass seeds is a very poorly studied aspect of their reproductive ecology, and robust estimates of dispersal events are only available for *Z. marina* populations, for which 95% of the seeds are retained within 30 m from the source.

6.5.3. *Z. noltii* is able to recover relatively quickly compared to other seagrass species (D'Avack et al., 2015; Tyler-Walters & Wilding, 2008a). However, potential recruitment of *Z. noltii* may be hampered by competition with infauna such as the ragworm *Hediste diversicolor* or lugworm *Arenicola marina* (Philippart, 1994; Hughes et al., 2000; cited in Tyler-Walters and Wilding, 2008a). Hughes et al. (2000) noted that *H. diversicolor* consumed leaves and seeds of *Z. noltii* by pulling them into their burrow, therefore reducing the survival of seedlings.

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

6.5.5. Recoverability of *Z. marina* will depend on recruitment from other populations where extraction occurs on a large scale across an entire bed. Although *Z. marina* seed dispersal may occur over large distances, high seedling mortality and seed predation may significantly reduce effective recruitment. Holt et al. (1997) suggested that recovery would take between 5-10 years, but in many cases would be longer.

6.5.6. Reed & Hovel (2006) found that removal of 90% of the substrate (which included seagrass plant material both above and below ground) in large 16 m^2 plots resulted in a significant loss of diversity and abundance of the associated epifauna. However, in smaller plots, or with a lower level of substrate removal, there was no observed correlation between seagrass loss and reduction in density or diversity of epifaunal species.

6.6. Seagrass harvest methods

6.6.1. Recovery rates will also be influenced by the method of harvesting. Cutting leaves, either mechanically or by hand, will leave root and rhizome structures in place. Effects of cutting are therefore likely to be similar to those caused by grazing, whereby a seagrass bed would be expected to recover to pre-harvesting density within a year (Peterken and Conacher, 1997; Ganter, 2000).

6.6.2. Surface penetrating harvesting methods which disturb the below ground biomass of seagrasses, such as dredging, is likely to be more detrimental. Dredging can also have indirect detrimental effects by increasing suspended sediment (reducing light for photosynthesis) and elevating sedimentation (resulting in smothering). Such conditions may also lead to excessive growth of opportunistic epiphytic algal species potentially compromising the health and viability of seagrasses by overlying and smothering. Although seagrasses can potentially recover from this type of disturbance, recovery times are likely to be longer than those caused by cutting.

6.6.3. Seagrass beds may also be disturbed during harvesting activities that result in trampling of the substrate. These physical disturbances may lead to habitat loss and fragmentation (Reed and Hovel, 2006). A study on seagrass species in Puerto Rico found that changes to seagrass biomass as a result of trampling were inversely related to trampling intensity and duration (Eckrich and Holmquist, 2000). Substrate firmness was also found to modify trampling effects, with firmer substrates being less susceptible to damage than softer substrates.

6.7. The seagrass meadow habitat

6.7.1. Many species use seagrasses as nursery grounds and so the harvesting of seagrasses can have a negative effect on these species. However, a study by Heck et al. (2003) reports that it may not be the seagrass feature itself which is increasing survival and growth rate of juvenile species, but rather the structure of the habitat. Heck et al.

(2003) report that there was very little difference between growth on seagrass habitats and other structured habitats that provide shelter.

Beach-casts

6.7.2. Evidence indicates that the removal of beach-casts will reduce biodiversity of this strandline habitat (Lavery et al., 1999; Dugan et al., 2003; Gilburn, 2012) and also the complexity of the trophic food web (Orr, 2013). Their removal also has the potential to change macrofaunal community structure and the prey availability for vertebrate species such as shorebirds (Dugan et al., 2003).

6.7.3. In Western Australia, cleaning the beach caused an immediate reduction in the biomass of macrophyte detritus and densities of epifauna and fish. Biomass at the cleaned beach returned to levels found in areas which had not been cleared (control beaches) within two months and it was concluded that there was no long term effect on sediment organic matter, density or richness values of benthic infauna (Lavery et al., 1999). Notably, although biomass richness recovered rapidly, the assemblage of species present was different in the cleaned and control beaches.

6.7.4. A food web model predicted that harvesting (i.e. gathering) beach-cast kelps would also result in a proportional and immediate decline in primary consumers (Orr, 2013). The recovery time of the primary consumers was predicted to be 1-2 years independent of harvest intensity.

6.7.5. This food web model also predicted a decline in the numbers of shorebirds feeding on beach-cast kelps following gathering. The rate of recovery of shorebirds would be slow (2 to 60 years) and proportional to gathering intensity (Orr, 2013). Where more than 50% of the beach-cast material is removed, waders would reduce to less than 10% of their pre-harvest population and the recovery of these species increased from 13 years to 45 – 60 years (Orr, 2013). Similar results were reported for gulls. In order to allow shorebird populations to recover within a decade following the cessation of gathering, Orr (2013) suggests that no more than 30-40% of the beach-cast kelps should be gathered. Birds moving elsewhere as a result of the loss of beach-cast material would be regarded as a particular issue in designated areas or if protected birds species were being affected (SNH, pers. comm.).

Opportunistic and Non-Native Species

6.7.6. The removal of native seaweeds could provide opportunity for the establishment of non-native seaweeds which could pose a threat to native species (ABPmer, 2013). As non-native species are difficult to eradicate, their introduction may permanently change the character of a habitat (OSPAR, 2009; ABPmer, 2013), having implications for those species which rely on seaweeds to provide habitat, shelter and food.

6.7.7. A large proportion of the large-scale variations in algal cover between areas in Denmark was found to be due to differences in water clarity and salinity (Krause-Jensen et al., 2007). This study reported that brackish waters, in particular, were vulnerable to an increase in opportunistic species. Further, a study in Norway found that the principal factors responsible for the replacement of *Saccharina latissima* by opportunistic and ephemeral filamentous algae in Skagerrak were wave and light exposure (Bekkby & Moy, 2011). Therefore, areas most vulnerable to the introduction of non-native seaweeds are likely to be brackish and sheltered waters as any changes in environmental conditions would be most predominant in these locations.

7. Climatic Factors

7.1. Climate Change

7.1.1. Over the last 50 years, it has become increasingly apparent that the world's climate is changing at an unprecedented rate. Evidence of an increase in average global temperatures, along with an increase in the concentration of greenhouse gases (GHG) in the atmosphere, has led to the conclusion that human activities such as the use of carbon based-fuels is the main reason for this increase[25]. Three of the major GHGs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In 2011, concentrations of these GHGs exceeded pre-industrial atmospheric concentrations by approximately 40%, 150%, and 20% respectively (IPCC, 2013).

7.1.2. The effects of this climate change include temperature increases (both air and water), sea level rise, and increases in extreme weather events, such as storms and flooding. Climate change is now considered to be one of the most serious environmental threats to sustainable development, with adverse consequences expected for human health, food security, economic activity, natural resources and physical infrastructure[26]. Adaptation to the effects of climate change is now acknowledged as necessary for responding effectively and equitably to the impacts of climate change.

7.1.3. Since 1961, average temperatures in all parts of Scotland have risen for every season (Sniffer, 2006), and over the past three decades sea-surface temperatures around the UK coast have risen by an average of 0.7°C (UKCIP, 2011).

7.1.4. In the 20th century, average UK sea levels increased by around 1 mm/year (UKCIP, 2011). Sea level will continue to rise with average global temperatures. Predictions suggest that by 2095 relative sea level will have risen by 23 to 39 cm (UKCIP, 2010).

7.1.5. Combined with the expected increase in the occurrence of extreme weather events (such as storms and flooding) these effects have the potential to cause a major threat to marine and coastal environments as well as to the human activities that they support (Defra, 2012). Coastlines characterised by soft sediment are likely to be more vulnerable to these effects (**Figure 24)** and coastal defences are already in place in parts of Scotland (**Figure 25**).

7.1.6. In addition, the ocean has taken up approximately 30% of anthropogenic carbon dioxide emissions, which is altering ocean chemistry by increasing acidity. This is a concern for marine ecosystems, with calcareous organisms being most at risk, as more acidic water

[25] Scotland's Environment (undated) Climate change [online] Available at: http://www.environment.scotland.gov.uk/our_environment/air_and_climate/climate_change.aspx (accessed 04/09/2015)
[26] ICAO (undated) Climate change adaptation [online] Available at: http://www.icao.int/environmental-protection/Pages/adaptation.aspx (accessed 30/11/2015)

increases the rates of calcium carbonate dissolution (Scottish Government (2012).

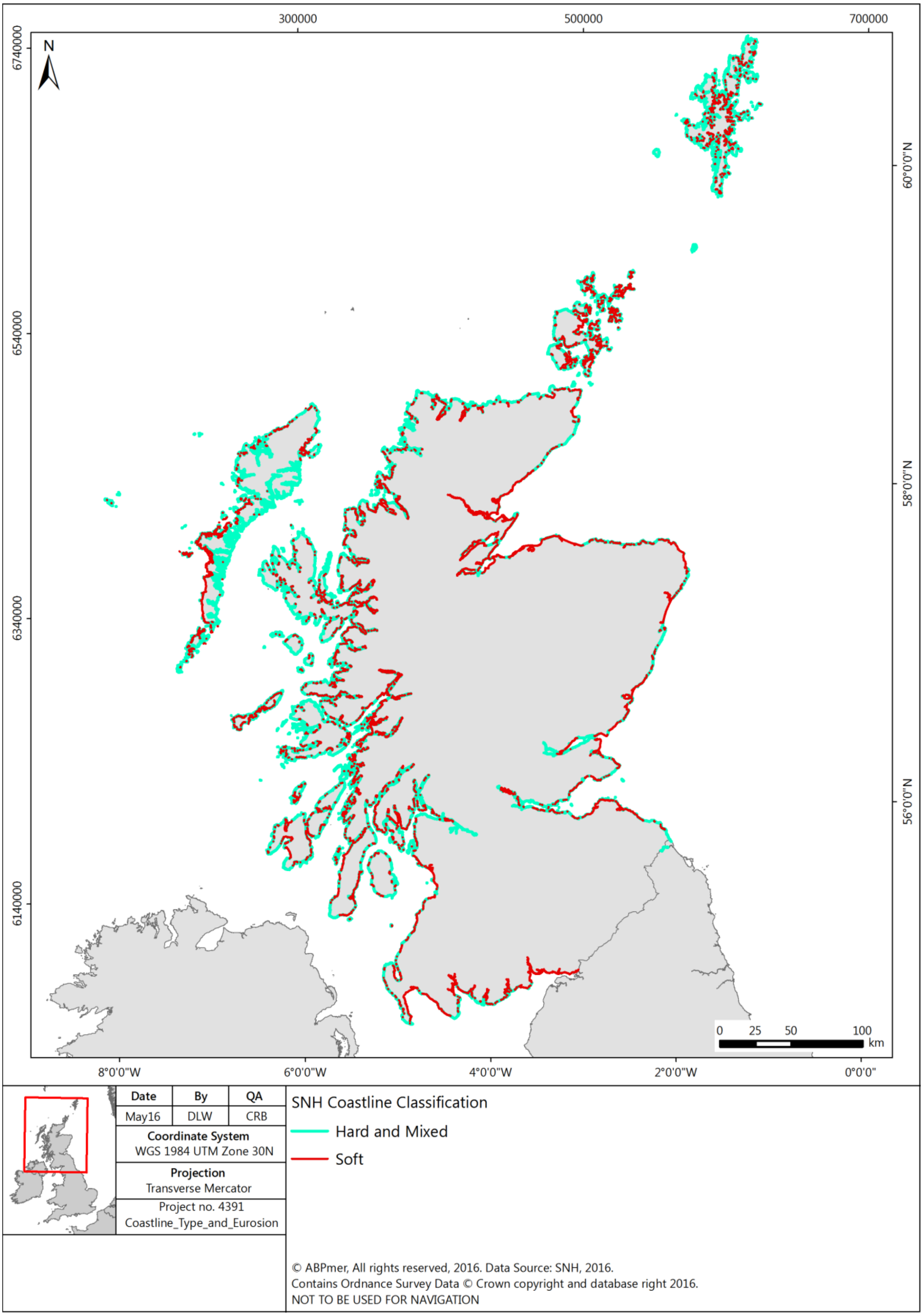


Figure 24: Classification of the Scottish coastline (hard/mixed or soft)

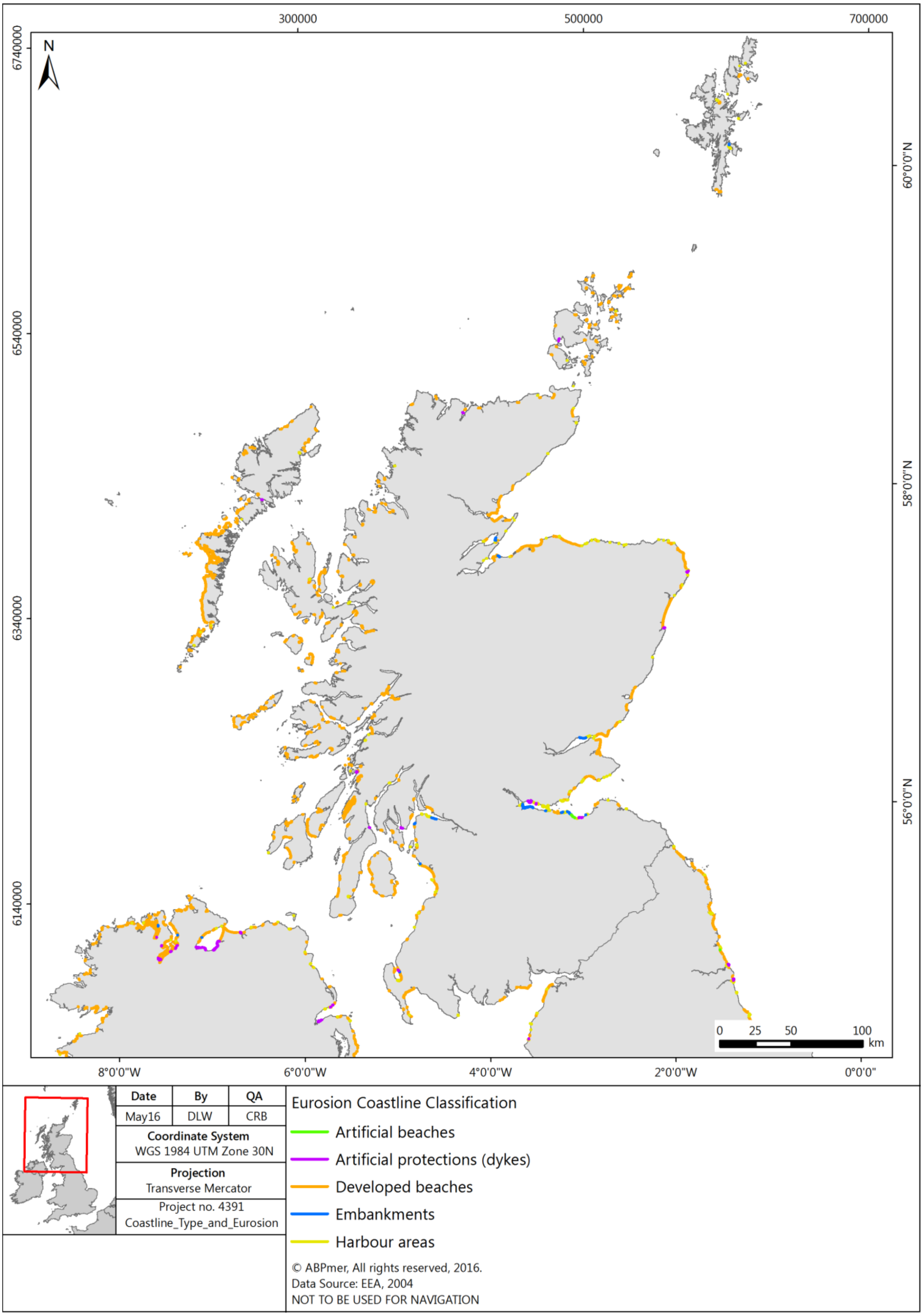


Figure 25: Location of coastal defences

7.2. Ecosystem Services

7.2.1. Seaweeds and seagrasses contribute to the following ecosystem services:

- Natural hazard protection – provision of a natural coastal defence through their wave dampening effect and in preventing and/or alleviating coastal erosion.
- Climate regulation –through their important role in the carbon cycle in terms of capturing, storing and exporting carbon.

Coastal Protection

7.2.2. Seaweeds, in particular kelp forests, and seagrasses are known for their capacity to attenuate waves and reduce current velocities (Fonseca & Cahalan, 1992; Mork, 1996; Bradley & Houser, 2009), which provides coastal protection. These species are able to provide such protection primarily due to their biogenic structures, as these protrude into the water column (Gambi et al., 1990; Bouma et al., 2005; Lowe et al., 2005; Luhar et al., 2010; Paul et al., 2012). The level of protection they provide varies seasonally, particularly during winter months, when they shed their blades or leaves or suffer storm damage and physical disturbance, which reduces the amount of biomass in the water column (Christianen et al., 2013).

7.2.3. Indirect coastal protection may be provided by beach-cast seaweeds that release nutrients to dune habitats, which in their turn stabilise local sediments and contribute to coastal protection (Orr, 2013). No scientific evidence has been found that suggests that drift deposits on beaches directly provide coastal protection. However, if present on a large enough scale, it is possible that they could dissipate wave energy, protecting sediments on a local scale from wave scour.

7.2.4. No evidence has been found to suggest that maerl habitats contribute significantly to coastal protection, apart from where they contribute to a large proportion of the sand in beaches (e.g. Coral Beach in Skye). Similarly, very little information regarding the coastal protection properties of seaweeds other than kelps has been found. The only exception to this is understorey macroalgae associated with kelp forests reducing current velocities (Eckman et al., 1989).

7.2.5. The following sections focus on the mechanisms by which kelps and seagrasses provide coastal protection.

Wave Dampening

7.2.6. *Laminaria hyperborea* forests are known to provide a buffer against storm surges through wave dampening and by reducing the velocity of breaking waves (Lovas & Torum, 2001). The extent of wave dampening is strongly influenced by the morphology, drag co-efficient, and density of the dominant kelp species; thus the magnitude of protection provided varies with species, and therefore may also vary with location (Gaylord et al., 2007). Smale et al. (2016) also found wave exposure to be an important factor in structuring *L. hyperborea* populations, with kelp density, biomass and age being greater in more exposed sites.

7.2.7. *L. hyperborea* forests off the coast of Norway have been found to reduce wave heights by as much as 60%, resulting in wave energy losses of 70-80% (Mork, 1996). It is expected that *L. hyperborea* forests around Scotland provide a similar level of protection that is likely to be locally important to coastal communities (Smale et al., 2013). The rocky seabed off the west coast of Uist supports a vast L. *hyperborea* forest which extends approximately 6-8 km offshore. Waverider buoys deployed off the western coast of the Outer Hebrides suggest that gross wave energy reduces from 58.1 to 14.9 kW/m between depths of 100 m and 15 m (Mollison, 1983). The greatest energy loss has been found to occur between 23 and 15 m depth where kelp beds are abundant (Mollison, 1983; Orr, 2013). Wave heights of over 11 m have been recorded 30 to 40 km offshore. When these same waves broke on the coast they had been reduced to around 1.5 - 2 m in height. The combination of shallow gradient and roughness created by the kelp forest is considered to greatly dissipate wave energy (Comhairle Nan Eilean Siar, 2013). The extreme damage caused by the 2005 storm in was attributed to the elevated sea state raising the wave base sufficiently to disengage from the protective effects of the kelp forest (Angus & Rennie 2014). Although this particular conclusion may be speculative, it is supported by the other evidence presented above that suggests kelps (specifically *L. hyperborea*) do play an important role in local coastal protection.

7.2.8. Seagrass beds are also effective at attenuating wave energy; however, small above-surface biomass means that the potential for direct attenuation is smaller than that of kelps. Despite this, the presence of the seagrass canopy helps to protect the sediment by deflecting water flow, reducing shear stress experienced by the bed and therefore erosion (Le Hir et al., 2007). Seagrasses are also effective at reducing current velocities, an ability that is a function of leaf density (Gambi et al., 1990; van Keulen & Borowitzka, 2002; Koch & Gust, 1999; Jackson et al., 2012). Dense seagrass beds are capable of reducing current speeds up to ten times more than unvegetated areas (Jackson et al., 2012). Evidence suggests that the deposition and accumulation of sediment within the bed can ultimately lead to a reduction in water depth, increasing the wave attenuation potential of the local area (Madsen et al., 2001; Bos et al., 2007; Houser & Hill, 2010). However, such effects may be ephemeral, with sediment release occurring in winter (Bos et al., 2007). Several studies have provided evidence to suggest that sediment accumulation and subsequent bathymetric changes do not occur in all seagrass beds. This process appears to be reliant upon the physical conditions of the location as well as the seagrass species present (Mellors et al., 2002; van Katwijk et al., 2010).

Flow Reduction

7.2.9. Kelp habitats are also able to attenuate current flow, an effect which can range from the seabed up to twice the height of the kelp (Lovas &

Torum, 2001). As with wave dampening, this ability is also a function of the morphology of the kelp canopy, but also relies upon density and the underlying assemblage of other red, green and brown seaweeds (Gaylord et al., 2007; Eckman et al., 1989). These underlying species help to further reduce flow in close proximity to the seabed, allowing for the deposition of sediment and larvae (Gaylord et al., 2007).

7.2.10. The reduction in flow speeds and the subsequent deposition of sediment tends to be a more important component of coastal protection in habitats where flora possess a relatively small above-ground biomass. This applies to seagrass beds composed of relatively short and highly flexible leaves that possess a smaller potential for direct wave-attenuation compared to stiffer, larger vegetation such as kelps (Bouma et al., 2005; Christianen et al., 2013).

7.2.11. A reduction in the blade density of seagrass habitats would have a knock-on effect on coastal protection by redistributing accumulated sediment, increasing water depth and subsequently reducing wave attenuation. Historical anecdotal evidence from the Isles of Scilly exists suggesting that dieback of seagrasses resulted in large fractions of mud being transported to the adjacent area (Jackson et al., 2012).

7.2.12. The predicted effects of climate change may place greater importance on the coastal protection ecosystem services provided by seaweed and seagrass communities, particularly in relation to wave dissipation and the protection of coastal areas from erosion. Predicted increases in sea level, increased frequency and magnitude of storm events and larger waves have the potential to significantly alter the coastline shape and the depth of near-shore areas, which could have associated impacts on the distribution and abundance of seaweeds and seagrasses in these areas (Hoegh-Guldberg et al., 2007). These features are at particular risk of being lost from more exposed locations.

7.2.13. Relative sea level rise over recent decades has been recorded as almost 6 mm per year in the Outer Hebrides (Rennie & Hansom, 2011). The soft sandy low-lying coasts of the Uists and Barra are particularly vulnerable and erosion may be expected to accelerate over coming years. As the wave base rises above the seabed and kelps in line with relative sea level rise, larger waves and therefore more energy will reach the shore than over past years thereby increasing vulnerability of the coast to flooding and in turn erosion.

Shoreline Stabilisation

7.2.14. In addition to hydrodynamic dampening, seaweeds and seagrasses are also able to contribute to coastal protection through shoreline stabilisation (Fonseca & Cahalan, 1992). Although shoreline stabilisation does not alter energy inputs, it allows the shoreline to be more robust and resilient to received wave energy, by binding sediments and reducing the amount of resuspension. Seagrasses possess roots and rhizomes that extend beneath the sediment surface. These structures can form dense mats that have an anchoring effect, stabilising sediments and increasing the critical bed shear stress required for bed erosion (Le Hir et al., 2007). Recent experimental evidence demonstrated that short, grazed seagrass beds with low above-surface biomass can still be effective at providing sediment stabilisation (Christianen et al., 2013). Seasonal changes in above-surface biomass resulting from the shedding of leaves or degradation due to high turbidity therefore do not mean that seagrass beds have lost their coastal protection value. Thus, seemingly insignificant low-biomass seagrass meadows may still offer significant coastal protection services, and should be valued as such (Christianen et al., 2013).

Formation of Dunes

7.2.15. The formation of dunes and the protection of the coastal zone from erosion is possibly one of the most important services supplied by beach-cast seaweed in the Uists, which is considered to be threatened by accelerated sea level rise (Angus, 2012) and the loss to human lives and property associated with an increase in flooding and storm surge (Orr, 2013). Beach-cast seaweed provides nutrients to dune plants, and promotes their growth, reproduction and survival, and thereby reduces the windblown transport of sand. This facilitates the retention of sediment and dune formation, thus buffering the coast against risks of erosion from flooding (Dugan & Hubbard, 2010; Orr, 2013).

7.3. Enhanced Ecosystem Resilience

7.3.1. Beaches which accumulate seaweed function as an interface for the processing and exchange of organic matter with other environments, rather than existing as enclosed ecosystems. Accumulations of beach-cast seaweed also increase the resilience of sandy beach food webs to perturbations, mainly through diversifying food resources available to higher trophic level fauna (Orr, 2013). Such perturbations may include erosion of sediments during and after storms.

7.4. Climate Regulation – Carbon Cycling, Storage and Sequestration

7.4.1. The term “carbon cycle” includes the exchange of carbon between the ocean and the atmosphere and has both a physical and biological component. The physical component is ultimately affected by the chemistry of seawater and is highly influenced by uptake of carbon dioxide by the oceans. The fixation of carbon by autotrophic (photosynthetic) organisms living within the oceans and its subsequent respiration forms the basis of the biological carbon cycle.

7.4.2. The proportion of carbon incorporated into biomass is said to be ‘stored’; thus coastal ecosystems such as kelp forests, maerl beds and seagrass beds are able to store carbon. The stored carbon is removed from the environment; however, respiratory processes following predation, physical disturbance or mortality of the seaweeds/seagrasses release the stored carbon back into the environment. Should carbon sequestration processes be in place on a large enough scale, seaweed and seagrass ecosystems possess the potential to have important climate implications and are termed ‘Blue Carbon Sinks’ (Nellemann et al., 2009). Their effectiveness as a carbon sink is highly dependent upon their long term capacity to store carbon.

Kelp

7.4.3. The most recent estimates of kelp cover (defined as areas where kelps exceed 20% total cover of the habitat) suggest that this comprises 2,155 km^2 of the seabed around the coast of Scotland (Burrows et al., 2014a). The average standing stock of kelps in Scotland has been estimated at two different values, 94 g C/m^2 (Walker and Richardson, 1955) and 187 g C/m^2 (Kain, 1979). Burrows et al. (2014b) suggests that the value provided by Walker and Richardson (1955) is lower than Kain (1979) because it is based on estimates of standing crop at the shallowest depths rather than the entire depth range. Using a cover value of 2,155 km^2, total estimates of kelp standing stock around Scotland are 202,000 t and 404,000 t C respectively which corresponds to fresh weight equivalents of 4.5 and 9.0 Mt (Burrows, et al., 2014b). Using averaged production rates (685 g $C/m^2/yr$), the estimated total production of Scottish kelps is 1,732,000 t C/yr. These values must be treated with caution due to the variability of production estimation methods, differing habitat- and depth-specific rates, varying biomass and the availability of light, nutrients and temperature. Furthermore, Smale et al. (2016) found that the range and maximal values of estimated standing stock of carbon contained within kelp forests may be greater than in historical studies, suggesting that this ecosystem property may have previously been undervalued. Despite these considerations, the estimated total production value gives a clear indication that kelps in Scottish waters represent a significant store of carbon (Smale et al., 2013). This comprises approximately 2% of the global kelp standing stock of carbon that was estimated by Laffoley & Grimsditch (2009).

7.4.4. While a small proportion of kelp-derived material is directly consumed by grazers and therefore transferred to higher trophic levels in situ (Sjøtun et al., 2006, Norderhaug & Christie, 2009), the vast majority of kelp-derived matter (>80%) is exported as detritus or dissolved organic matter into adjacent habitats (Krumhansl & Scheibling, 2012). These exports form an important food source for coastal food webs (see Section 4.3), but may also be incorporated into adjacent coastal sediments (Burrows et al., 2014b). As the majority of kelp beds grow on rocky substrates where burial is not possible, they do not possess the ability to directly sequester carbon. The only pathway available for kelp habitats to sequester carbon is by acting as carbon donors to other habitats capable of long term storage (Hill et al., 2015). Although significant amounts of carbon are exported out of kelp habitats, little evidence exists to quantify the rate of short or long term incorporation of kelp detritus into coastal sediments. Consequently, kelp beds are considered to have very little ability to sequester carbon.

Seagrass

7.4.5. Although the exact extent of seagrass beds (*Zostera* spp) is currently unknown, it is estimated that seagrass habitat covers an area of approximately 15.9 km^2 (Burrows et al., 2014b). Production rates of seagrass beds are generally high but vary between species. Annual primary productivity of *Zostera marina* can range from 69 to 814 g C/m^2 (Borum & Wium-Andersen, 1980; Wium-Andersen & Borum, 1984. In contrast, Mediterranean species such as Posidonia oceanica can fix 550-1000 g C/m^2/yr, a value comparable to kelp habitats (Borum & Wium-Andersen, 1980).

7.4.6. The ability of seagrasses to slow current flows provides the potential to trap both seagrass detritus and detritus of allochthonous origin (terrestrial and planktonic) (Kennedy et al., 2010). Thus seagrass beds have the potential to act as carbon receivers, potentially storing carbon from external ecosystems as well as their own. An average net sequestration rate for seagrass beds has been estimated at 83 g C/m^2/yr (Laffoley & Grimsditch, 2009). Combining this average with the estimated extent of seagrass beds in Scottish waters gives a national sequestration capacity of 1321 t C/yr (Burrows et al., 2014b).

7.4.7. However, this estimate must be treated with caution as the average net sequestration rate of 83 g C/m^2/yr is based on beds populated by *Cymodocea nodosa* and *Posidonia oceanica*, whereas seagrass species in Scotland comprise *Zostera marina*, *Z. noltii*, and *Ruppia maritima*. There is little knowledge of the carbon burial rates within beds made up of these species, thus the role of Scottish seagrass beds as carbon sequesters is mostly unknown (Jackson et al., 2012). One of the few pieces of research into the sequestration rates of *Zostera* spp. indicated that a Spanish *Z. marina* bed sequestered carbon at a rate of 0.52 g C/ha/yr (Cebrián et al., 1997)[27].This value is undoubtedly variable on a temporal and spatial scale due to changes in the physical environment (such as differing rates of accretion) and vegetative traits of the seagrasses (Jackson et al., 2012; Kennedy et al., 2010). However rates of this scale are so small they are negligible, therefore there is the potential that Scottish seagrass beds are not able to significantly sequester carbon.

Maerl

7.4.8. Much like seagrasses, given the correct environmental conditions, maerl can form extensive beds. Unlike other seaweed, the calcium carbonate skeleton of maerl does not break down quickly. Consequently maerl beds in Scottish waters represent a continuous standing stock of organic and inorganic carbon that has likely been accreted since the Holocene deglaciation period (Burrows et al., 2014b).

7.4.9. Primary productivity of maerl can reach 407 g C/m^2/yr which is then trapped in the skeleton, resulting in maerl beds representing a long term carbon store irrespective of whether the algae within the skeleton is living (Burrows et al., 2014b). Relative to seagrasses and kelps, growth rates of maerl are slow at approximately 0.25 mm/yr. Despite this, beds can be extensive and deep, resulting in accretion rates varying from 420 to 1,432 g $CaCO_3$/m^2/yr depending upon species composition of the bed (Freiwald & Henrich, 1994). Based on these values, Burrows et al.

[27] 1 hectare (ha) is 10,000 m^2 : in comparable units this rate is equivalent to 0.000052 g C/m^2/yr

(2014b) estimate that 440,561 tC are locked within maerl deposits in Scottish waters. Again this is expected to be an underestimate due to the volume of dead maerl in other sediments not identified as maerl beds and the likely presence of a number of undiscovered beds. While their slow growth rates provide a small annual sequestration capacity, their longevity (centuries) means that sequestered carbon is locked away at geological timescales.

Effects of Climate Change on Seaweeds and Seagrasses

7.4.10. Climate change has the potential to affect the carbon sequestration capacity of kelp, seagrass and maerl habitats. The effects of climate change are not well understood, but are mostly predicted to be detrimental. Kelps and seagrasses are likely to be vulnerable to the increases in the occurrence of severe storms which may cause physical damage to and reduce carbon stored in the standing stock. For seagrasses, reduction in canopy density resulting from physical damage may also decrease the habitat's ability to trap sediment and deflect wave energy away from the bed. Sediments storing carbon are therefore likely to be more vulnerable to wave scour and subsequent re-suspension in severe storms. Such storm events are also likely to increase the turbidity of the water, through increased sediment input, which could detrimentally affect growth rates and therefore the carbon sequestration capacity of kelp, seagrass and maerl beds.

7.4.11. Shelf seas around the UK are predicted to be 1.5 to 4°C warmer by the end of the 21st Century (UK Climate Projections, 2009). The direct effect of temperature increase on kelp, seagrass and maerl communities is likely to vary between each species. However, species present in Scotland are temperate and generally become stressed by high temperatures. Consequently, increased water temperatures are likely to reduce growth rates (Steneck et al., 2002; Short & Neckles, 1999; Hiscock et al., 2004). Such an effect may be offset in kelp and seagrass species that are able to utilize increased CO_2 concentrations associated with ocean acidification (Koch et al., 2013). In contrast, ocean acidification will make it more difficult for maerl to deposit calcium carbonate and increase the dissolution rate of deposits. Ocean acidification therefore has the potential to slow the sequestration of carbon in maerl beds and release some of the carbon laid down by these deposits, including those incorporated in sediments not classed as maerl beds.

7.4.12. The exact effects of climate change are unclear; however, Connell & Russell (2010) suggest that turf-forming algae may become more competitive than large macroalgae under the effect of elevated CO_2. This successional change from larger to smaller plants might see a reduction in the potential carbon sequestration offered by seaweeds around Scotland.

7.5. Environmental Effects of Harvesting

Natural Hazard Protection - Coastal Protection

Kelps

7.5.1. Harvesting live kelps will reduce their density and height, attributes which are crucial to the coastal defence capabilities of this habitat. Dune erosion along the Norwegian coast, for example, has been attributed to the extraction of kelps (Løvas & Tørum, 2001). Density of the kelp canopy has been positively linked with the ecosystem's ability to attenuate wave and current velocities (see **Section 4.4**). Other research has highlighted the importance of water level in coastal erosion and the likelihood of marine flooding (Angus & Rennie, 2014; Løvas & Tørum, 2001), suggesting that raising water levels disengages the wave base from the protective effects of the kelps, increasing the energy reaching the shoreline, and therefore increasing coastal erosion. Using this information, it can be inferred that reducing the height of the kelp canopy through harvesting is likely to affect the habitat's ability to attenuate wave energy and therefore provide coastal protection on a local scale.

7.5.2. The effects of seaweed harvesting have been found to result in changes that are comparable to those caused by natural disturbance (e.g. storms), as both remove either a proportion or all of the targeted species (Foster and Barilotti, 1990). Such removal provides space for other species to colonise the harvested area. As the potential to offer coastal protection is closely linked with the morphological traits of seaweed species, the successional species moving into the area post-harvest may not offer the same level of protection as the original species.

7.5.3. The extent to which a reduction in kelp density, height, and/or the level of succession will affect coastal protection is likely to depend upon the intensity and method of harvesting. Modern trawling/dredging is used as a sustainable harvesting practice for kelps in Norway. The Norwegian kelp dredge involves removing the entire mature adult plant (including the holdfast) but leaves small immature plants less than 20 cm length. Mechanical cutting of kelps is less widely used, having been phased out in the late 60s (Vea & Ask, 2011). This method involved the removal of kelps irrespective of size and is therefore deemed to be a less sustainable method of harvesting that would have a larger impact upon coastal defences as recovery times are far longer. Hand harvesting of live kelps is assumed to have a negligible effect on coastal protection as its potential scale and magnitude is likely to be much less than dredging and cutting practices.

Beach-casts

7.5.4. Drift kelp deposits on beaches are unlikely to provide significant direct coastal protection, however it is an important source of nutrients to dune plants that stabilise coastal sediments (see **Section 4.4**). The removal of drift kelps may therefore have an indirect effect upon coastal protection by having a negative effect on the growth of coastal plants and therefore on dune formation (Dugan & Hubbard, 2010).

7.5.5. Overall, based on the evidence it is possible that harvesting living or beach-cast kelps in areas where the inshore coastline is soft (e.g. beaches) could increase their potential for coastal erosion. Areas that are particularly vulnerable are the beaches on the west coast of the Outer Hebrides, Tiree, Orkney, Shetland and the west coast of the Scottish mainland (**Figures 21** and **22**). Conversely, areas of the coastline that are already protected by coastal defences or comprise hard rocky substrate are unlikely to be affected by a reduction in coastal protection associated with wild harvesting (**Figures 21 and 22**).

Other Groups of Seaweed

7.5.6. The potential coastal protection offered by other seaweeds (namely wracks, red seaweeds and green seaweeds) is generally limited to their contribution to beach-cast seaweed and where they comprise understorey macroalgae associated with kelp beds (**Section 4.4**). Although no evidence of this was found in the literature, living intertidal seaweeds are also likely to absorb and reduce wave energy. However, given that they are primarily found on exposed rocky shores they are unlikely to contribute significantly to coastal protection.

Seagrasses

7.5.7. Were commercial harvesting to take place, this assessment assumes that the effects would be similar to those caused by better documented pressures such as shellfish trawling and grazing. Grazing is used as a proxy for harvesting using cutting methods (both hand and mechanical cutting), while shellfish trawling is used as a proxy for harvesting by trawling/ sledging/ dredging.

7.5.8. The extent to which harvesting will affect coastal protection provided by seagrasses is likely to depend upon the harvesting method used. Harvesting seagrasses through cutting the leaves from live plants is likely to result in similar effects to those caused by grazing (Christianen et al., 2013) as below ground biomass is left in place while above ground biomass can be significantly reduced (Vonk et al., 2010). Although these beds are likely to have lost some of their ability to attenuate and deflect wave energy directly, the below ground biomass of grazed seagrass beds is still likely to provide coastal protection through sediment stabilisation (see **Section 4.4**). Thus, although more wave energy is able to propagate to the seabed relative to a dense seagrass bed, the anchoring effect of the below ground biomass would still help protect against wave scour.

7.5.9. Trawling is a more destructive practice, with a single pass capable of removing 65% of seagrass biomass (Peterson et al., 1987). As dredges penetrate the sediment surface above and below ground biomass is removed. This removes the sediment stability afforded by roots and rhizomes, ultimately making the local sediments more vulnerable to wave scour and subsequent erosion. This would lead to increases in suspended sediment concentrations and a lowering of the seabed, reducing the wave attenuating potential of the local area, increase energy propagating to the coast and therefore increasing the potential for coastal erosion.

7.5.10. Seagrass beds may also be disturbed by trampling during harvesting activities which could lead to habitat loss/fragmentation (Reed and Hovel, 2006) and in turn result in an increase in the potential for coastal erosion. The level of disturbance (and in turn coastal erosion) is related to the intensity and duration of trampling, as well as the firmness of the substrate, with firmer substrates being less susceptible to damage compared to softer substrates (Eckrich and Holmquist, 2000).

7.5.11. Regrowth rates of grazed seagrasses (*Zostera* spp.) tend to be fast, with even intensively grazed beds returning to a pre-grazed state within a year (Peterken & Conacher, 1997; Ganter, 2000). This relatively fast recovery rate is likely to be a result of regrowth from the unaffected below ground biomass. The duration of effect from the cutting of seagrasses is therefore likely to be in the order of one year. The more destructive effects of trawling have been found to result in longer recovery times that range from two years (Preen et al., 1995) to no recovery occurring at all (Giesen et al., 1990). The recovery of seagrass, as well as adjacent seagrass not directly affected by dredging, is likely to be hindered by the increased levels of turbidity associated with the dredging activity. The scale of harvesting that would maintain adequate levels of coastal defence are currently unknown, however cutting appears to be the least detrimental harvesting option.

7.5.12. It is unlikely that the amount of seagrass detritus washed up on beaches has a significant effect on coastal protection. It is therefore not considered in this assessment.

7.6. Climate Regulation - Carbon Cycling, Storage and Sequestration

Kelps

7.6.1. The accumulation of detritus within kelp habitats is very small. Kelp-derived matter is respired, consumed or exported to adjacent habitats. Consequently, kelp habitats are not effective in acting as long term carbon stores. The majority of carbon stored within kelp habitats is contained within the living kelps and is therefore a function of the standing stock (Laffoley & Grimsditch, 2009). Harvesting wild kelps will remove some of the standing stock, reducing the amount of stored carbon in kelp beds throughout Scotland.

7.6.2. The large biomass turnover of kelp habitats results in large amounts of kelp-derived detritus being produced. Approximately 80% of this detritus is exported to adjacent habitats (Krumhansl & Scheibling, 2012; Burrows et al., 2014b). If the correct processes are in place, kelp habitats are able to donate significant amounts of carbon to adjacent carbon stores (Hill et al., 2015), however the proportion of exported material incorporated into carbon stores is unknown but likely to be small (Burrows et al., 2014b). Furthermore, a proportion of the carbon stored in this kelp detritus is released back into the atmosphere through bacterial breakdown. Reducing standing stocks of kelps through wild harvesting is likely to reduce the amount of detritus produced and subsequently exported and stored in adjacent habitats.

7.6.3. The magnitude of the harvesting effect is likely to depend upon the scale and type of harvesting undertaken, as well as the recovery rate of kelps. Kelps harvested by trawling/dredging/sledging leaves small kelps in situ, thus the habitat is able to return to pre-harvest size and density within a few years of the disturbance if harvesting levels are sustainable (Christie et al., 1998). As a result, any reduction in carbon storage is only likely to last a few years if appropriate management is in place. Harvesting via hedge cutting removes all kelps irrespective of size and is therefore more likely to be less sustainable. Effects may therefore be similar to those caused by overgrazing (Mann, 1977) and are likely to result in longer recovery times relative to those of habitats where juvenile kelps have been left intact. The collection of beach-cast seaweeds and seagrasses could potentially result in a reduction in the release of stored carbon back into the atmosphere through a reduction in microbial decomposition.

Maerl

7.6.4. The calcium carbonate skeletons produced by maerl form long lasting carbon deposits, and although the production rates are small relative to seagrasses and kelps, the extensive and deep beds form a significant carbon sink in Scottish waters (see **Section 4.4**). Harvesting practices are likely to impact upon the amount of live maerl, directly (as a result of removal) and indirectly, because of reduced survival resulting from increased levels of suspended sediment and physical disturbance (Burrows et al., 2014b). This may not greatly affect the overall carbon standing stock held in maerl deposits, but is likely to reduce the potential for future carbon sequestration, slowing the growth of the carbon reservoir (Burrows et al., 2014b). The magnitude of effect would therefore be dependent on the scale of commercial harvest and the ratio of live:dead material extracted.

Other Groups of Seaweed

7.6.5. There is no evidence that other seaweeds (namely wracks, red seaweeds and green seaweeds) are significant carbon stores and potential sinks of carbon. The impacts of harvesting these other types of seaweed on the carbon cycle, storage capacity and sequestration rates are therefore unknown but unlikely to be significant.

Seagrasses

7.6.6. The extent of any reduction in carbon storage potential due to harvesting is likely to be a function of the harvesting method. Cutting live seagrasses is likely to have an effect similar to grazing, decreasing the density of above surface biomass and therefore reducing the ability of the bed to slow current flow and trap sediment. The reduction in density of above surface biomass is also likely to increase the exposure of the bed to wave scour. However, this method leaves the stabilizing roots and rhizomes in place. Grazed seagrass beds may recover to a pre-grazed state within a year (Peterken & Conacher, 1997; Ganter, 2000), hence the effect of cutting on the ability of seagrasses to act as a carbon sink is minimal. Dredging is likely to have a more detrimental, long-lasting impact on carbon sequestration. Recovery times from this disturbance tend to be longer (see **section above on Natural Hazard Regulation - Coastal Protection**) and the removal of below ground biomass make sediments more susceptible to erosion, ultimately resulting in previously stored carbon being reintroduced into the marine environment.

8. Cultural Heritage

8.1. Introduction

8.1.1. Throughout human history the coastal environment around Scotland has provided food, defence and a means for trade and communication. As a result, a wide range of archaeological features are located along the coast and in the marine environment. These include the remains of ships and aircraft lost at sea, harbours, lighthouses and other structures relating to transport and trade by sea and the remains of human settlement. Due to sea level rise, previously terrestrial sites may now be located in the marine environment. This is particularly noticeable on the coasts of the Orkney and Shetland where numerous Neolithic and Mesolithic structures are now below sea level (Historic Scotland, n.d. a).

8.1.2. While many heritage features lie wholly within the marine environment, numerous features are also located in coastal areas. It is believed that there as many as 38,000 historic and unprotected sites of interest in marine and coastal environments around Scotland (Scottish Government, 2011). Managed and accessible coastal or marine heritage sites are much fewer in number, with 97 currently existing in Scotland. These include World Heritage Sites (St Kilda and Heart of Neolithic Orkney), coastal properties in care of Historic Environment Scotland, maritime and coastal heritage museums, and designated wreck sites (Scottish Government, 2011). Protected wrecks (protected places and controlled sites) under the Protection of Military Remains Act 1986 (Designation of Vessels and Controlled Sites) Order 2012 are shown in **Figure 26**.

8.1.3. Historic Environment Scotland (HES) is directly responsible for safeguarding the Scottish historic environment, including marine and coastal features. One mechanism whereby HES can provide protection to marine archaeological sites is through the designation of Historic Marine Protected Areas (HMPA). These areas are designated under the Marine (Scotland) Act 2010 for the purpose of preserving marine historic assets of national importance, including but not limited to significant historic shipwrecks, remains relating to important fleet anchorages, battle sites or navigational hazards (where multiple wrecks and other features exist) and submerged prehistoric landscapes (if structural or artefact-based evidence is identified on the seabed). Currently there are seven designated HMPAs around Scotland (**Figure 27**). These are (Historic Scotland, n.d. b):

- Drumbeg (Sutherland, Highland);
- Mingary (Ardnamurchan, Highland);
- Kinlochbervie (Sutherland, Highland);
- Campania (Firth of Forth, Fife);
- Out Skerries (Shetland);
- Dartmouth (Morvern, Highland); and
- Duart Point (Mull, Argyll and Bute)

8.1.4. There is also one proposed HMPA, Iona, located in the Clyde (Figure 27).

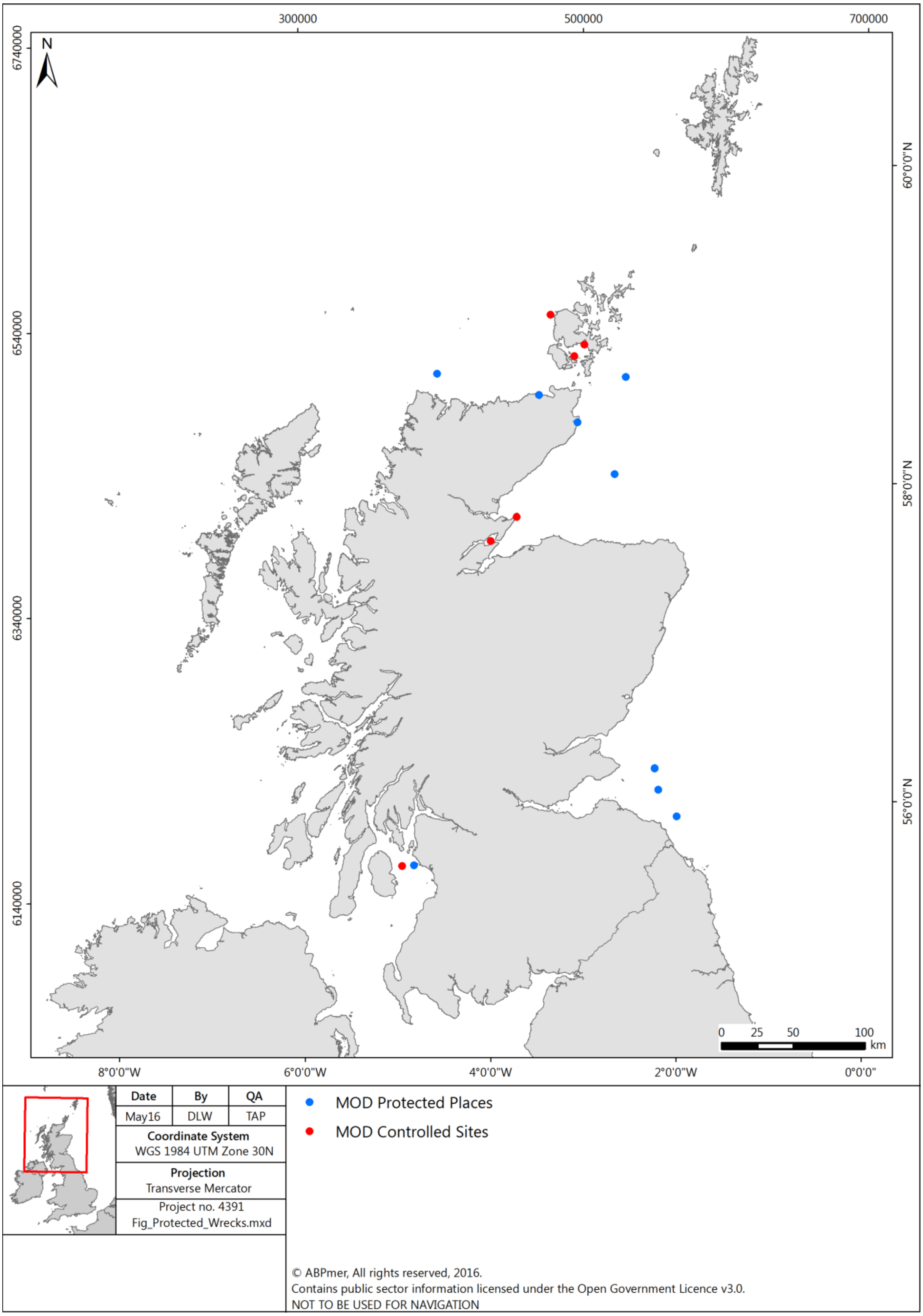


Figure 26: Location of protected wrecks in Scotland

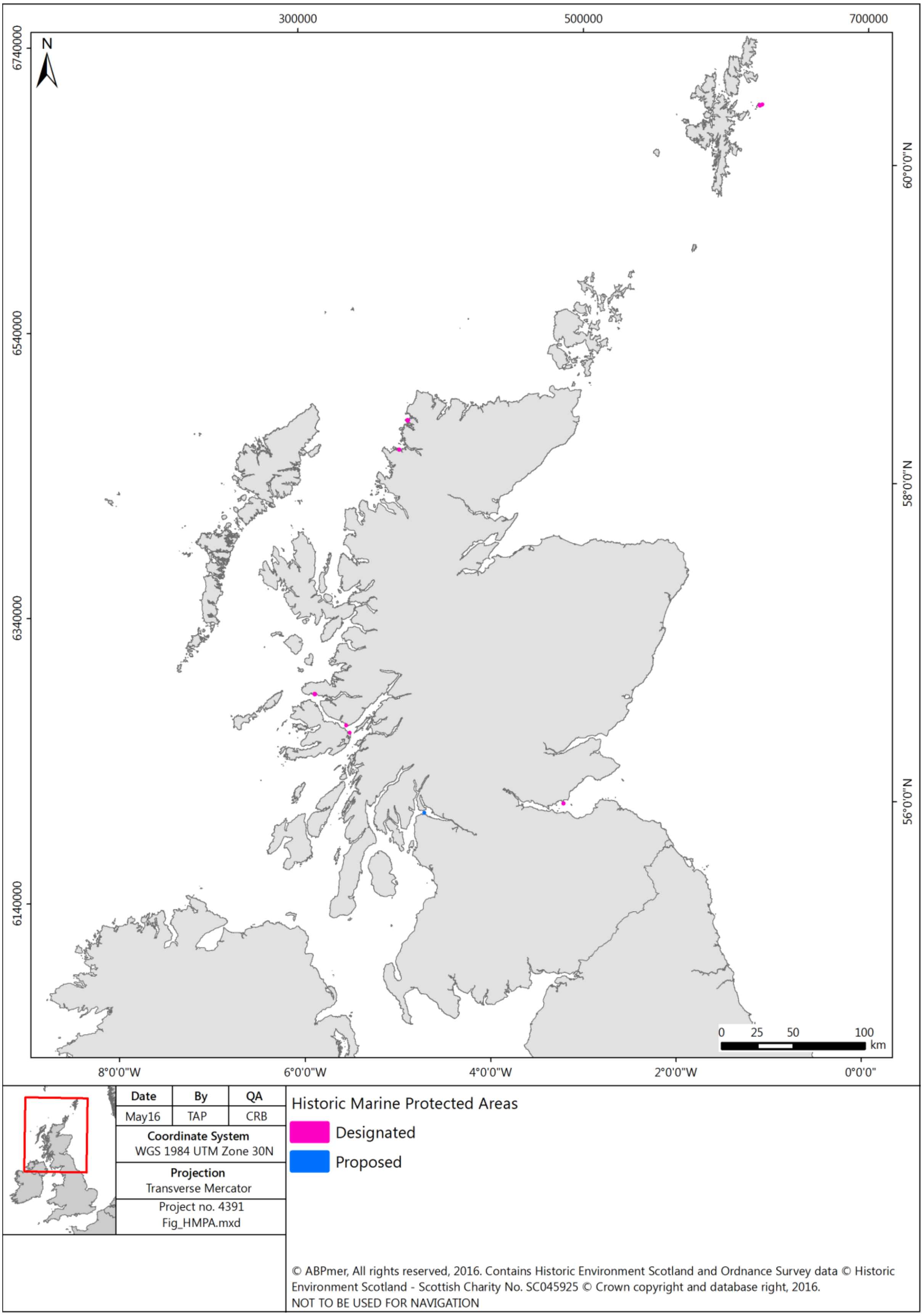


Figure 27: Location of designated and proposed HMPA

8.1.5. Other forms of statutory designation protecting cultural heritage sites around the coast of Scotland are afforded to listed buildings, scheduled monuments and war graves through the Historic Environment Scotland Act 2014 and the Protection of Military Remains Act 1986 (Historic Scotland, n.d. c).

8.1.6. In addition to designated heritage assets, there are many undesignated/uncertain/unknown assets. There is a significant data gap associated with these, particularly in relation to underwater heritage assets.

8.1.7. The protection afforded to designated coastal and marine archaeological sites tends to prevent direct human disturbance. However, the environment can also pose a serious threat to the conservation of these sites and undesignated/uncertain/unknown assets. Coastal erosion is a major issue for archaeological sites in many areas around Scotland (Historic Scotland, n.d. d). Sea level rise and the increased frequency of storm events associated with climate change are likely to worsen the situation; endangering coastal and marine archaeological sites (see Section 4.4).

8.1.8. In addition to archaeological features, the cultural tradition of crofting has been carried out for hundreds of years in Scotland (SNH, 2012). Crofters play a key role in maintaining the machair[28] and other wildlife through traditional practices. These include using natural fertilizers such as seaweed, namely kelp (*Laminaria* sp.). Large quantities are washed up by the winter storms and collected fresh from the beach when the winds and tides allow (RSPB Machair LIFE+, 2014a). Seaweed is then left in piles for several weeks to decompose which concentrates the nutrients and reduces its volume for spreading. Rotten seaweed is spread on the machair during late winter/early spring before it is cultivated. Seaweed helps to bind the sandy soils and its use allows for a wide range of arable and fallow wildflowers to grow because they are not engulfed by more vigorous plants boosted by artificial fertiliser.

8.1.9. The use of these natural fertilisers adds bulk, improves fragile soils and increases productivity. The Crofters (Scotland) Act 1993 (as amended) gives crofters access to reasonable use of seaweed under Common Grazings regulations. This is largely confined to the gathering of beach-cast *Laminaria* spp. and other mixed species for spreading on machair land in the Western Isles (SNH, 2012). Little information is available about the extent or size of such gathering from beaches (The Scottish Government, 2013). However, the extent of spreading on the machair has been estimated between 2011 and 2013 to be a total of 317ha in the Uists and Berneray in the Western Isles (RSBP Machair LIFE+, 2014b).

8.1.10. It is worth noting also that there is an ancient breed of sheep in North Ronaldsay (Orkney) that played a key role in the cultural development of North Ronaldsay in the 1800s. This breed of sheep is confined to the seashore by the drystone dyke encircling the island, and

[28] A rare and rich coastal grassland which occurs in Western Scotland mostly in the Western Isles.

survives on a diet of seaweed to which it has become adapted (The Orkney Sheep Foundation, 2016).

8.2. Effects of Harvesting on Cultural Heritage

8.2.1. Terrestrial archaeological features (e.g. monuments, light houses) will not be affected by seaweed or seagrass harvesting which take place in the marine environment and along the coastal fringe. Any potential indirect effects on the land (e.g. access) would be managed under the existing Town and Country Planning system. Terrestrial heritage features are therefore scoped out of the SEA.

8.2.2. Wild harvesting activities have the potential to affect underwater archaeological features. These include shipwrecks, prehistoric landscapes and war graves (see Section 8.1). The potential effects on these heritage features are discussed below in relation to the broad groups of seaweeds and seagrasses.

Kelps

8.2.3. Although trawling/sledging/dredging methods used to harvest kelp are designed to avoid physical disturbance of the seabed (see Table 5), the removal of entire plants by these devices could disturb the seabed and any underwater heritage features that may be associated with it. Kelps do not have roots. Instead, they secure themselves onto substrate made of rock or cobble by their holdfasts. They are therefore unlikely to be attached to archaeological features that comprise softer material, for example submerged landscapes or wooden shipwrecks. They may, however, be attached to archaeological features comprising harder material such as the metal hulls of shipwrecks. Overall, the likelihood of this method of harvesting affecting underwater archaeological features (either designated or undesignated/uncertain/unknown) is considered to be low. In the interests of best practice, however, it would be advisable for operators to avoid areas of known charted wreck sites and archaeological features.

8.2.4. Other methods of harvesting kelp that involve hand or mechanical cutting methods will not disturb the seabed and will therefore not impact cultural heritage features.

Maerl

8.2.5. The primary means of harvesting maerl is by dredging. Maerl does not have roots but accumulates subtidally as dense beds of calcareous material. The extraction of maerl by dredgers would therefore disturb the underlying seabed and potentially any associated archaeological features (either designated or undesignated/uncertain/unknown). Furthermore, the recoverability of maerl is very low given their very slow growth rates. Therefore, depending on the nature of the underlying substratum (hard versus soft), the removal of maerl could lead to an increase in the potential for erosion (see Section 6.3) and exposure of any underlying cultural heritage features. Maerl harvesting is therefore considered a significant risk for cultural heritage.

Other Groups of Seaweed

8.2.1. Harvesting other groups of seaweed involves hand or mechanical cutting methods that are considered to be non-invasive. These will therefore not impact cultural heritage features.

Seagrasses

8.2.2. Although not common practice, any trawling/sledging/dredging of seagrass beds would result in the uprooting of this plant. In contrast to kelps, seagrasses have roots and occur on soft substrate, typically sandy or muddy sediment. The complete removal of these plants is therefore more likely to disturb any underlying cultural heritage features (either designated or undesignated/uncertain/unknown) that might be present. Furthermore, the regeneration of areas where seagrass is harvested using these methods would be slow and could lead to an increase in the potential for erosion (see Section 6.3). This in turn could result in the exposure of cultural features. This activity has been assessed as a medium risk to high risk on a site by site basis.

8.2.3. Other methods of harvesting seagrass that involve hand or mechanical cutting methods will not disturb the seabed and will therefore not impact cultural heritage features.

Beach-casts

8.2.4. Harvesting beach-cast seaweed may affect the ability of cast seaweed to provide coastal erosion protection and, therefore, protect underlying historic environment features that are vulnerable to such erosion. Overall, harvesting beach-casts in areas where the coastline is soft (e.g. beaches) could increase the potential for coastal erosion although the evidence in support of this is limited. However, the degree of erosion would be small and unlikely to be of a magnitude that would expose any underlying archaeological features (either designated or undesignated/uncertain/unknown).

8.2.5. Mechanical gathering of beach-casts involves the use of large vehicles such as tractors or JCBs which could also disturb the shore. These vehicles can leave tracks on beaches and result in some minor disturbance of the surface layer of the sediment. The depth of penetration by the tyres, however, is very small (of the order of a few centimetres) and therefore unlikely to affect any cultural heritage features.

8.2.6. Harvesting beach-cast seaweed also has the potential to reduce the availability of this resource for crofters. The degree of effect on this cultural tradition will depend on the scale of harvesting. Small scale (artisanal) hand gathering is unlikely to be an issue whereas large scale mechanical harvesting could be more of an issue. It will therefore be important for crofters to be consulted prior to any large scale harvesting of beach-cast kelp to ensure that any potential interactions are avoided or minimised (see Section 6.6).

9. Risk Matrix and Mitigation Measures

9.1. Risk Matrix

9.1.1. The potential effects of wild harvesting that have been discussed in the preceding sections have been documented in a risk matrix (**Table 12**). This presents information on the relative risks associated with harvesting each of the key seaweed and seagrass groups on each of the SEA topics. The evidence base underlying the risk matrix is provided in **Appendix E**.

9.1.2. The risk level that has been assigned represents the likely interaction of each harvesting method on each seaweed and seagrass group. The risk level was based on a consideration of the likely sensitivity of each group (i.e. its resistance/tolerance) to different harvesting methods and the rate of (or time taken for) recovery (termed recoverability or resilience) once the pressure has been removed. The consideration of different harvesting methods allows the potential scale and duration of the loss associated with that method/activity type (i.e. its magnitude/intensity, extent/coverage, frequency/duration and seasonality) to be taken into account.

9.1.3. The matrix provides a distinction between the regeneration of the target seaweed and/or seagrass resource itself (i.e. the biotope) and the regeneration of its whole ecosystem which is reflected by other ecological functions (i.e. ecological interactions, food web dynamics and production). A cumulative risk level is also included which indicates the highest risk across all SEA topics.

9.1.4. The assigned risk level has been based on the best available scientific evidence and impartial expert judgement. The evidence database that informed this risk matrix has been incorporated into the reference list provided in **Section 13**. The level of confidence in the risk levels assigned to the matrix has been considered and is included as high (h), medium (m) and low (l) in **Table 12**. This takes account of the quality of the evidence or information, the degree to which evidence is applicable to the assessment and the degree of agreement between evidence types (**Table 13**).

Table 12: Levels of risk associated with wild harvesting broad groups of seaweed and seagrass

	High		Low
	Medium		Not applicable/no interaction

Target species	Harvesting method	Biodiversity, Flora and Fauna				Climatic Factors		Cultural Heritage		Cumulative risk
		Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling	Underwater Heritage Features	Crofting	
Wracks	Hand Cutting	***	**	*	*	*	*	*		
	Trawling/sledging/dredging									
	Mechanical 'hedge' cutting	***	**	*	*	*	*	*		
	Hand gathering									
	Mechanical gathering									
Kelps	Hand Cutting	**	**	*	*	*	*	*		
	Trawling/sledging/dredging	***	**	**	**	**	**	*		
	Mechanical 'hedge' cutting	***	**	**	**	**	**	*		
	Hand gathering	***	**	**	*	**	*	*	*	

Target species	Harvesting method	Biodiversity, Flora and Fauna				Climatic Factors		Cultural Heritage		Cumulative risk
		Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling	Underwater Heritage Features	Crofting	
	Mechanical gathering	***	**	**	*	**	*	*	*	
Green Seaweeds	Hand Cutting	*	*	*	*	*	*	*		
	Trawling/sledging/dredging									
	Mechanical 'hedge' cutting									
	Hand gathering									
	Mechanical gathering									
Red Seaweeds	Hand Cutting	**	*	*	*	*	*	*		
	Trawling/sledging/dredging									
	Mechanical 'hedge' cutting									
	Hand gathering									
	Mechanical gathering									
Maerl	Hand Cutting									

Target species	Harvesting method	Biodiversity, Flora and Fauna				Climatic Factors		Cultural Heritage		Cumulative risk
		Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling	Underwater Heritage Features	Crofting	
	Trawling/sledging/dredging	**	*	*	*		**	*		
	Mechanical 'hedge' cutting									
	Hand gathering									
	Mechanical gathering									
Seagrasses	Hand Cutting	***	**	**	*	**	**	*		
	Trawling/sledging/dredging	***	**	**	*	**	**	*		
	Mechanical 'hedge' cutting	***	**	**	*	**	**	*		
	Hand gathering	***	**	**	*	*		*		
	Mechanical gathering	***	**	**	*	*		*		

Confidence included in the table as high (***), medium (**) and low (*). See Table 13.

Table 13: Criteria used to assign confidence level to evidence base underpinning the risk matrix

Confidence Level	Criteria
High (***)	Based on peer reviewed papers (observational or experimental) or grey literature reports by established agencies. Assessment based on the same pressures acting on the same receptor in Scotland. Studies agree on the direction and magnitude (of impact or recovery).
Medium (**)	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement. Assessment based on similar pressures on the receptor in other areas. Studies agree on direction but not magnitude (of impact or recovery).
Low (*)	Based on expert judgement. Assessment based on proxies for pressures e.g. natural disturbance events, grazing. Studies do not agree on direction or magnitude (of impact or recovery).

9.1.5. Based on the risk matrix, harvesting for maerl should be prohibited in Scottish waters. The only likely method of harvesting possible for this group is dredging. Although there is limited direct evidence available of the effects of extracting maerl, expert judgement indicates that the risk of significant ecological and environmental effects would be high given the slow growth rate of these species. These species are also protected by MPA designations.

9.1.6. There is more evidence available on the effects of harvesting wracks, kelps and seagrasses by different harvesting methods. Based on the evidence, certain methods of wild harvesting are considered to be unsustainable and should be prohibited, namely mechanical cutting of living kelps and trawling/sledging/ dredging of living seagrasses. Other methods of harvesting kelps and seagrasses might require more detailed assessment and site specific management depending on the scale of the harvesting (e.g. restrictions on harvesting methods, seasonal constraints etc.) because the ecological and/or environmental effects might potentially be significant. This would also be the case for harvesting of wracks and beach-cast material.

9.1.7. The ecological and environmental effects of wild harvesting of green and red seaweeds are likely to be small or negligible. However, there is very limited evidence of the effects of harvesting on these seaweeds and therefore the low risk assigned to these should be treated with caution.

9.2. Mitigation

9.2.1. Mitigation and enhancement measures will need to be considered where potentially significant effects may arise to ensure that wild harvesting activities are sustainable. With appropriate mitigation measures in place the residual effects may be reduced or minimised.

9.2.2. The specific mitigation that is appropriate will depend on the extent and scale of extraction which will only be known at the project level. In particular, it is important that any survey and monitoring requirements (particularly those used to develop sustainable harvesting strategies) reflect the scale, scope and complexity of the harvesting (Netalgae, 2012), as well as the level of risk (and confidence limits) of an ecological or environmental impact (see**Table 12**). At the same time, however, monitoring requirements should be proportionate to the scale of activity and the level of risk.

9.2.3. Potential mitigation measures that developers will need to consider at the project level where relevant and necessary are included in **Table 14.** These include recommended sustainable practices based on a review of current management practices in Europe (Netalgae, 2012).

Table 14: Generic mitigation measures to be considered at project level

Mitigation Measure	Example of Methods
Adoption of monitoring programmes	• Prior to any harvesting, undertake an assessment of the status and biomass of the stock and also estimate percentage coverage of particular species of interest (e.g. Blight *et al.*, 2011); • Undertake pre- and post-harvesting survey work to record damage and regeneration of plants; • Record volumes, biomass and area of each species of seaweed harvested, along with date and location; and • Consider the use of nearby reference areas that are not harvested to help determine the scale of impact.
Alternative “less damaging” methods of harvesting and applying recommended harvesting techniques for specific species to encourage regeneration of harvested areas	• Cutting heights should generally be as high as possible and well above the point of growth (e.g. the meristem for kelps) and the holdfast left attached. The only case where this may not be feasible is in the case of *Laminaria hyperborea* where the stipes (which are below the meristem) are targeted for commercial use, and where the most sustainable mechanical methods involve removing the entire mature plant and leaving smaller immature plants to continue to grow.; • Where possible and relevant, less than one third (i.e. 33%) of an individual plant should be harvested to allow for regrowth; and • Avoid the entire removal of any plants apart from the case of *L. hyperborea* as explained above.

Mitigation Measure	**Example of Methods**
Rotational fallowing and harvesting regimes i.e. providing fallow areas that are not harvested or harvested less frequently to ensure resource sustainability (re-growth and/or recruitment)	• The total amount harvested should be set in accordance to the status and availability of the wild resource and the recovery rates of individual species. Only a small percentage of standing stock should be harvested where possible. For example, Comhairle Nan Eilean Siar (2013) advise that the annual harvest of *Ascophyllum nodosum* should be no more than 25% of the total accessible biomass; • Rotate harvesting areas to allow ample time for recovery. Harvested areas should be left for a period of time before harvesting again. The length of time will depend on the rates of recovery of the habitat and associated species, noting that growth rates of particular species can be site specific; and • Do not collect beach-cast seaweed from the entire length of strandlines. Leave larger proportions in place particularly during the months when overwintering birds may depend on it as a food source (October to March).
Harvest seaweeds during the active growth season to allow for quicker recovery	• Harvest *Laminaria hyperborea* when growth of adults and juveniles is most rapid between winter and the end of summer (January to September) (Sjøtun *et al.*, 1996); and • Harvest *Ulva* spp. during the rapid growth phase in spring and summer (May to August).
Harvest seaweeds outside of the reproductive season and ensure a substantial proportion of mature plants remain	• Harvest *Himanthalia elongata* in summer (June to August) after the reproductive season if possible. If harvesting occurs during the reproductive season, then only one of the two main fronds should be harvested. Harvest *Saccharina latissima*, *Alaria esculenta, F. vesiculosus, F. serratus* during spring and summer (April to August), avoiding the autumn/winter reproductive season (October to February); and • Avoid harvesting *A. nodosum* during the spring (March to May) reproductive peak.
Avoidance of 'by catch' including brittlestars, stalked jellyfish, bryozoans, molluscs or their eggs	• Where appropriate, rinse collected plants *in situ* to remove the majority of epifauna.

Mitigation Measure	Example of Methods
Limit and/or avoid harvesting in vulnerable areas	• Limit/avoid harvesting in wave exposed and erosion prone coastal areas (e.g. dunes) where kelps dissipate wave energy (**Figure 28**) • Limit/avoid harvesting in designated sites where appropriate, i.e. where seaweeds (e.g. kelps) are a qualifying or supporting feature of the site (**Figure 29** and **Figure 30**) and where seaweeds potentially support bird features (**Figure 20**); • Follow the Scottish Marine Wildlife Watching Code[29]; • Limit/avoid harvesting near charted archaeological features and HMPAs (**Figure 26** and Figure 27); • Limit/avoid harvesting beach-cast seaweed between October and April (SNH, pers. comm.); • Avoid harvesting kelp in areas with high abundance of grazing sea urchins (Sjøtun *et al*., 2000); and • Consult crofters prior to large scale harvesting of beach-cast kelp to ensure that potential interactions are avoided or minimised.
Take extra care when harvesting to ensure that species or spores are not transferred to other areas.	• Follow 'Check, Clean, Dry' biosecurity principles, checking, cleaning and drying all equipment and clothing when moving between sites to ensure that invasive species, pests and diseases are not spread to new areas[30]; and • Develop a biosecurity plan as part of the monitoring strategy.

[29] http://www.marinecode.org/guide-g.asp
[30] https://secure.fera.defra.gov.uk/nonnativespecies/checkcleandry/#

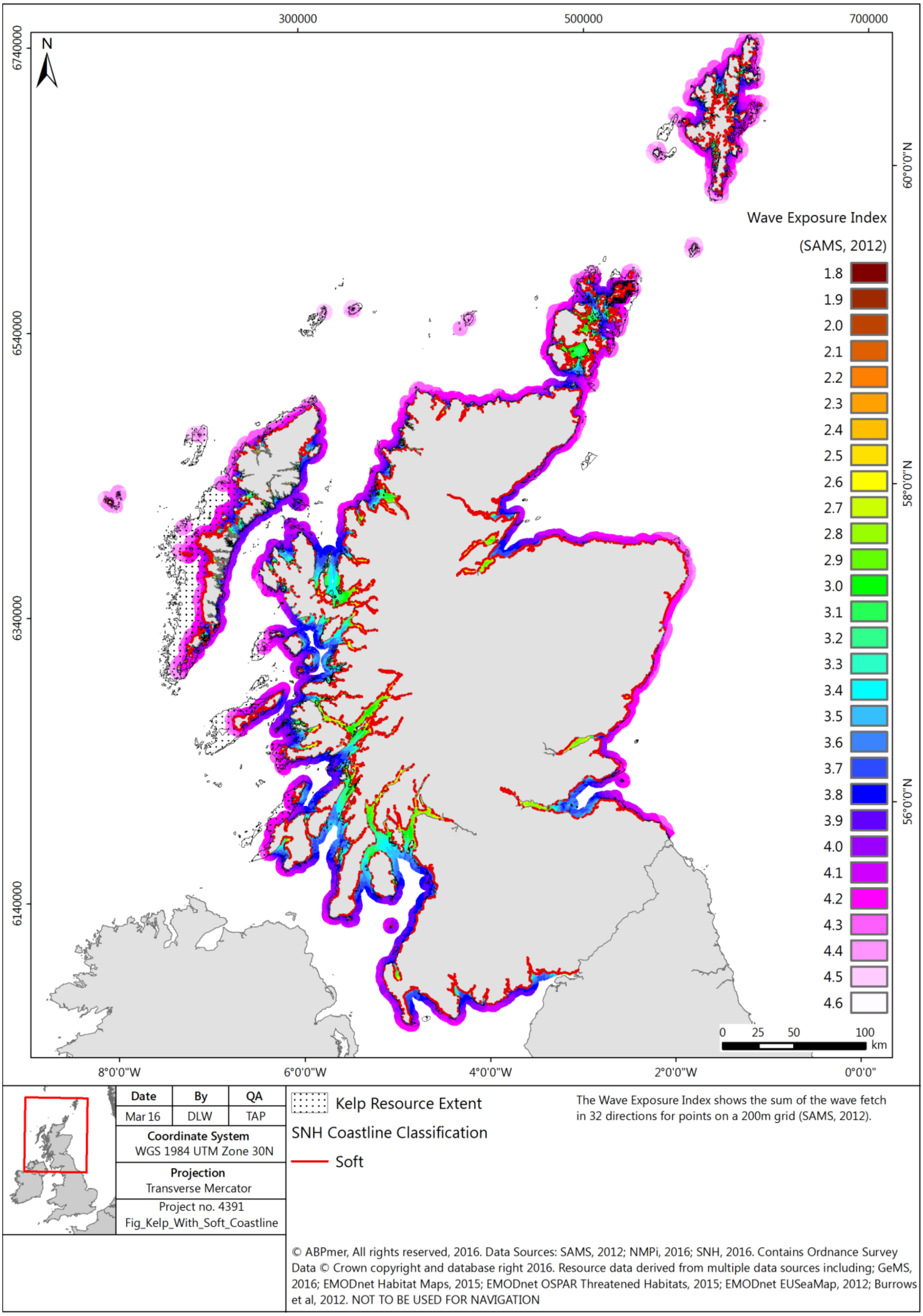


Figure 28: Distribution of kelp and areas of coastline that are wave exposed and soft

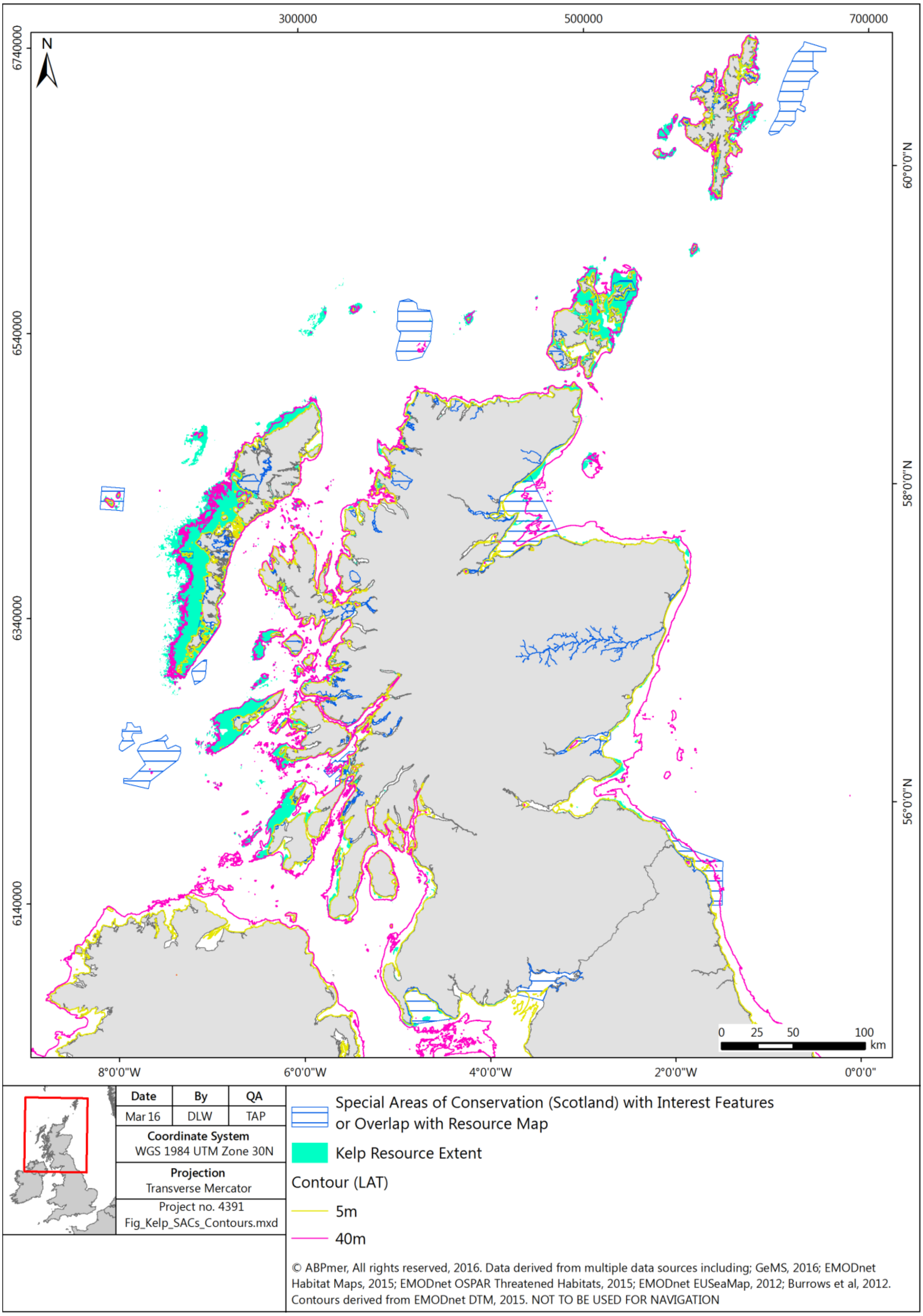


Figure 29: Distribution of kelp and SACs with interest features that could potentially support seaweed

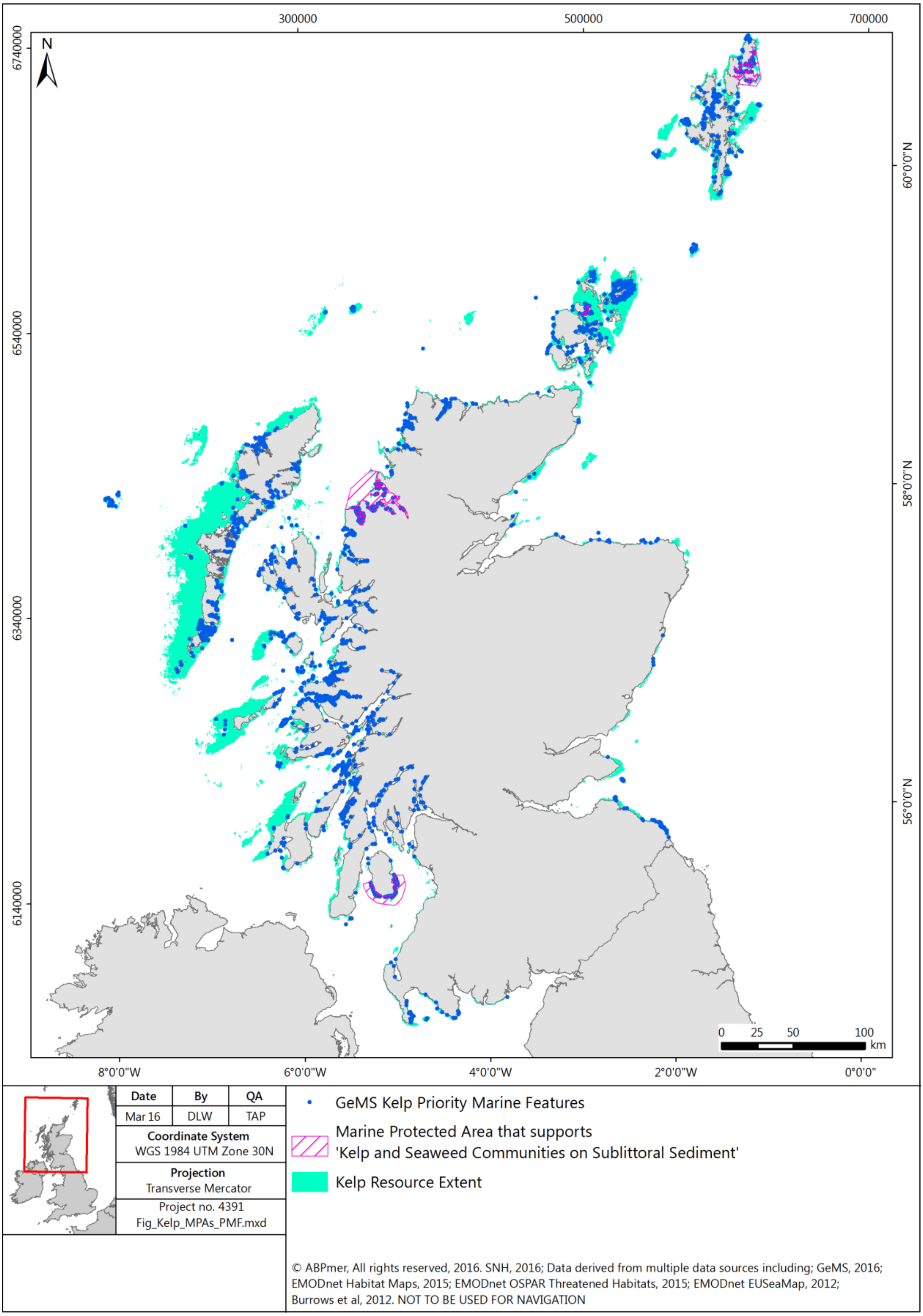


Figure 30: Distribution of kelp and relevant PMFs and MPAs that support this feature

10. Reasonable Alternatives

10.1. Introduction

10.1.1. The Act requires the assessment of reasonable alternatives. This section is a discussion of the four reasonable alternatives listed at paragraph 2.4.

10.2. Do-nothing scenario

10.2.1. The “do nothing” option is to continue with the existing licensing/leasing arrangements as detailed in paragraph 3.14 Current regulation of wild harvesting. The roles of the Scottish Government licensing regime, the land owner (including the Crown Estate) and Scottish Natural Heritage (SNH) are described. Note that in this context, the seabed is included as land.

10.3. All wild harvesting activities to require consent through marine licensing

10.3.1. Managing all harvesting activities through marine licensing is not considered proportionate, given that existing small-scale artisanal practices are already being undertaken sustainably. However, the SEA has identified that unmanaged large-scale wild harvesting will result in significant environmental effects. As such large-scale harvesting will require a vessel, and will remove seaweed from the seabed, the marine licensing should be able to ensure that such harvesting is conducted sustainably.

10.4. Use a combination of existing permissions and marine licensing

10.4.1. Another alternative is to introduce thresholds into the consenting process, such that harvesting by artisanal harvesters should require a marine licence if volumes harvested exceed a set amount. However, at this early stage in the review of the industry, it would be difficult to identify an appropriate threshold. In addition, thresholds would need to be species-specific and, possibly, directed to particular locations. The views of stakeholders are sought on this alternative.

10.5. Stop all harvesting activities

10.5.1. Based on the outcomes of the SEA, stopping all harvesting activities is not a reasonable alternative, as there is no evidence that existing harvesting is resulting in significant adverse environmental effects. Such a ban would result in the collapse of the existing industry and prohibit sustainable large-scale harvesting. This would have associated socio-economic consequences (e.g. loss of income for coastal communities).

11. Cumulative Effects

11.1.1. The Act requires the consideration of cumulative and synergistic environmental effects that may arise from licensing wild harvesting in conjunction with other plans, programmes and policies.

11.1.2. The policy context within which licensing decisions is set by the National Marine Plan. The National Marine Plan provides the over-arching marine planning policy framework. This includes policies relating to activities where the marine planning and terrestrial systems overlap, for example those which occur on and around the coast or in coastal waters, such as aquaculture.

11.1.3. A review of the environmental policy context is provided in **Section 3.15**.

11.1.4. However other plans, programmes and policies for which there could be cumulative effects include the Sectoral Marine Plans for wind, wave and tidal energy in Scottish Waters, regional marine plans and policy for seaweed cultivation.

11.1.5. **Table 15** provides a summary of the likely effects of licensing decisions for wild harvesting on the environmental topic areas scoped into the assessment, and how these are likely to act together with other plans, programmes and policies. A cumulative risk level is also included in the risk matrix, which indicates the highest risk across all SEA topics.

11.1.6. The focus of any regulation for wild harvesting is to ensure it is only undertaken where sustainable. The principles of sustainable development and protection of Scotland's marine environment are also key threads of wider Scottish policy (e.g. the National Marine Plan, Scottish Biodiversity Strategy). Regulation of large-scale wild harvesting activities therefore provides a means to mitigate potential negative environmental impacts.

Sumary of Cumulative Effects

11.1.7. On the whole, this SEA and the consideration of potential cumulative and synergistic effects demonstrate how the nature and extent of any potential impacts depends on the method and scale of harvesting, and the composition and sensitivity of the corresponding marine ecosystems. It also demonstrates the interdependence of licensing, the seaweed industry and its stakeholders, the processes currently in place, and the combined role that they will need to play to ensure the sustainable growth of wild harvesting industries into the future.

Table 15: Summary of likely cumulative environmental effects with wider marine policy and planning

Environmental Topic	Cumulative Effects of Licensing	Cumulative Effects with Other Plans, Programmes and Policies
Biodiversity, Flora and Fauna	Demonstration of biodiversity, flora and fauna considerations at consenting stage and mitigation where necessary. Supporting good practices and sustainable harvesting in the wild may complement wider biodiversity objectives and have long-term benefits in the management of natural seaweed stocks and the ecosystems they service.	A consenting mechanism helps ensure that wild harvesting is sustainable and therefore any adverse effects on biodiversity, flora and fauna in-combination with other plans, programmes and policies will be mitigated.
Climatic Factors	Demonstration of mitigation measures against potential wave and coastal process impacts where necessary.	A consenting mechanism helps ensure that wild harvesting is sustainable and therefore any negative effects on climatic factors in-combination with other plans, programmes and policies will be mitigated.

12. Summary and Conclusions

12.1. Introduction

12.1.1. The wild seaweed harvesting sector has indicated its aspiration to develop industrial-scale harvesting around Scotland. The aim of this SEA is to assess the potential environmental effects of wild harvesting of seaweeds and seagrasses and in turn inform future regulation.

12.1.2. Seaweeds and seagrasses are important resources which may be harvested sustainably. However, sustainable management is not straightforward. Both seaweeds and seagrasses have complicated life histories. Failure to take account of this in the management of harvesting operations could have adverse consequences for these habitats (SNH, 2016). Damage to growing areas of individual plants can affect regeneration and the removal of target species by harvesting will impact the ecological structure and function of these habitats and also the ecosystem services that they provide.

12.2. Harvesting

International experience of large scale harvesting

12.2.1. Although not straightforward, sustainable commercial scale harvesting of certain species is possible and is taking place in other countries, such as Norway and Chile where annual live extractions of kelp by trawlers reaches 200,000 tonnes (Vasquez, 2008; Vea & Ask, 2011; Smale et al., 2013; Burrows et al., 2014a). The ability to sustainably remove such quantities at these locations has been attributed to the rapid recruitment and growth of kelps, the species associated with the kelp beds, and the implementation of appropriate and functional management of the resource (Smale et al., 2013).

Vulnerability of Maerl and Seagrass

12.2.2. The SEA has identified that the sustainable extraction of maerl is not possible and that harvesting of maerl should be prohibited (**Section 9**). Although the evidence indicates that the sustainable harvesting of seagrass might be possible, the seagrass beds found in Scotland are typically small (**Section 3.2**) and unlikely to support wild harvesting activities. The commercial harvesting of seagrass should therefore also be prohibited.

Small Scale harvesting

12.2.3. Current small scale (i.e. artisanal) hand cutting or picking of wild seaweed in Scotland managed through existing regulation is unlikely to result in significant adverse environmental impacts. However, management will need to take account of species and location as well as scale and for the cumulative impacts of small harvesting operations, the sensitivity of particular location and the future expansion of the industry. It is recognised that there is a risk that small seaweeds (namely green and red seaweeds) could be completely cleared from an area by these small scale harvesting activities. However, there is no information available on what would be considered a significant volume of removal for these small seaweeds and therefore at this stage in the absence of evidence it is not possible to propose an accurate threshold for triggering regulation of these activites.

12.2.4. Although small scale harvesting activities are currently not regulated under marine licensing, operators will still need to continue to consult SNH in the context of a number of legislative duties. These include advice on the need for an HRA, mitigating against disturbance to wildlife under the Wildlife and Countryside Act 1981, the need for a SSSI consent under the Nature Conservation (Scotland) Act 2004, European Protected Species (EPS), impacts on features of MPAs and management of the risks associated with invasive non native species.

Consequences of large scale harvesting

12.2.5. The SEA has confirmed that significant adverse effects can occur as a result of large scale (i.e. industrial) mechanised harvesting of seaweeds (namely kelps and wracks). These primarily relate to impacts on the ecological function of these important habitats (namely ecological interactions, food web dynamics and production) as well as on the ecosystem services that they provide (including coastal protection and carbon sequestration), and that these impacts may be further exacerbated in the future with the predicted effects of climate change. Such harvesting also has the potential to affect cultural heritage (namely underwater heritage assets and the collection of beach-cast seaweeds by crofters). Potential issues include but are not limited to:

- Loss of habitat and/or shelter for a range of plants and animals, alongside loss of direct and indirect food sources. This has consequences for detrital grazers and suspension feeders, as well as higher trophic levels, e.g. mammals, birds and fish;
- Loss of nursery grounds for juvenile invertebrates and fish, with consequences for higher trophic levels and commercial fish stocks;
- Loss of the physical modification effects of seaweed, e.g. wave damping, which may result in increases in coastal erosion and/or flooding events;
- Loss of carbon stores and sinks provided by some seaweed species; and
- Loss of or damage to cultural heritage assets and reduction in resource available to crofters.

12.2.6. Many of these effects are likely to be site specific and will depend on a range of factors, including the species to be harvested, the harvesting method, the amount taken, the timing (season) of harvest, the harvesting location and its environmental context, and the time allowed for regeneration prior to harvesting again. Harvesting practices, most notably the extent and scale of harvesting (i.e. frequency of harvesting, the proportion of a seaweed community harvested, and the proportion of an individual plant harvested) and the species harvested have been identified as key factors in ensuring plant regeneration and recovery of harvest areas, and ensuring the sustainability of the resource and the biodiversity it supports.

Cumulative Effects in an expanded industry

12.2.7. Although there is no evidence that small scale artisanal hand cutting or gathering of living and beach-cast seaweeds at discrete locations have significant environmental effects, there is the potential for significant cumulative effects as a result of multiple harvesting activities. However, we do not know what the cumulative effects of a large number of small-scale activities being undertaken within the same geographic location or the cumulative effects of potential small scale harvesting operations in conjunction with large scale industrial operations would be. These would need to be considered in the cumulative assessments of individual licence applications.

Mitigation

12.2.8. One way to help manage and mitigate these potential cumulative effects would be to create a public register of seaweed harvesting activities. This would provide a record of the harvesting activities that are being undertaken or are proposed to be undertaken. It is recognised that there could be issues regarding commercial confidentiality and also issues concerning how it would be administered. Although Marine Scotland is unlikely to be able to resource the management of such a register, it may be possible for industry to take forward such an initiative as a form of self-regulation.

12.2.9. Following the conclusion of a consultation, Marine Scotland intends to prepare a guidance note to assist licence application. This will include information on key issues associated with wild harvesting that have been identified in the SEA. It will also include information on issues that fall outside the scope of the assessment but will need to be considered at the project-level by industry (see **Sections 2.3.4** and **2.3.5**). A link to the risk matrix that has been developed as part of this SEA will also be provided together with a link to the evidence base (**Section 9** and **Appendix E**). This matrix will be managed and periodically updated by Marine Scotland in light of any new evidence to ensure that it is based on the best available scientific information.

12.2.10. GIS data layers that have been created as part of this SEA, namely the distribution of the current seaweed and seagrass resource, will be included on Marine Scotland's National Marine Plan interactive (NMPi) site[31] .

[31] http://www.gov.scot/Topics/marine/seamanagement/nmpihome

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14. Appendix A: Spatial Data

14.1. Spatial Data used in the preparation of this SEA

14.1.1. These maps are based on the latest available spatial data, namely:

- Geodatabase of Marine Features in Scotland (GeMS);
- EMODnet fine, medium and broad scale EUNIS habitat layers;
- OSPAR threatened and/or declining habitats;
- EUSeaMap predictive EUNIS habitat layers; and
- Burrows et al. (2014a) kelp suitability layers.

14.1.2. EUSeaMap was used to provide an underlying basemap of predicted broadscale habitat types likely to support relevant seaweed and seagrass groups. This information was then overlaid with predictive information on suitable kelp habitat from Burrows et al. (2014a) to characterise potential areas of kelp. The distribution maps were then further refined with the relevant fine, medium and broad scale EUNIS habitat information and OSPAR threatened and/or declining habitats from EMODnet. Records from GeMS were then overlaid to add detail to the distribution maps and confirm the presence of seaweed and seagrass features.

14.1.3. Other seaweed and seagrass survey and mapping data do exist in Scotland. However, there has been no co-ordinated survey of the distribution and abundance of either seaweeds or seagrasses in Scotland. A significant large scale survey of the seaweed resources of Scotland was undertaken by the Scottish Seaweed Research Association in the 1940s (Walker, 1947). However, this dataset has not been digitised and was therefore not readily available for use within the timescale for this study.

14.1.4. A confidence level of high, medium or low has been assigned to each map layer according to the resolution and origin/nature of the underlying spatial data (Table A1). Any seaweeds or seagrasses that have been mapped and overlap, for example areas that have been assigned a low confidence, are based on predicted data and/or broad scale mapping information.

Table A1 Criteria used to assign confidence level to data sources

Confidence Level	**Criteria**
High (H)	Spatial data layers that are based on survey records and/or fine-scale mapping information (i.e. MESH records and MESH fine-scale habitats).
Medium (M)	Spatial data layers that are based on medium-scale mapping information (i.e. MESH medium-scale habitats).
Low (L)	Spatial data layers that are based on predicted (i.e. modelled) data because they have not been validated (ground-truthed) and/or broad-scale mapping information (i.e. MESH broad-scale habitats, Burrows *et al.* (2014a) predictive kelp layers and EUSeaMap broad-scale habitats).

14.1.5. The confidence level assigned to the combined distribution of seaweeds and seagrasses is shown in **Figure A1**

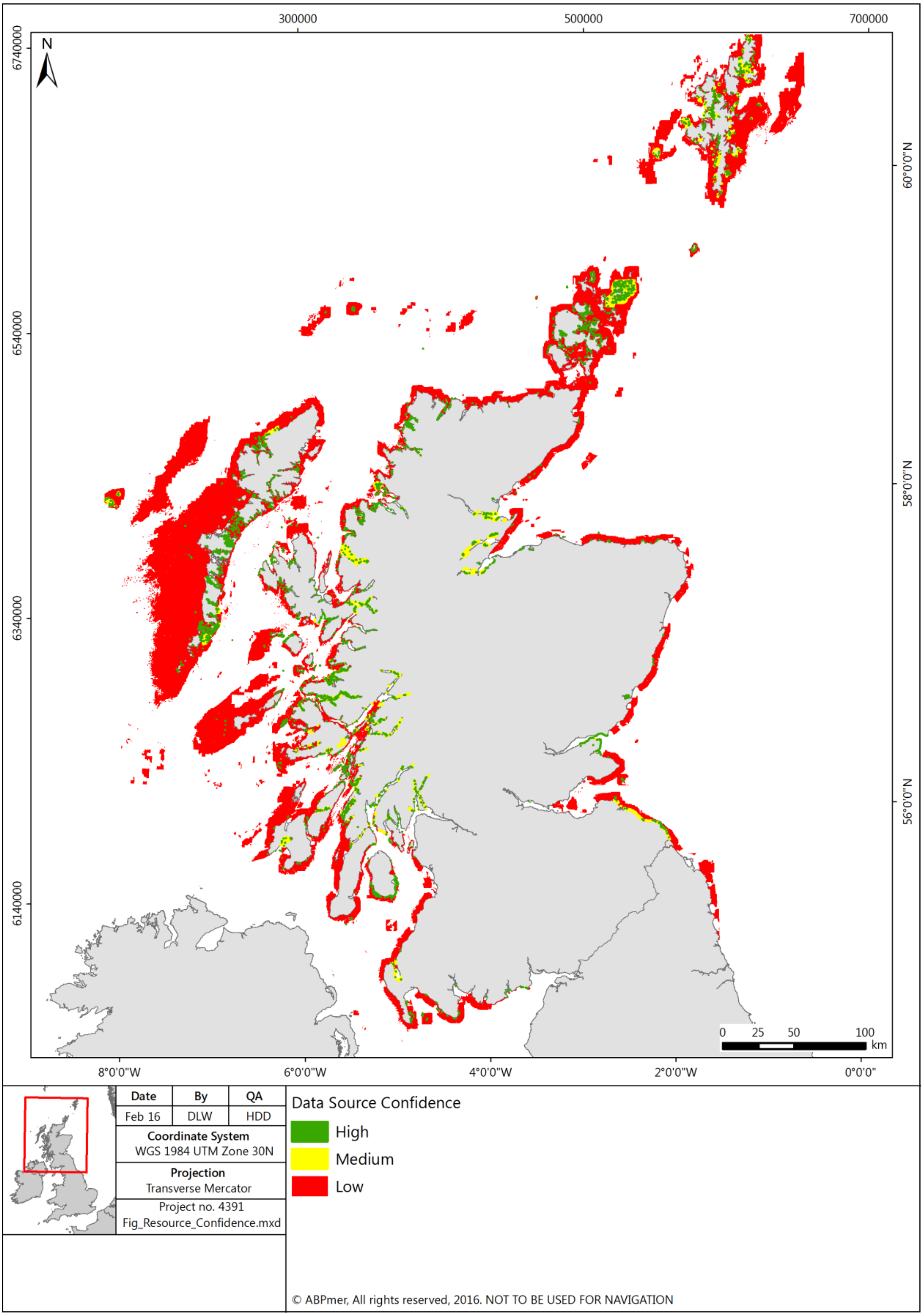

Figure A1: Level of confidence in the combined mapped distribution of seaweeds and seagrasses in Scotland

15. Appendix B: Environmental Protection Objectives

Table B1: Review of environmental protection objectives

Plan, Programme or Strategy	**Objectives**	**Implications/ Comments**
General Marine		
International		
UN Convention on the Law of the Sea 1982 (UNCLOS)[32]	Defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of natural resources. It enshrines the notion that all problems of ocean space are closely interrelated and need to be addressed as a whole. Includes the framework for the establishment of territorial waters to 12 nautical miles .	This framework emphasises the need to balance competing interests and objectives within the marine environment.
European		
European Marine Strategy Framework Directive 2008 (MSFD)[33]	The MSFD is the most recent marine obligation on EU Member States. It extends the requirements of the WFD into seas beyond 1nm. The MSFD requires Member States to 'take necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest'. Coastal waters are also covered by the directive, and the Directive sets out the requirement for member states to develop a marine strategy.	Important overarching protective policy for the marine environment, and the new licensing regime for wild harvesting of seaweed and seagrass should seek to ensure that it supports the objectives of good environmental status.

[32] United Nations Convention on the Law of the Sea of 10 December 1982 [online] Available at: http://www.un.org/Depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm Accessed on 18 May 2016.
[33] Directive 2008/56/EC Establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) [online] Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF Accessed on 18 May 2016.

Plan, Programme or Strategy	**Objectives**	**Implications/ Comments**
European Integrated Maritime Policy 2007[34]	Aims to deliver a sustainable development approach for Europe's oceans and seas. Its scope includes: a marine transport strategy and new ports policy; research and data collection and management strategies, and work to mitigate climate change and reduce the impact of and adapt to the effects of climate change on coastal regions. It aims to promote the development of an environmentally safe aquaculture industry.	Recognises the conflicting demands on the marine environment and supports improved management. This provides an important framework for the consenting mechanism for wild harvesting.
United Kingdom		
Coast Protection Act 1949 (as amended by The Coast Protection (Notices) (Scotland) Regulations 1988[35] and The Coast Protection (Notices) (Scotland) Amendment Regulations 1996)[36]	Sets out the licensing and regulatory framework within which activities including navigation and flood defences are set. Aims to protect the coast from erosion and encroachment and to ensure safety in navigation. Excludes some tidal waters in Scotland. Local authorities which include coastline within their boundaries are designated as coastal protection authorities and given specific duties and powers to undertake coastal defence works where necessary.	The potential changes in coastal processes associated with harvesting industry activities suggest that the the aims of the legislation (coastal and navigational protection) should be considered in licensing decisions.

[34] An Integrated Maritime Policy for the European Union [online] Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0575:FIN:EN:PDF Accessed on 18 May 2016.
[35] The Coast Protection (Notices) (Scotland) Regulations 1988 [online] Available at: http://www.legislation.gov.uk/uksi/1988/957/contents/made Accessed on 18 May 2016.
[36] The Coast Protection (Notices) (Scotland) Amendment Regulations 1996 [online] Available at: http://www.legislation.gov.uk/uksi/1996/141/contents/made Accessed on 18 May 2016.

Plan, Programme or Strategy	**Objectives**	**Implications/ Comments**
Marine and Coastal Access Act 2009[37]	The key issues covered by the Act comprise: the creation of a Marine Management Organisation (MMO); planning in the marine area; licensing activities in the marine area; marine nature conservation; managing marine fisheries; reform of inland and migratory fisheries; modernisation and streamlining of enforcement powers; administrative penalties scheme for domestic fisheries offences; and access to coastal land. Applies outside 12 NM in Scotland.	This sets out the broader policy context within which the licensing decisions should be made.
Our seas – a shared resource – High level marine objectives for the UK[38]	Sets out high level objectives for the UK marine environment. This includes achieving a sustainable marine economy, ensuring a strong, healthy and just society, living within environmental limits, promoting good governance and using sound science responsibly.	This provides a broader framework for licensing decisions, supporting sustainable development of the marine environment.
UK Marine Policy Statement (2011)[39]	The Marine Policy Statement (MPS) is the framework for preparing Marine Plans and taking decisions affecting the marine environment. It will contribute to the achievement of sustainable development in the United Kingdom marine area. It has been prepared and adopted for the purposes of section 44 of the Marine and Coastal Access Act 2009.	This provides a broader framework for licensing decisions, supporting sustainable development of the marine environment.
Scotland		

[37] Marine and Coastal Access Act 2009 [online] Available at: http://www.legislation.gov.uk/ukpga/2009/23/pdfs/ukpga_20090023_en.pdf Accessed on 18 May 2016.
[38] HM Government in association with Northern Ireland Executive, The Scottish Government and the Welsh Assembly Government (2009) [online] Available at:
http://www.scotland.gov.uk/Resource/Doc/1057/0080305.pdf Accessed on 18 May 2016.
[39] UK Marine Policy Statement (2011) [online] Available at: https://www.gov.uk/government/publications/uk-marine-policy-statement Accesed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Marine (Scotland) Act 2010[40]	Provides a framework to manage activities with Scotland's marine environment in a sustainable way. Notes the importance of protecting seas whilst facilitating sustainable economic growth. Introduces a new statutory marine planning system, a simpler licensing system, improved marine nature and historic conservation with new powers to protect and manage areas of importance for marine wildlife, habitats and historic monuments; improved protection for seals and enforcement powers.	This provides a broader framework for licensing decisions.
National Marine Plan (2015)[41]	This Plan covers the management of both Scottish inshore waters (out to 12 nm) and offshore waters (12 to 200 nm). It also applies to the exercise of both reserved and devolved functions.	This provides a broader framework for licensing decisions.
Regional Marine Plans	The Marine (Scotland) Act in 2010 introduced a new era for the management of Scotland's seas and the resulting National Marine Plan sets the wider context for planning within Scotland, including what should be considered when creating local, regional marine plans. Scottish Marine Regions have been created which cover sea areas extending out to 12 nm. Regional Marine Plans will be developed in turn by Marine Planning Partnerships, allowing more local ownership and decision making about specific issues within their area. The Clyde and Shetland Isles will be the first regions to take forward regional marine planning.	This provides a broader framework for licensing decisions.

[40] Marine (Scotland) Act 2010 [online] Available at: http://www.legislation.gov.uk/asp/2010/5/pdfs/asp_20100005_en.pdf Accessed on 18 May 2016.
[41] National Marine Plan (2015) [online] Available at: http://www.gov.scot/Publications/2015/03/6517 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Biodiversity, Flora & Fauna		
International		
UN Convention on Biological Diversity (1992)[42]	The three main objectives of the CBD are: • the conservation of biodiversity; • the sustainable use of biodiversity; and • the sharing of benefits from the use of genetic resources (including by • appropriate access to these resources). Article 6 requires that all parties to the Convention develop national biodiversity strategies, plans or programmes, and that they seek to integrate the provisions of these across other policy sectors. Article 7 requires the identification of key resources and their protection. Monitoring of potentially damaging processes and activities should also be undertaken. Two policy decisions came from the 1995 Conference of the Parties known as the Jakarta Mandate on marine and coastal biodiversity. Commitments include the development of a global system of marine and coastal protected areas, blocking the pathways of invasions of alien species, increasing ecosystem resilience to climate change, and developing, encouraging, and enhancing implementation of wide-ranging integrated marine and coastal area management.[43]	This broader framework sets the context within which specific environmental protection objectives have been developed. The principles defined within the Convention should be supported by licensing decisions.
Bonn Convention on the Conservation of Migratory Species of Wild Animals 1979[44]	Aims to conserve terrestrial, marine and avian species throughout their range through international co-operation.	As with the previous Convention, these conservation objectives should be considered in the development of the new conseting regime.

42 Convention on Biological Diversity [online] Available at: http://www.cbd.int/convention/text/ Accessed on 18 May 2016.
43 CBD and the Jakarta Mandate [online] Available at: http://www.cbd.int/idb/2012/?ttle Accessed on 18 May 2016.
44 Introduction to the Convention on Migratory Species [online] Available at: http://www.cms.int/en/legalinstrument/cms Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Convention on Wetlands of International Importance 1971 (amended 1982/87)[45]	Otherwise known as the Ramsar Convention, this emphasises the special value of wetlands, particularly as a key habitat for waterfowl, and this includes estuaries, tidal flats and near shore marine areas. The Convention resulted in designation of sites for management, sustainable use and conservation.	Licensing decisions should uphold commitments to environmental protection.
Convention for the Protection of the Marine Environment of the North- East Atlantic (OSPAR Convention) (1992)[46] and Council Decision 2000/340/EC of 8 May 2000 concerning the approval, on behalf of the Community, of the new Annex V to the Convention for the Protection of the Marine Environment of the North- East Atlantic[47]	The aim of the Oslo and Paris Convention (OSPAR Convention) is to prevent and eliminate pollution and to protect the maritime area against the adverse effects of human activities. This Convention led to establishment of a cross-regional commission promoting an ecosystems approach to marine management, including establishment of a network of Marine Protected Areas. Its five work areas are biodiversity and ecosystems, eutrophication, hazardous substances, offshore industry, and radioactive substances). Climate change is also a key cross-cutting theme. Also includes a Biological Diversity and Ecosystems Strategy. The scope of the OSPAR Convention was limited to four main areas defined in four Annexes (on the prevention and elimination of pollution from land-based sources, by dumping or incineration, and from offshore sources, and on the assessment of the quality of the marine environment). A new Annex V was prepared, on the protection and conservation of the ecosystems and biological diversity of the maritime area. Under it, the Contracting Parties must adopt the necessary measures in order to protect and conserve the ecosystems and the biological diversity of the maritime area, and to restore, where practicable, maritime areas which have been adversely affected.	The ecosystems approach to marine planning should be considered in decision making.

[45] Convention on Wetlands of International Importance 1971 (amended 1982/87) [online] Available at: http://www.ramsar.org/about/the-ramsar-convention-and-its-mission Accessed on 18 May 2016.
[46] Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) [online] Available at: http://www.ospar.org/convention/text Accessed 18 May 2016.
[47] 2000/340/EC: Council Decision of 8 May 2000 concerning the approval, on behalf of the Community, of the new Annex V to the Convention for the Protection of the Marine Environment of the North-East Atlantic on the protection and conservation of the ecosystems and biological diversity of the maritime area and the corresponding Appendix 3 [online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000D0340 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Agreement on the Conservation of African-Eurasian Migratory Waterbirds 1995 (AEWA)[48]	An independent international treaty developed under the auspices of the United Nations Environment Programme (UNEP)/Convention on Migratory Species. The AEWA covers 255 species of birds ecologically dependent on wetlands for at least part of their annual cycle, including species of divers, grebes, cormorants, herons, ducks, swans, geese, waders, gulls, and terns. An action plan addresses issues including: species and habitat conservation, management of human activities, research, monitoring, education and implementation.	Licensing decisions should take into account the priority afforded to the protection of bird species present within the Scottish terrestrial, coastal and marine environment.
Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas 1992 (ASCOBANS)[49]	An agreement on the protection of small cetaceans, noting that the migratory nature of dolphins, porpoises and whales means that they can be vulnerable to a range of marine activities and issues including marine pollution and by-catch.	As noted above, the high priority given to protection of these species should be taken into account in licensing decisions.
European		
Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive)[50]	Established a commitment to designating networks of sites of ecological importance across Europe. These are known as Natura 2000 sites and include special protection areas (SPAs designated under the Birds Directive – see following paragraph) and special areas of conservation (SACs).	Commitments to protecting habitats and species should be upheld by licensing decisions.

48 African-Eurasian Waterbird Agreement [online] Available at: http://www.unep-aewa.org/ Accessed on 18 May 2016.
49 Convention on migratory species Agreement on the conservation of small cetaceans of the Baltic and North Seas [online] Available at: http://www.ascobans.org/es/documents/agreement-text Accessed on 18 May 2016.
50 Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) [online] Available at: http://europa.eu/legislation_summaries/environment/nature_and_biodiversity/l28076_en.htm Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Council Directive 2009/147/EC (as amended) on the conservation of wild birds (the Birds Directive)[51]	Protects all wild birds (together with their nests and eggs) and their associated habitats. Commitment to designation of SPAs (included in Natura 2000 sites - see preceding paragraph).	Objectives to protect important species and habitats, including internationally designated sites, should be supported by licensing decisions.
Bern Convention on the Conservation of European Wildlife and Natural Habitats (1979)[52]	Aims to ensure conservation and protection of wild plant and animal species and their natural habitats and to promote co-operation between European states to protect biodiversity. Implemented in UK law by the Wildlife and Countryside Act (1981 and as amended).	The broader framework for environmental protection across Europe should be supported by licensing decisions.
Water Framework Directive (WFD) 2000/60/EC[53]	This provides an overarching strategy, including a requirement for EU Member States to ensure that they achieve 'good ecological status' by 2015. River Bain Management Plans (RBMP) were defined as the key means of achieving this. The Recent Marine Strategy Directive will extend coverage of coastal waters beyond 1 nm.	Licensing decisions should take account of the implications of harvesting on meeting 'good ecological status'.

[51] Council Directive 79/409/EEC on the conservation of wild birds [online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0147 Accessed on 18 May 2016.
[52] The Convention on the Conservation of European Wildlife and Natural Habitats [online] Available at: http://conventions.coe.int/Treaty/EN/Treaties/Html/104.htm Accessed on 18 May 2016.
[53] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy [online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
The Pan-European Biological and Landscape Diversity Strategy (1995)[54]	The Strategy aims to reverse the decline of landscape and biological diversity, by promoting innovation and proactive policy making. It supports preceding measures for protecting natural heritage, and aims to supplement this by further promoting a number of action themes relating to different environmentalresources. The long-term objectives of the strategy are: • The establishment of a Pan-European Ecological Network to conserve ecosystems, habitats, species and landscapes that are of European importance; • The sustainable management and use of Europe's biodiversity; • Integrating biodiversity conservation and sustainability into the activities of other sectors, such as agriculture, forestry, fisheries, industry, transport and tourism; • Improving information on and awareness of biodiversity and increasing public participation in conservation actions; • Improving our understanding of the state of Europe's biodiversity; and • Assuring that adequate funds are made available to implement the strategy.	Licensing decisions should support the objectives of conservation and sustainability.
Our life insurance, our natural capital: an EU Biodiversity Strategy to 2020[55]	The strategy has six main targets and 20 actions to halt the loss of biodiversity and ecosystem services in the EU by 2020. The six targets cover: • Full implementation of EU nature legislation to protect biodiversity; • Better protection for ecosystems, and more use of green infrastructure; • More sustainable agriculture and forestry; • Better management of fish stocks; • Tighter controls on invasive alien species; and • A bigger EU contribution to averting global biodiversity loss.	Licensing decisions should support these targets by taking into account integration of biodiversity protection and enhancement.
United Kingdom		

[54] Pan-European Biological and Landscape Diversity Strategy [online] Available at: http://www.tematea.org/?q=node/1460 Accessed on 18 May 2016.
[55] Our life insurance, our natural capital: an EU biodiversity strategy to 2020 [online] Available at: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/EP_resolution_april2012.pdf Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Wildlife and Countryside Act 1981 (as amended)[56]	Provides the framework for protection of species other than European Protected Species. Sets out protection objectives for specified birds and wild animals. The Act's various schedules detail the species that are protected under the Act, including dolphins, porpoises, and numerous birds such as geese and ducks. This was reviewed and updated in December 2008 and it was recommended that several further species of marine fish should be added to the lists attached to the Act, including shark, seahorse and ray species.	Licensing decisions should take into account the particular protection afforded to key terrestrial, coastal and marine species.
The Conservation (Natural Habitats, &c) Regulations 1994[57]	Transposes the requirements for protection of designated sites under the Habitats and Birds Directives, and the framework for protection of European Protected Species. Applies within 12nm. Several marine species are protected by various development consenting regimes covered by the Act. This includes marine turtles, all species of dolphins, porpoise and whale, seals and several types of marine fish (Atlantic salmon etc.).	Licensing decisions should take into account the particular protection afforded to key terrestrial, coastal and marine species.

[56] Wildlife and Countryside Act 1981 [online] Available at: http://www.legislation.gov.uk/ukpga/1981/69 Accessed on 18 May 2016.
[57] The Conservation (Natural Habitats, &c) Regulations 1994 [online] Available at: http://www.legislation.gov.uk/uksi/1994/2716/contents/made Accessed on 18 May 2016

Plan, Programme or Strategy	**Objectives**	**Implications/ Comments**
UK Biodiversity Action Plan 1994 (UKBAP) (Since the creation of the UK BAP devolution has led the four countries of the UK (England, Northern Ireland, Scotland and Wales) to produce their own country biodiversity groups and country biodiversity strategies. In 2007, however, a shared vision for UK biodiversity conservation was adopted by the devolved administrations and the UK governments, and is described in 'Conserving Biodiversity – the UK Approach' (see paragraph below)	In response to the 1992 Convention on Biological Diversity (CBD), this describes the UK's biological resources, commits a detailed plan for the protection of these resources. Sets out 1150 species and 65 habitats which are priorities for conservation action in the UK. The list was last updated in 2007 and includes 87 species in the marine group. Numerous habitats are also relevant to Scotland's marine environment, including several which are specific to coastal areas (saltmarsh, sand dunes) or the marine environment (including machair, maerl beds, kelp and seaweed communities, and sea loch egg wrack beds amongst others).	The UKBAP specifically identified numerous habitats and species in the coastal and marine environment which should be protected. Licensing decisions should seek to ensure that harvesting activity does not adversely affect these priorities.

Plan, Programme or Strategy	**Objectives**	**Implications/ Comments**
Conserving Biodiversity –the UK Approach (2007) [58]	A framework document for biodiversity identifies six priorities for implementing biodiversity objectives within the integrating framework of an ecosystem approach: • Protecting the best sites for wildlife; • Targeting action on priority species and habitats; • Embedding proper consideration of biodiversity and ecosystem services in all relevant sectors of policy and decision-making; • Engaging people, and encouraging behaviour change; • Developing and interpreting the evidence base; and • Ensuring that the UK plays a proactive role in influencing the development of Multilateral Environmental Agreements, and contributes fully to their domestic delivery.	Emphasises an ecosystem approach to managing biodiversity, and recognises the need to allow for the impacts of climate change within the network of marine protected areas.
Scotland		
Nature Conservation (Scotland) Act 2004[59]	Introduced a 'duty to further the conservation of biodiversity' for all public bodies, and sets out more specific provisions within this including for Sites of Special Scientific Interest. Also states a requirement for the preparation of a Scottish Biodiversity Strategy, to which all public bodies should pay regard. Applies to 12 nm around Scotland and includes protection measures for marine species	Biodiversity protection objectives cover the coast and the immediate offshore environment. Licensing decisions should take account of biodiversity protection objectives.

[58] Conserving Biodiversity the UK Approach (2007) [online] Available at: http://jncc.defra.gov.uk/PDF/UKBAP_ConBio-UKApproach-2007.pdf Accessed on 18 May 2016.
[59] Nature Conservation (Scotland) Act 2004 [online] Available at: http://www.legislation.gov.uk/asp/2004/6/pdfs/asp_20040006_en.pdf Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Scotland's Biodiversity – It's In Your Hands. A strategy for the conservation and enhancement of biodiversity in Scotland (2004)[60]	Sets out Scottish aims relating to biodiversity over 25 year period. Seeks to go beyond a previous emphasis on protecting individual sites to achieve conservation at a broader scale. Aims to halt loss and reverse decline of key species, to raise awareness of biodiversity value at a landscape or ecosystem scale, and to promote knowledge, understanding and involvement amongst people. The Strategy notes the importance and health of Scotland's ecosystems, and summarises key trends.	Licensing decisions should note and aim to support recognised ecosystems and recognise potential impacts on these.
2020 Challenge for Scotland's Biodiversity - A Strategy for the conservation and enhancement of biodiversity in Scotland[61]	The 2020 Challenge for Scotland's Biodiversity is Scotland's response to the Aichi Targets set by the United Nations Convention on Biological Diversity, and the European Union's Biodiversity Strategy for 2020. It is a supplement to the Scotland's Biodiversity: It's in Your Hands (2004). The two documents together comprise the Scottish Biodiversity Strategy. The 2020 Challenge document provides greater detail in some areas, responds to the new international targets, and updates some elements of the 2004 document.	Licensing decisions should help to maintain and enhance marine and coastal biodiversity.
The Marine (Scotland) Act 2010 (the Act) repealed the Conservation of Seals Act 1970 on 31st January 2011	On 31 January 2011, Part 6 of the Marine (Scotland) Act 2010 came into force. Part 6 seeks to balance seal conservation with sustainable fisheries and aquaculture and its introduction means: • It is an offence to kill or injure a seal except under licence or for welfare reasons, outlawing unregulated seal shooting that was permitted under previous legislation; • A number of seal conservation areas around Scotland will begin to be introduced, designed to protect vulnerable, declining common seal populations; and • A new seal licensing system, providing a well regulated and monitored context for seal management in Scotland has been introduced.	Licensing decisions should take into account the particular protection afforded to seals.

[60] Scotland's Biodiversity – It's In Your Hands. A strategy for the conservation and enhancement of biodiversity in Scotland (2004) [online] Available at: http://www.gov.scot/Publications/2004/05/19366/37239 Accessed on 18 May 2016.
[61] 2020 Challenge for Scotland's Biodiversity - A Strategy for the conservation and enhancement of biodiversity in Scotland (2013) [online] Available at: http://www.gov.scot/Publications/2013/06/5538 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
A Strategy for Marine Nature Conservation in Scotland's Seas[62]	The strategy sets out aims and objectives for protecting and, where appropriate, enhancing valuable marine biodiversity in the marine area where Scottish Ministers have devolved responsibility (Scottish territorial waters and the Scottish offshore region). The strategy is designed to facilitate co-operation in pursuit of shared marine objectives in the UK and to meet national and international obligations. These include the achievement of Good Environmental Status under the Marine Strategy Framework Directive (MSFD).	Licensing decisions should help to maintain and enhance marine biodiversity.
Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended)[63]		
River Basin Management Plans for the Scotland and Solway Tweed River Basin Districts 2009 - 2015[64]	Notes the key pressures and their environmental impacts on Scottish water bodies including coastal areas. Key issues affecting coastal areas include diffuse and point source pollution, organic matter and ammonia, faecal pathogens, toxic substances, and loss of intertidal areas. Some of these issues may be exacerbated by climate change. Environmental objectives for coastal waters include improving the status of coastal waters and estuaries, and improving the structure and condition of the bed and shores of coastal water bodies.	The objectives defined by RBMP covering Scotland are of indirect relevance to licensing decisions.
Climatic Factors		
Scotland		

[62] A Strategy for Marine Nature Conservation in Scotland's Seas (2011) [online] Available at: http://www.gov.scot/Topics/marine/marine-environment/Conservationstrategy/marineconstrategy Accessed on 18 May 2016.
[63] Water Environment (Controlled Activities) (Scotland) Regulations 2011 as amended [online] Available at: http://www.legislation.gov.uk/ssi/2011/209/contents/made Accessed on 18 May 2016.
[64] Scotland River Basin Management Plan and Solway Tweed River Basin Management Plan [online] Available at: http://www.sepa.org.uk/water/river_basin_planning.aspx Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Climate Change (Scotland) Act 2009[65]	The Climate Change (Scotland) Act includes a greenhouse gas emissions reduction target of 80% by 2050 and an interim target of 42% by 2020. Proposals include setting of targets for 2050 and interim periods, requirement for annual reporting, and provisions for meeting targets through additional policies and legislation. The targets include emissions from the aviation and shipping sectors.	Licensing decisions should take into account the need to meet emissions targets.
Climate Change Delivery Plan: meeting Scotland's statutory climate change targets (2009)[66]	Sets out the measures required to meet Scotland's targets for climate change mitigation included in the Act (above). Includes commitments to the development of the renewable energy sector, including marine renewables. Also aims to reduce emissions from aviation and shipping. Further reductions could arise from the use of biofuels in shipping and improved energy efficiency measures, but interventions will be required to achieve this. Notes that shipping can be an efficient mode of freight transport, despite the recorded emissions from the sector.	Licensing decisions should take into account the measures required to meet targets for climate change mitigation.
Climate Change Sector Adaptation Action Plan: Marine and Fisheries (2011)[67]	Sets out a number of objectives including raising awareness of climate change to the wider marine stakeholder community (through the Marine Strategy Forum). Also aims to build evidence to support future adaptation action and build further policies that respond to impacts.	Licensing decisions should take into account the need to adapt to the impacts of climate change in the future.

[65] Climate change (Scotland) Act 2009 [online] Available at: http://www.legislation.gov.uk/asp/2009/12/contents Accessed on 18 May 2016.
[66] Scottish Government (2009) Climate Change Delivery Plan [online] Available online: http://www.scotland.gov.uk/Resource/Doc/276273/0082934.pdf Accessed on 18 May 2016.
[67] Scotland's Climate Change Adaptation Framework Marine and Fisheries Sector Action Plan [online] Available at: http://www.scotland.gov.uk/Resource/Doc/175776/0114919.pdf Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Climate Ready Scotland Scottish Climate Change Adaptation Programme (2014)[68]	This is the first Scottish Climate Change Adaptation Programme as required by section 53 of the Climate Change (Scotland) Act 2009. It addresses the impacts identified for Scotland in the UK Climate Change Risk Assessment (CCRA) published under section 56 of the UK Climate Change Act 2008. It sets out Scottish Ministers objectives in relation to adaptation to climate change, their proposals and policies for meeting those objectives, and the period within which those proposals and policies will be introduced. The Programme also sets out the arrangements for wider engagement in meeting those objectives.	Licensing decisions should take into account the commitment to adapt to the impacts of climate change.
Flood Risk Management (Scotland) Act 2009[69]	Includes new measures for sustainable flood risk management. This includes co-ordination and co-operation between relevant organisations, development of flood risk assessment and planning and tools for delivery and enforcement. Applicable to coastal flood protection measures.	Licensing decisions should consider this, particularly as harvesting could have potential impacts on the natural coastal protection afforded by seaweeds and seagrasses.
Cultural Heritage		
International		
UNCLOS 1982 was ratified by the UK in 1997[70]	Article 303 stipulates that 'states have the duty to protect objects of an archaeological and historical nature found at sea and shall co-operate for this purpose' and provides for coastal states to exert a degree of control over the archaeological heritage to 24 nm.	Licensing decisions should support commitments to protect the offshore historic environment.
United Kingdom		
Protection of Wrecks Act 1973[71]	The 1973 Act provides protection for designated wrecks and for the designation of dangerous sites.	Licensing decisions should take into account effects on protected wrecks.

[68] Climate Ready Scotland Scottish Climate Change Adaptation Programme (2014) [online] Available at: http://www.gov.scot/Publications/2014/05/4669 Accessed on 18 May 2016.
[69] Flood Risk Management (Scotland) Act 2009 [online] Available at: http://www.scotland.gov.uk/Topics/Environment/Water/Flooding/FRMAct Accessed on 18 May 2016.
[70] United Nations Convention on the Law of the Sea [online] Available at: http://www.un.org/Depts/los/convention_agreements/texts/unclos/unclos_e.pdf Accessed 18 May 2016.
[71] Protection of Wrecks Act 1973 [online] Available at: http://www.legislation.gov.uk/ukpga/1973/33 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Ancient Monuments and Archaeological Areas Act 1979[72]	Provides for the protection of archaeological heritage, including the scheduling of 'monuments'. The Act, which is administered by Historic Scotland, primarily deals with terrestrial locations but there is provision to designate nautical sites.	Licensing decisions should take into account potential impacts on nautical archaeology as a result of harvesting activities.
Protection of Military Remains Act 1986[73]	Identifies scope for protected places and controlled sites, covering vessels. This reflects the status of these sites as war graves.	Licensing decisions should take into account the protection afforded to these types of sites.
Scotland		
Historic Environment Scotland Act 2014[74]	The Act establishes Historic Environment Scotland (HES) as a new Non Departmental Public Body (NDPB) which will take over the functions of Historic Scotland and the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS). In addition to changes to legislation reflecting HES' role and legal status, the Act changes processes for the designation of sites and buildings (by scheduling and listing) and for scheduled monuments, listed buildings and conservation areas consent. It also creates new rights of appeal against certain HES decisions.	Licensing decisions should take into account the protection afforded to these types of sites.
Our Place In Time - The Historic Environment Strategy for Scotland (2014)[75]	Scotland's first ever Historic Environment Strategy is a high level framework which sets out a 10 year vision for the historic environment. The key outcome is to ensure that the cultural, social, environmental and economic value of Scotland's historic environment continues to make a strong contribution to the wellbeing of the nation and its people. It was developed collaboratively and identified the need for strategic priorities to help align and prioritise sector activity towards a common goal.	Licensing decisions should take account of the aims of protecting the historic environment.

[72] Ancient Monuments and Archaeological Areas Act 1979 [online] Available at: http://www.legislation.gov.uk/ukpga/1979/46 Accessed on 18 May 2016.
[73] Protection of Military Remains Act 1986 [online] Available at: http://www.legislation.gov.uk/uksi/2009/3380/contents/made Accessed on 18 May 2016.
[74] Historic Environment Scotland Act 2014 [online] Available at: http://www.legislation.gov.uk/asp/2014/19/contents/enacted Accessed on 18 May 2016.
[75] Our Place In Time - The Historic Environment Strategy for Scotland (2014) [online] Available at: http://www.gov.scot/Publications/2014/03/8522 Accessed on 18 May 2016.

Plan, Programme or Strategy	Objectives	Implications/ Comments
Crofters (Scotland) Act 1993 (as amended)[76]	The Crofters (Scotland) Act 1993 (as amended) gives crofters access to reasonable use of seaweed under Common Grazings regulations, although rights are not general but attached to particular tenancies.	Licensing decisions will need to take account of the rights of crofters.

[76] Crofters (Scotland) Act 1993 (as amended) [online] Available at: http://www.crofting.scotland.gov.uk/userfiles/file/Act_and_Policy/Crofters-Scotland-Act.pdf Accessed 18 May 2016.

16. Appendix C: Background Information on Seaweeds and Seagrasses

Table C1: Main seaweed and seagrass species found in Scotland

Species Name	Recent Other Species Names	Common Name	General Location on Shore	Growth Cycle/ Seasonal Variability	Nature of Resource
BROWN SEAWEEDS					
Wracks or rockweeds					
Ascophyllum nodosum		Egg wrack / knotted wrack / knobbed wrack	Found in mid eulittoral areas and is generally typical of sheltered shores.	The species is very long lived and has low recruitment. Growth rate is very slow in germlings but increases as the plant ages. During the first year growth takes place at 0.2 cm per year, rising to 1.5 cm per year in the second year. The holdfasts of *Ascophyllum nodosum* are thought to persist for several decades from which new fronds regenerate.	Living
Pelvetia canaliculata		Channel(led) wrack/ sea sprigs	Grows only in upper eulittoral on sheltered shores or in sheltered areas of more exposed shores.	A perennial species; it is at least two years old before it reaches maturity, and has a life span of up to 4 or 5 years, growing 3 to 4 cm per year.	Living
Fucus vesiculosus		Bladder wrack/ rock kelp	Grows mainly in mid eulittoral.	As it can survive in a wide range of exposures, it can grow more than 0.5 cm per week in optimum sheltered summer conditions, eventually reaching sizes of up to 1.5 and 2 metres, and achieve a life span of up to 5 years.	Living

Species Name	**Recent Other Species Names**	**Common Name**	**General Location on Shore**	**Growth Cycle/ Seasonal Variability**	**Nature of Resource**
Fucus serratus		Serrated wrack/ toothed wrack/ saw wrack	Grows mainly on lower eulittoral.	Its growth rate varies considerably depending on environmental conditions, but can range from 4 to 12 cm per year. *Fucus serratus* plants may become detached and lost to winter storms. It lives for 2 to 5 years.	Living
*Fucus spiralis**		Spiral wrack / spiralled wrack	Grows mainly in upper eulittoral in sheltered locations.	It has a life span of 2 to 5 years, and is mature at 2 years. Reproduction usually begins before or during the second year of growth, from the end of winter through spring and into summer.	Living
Himanthalia elongata		Thongweed/ sea spaghetti	Found on open rock platforms mainly on lower eulittoral.	It has a life span of about 18-21 months, and is mature and able to reproduce at 9 months. Usually annual. Reproductive fronds, which are the harvested thong-like part of the plant, grow throughout the winter and spring, before summer reproduction. Plant then falls off rock and disintegrates.	Living
Sargassum muticum		Wireweed	Grows mainly on lower eulittoral.	It has a long life span (3 to 4 years) and high growth rate (10 cm per day).	Living
Kelps					
Saccharina latissima	*Laminaria saccharina*	Sweet kombu/ sugar kelp / Atlantic kombu / sea belt	Found in eulittoral/infralittoral fringe.	Although it is present year-round and is considered a perennial with a life span of 2 to 5 years, the blade dies back in the autumn and winter, and re-grows in the late winter and spring. Maximum growth rates have been measured during the late winter and spring with minimum growth during the late summer and autumn in response to the onset of shorter days. The second season tends to exhibit the most growth.	Living

Species Name	Recent Other Species Names	Common Name	General Location on Shore	Growth Cycle/ Seasonal Variability	Nature of Resource
Laminaria hyperborea		Kelp / oarweed / cuvie / tangle	Found in eulittoral/infralittoral fringe.	It is a long-lived perennial species in contrast to other *Laminaria* species in the upper sublittoral, which have a typical life of about 3 years. In Scotland it has a life span generally of 5 to 7 years, with 12 to 15 year old plants sometimes found. Blade area and stipe length of adults grow rapidly until about 5 years old. In 1-year old *Laminaria hyperborea* plants however, growth mainly occurred in the lamina in order to maximize the area for photosynthesis in the light limited understorey. *Laminaria hyperborea* also follows a distinct seasonal growth pattern. Peak growth occurs during winter to spring/summer (November to June) and stops at the end of summer, although metabolic rate remains high. Each November the new blade starts growing below the old one, leaving a distinct collar between the two; the growth continues until around June. Nutrients from the old blade contribute to the growth of the new blade, and the old blade tissue is shed in the spring and early summer. A completely new frond is formed each year, unlike the other *Laminaria* species.	Living and beach-cast

Species Name	**Recent Other Species Names**	**Common Name**	**General Location on Shore**	**Growth Cycle/ Seasonal Variability**	**Nature of Resource**
Laminaria digitata		Kombu/ Atlantic oarweed / kelp / tangle / sea girdle	Found in eulittoral/infralittoral fringe.	This perennial species lives for 3 to 6 years, and in some cases reached 10 years. *Laminaria digitata* grows more slowly from late summer to January, and then experiences rapid growth from February through July. Growth is from the meristem at the junction between the stipe and the frond, rather than the tips.	Living
Alaria esculenta		Dabberlocks / bladder Locks / edible kelp / honeyware	Found on lower eulittoral in subtidal fringe on wave exposed areas.	Its highest seasonal growth rate can reach 20 - 25 cm per month. It is a perennial which can lives up to 7 years in some locations.	Living
GREEN SEAWEEDS					
Ulva intestinalis	*Enteromorpha intestinalis*	Aonori/ sea greens/ gutweed/ grass kelp	Found throughout the eulittoral but very common on upper shore	This is a summer annual, decaying and forming masses of bleached white fronds towards the end of the season. Its growth rate is about 0.15-0.25 cm/day.	
Ulva lactuca		Sea lettuce	Found throughout the eulittoral but very common on upper shore	It is present year round, but most abundant in summer and autumn.	Living
RED SEAWEEDS					
Chondrus crispus		Carragheen moss / Irish moss	Grows throughout the eulittoral on a variety of surfaces.	This is a perennial seaweed that is present year round. Its fronds typically have a life of two to three years but may live up to six years in sheltered waters. The holdfast is much longer lived and is capable of regenerating new fronds after disturbance.	Living

Species Name	**Recent Other Species Names**	**Common Name**	**General Location on Shore**	**Growth Cycle/ Seasonal Variability**	**Nature of Resource**
Mastocarpus stellatus	*Gigartina stellata*	Often confused with *Chondrus crispus* and also called Carragheen moss / False Irish moss	Grows throughout the eulittoral on a variety of surfaces.	Complex life cycle and a species that takes on many varied morphologies. Recent molecular studies suggest speciation may be taking place (J. Brodie, NaturalHistory Museum, pers. comm.). Not only do the male and female gametophyte individuals exhibit different morphologies, the tetrasporophyte individual is so completely different that it was originally described as a different species.	Living
Palmaria palmata		Dulse	Grows in the lower eulittoral/infralittoral fringe and can be very abundant.	This is a perennial species with new growth every year, whose holdfast could remain for several years.	Living
Osmundea pinnatifida	*Laurencia pinnatifida*	Pepper dulse	Found in a variety of habitats on mid and lower shore may be mingled with mats/turfs.		Living
Porphyra umbilicalis		Purple nori / laver/ tough laver	Generally found in the upper eulittoral.	It has a short lifespan, but because is reproduces quickly it can be found throughout the year.	Living
Porphyra purpurea		Purple laver	Occurs generally in the lower eulittoral in very sheltered areas.	This species occurs throughout the year and is an aseasonal annual.	Living
Maerl					
Lithothamnion glaciale		maerl	Upper infralittoral.	Little is known about growth rates of this species. It is a slow growing species with recorded growth rates of up to 13 microns per day.	Calcified seaweed
Phymatolithon calcareum		maerl	Upper infralittoral.	This seaweed is extremely slow growing, amassing only about 1 to 2 mm of growth per year, but may live to be over 100 years old.	Calcified seaweed

Species Name	Recent Other Species Names	Common Name	General Location on Shore	Growth Cycle/ Seasonal Variability	Nature of Resource
SEA GRASSES					
Zostera marina		Common eelgrass/ seawrack	Grows on lower eulittoral and upper infralittoral.	*Zostera* spp. are perennials but may act as annuals under stressful conditions. Perennial populations show a seasonal changes in leaf growth, the long leaves found in summer are replaced by shorter, slow growing leaves in winter. The growth rates of perennial populations is around 5 m/year. Annual populations may expand at 30 m/year in good conditions.	Living and beach-cast
Zostera noltii		Dwarf eelgrass	Grows mainly in mid eulittoral.	New leaves appear in spring and eelgrass meadows develop over intertidal flats in summer, due to vegetative growth. Leaf growth stops in September/October and leaves are shed although *Zostera noltii* keeps its leaves longer than *Zostera marina* in winter. In the following season, regrowth occurs from the remaining rhizomes. Its growth is rapid with reported growth rates of around 0.2 cm/day (winter minimum) to ca 0.8-0.9 cm/day (summer maximum) in the Mediterranean (with winter temperature of 12 °C and summer maximum temperature of 23.2 °C).	Living and beach-cast

Species Name	Recent Other Species Names	Common Name	General Location on Shore	Growth Cycle/ Seasonal Variability	Nature of Resource
Ruppia spp.		Widgeonweeds / tasselweed	Grows in the upper infralittoral.	Wigeongrass in southwest Canada can germinate and produce mature drupelets in about 2 months whereas, in southern France, other annual plants take as long as 5 months to mature. In climates where spring and autumn growth peaks occur, plants probably grow faster in the spring.	Living and beach-cast

*This probably encompasses three species of wrack, of which *Fucus spiralis* and another species (currently called *Fucus guiryi*) occur in Scotland. These are likely to be ecologically distinct with the real *F. spiralis* occurring in the upper eulittoral and in sheltered places.

Table C2: Key EUNIS habitats and spatial data layers comprising the broad seaweed and seagrass groups

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
Wracks	A1.15	Fucoids in tide-swept conditions	MESH, GeMS
	A1.151	[*Ascophyllum nodosum*], sponges and ascidians on tide-swept mid eulittoral rock	MESH, GeMS
	A1.152	*Fucus serratus*, sponges and ascidians on tide-swept lower eulittoral rock	GeMS
	A1.153	[*Fucus serratus*] with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata	MESH, GeMS
	A1.2	Moderate energy littoral rock	MESH
	A1.21	Barnacles and fucoids on moderately exposed shores	MESH
	A1.2142	[*Fucus serratus*] and under-boulder fauna on exposed to moderately exposed lower eulittoral boulders	MESH
	A1.3	Low energy littoral rock	MESH
	A1.31	Fucoids on sheltered marine shores	MESH
	A1.312	[*Fucus spiralis*] on sheltered upper eulittoral rock	MESH
	A1.313	[*Fucus vesiculosus*] on moderately exposed to sheltered mid eulittoral rock	MESH
	A1.3132	[*Fucus vesiculosus*] on mid eulittoral mixed substrata	MESH
	A1.314	[*Ascophyllum nodosum*] on very sheltered mid eulittoral rock	MESH
	A1.3141	[*Ascophyllum nodosum*] on full salinity mid eulittoral rock	MESH
	A1.3142	[*Ascophyllum nodosum*] on full salinity mid eulittoral mixed substrata	MESH
	A1.32	Fucoids in variable salinity	MESH
	A1.321	[*Pelvetia canaliculata*] on sheltered variable salinity littoral fringe rock	MESH
	A1.324	[*Ascophyllum nodosum*] and [*Fucus vesiculosus*] on variable salinity mid eulittoral rock	MESH
	A1.325	[*Ascophyllum nodosum*] ecad. [*mackaii*] beds on extremely sheltered mid eulittoral mixed substrata	MESH, GeMS
	A1.327	[*Fucus ceranoides*] on reduced salinity eulittoral rock	MESH
	A2.4	Littoral mixed sediments	MESH
	A3.22	Kelp and seaweed communities in tide-swept sheltered conditions	MESH

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A3.3	Atlantic and Mediterranean low energy infralittoral rock	MESH
	A3.34	Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	MESH, GeMS
	A3.341	Mixed fucoids, [*Chorda filum*] and green seaweeds on reduced salinity infralittoral rock	MESH, GeMS
	A3.342	[*Ascophyllum nodosum*] and epiphytic sponges and ascidians on variable salinity infralittoral rock	GeMS
	A3.344	[*Fucus ceranoides*] and [*Enteromorpha*] spp. on low salinity infralittoral rock	MESH, GeMS
Kelps	A1.3	Low energy littoral rock	MESH
	A3.1	Atlantic and Mediterranean high energy infralittoral rock	MESH, EUSeaMap
	A3.11	Kelp with cushion fauna and/or foliose red seaweeds	MESH
	A3.113	[*Laminaria hyperborea*] forest with a faunal cushion (sponges and polyclinids) and foliose red seaweeds on very exposed infralittoral rock	MESH, GeMS
	A3.115	[*Laminaria hyperborea*] with dense foliose red seaweeds on exposed infralittoral rock	MESH, GeMS
	A3.1151	[*Laminaria hyperborea*] forest with dense foliose red seaweeds on exposed upper infralittoral rock	GeMS
	A3.1152	[*Laminaria hyperborea*] park with dense foliose red seaweeds on exposed lower infralittoral rock	MESH, GeMS
	A3.12	Sediment-affected or disturbed kelp and seaweed communities	MESH
	A3.122	[Laminaria saccharina] and/or [Saccorhiza polyschides] on exposed infralittoral rock	MESH
	A3.123	[*Laminaria saccharina*], [*Chorda filum*] and dense red seaweeds on shallow unstable infralittoral boulders and cobbles	MESH
	A3.125	Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock	MESH
	A3.126	[*Halidrys siliquosa*] and mixed kelps on tide-swept infralittoral rock with coarse sediment	MESH, GeMS

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A3.2	Atlantic and Mediterranean moderate energy infralittoral rock	EUSeaMap
	A3.21	Kelp and red seaweeds (moderate energy infralittoral rock)	MESH
	A3.2111	[*Laminaria digitata*] on moderately exposed sublittoral fringe bedrock	MESH
	A3.212	[*Laminaria hyperborea*] on tide-swept, infralittoral rock	MESH, GeMS
	A3.2121	[*Laminaria hyperborea*] forest, foliose red seaweeds and a diverse fauna on tide-swept upper infralittoral rock	MESH, GeMS
	A3.2122	[*Laminaria hyperborea*] park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock	GeMS
	A3.213	[*Laminaria hyperborea*] on tide-swept infralittoral mixed substrata	GeMS
	A3.2131	[*Laminaria hyperborea*] forest and foliose red seaweeds on tide-swept upper infralittoral mixed substrata	MESH, GeMS
	A3.2132	[*Laminaria hyperborea*] park and foliose red seaweeds on tide-swept lower infralittoral mixed substrata	MESH, GeMS
	A3.214	[*Laminaria hyperborea*] and foliose red seaweeds on moderately exposed infralittoral rock	MESH
	A3.2141	[*Laminaria hyperborea*] forest and foliose red seaweeds on moderately exposed upper infralittoral rock	MESH, GeMS
	A3.2142	[*Laminaria hyperborea*] park and foliose red seaweeds on moderately exposed lower infralittoral rock	MESH, GeMS
	A3.2143	Grazed [*Laminaria hyperborea*] forest with coralline crusts on upper infralittoral rock	MESH, GeMS
	A3.2144	Grazed [*Laminaria hyperborea*] park with coralline crusts on lower infralittoral rock	MESH, GeMS
	A3.22	Kelp and seaweed communities in tide-swept sheltered conditions	MESH
	A3.221	[*Laminaria digitata*], ascidians and bryozoans on tide-swept sublittoral fringe rock	MESH, GeMS
	A3.222	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock	MESH, GeMS

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A3.223	Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids	MESH, GeMS
	A3.224	[*Laminaria saccharina*] with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock	MESH
	A3.3	Atlantic and Mediterranean low energy infralittoral rock	MESH
	A3.31	Silted kelp on low energy infralittoral rock with full salinity	MESH, EUSeaMap
	A3.312	Mixed [*Laminaria hyperborea*] and [*Laminaria saccharina*] on sheltered infralittoral rock	MESH
	A3.3121	Mixed [*Laminaria hyperborea*] and [*Laminaria saccharina*] forest on sheltered upper infralittoral rock	MESH
	A3.313	[*Laminaria saccharina*] on very sheltered infralittoral rock	MESH
	A3.3132	[*Laminaria saccharina*] forest on very sheltered upper infralittoral rock	MESH
	A3.314	Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock	MESH
	A3.32	Kelp in variable or reduced salinity	GeMS
	A3.322	[*Laminaria saccharina*] and [*Psammechinus miliaris*] on variable salinity grazed infralittoral rock	MESH, GeMS
	A3.323	*Laminaria saccharina* with *Phyllophora* spp. and filamentous green seaweeds on variable or reduced salinity infralittoral rock	GeMS
	A5.52	Kelp and seaweed communities on sublittoral sediment	MESH
	A5.521	[*Laminaria saccharina*] and red seaweeds on infralittoral sediments	GeMS
	A5.5211	Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles	GeMS
	A5.5212	[*Laminaria saccharina*] and robust red algae on infralittoral gravel and pebble	GeMS
	A5.5213	[*Laminaria saccharina*] and filamentous red algae on infralittoral sand	GeMS
	A5.5214	[*Laminaria saccharina*] with red and brown seaweeds on lower infralittoral muddy mixed sediment	GeMS

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A5.522	[*Laminaria saccharina*] and [*Chorda filum*] on sheltered upper infralittoral muddy sediment	MESH, GeMS
	A5.523	[*Laminaria saccharina*] with [*Psammechinus miliaris*] and/or [*Modiolus modiolus*] on variable salinity infralittoral sediment	GeMS
	A5.524	[*Laminaria saccharina*], [*Gracilaria gracilis*] and brown seaweeds on full salinity infralittoral sediment	GeMS
Green seaweeds	A1.3	Low energy littoral rock	MESH
	A2.1	Littoral coarse sediment	MESH
	A2.4	Littoral mixed sediments	MESH
	A2.8	Features of littoral sediment	MESH
	A2.821	Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata	MESH
	A3.3	Atlantic and Mediterranean low energy infralittoral rock	MESH
	A3.323	[*Laminaria saccharina*] with [*Phyllophora*] spp. and filamentous green seaweeds on variable or reduced salinity infralittoral rock	MESH, GeMS
	A3.34	Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	GeMS
	A3.341	Mixed fucoids, [*Chorda filum*] and green seaweeds on reduced salinity infralittoral rock	MESH, GeMS
	A3.344	[*Fucus ceranoides*] and [*Enteromorpha*] spp. on low salinity infralittoral rock	MESH, GeMS
	A5.528	Filamentous green seaweeds on low salinity infralittoral mixed sediment or rock	MESH
	A5.5343	[*Ruppia maritima*] in reduced salinity infralittoral muddy sand	MESH
Red seaweeds	A1.3	Low energy littoral rock	MESH
	A3.1	Atlantic and Mediterranean high energy infralittoral rock	EUSeaMap
	A3.11	Kelp with cushion fauna and/or foliose red seaweeds	MESH
	A3.2	Atlantic and Mediterranean moderate energy infralittoral rock	EUSeaMap
	A3.21	Kelp and red seaweeds (moderate energy infralittoral rock)	MESH

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A3.2132	[*Laminaria hyperborea*] park and foliose red seaweeds on tide-swept lower infralittoral mixed substrata	GeMS
	A3.222	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock	GeMS
	A3.223	Mixed kelp and red seaweeds on infralittoral boulders, cobbles and gravel in tidal rapids	GeMS
	A3.3	Atlantic and Mediterranean low energy infralittoral rock	MESH
	A3.321	Codium spp. with red seaweeds and sparse *Laminaria saccharina* on shallow, heavily-silted, very sheltered infralittoral rock	GeMS
	A3.33	Mediterranean submerged fucoids, green or red seaweeds on full salinity infralittoral rock	MESH
	A3.34	Submerged fucoids, green or red seaweeds (low salinity infralittoral rock)	MESH, GeMS
	A3.344	[*Fucus ceranoides*] and [*Enteromorpha*] spp. on low salinity infralittoral rock	GeMS
Calcified seaweeds (namely maerl)	A5.51	Maerl beds	MESH, GeMS
	A5.511	[*Phymatolithon calcareum*] maerl beds in infralittoral clean gravel or coarse sand	MESH, GeMS
	A5.5111	[*Phymatolithon calcareum*] maerl beds with red seaweeds in shallow infralittoral clean gravel or coarse sand	MESH
	A5.5112	[*Phymatolithon calcareum*] maerl beds with [*Neopentadactyla mixta*] and other echinoderms in deeper infralittoral clean gravel or coarse sand	MESH
	A5.512	[*Lithothamnion glaciale*] maerl beds in tide-swept variable salinity infralittoral gravel	MESH, GeMS
Seagrasses	A2.61	Seagrass beds on littoral sediments	MESH, GeMS
	A2.6111	[*Zostera noltii*] beds in littoral muddy sand	MESH
	A5.5	Sublittoral macrophyte-dominated sediment	MESH

Broad Group	EUNIS Habitat Codes	EUNIS Habitat Name	Spatial Data Layer Source(s)
	A5.53	Sublittoral seagrass beds	MESH, GeMS
	A5.5331	[*Zostera marina*]/[*angustifolia*] beds on lower shore or infralittoral clean or muddy sand	MESH, GeMS
	A5.5343	[*Ruppia maritima*] in reduced salinity infralittoral muddy sand	MESH, GeMS
Beach-cast seaweeds/ seagrasses	A2.21	Strandline	MESH
	A2.211	Talitrids on the upper shore and strandline	MESH

17. Appendix D: Protected Sites Supporting Sensitive Features

Table D1: SPAs Supporting Bird Features Sensitive to Harvesting Activities

Feature	Site
Cormorant (*Phalacrocorax carbo*), breeding	Calf of Eday
	East Caithness Cliffs
	Forth Islands
	Firth of Forth
	Firth of Tay and Eden Estuary
	Inner Moray Firth
	Upper Solway Flats and Marshes
Eider (*Somateria mollissima*), non-breeding	Firth of Forth
	Firth of Tay and Eden Estuary
	Montrose Basin
	Ythan Estuary, Sands of Forvie and Meikle Loch
Goosander (*Mergus merganser*), non-breeding	Firth of Tay and Eden Estuary
	Inner Moray Firth
Great black-backed gull (*Larus marinus*), breeding	Calf of Eday
	Copinsay
	East Caithness Cliffs
	Hoy
	North Rona and Sula Sgeir
Guillemot (*Uria aalge*), breeding	Ailsa Craig
	Buchan Ness to Collieston Coast
	Calf of Eday
	Canna and Sanday
	Cape Wrath
	Copinsay
	East Caithness Cliffs
	Fair Isle
	Flannan Isles
	Forth Islands
	Foula
	Fowlsheugh
	Handa
	Hermaness, Saxa Vord and Valla Field
	Hoy
	Marwick Head
	Mingulay and Berneray
	North Caithness Cliffs
	North Colonsay and Western Cliffs
	North Rona and Sula Sgeir
	Noss
	Rousay

Feature	Site
	Rum
	Shiant Isles
	St Abb's Head to Fast Castle
	St Kilda
	Sule Skerry and Sule Stack
	Sumburgh Head
	Troup, Pennan and Lion's Heads
	West Westray
Herring gull (*Larus argentatus*), breeding	Ailsa Craig
	Buchan Ness to Collieston Coast
	Canna and Sanday
	East Caithness Cliffs
	Forth Islands
	Fowlsheugh
	St Abb's Head to Fast Castle
	Troup, Pennan and Lion's Heads
Lesser black-backed gull (*Larus fuscus*), breeding	Ailsa Craig
	Forth Islands
Long-tailed duck (*Clangula hyemalis*), non-breeding	Firth of Forth
	Firth of Tay and Eden Estuary
	Moray and Nairn Coast
Mallard (*Anas platyrhynchos*), non-breeding	Firth of Forth
	Upper Solway Flats and Marshes
Puffin (*Fratercula arctica*), breeding	Canna and Sanday
	Cape Wrath
	East Caithness Cliffs
	Fair Isle
	Flannan Isles
	Forth Islands
	Foula
	Hermaness, Saxa Vord and Valla Field
	Hoy
	Mingulay and Berneray
	North Caithness Cliffs
	North Rona and Sula Sgeir
	Noss
	Shiant Isles
	St Kilda
	Sule Skerry and Sule Stack
Razorbill (*Alca torda*), breeding	Cape Wrath
	East Caithness Cliffs
	Fair Isle
	Flannan Isles
	Forth Islands
	Foula
	Fowlsheugh
	Handa
	Mingulay and Berneray
	North Caithness Cliffs

Feature	Site
	North Rona and Sula Sgeir
	Shiant Isles
	St Abb's Head to Fast Castle
	St Kilda
	Troup, Pennan and Lion's Heads
	West Westray
Red-breasted merganser (*Mergus serrator*), non-breeding	Cromarty Firth
	Firth of Forth
	Firth of Tay and Eden Estuary
	Inner Moray Firth
	Moray and Nairn Coast
Red-throated diver (*Gavia stellata*), breeding	Caithness and Sutherland Peatlands
	Foula
	Hermaness, Saxa Vord and Valla Field
	Hoy
	Lewis Peatlands
	Mointeach Scadabhaigh
	Orkney Mainland Moors
	Otterswick and Graveland
	Ronas Hill - North Roe and Tingon
	Rum
Red-throated diver (*Gavia stellata*), non-breeding	Firth of Forth
Scaup (*Aythya marila*), non-breeding	Cromarty Firth
	Firth of Forth
	Inner Moray Firth
	Upper Solway Flats and Marshes
Shag (*Phalacrocorax aristotelis*), breeding	Buchan Ness to Collieston Coast
	Canna and Sanday
	East Caithness Cliffs
	Fair Isle
	Forth Islands
	Foula
	Hermaness, Saxa Vord and Valla Field
	Mingulay and Berneray
	Shiant Isles
	St Abb's Head to Fast Castle
	Sule Skerry and Sule Stack
Teal (*Anas crecca*), non-breeding	Dornoch Firth and Loch Fleet
	Inner Moray Firth
Velvet scoter (*Melanitta fusca*), non-breeding	Firth of Forth
	Firth of Tay and Eden Estuary
	Moray and Nairn Coast
Wigeon (*Anas penelope*), non-breeding	Cromarty Firth
	Dornoch Firth and Loch Fleet
	Firth of Forth

Feature	Site
	Inner Moray Firth
	Montrose Basin
	Moray and Nairn Coast

Table D2: dSPAs Supporting Bird Features Sensitive to Harvesting Activities

Feature	Site
Black-throated diver, non-breeding	West Coast of the Outer Hebrides
Common scoter, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	Solway Firth
	Solway Firth
Eider, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	Pentland Firth and Scapa Flow
	North Orkney
	East Mainland Coast, Shetland
	West Coast of the Outer Hebrides
	Sea of the Hebrides, Coll and Tiree
	Sound of Gigha
Goosander, non-breeding	Solway Firth
Great northern diver, non-breeding	Moray Firth
	Pentland Firth and Scapa Flow
	North Orkney
	East Mainland Coast, Shetland
	West Coast of the Outer Hebrides
	Sea of the Hebrides, Coll and Tiree
	Sound of Gigha
Guillemot, breeding	Pentland Firth and Scapa Flow
Guillemot, non-breeding	Firth of Forth and St Andrew's Bay Complex
Herring gull, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Solway Firth
long-tailed duck , non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	Pentland Firth and Scapa Flow
	North Orkney
	East Mainland Coast,

Feature	Site
	Shetland
	West Coast of the Outer Hebrides
Puffin, breeding	Firth of Forth and St Andrew's Bay Complex
Razorbill, breeding	Firth of Forth and St Andrew's Bay Complex
Red-breasted merganser, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	Pentland Firth and Scapa Flow
	North Orkney
	East Mainland Coast, Shetland
	West Coast of the Outer Hebrides
	Sound of Gigha
Red-throated diver, breeding	Pentland Firth and Scapa Flow
	North Orkney
	East Mainland Coast, Shetland
	Bluemull and Colgrave Sounds
	West Coast of the Outer Hebrides
	Rum
Red-throated diver, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	Solway Firth
Scaup, non-breeding	Moray Firth
Shag, breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
Shag, non-breeding	Moray Firth
	Pentland Firth and Scapa Flow
	North Orkney
Velvet scoter, non-breeding	Firth of Forth and St Andrew's Bay Complex
	Moray Firth
	North Orkney

Table D3: Nature Conservation MPAs Supporting Bird Features Sensitive to Harvesting Activities

Feature	Site
Black guillemot, breeding	Clyde Sea Sill
	East Caithness Cliffs
	Fetlar to Haroldswick
	Monach Isles
	Papa Westray
	Small Isles

Table D4: SSSIs Supporting Bird Features Sensitive to Harvesting Activities

Feature	Site
Cormorant (*Phalacrocorax carbo*), breeding	Abbey Burn Foot to Balcary Point
	Calf of Eday
	Forth Islands
	Mochrum Lochs
	Port o' Warren
	Rosemarkie to Shandwick Coast
	Sanda Islands
	Ulva, Danna and the McCormaig Isles
Cormorant (*Phalacrocorax carbo*), non-breeding	Firth of Forth
	Inner Clyde
	Inner Tay Estuary
	Longman and Castle Stuart Bays
Eider (Somateria mollissima), breeding	Firth of Forth
	Isle of May
	Montrose Basin
	Sands of Forvie and Ythan Estuary
Goosander (*Mergus merganser*), non-breeding	Beauly Firth
	Tayport - Tentsmuir Coast
Great black-backed gull (*Larus marinus*), breeding	Borgue Coast
	Eilean Hoan
	Hoy
	North Rona and Sula Sgeir
	Sanda Islands
Guillemot (*Uria aalge*), breeding	Abbey Burn Foot to Balcary Point
	Berriedale Cliffs
	Bullers of Buchan Coast
	Cape Wrath
	Collieston to Whinnyfold Coast
	Copinsay
	Craig Hammel to Sgaps Geo
	Duncansby Head
	Dunnet Head
	Fair Isle
	Flannan Isles
	Foula
	Fowlsheugh
	Gamrie and Pennan Coast
	Handa Island

Feature	**Site**
	Hermaness
	Hoy
	Isle of May
	Marwick Head
	Mingulay and Berneray
	North Rona and Sula Sgeir
	Noss
	Ramna Stacks and Gruney
	Red Point Coast
	Rousay
	Sanda Islands
	Saxa Vord
	Scare Rocks
	Shiant Islands
	St Abb's Head to Fast Castle
	St Kilda
	Stroma
	Sumburgh Head
	West Colonsay Seabird Cliffs
	West Westray
Herring gull (*Larus argentatus*), breeding	Inchmickery
Lesser black-backed gull (*Larus fuscus*), breeding	Inchmickery
Long-tailed duck (*Clangula hyemalis*), non-breeding	Firth of Forth
	Tayport - Tentsmuir Coast
Mallard (*Anas platyrhynchos*), non-breeding	Firth of Forth
Puffin (*Fratercula arctica*), breeding	Cape Wrath
	Flannan Isles
	Forth Islands
	Foula
	Fowlsheugh
	Gamrie and Pennan Coast
	Hermaness
	Isle of May
	North Rona and Sula Sgeir
	Sanda Islands
	Shiant Islands
	St Kilda
	Staffa
	Sule Skerry
	Sumburgh Head
	Whiting Ness - Ethie Haven
Razorbill (*Alca torda*), breeding	Abbey Burn Foot to Balcary Point
	Berriedale Cliffs

Feature	Site
	Cape Wrath
	Collieston to Whinnyfold Coast
	Craig Hammel to Sgaps Geo
	Fair Isle
	Flannan Isles
	Foula
	Fowlsheugh
	Gamrie and Pennan Coast
	Handa Island
	Mingulay and Berneray
	Mull of Galloway
	North Rona and Sula Sgeir
	Sanda Islands
	Shiant Islands
	St Kilda
	West Colonsay Seabird Cliffs
	West Westray
Red-breasted merganser (*Mergus serrator*), non-breeding	Beauly Firth
	Cromarty Firth
	Eden Estuary
	Firth of Forth
	Inner Clyde
	Longman and Castle Stuart Bays
	Tayport - Tentsmuir Coast
Red-throated diver (*Gavia stellata*), breeding	Graveland
	Hoy
	Mill Loch
	Mointeach Scadabhaigh
	Otterswick
	Ronas Hill - North Roe
	Tingon
	Valla Field
	West Mainland Moorlands
Red-throated diver (*Gavia stellata*), non-breeding	Firth of Forth
	Inner Clyde
Scaup (*Aythya marila*), non-breeding	Eden Estuary
	Firth of Forth
	Upper Solway Flats and Marshes
Shag (Phalacrocorax aristotelis), breeding	Berriedale Cliffs
	Bullers of Buchan Coast
	Canna and Sanday
	Fair Isle

Feature	Site
	Foula
	Inchmickery
	Isle of May
	Sanda Islands
	Scare Rocks
	Shiant Islands
	Staffa
	Sule Skerry
	Sumburgh Head
	Ulva, Danna and the McCormaig Isles
	Whiting Ness - Ethie Haven
Velvet scoter (*Melanitta fusca*), non-breeding	Eden Estuary
	Firth of Forth
Wigeon (*Anas penelope*), non-breeding	Cromarty Firth
	Dornoch Firth
	Firth of Forth
	Longman and Castle Stuart Bays
	Montrose Basin
	Munlochy Bay

Table D5: Designated sites with ornithological interests dependent on cast seaweed and/or intertidal seaweed beds

Site	Council Area	
Internationally important		
South Uist Machair & Lochs SPA (and SSSI)	Comhairle nan Eilean Siar (Western Isles)	ringed plover
North Uist Machair & Islands SPA (and SSSI)		purple sandpiper ringed plover ruddy turnstone
East Sanday Coast SPA	Orkney Islands	
Sleibhtahn agus Cladadh Thiriodh (Tiree Wetlands & Coast) SPA and SSSI	Tiree, Argyll & Bute	ringed plover ruddy turnstone
Nationally important[77]		
Isle of May SSSI	Fife	purple sandpiper ruddy turnstone
Papa Stour SSSI	Shetland Islands	ringed plover
Rosehearty to Fraserburgh Coast SSSI	Aberdeenshire	purple sandpiper ruddy turnstone
Whiting Ness to Ethie SSSI	Angus	purple sandpiper ruddy turnstone

[77] These SSSIs are in addition to the SSSIs that underpin the identified SPAs.

Table D6: SACs Supporting Marine Mammal Features Sensitive to Harvesting Activities

Feature	**Site**
Harbour seal (*Phoca vitulina*)	Ascrib, Isay and Dunvegan
	Dornoch Firth and Morrich More
	Eileanan agus Sgeiran Lios mor
	Firth of Tay and Eden Estuary
	Mousa
	Sanday
	South-East Islay Skerries
	Yell Sound Coast
Grey seal (*Halichoerus grypus)*	Faray and Holm of Faray
	Isle of May
	Monach Islands
	North Rona
	Treshnish Isles
Otter (*Lutra lutra*)	Dornoch Firth and Morrich More
	Inverpolly
	Loch nam Madadh
	Rum
	Sunart
	Yell Sound Coast

18. Appendix E: Evidence Base

Table E1: Evidence used to inform risk matrix (Table 12 in the main report)

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
General	ABPmer, 2013. Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 Sites. Reports II, III and V. R. 2070. Report for Marine Institute.	Foster, M.S. and Barilotti, D.C., 1990. An approach to determining the ecological effects of seaweed harvesting: a summary. In Thirteenth International Seaweed Symposium (pp. 15-16). Springer Netherlands.			Lowe, R.J., Koseff, J.R., Monismith, S.G. 2005. Oscillatory flow through submerged canopies: 1. Velocity structure. Journal of Geophysical Research-Oceans 110: 1– 17.	Nellemann *et al*., 2009. Blue Carbon. A Rapid Response Assessment, United Nations Environment Programme, GRID-Arendal.
	Airoldi, L., and Beck, M. W. 2007. Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: an Annual Review,	Jones, L.A., Hiscock, K. and Connor, D.W., (2000). Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation				UK Climate Projections, 2009. UKCP09 scientific reports. Available at: http://ukclimateprojections.metoffice.gov.uk/ [accessed 09/02/2016]

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	45: 345–405.	and management of marine SACs. Joint Nature Conservation Committee, Peterborough.				
	Boney, A.D., 1965. Aspects of the biology of the seaweeds of economic imprtance. Advances in Marine Biology, 3, 105^253.	Wells, E., Wilkinson, M., Wood, P., Scanlan, C., and Best, M. 2007. Water Framework Directive development of classification tools for ecological assessment: Macroalgae Species Richness. Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG) [Online] Available at: http://www.wfduk.org/sites/default/fil				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
		es/Media/Characterisation%20of%20the%20water%20environment/Biological%20Method%20Statements/Intertidal%20Rocky%20Shore%20Macroalgae%20Species%20Richness%20Technical%20Report.pdf [accessed 12/02/16]				
	Centre for Conservation Ecology and Environmental Science (CCEES) and ABPmer, 2010. Description of the ecosystem services provided by broad-scale habitats and features of conservation importance that are likely to be protected by					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Marine Protected Areas in the Marine Conservation Zone Project area. Final Report.					
	Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland, Version 04.05 JNCC.					
	Foster, M.S. and Barilotti, D.C., 1990. An approach to determining the ecological effects of seaweed harvesting: a summary. In Thirteenth					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	International Seaweed Symposium (pp. 15-16). Springer Netherlands.					
	Jones, L.A., Hiscock, K. and Connor, D.W., (2000). Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. Joint Nature Conservation Committee, Peterborough.					
	Lavery, P., Bootle, S. & Vanderklift, M. 1999. Ecological effects of macroalgal harvesting on beaches in the					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Peel-Harvey Estuary, Western Australia. Estuarine, Coastal and Shelf Science, 49: 295–309.					
	Lieberknecht, L.M., Vincent, M.A., and Connor, D.W. 2004. The Irish Sea pilot: Report on the identification of nationally important marine features in the Irish Sea. JNCC Report 347.					
	Norton, T.A., and Powell H.T., 1979. Seaweeds and rocky shores of the Outer Hebrides. Proceedings of the Royal Society of Edinburgh, 77B, 141-153.					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	PlantLink England and PlantLink Cymru undated. Enjoying foraging sustainably. Responsible collection principles.					
	Unsworth, R.K.F and Cullen-Unsworth, L.C. 2015. Pen Llŷn a'r Sarnau Special Area of Conservation (SAC) Porthdinllaen Seagrass Project: A review of current knowledge					
	Wilkinson, M. and Wood, P., 2003. Type-specific reference conditions for macroalgae and angiosperms in Scottish transitional and					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	coastal waters. Final report - 2003. SEPA project reference 230/4136 157pp.					
Wracks	Environment and Resource Technology Ltd. (ERT) Undated. Littoral seaweed resource assessment and management in the Western Isles. Condensed from the report produced by Environment and Resource Technology Ltd for the Minch Project. [Online] Available at: http://www.cne-siar.gov.uk/minch/seaweed/seaweed.htm#TopOfPage [Accessed 24/5/16]	Boaden, P.J. and Dring, M.J. 1980. A quantitative evaluation of the effects of Ascophyllum harvesting on the littoral ecosystem. Helgoländer Meeresuntersuchungen 33: 700-710.				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Holt, T.J., Hartnoll, R.G. and Hawkins, S.J. 1997. The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, Zostera beds and Sabellaria spinulosa reefs. English Nature, Peterborough.	Jackson. A., 2008. Fucus serratus Toothed wrack. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1326 [accessed on 23/02/2016]				
	Fernández, Á., Arenas, F., Trilla, A., Rodríguez, S., Rueda, L. & Martínez, B., 2015. Additive effects of emersion	Jenkins, S.R., Norton, T.A. and Hawkins, S.J. 2004. Long term effects of Ascophyllum nodosum canopy removal on mid				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	stressors on the ecophysiological performance of two intertidal seaweeds. Marine Ecology Progress Series,536: 135-147.	shore community structure. Journal of the Marine Biological Association of the United Kingdom 84: 327-329.				
	Guiry, M.,D., 1997. Went Memorial Lecture 1996. Research and development of a sustainable Irish seaweed industry. Occasional Papers in Irish Science and Technology Royal Dublin Society No 14:1–11.	Kelly, L., Collier, L., Costello, M. J., Diver, M., McGarvey, S., Kraan, S., Morrissey, J. & Guiry, M. D. 2001. Impact Assessment of Hand and Mechanical Harvesting of Ascophyllum nodosum on Regeneration and Biodiversity. Marine Resource Series, Marine Institute				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Hill, J.M. and White, N. 2008. Ascophyllum nodosum. Knotted wrack. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 11/02/2016]. Available from: http://www.marlin.ac.uk/species/detail/1336	McLaughlin, E., Kelly, J., Birkett, D., Maggs, C. and Dring, M. 2006. Assessment of the Effects of Commercial Seaweed Harvesting on Intertidal and Subtidal Ecology in Northern Ireland. Environment and Heritage Service Research and Development Series. No. 06/26.				
	Jackson. A., 2008. Fucus serratus Toothed wrack. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1326 [accessed on 23/02/2016]					
	Kelly, L., Collier, L., Costello, M. J., Diver, M., McGarvey, S., Kraan, S., Morrissey, J. & Guiry, M. D. 2001. Impact Assessment of Hand and Mechanical Harvesting of Ascophyllum nodosum on Regeneration and Biodiversity.					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Marine Resource Series, Marine Institute					
	Knight, M. and Parke, M., 1950. A biological study of Fucus vesiculosus L. and Fucus serratus L. Journal of the Marine Biological Association of the United Kingdom, 29, 439-514.					
	Mclachlan, J. and Bidwell, R. G. 1978. Photosynthesis of eggs, sperm, zygotes and embryos of Fucus serratus. Can. J. Bot., 56: 371-373.					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	McLaughlin, E., Kelly, J., Birkett, D., Maggs, C. and Dring, M. 2006. Assessment of the Effects of Commercial Seaweed Harvesting on Intertidal and Subtidal Ecology in Northern Ireland. Environment and Heritage Service Research and Development Series. No. 06/26.					
	Tyler, P., 1994. Ascophyllum harvesting in the Outer Hebrides. Unpublished MSc Thesis, Heriot-Watt University.					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	White, N. 2008a. Pelvetia canaliculata Channelled wrack. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. . [cited 11/02/16] Available from: http://www.marlin.ac.uk/species/detail/1342					
	White, N. 2008b. Fucus spiralis Spiral wrack. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 11/02/16] Available from: http://www.marlin.ac.uk/species/detail/1337					
	White, N. 2008c. Fucus vesiculosus Bladder wrack. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 11/02/16] Available from:					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	http://www.marlin.ac.uk/species/detail/1330					
Kelps	Amsler, C. D. and Neushul, M. 1991. Photosynthetic physiology and chemical composition of spores of the Kelps Macrocystis pyrifera, Nereocystis luetkeana, *Laminaria* farlowii and Pterogophora californica. J. Phycol. 27: 26-34.	Birkett, D.A., Maggs, C.A., Dring, M.J., Boaden, P.J.S. and Seed, R. 1998. Infralittoral Reef Biotopes with Kelp Species (volume VII). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. Scottish Association of Marine Science (UK Marine SACs Project). 174p.	Bernstein, B.B., Williams B.E. & Mann, K.H. 1981. The role of behavioural responses to predators in modifying sea urchins (Strongylocentrotus droebachiensis) destructive grazing and seasonal foraging patterns. Marine Biology, 63: 39-49.	Dayton P. K. 1985. Ecology of kelp communities. Annual Review of Ecology and Systematics, 16: 215-245.	Angus, S. 2012. Ecosystem services provided by tangle *Laminaria* hyperborea on the west coast of the Uists, Outer Hebrides. CoastAdapt. Inverness: Scottish Natural Heritage.	Bellamy, D. J., John, D. M. and Whittick, A. 1968. The “kelp forest ecosystem” as a “phytometer” in the study of pollution of the inshore environment. Underwater Association Report 79-82.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Bekkby, T. and Moy, F.E. 2011. Developing spatial models of sugar kelp (Saccharina latissima) potential distribution under natural conditions and areas of its disappearance in Skagerrak. Estuarine, Coastal and Shelf Science, 95: 477-483.	Blight, A. J. & Thompson, R. C. 2008. Epibiont species richness varies between holdfasts of a northern and a southerly distributed kelp species. Journal of the Marine Biological Association of the United Kingdom, 88: 469-475.	Christie, H., S. Fredriksen, and E. Rinde. 1998. Regrowth of kelp and colonization of epiphyte and fauna community after kelp trawling at the coast of Norway. Hydrobiologia 375–376:49–58.	Duggins, D.O., Simenstad, C.A. and Estes, J.A. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science, 245, 170-173.	Angus, S. and Rennie, A., 2014. An Ataireachd Aird: The storm of January 2005 in the Uists, Scotland. Ocean & Coastal Management, 94, pp.22-29.	Burrows, M.T., Kamenos, N.A., Hughes, D.J., Stahl, H., Howe, J.A. and Tett, P., 2014. Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment. Review, 17, 101-161.
	CDFG E.I.R. 2001. Calif.Dept.of Fish and Game.Final Environmental Document –Giant and Bull Kelp Commercial and Sport Fishing Regulations - Section 30 and 165,Title 14,California	Bodkin, J. L. 1988. Effects of kelp forest removal on associated fish assemblages in central California. Journal of Experimental Marine Biology and Ecology 117:227- 238.	Dugan, J.E., Hubbard, D.M., McCrary, M.D., & Pierson, M.O. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of	Johnston, C.S., Jones, R.G., and Hunt, R.D. 1977. A seasonal carbon budget for *Laminaria*n population in a Scottish sea-loch. Helgolander wiss Meeresrunters. 30, 527 -545	Bellamy, D. J., John, D. M. and Whittick, A. 1968. The "kelp forest ecosystem" as a "phytometer" in the study of pollution of the inshore environment. Underwater Association Report 79-82.	Connell, S. D. and B. D. Russell. 2010. The direct effects of increasing CO_2 and temperature on non-calcifying organisms: increasing the potential for phase shifts in kelp forests. Proc. Biol. Sci.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Code of Regulations (Eds. Larson and Mc Peak).		southern California. Estuarine, Coastal and Shelf Science 58:25–40			277:1409–1415.
	Chapman, A. R. O. 1984. Reproduction, recruitment and mortality in two species of *Laminaria* in South West of Nova Scotia. Journal of Experimental Marine Biology & Ecology, 78: 99-109.	Bodvin, T., Steen, H. and Moy, F., 2014b. Effekter av tarehøsting på fisk og skalldyr i Vikna, Nord-Trøndelag 2013.	Jones, N.S. and Kain, J.M., 1967. Subtidal algal recolonisation following removal of Echinus.Helgol ander Wissenschaftliche Meeresuntersuch ungen, 15, 460-466.	Jones, N.S. and Kain, J.M., 1967. Subtidal algal recolonisation following removal of Echinus.Helgol ander Wissenschaftliche Meeresuntersuch ungen, 15, 460-466.	Bouma, T.J., De Vries, M.B., Low, E., Peralta, G., Tánczos, I.C., van de Koppel, J. and Herman, P.M.J., 2005. Trade-offs related to ecosystem engineering: a case study on stiffness of emerging macrophytes. Ecology, 86(8), pp.2187-2199.	Duggins, D.O., Simenstad, C.A. and Estes, J.A. 1989. Magnification of secondary production by kelp detritus in coastal marine ecosystems. Science, 245, 170-173.
	Christie, H., S. Fredriksen, and E. Rinde. 1998. Regrowth of kelp and colonization of epiphyte and fauna community after kelp trawling	Bodvin, T., Steen, H., Hansen, H.Ø., Sannæs, H., Bosgraaf, S. and Moy, F., 2014a. Effekter av tarehøsting på fisk og skalldyr,	Mann, K. H. 1977. Destruction of kelp-beds by sea urchins: a cyclical phenomenon or irreversible degradation? Helgoland wiss	Kirkman, H., and Kendrick, G.A., 1997. Ecological significant and commercial harvesting of drifting and beach-cast	Dugan, J.E., Hubbard, D.M., 2010. Loss of coastal strand habitat in southern California: the role of beach	Hill, R., Bellgrove, A., Macreadie, P.I., Petrou, K., Beardall, J., Steven, A. and Ralph, P.J., 2015. Can macroalgae contribute to blue

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	at the coast of Norway. Hydrobiologia 375–376:49–58.	Flatanger 2014.	Meeresunters 30:455–467.	macro-algae and seagrasses in Australia: a review. Journal of Applied Phycology. 9: 311 - 326	grooming. Estuaries and Coasts 33 (1), 67–77.	carbon? An Australian perspective. Limnology and Oceanography, 60(5), pp.1689-1706.
	Dayton P. K. 1985. Ecology of kelp communities. Annual Review of Ecology and Systematics, 16: 215-245.	Burrows, M.T., Smales, D., O'Connor, N., Van Rein, H and Moore, P. 2014. Marine Strategy Framework Directive Indicators for UK Kelp Habitats Part 1: Developing proposals for potential indicators. JNCC Report No. 525. SAMS/MBA/QUB/ UAber for JNCC, JNCC Peterborough.	Norderhaug, K. M., Fredriksen, S. & Nygaard, K. 2003. Trophic importance of *Laminaria* hyperborea to kelp forest consumers and the importance of bacterial degradation to food quality. Marine Ecology Progress Series, 255:135-144	Krumhansl, K.A. and Scheibling, R.E., 2012. Production and fate of kelp detritus. Marine Ecology Progress Series, 467, pp.281-302.	Eckman, J. E., Duggins, D. O., and Sewell, A. T. 1989. Ecology of under storey kelp environments. I. Effects of kelps on flow and particle transport near the bottom. Journal of Experimental Marine Biology and Ecology. 129:173–187.	Koch, M., G. Bowes, C. Ross, and X.-H. Zhang. 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. Glob. Change Biol. 19:103–132.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Edwards, A. 1980. Ecological studies of the kelp, *Laminaria* hyperborea, and its associated fauna in South-West Ireland. Ophelia, 19: 47-60.	Christie, H., Jorgensen, N. M., Norderhaug, K. M. & Waage-Nielsen, E. 2003. Species distribution and habitat exploitation of fauna associated with kelp (*Laminaria* hyperborea) along the Norwegian coast. Journal of the Marine Biological Association of the United Kingdom, 83: 687-699.	Norderhaug, K.M. and Christie, H.C., 2009. Sea urchin grazing and kelp re-vegetation in the NE Atlantic. Marine Biology Research, 5(6), pp.515-528.	Mann, K. H. 1972. Ecological energetics of the seaweed zone in a marine bay on the Atlantic coast of Canada: I. Zonation and biomass of seaweeds. Mar. Biol. 12:1-10.	Gaylord, B., Rosman, J.H., Reed, D.C., Koseff, J.R., Fram, J., MacIntyre, S., Arkema, K., McDonald, C., Brzezinski, M.A., Largier, J.L. and Monismith, S.G., 2007. Spatial patterns of flow and their modification within and around a giant kelp forest. Limnology and Oceanography, 52(5), pp.1838-1852.	Krumhansl, K.A. and Scheibling, R.E., 2012. Production and fate of kelp detritus. Marine Ecology Progress Series, 467, pp.281-302.
	Frederiksen, S., Sjoetun, K., Lein, T. E. & Rueness, J. 1995. Spore dispersal in *Laminaria* hyperborea (Phaeophyceae).	Dugan, J.E., Hubbard, D.M., McCrary, M.D., & Pierson, M.O. 2003. The response of macrofauna communities and	Orr, K.K. 2013. Predicting the ecosystem effects of harvesting beach-cast kelp for biofuel. PhD thesis. University of Aberdeen.	Mann, K. H. 1982. Ecology of coastal waters: a systems approach: University of California Pr.	Løvås, S.M. and Tørum, A., 2001. Effect of the kelp *Laminaria* hyperborea upon sand dune erosion and water particle velocities.	Laffoley, D. d. A. and Grimsditch, G. 2009. The management of natural coastal carbon sinks.Gland, Switzerland:

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Sarsia, 80:47-54.	shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science 58:25–40			Coastal Engineering, 44(1), pp.37-63.	IUCN.
	Gunnarson, K., 1991. Populations de *Laminaria* hyperborea et *Laminaria* digitata (Pheophycees) dans la Baie de Breidifjrdur, Islande. Rit Fiskideildar, 12: 1-148.	Edwards, A. 1980. Ecological studies of the kelp, *Laminaria* hyperborea, and its associated fauna in South-West Ireland. Ophelia, 19: 47-60.	Sjøtun, K., Christie, H. and Helge Fosså, J., 2006. The combined effect of canopy shading and sea urchin grazing on recruitment in kelp forest (*Laminaria* hyperborea). Marine Biology Research, 2(01), pp.24-32.	Nybakken, J.W. 2001. Marine Biology: An Ecological Approach. Fifth Edition. Benjamin Cummings. 516pp	Mann, K. H. 1982. Ecology of coastal waters: a systems approach: University of California Pr.	Mann, K. H. 1982. Ecology of coastal waters: a systems approach: University of California Pr.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Hawkins, S. J. & Harkin, E. 1985: Primary canopy removal experiments in algal dominated communities low on the shore and in the shallows subtidal of the Isle of Man. Botanica Marina, XXVIII: 223-230.	Gilburn, A.S. 2012. Mechanical grooming and beach award status are associated with low strandline biodiversity in Scotland. Estuarine, Coastal and Shelf Science 107:81–88	Stamp, T.E. and Hiscock, K. 2015. Grazed *Laminaria* hyperborea forest with coralline crusts on upper infralittoral rock. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/333 [accessed 18.02.16]	Orr, K.K. 2013. Predicting the ecosystem effects of harvesting beach-cast kelp for biofuel. PhD thesis. University of Aberdeen.	Mollison, D., 1983. Wave energy losses in intermediate depths. Applied Ocean Research 5(4): 234-237	Norderhaug, K.M. and Christie, H.C., 2009. Sea urchin grazing and kelp re-vegetation in the NE Atlantic. Marine Biology Research, 5(6), pp.515-528.
	Hill, J.M. 2008. *Laminaria* digitata Oarweed. In Tyler-Walters H. and Hiscock K. (eds) Marine Life	Hawkins, S. J. & Harkin, E. 1985: Primary canopy removal experiments in algal dominated	Vanderklift, M. A. and Wernberg, T. 2008. Detached kelps from distant sources are a food subsidy for	Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. & Hawkins, S.J., 2013. Threats	Mork, M. 1996. The effect of kelp in wave damping. Sarsia 80: 323–327.	Smale, D.A., Burrows, M.T., Evans, A.J., King, N., Sayer, M.D.J., Yunnie, L.E. and Moore, P.J.,

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 11/02/16] Available from: http://www.marlin.ac.uk/species/detail/1386	communities low on the shore and in the shallows subtidal of the Isle of Man. Botanica Marina, XXVIII: 223-230.	sea urchins. Oecologia, 157: 327-335.	and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. Ecol ogy and evolution, 3 (11), 4016-4038.		2016. Linking environmental variables with regional-scale variability in ecological structure and standing stock of carbon within UK kelp forests. Marine Ecology Progress Series 542: 79-95
	Hoffmann, A.J. and Camus, P. 1989. Sinking rates and viability of spores from benthic algae in central Chile. Journal of Experimental Marine Biology and Ecology. 126 (3): 281 – 291.	Juanes, F. 2007. Role of habitat in mediating mortality during the postsettlement transition phase of temperate marine fishes. Journal of Fish Biology, 70: 661–677.	Warner, G.F., 1984. Diving and Marine Biology. The Ecology of the Sublittoral. Cambridge Studies in Modern Biology, no. 3, Cambridge University Press, Cambridge.	Stamp, T.E. and Hiscock, K. 2015. Grazed *Laminaria* hyperborea forest with coralline crusts on upper infralittoral rock. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth:	Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. & Hawkins, S.J., 2013. Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. Ecol ogy and evolution, 3 (11), 4016-4038.	Vasquez, J. 2008. Production, use and fate of Chilean brown seaweeds: re-sources for a sustainable fishery. Journal of Applied Phycology. 20:457–467.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
				Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/333 [accessed 18.02.16]		
	Kain, J. M. 1975. The biology of *Laminaria* hyperborea. VII. Reproduction of the sporophyte. J. Mar. Biol. Ass.UK, 55:567-582.	Orr, K.K. 2013. Predicting the ecosystem effects of harvesting beach-cast kelp for biofuel. PhD thesis. University of Aberdeen.		Vanderklift, M. A. and Wernberg, T. 2008. Detached kelps from distant sources are a food subsidy for sea urchins. Oecologia, 157: 327-335.	Vasquez, J. 2008. Production, use and fate of Chilean brown seaweeds: re-sources for a sustainable fishery. Journal of Applied Phycology. 20:457–467.	Walker, F. T. and Richardson, W. D. 1955. An ecological investigation of *Laminaria* cloustoni edm. (L.hyperborea Fosl.) around Scotland. Journal of Ecology, 43, 26-38.
	Kain, J. M. 1979. A view of the genus *Laminaria*. Oceanography and Marine Biology an Annual Review, 17, 101-161.	Seitz, R. D., Wennhage, H., Bergstro¨m, U., Lipcius, R. N., and Ysebaert, T. 2013. Ecological value of coastal habitats for commercially and ecologically		Vetter, E. W. and Dayton, P. K. 1998. Macrofaunal communities within and adjacent to a detritus-rich submarine canyon system.	Walker, F. T. and Richardson, W. D. 1955. An ecological investigation of *Laminaria* cloustoni edm. (L.hyperborea Fosl.) around Scotland. Journal	

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
		important species. ICES Journal of Marine Science. doi:10.1093/icesjms/fst152.		Deep Sea Research Part II: Topical Studies in Oceanography, 45: 25-54.	of Ecology, 43, 26-38.	
	Kain, J. M., 1964. Aspects of the biology of *Laminaria* hyperborea (L). Survival and growth of gametophytes. J. mar. biol. Ass. UK, 44: 415-433.	Sjøtun, K. and Lorentsen, S-H. 2000. Kelp forest (*Laminaria* hyperborea) as habitat for juvenile gadoids. Poster presented at the 3rd European Phycological Congress, Belfast, North-Ireland, 21-26 July, 2003.				
	Kain, J.M. and Jones, N. S. 1969. The biology of *Laminaria* hyperborea. V. Comparison with early stages of competitors. Journal of the	Steen, H., 2010. Undersøkelser i forbindelse med prøvehøsting av stortare i Nord-Trøndelag 2010.				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Marine Biological Association of the United Kingdom 49: 455-473.					
	Kelly, E. (ed.) 2005. The role of kelp in the marine environment. Irish Wildlife Manuals, No. 17. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland.	Steen, H., Bodvin, T. and Moy, F., 2013. Effekter av tarehøsting på fisk og skalldyr Nord-Trøndelag 2012.				
	Krause-Jensen, D., Carstensen, J. and Dahl, K. 2007. Total and opportunistic algal cover in relation to environmental variables. Marine Pollution Bulletin,55: 114-125	Steen, H., Husa, V., Bodvin, T., Moy, F., Hansen, H.Ø., Sannæs, H. and Bosgraaf, S., 2014. Undersøkelser av stortarehøsting i Nordland i 2014.				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	MacDonald, D.S., Little, M., Eno, N.C. and Hiscock, K. 1996. Disturbance of benthic species by fishing activities: a sensitivity index. Aquatic Conservation: Marine and Freshwater Ecosystems 6(4): 257-268.	Steneck, R.S., Graham, M.H., Bourque, B.J., Corbett, D., Erlandson, J.M., Estes, J.A. and Tegner, M.J., 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental conservation, 29(04), pp.436-459				
	Mann, K. H. 1973. Seaweeds: Their productivity and strategy for growth. Science. 182: 975 - 983	Wilkinson, M., Scanlan, C.M. and Tittley, I. 1987. The attached algal flora of the estuary and Firth of Forth. Proceedings of the Royal Society of Edinburgh 93B: 343-354.				

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Mann, K. H. 1977. Destruction of kelp-beds by sea urchins: a cyclical phenomenon or irreversible degradation? Helgoland wiss Meeresunters 30:455–467.					
	McMath, A., Cooke, A., Jones, M., Emblow, C.S., Wyn, G., Roberts, S., Costello, M.J., Cook, B. and Sides, E.M. 2000. Sensitivity Mapping Of inshore marine biotopes in the southern Irish Sea (SensMap): Final report. Report by the Countryside Council for Wales (CCW), Ecological Consultancy					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Services Ltd (Ecoserve), Dúchas, the Heritage Service.					
	Moore. P. G. 1973. The kelp fauna of north-east Britain. II. Multivariate classification: turbidity as an ecological factor. Journal of Experimental Marine Biology and Ecology. 13: 127 - 163					
	North, W. 1971. Growth of individual fronds of the mature giant kelp, Macroystis. In The Biology of giant kelp beds (Macroystis) in California, edited					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	by W. North. Beihefte zur Nova Hedwigia Heft 32, Verlag von J. Cramer, 123 - 168					
	Pérez, R. 1971. Écologie, croissance et régénération, teneurs en acide alginique de *Laminaria* digitata sur les cotes de la Manche. Revue Travail de Institut des Peches Maritimes, 35:287-346.					
	Scheibling, R.E. and Gagnon, P., 2006. Competitive interactions between the invasive green alga Codium fragile ssp. tomentosoides and native canopy-forming					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	seaweeds in Nova Scotia(Canada). Marine Ecology Progress Series, 325: 1-14.					
	Sjøtun, K., Fredriksen, S., Lein, T.E., Rueness, J. and Sivertsen, K., 1993. Population studies of *Laminaria* hyperborea from its northern range of distribution in Norway. Proceedings of the International Seaweed Symposium, 14: 215-221.					
	Smith, B. D. 1985. Recovery following experimental harvesting of *Laminaria* longicruris and					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Laminaria digitata in South Western of Nova Scotia. Helgolander Meeres Untersuchungen, 39: 83-101					
	Steen, H., Bodvin, T., Moy, F., Sannæs, H. and Hansen, H.Ø., 2015. Undersøkelser av stortarehøsting i Nordland i 2015.					
	Steneck, R.S., Graham, M.H., Bourque, B.J., Corbett, D., Erlandson, J.M., Estes, J.A. and Tegner, M.J., 2002. Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental conservation,					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	29(04), pp.436-459					
	Vea, J. and Ask, E., 2011. Creating a sustainable commercial harvest of *Laminaria* hyperborea, in Norway. Journal of Applied Phycology, 23(3), pp.489-494.					
	Vea, J. and Ask, E., 2011. Creating a sustainable commercial harvest of *Laminaria* hyperborea, in Norway. Journal of Applied Phycology, 23(3), pp.489-494.					
	Waage-Nielsen, E., Christie, H. and Rinde, E.					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	2003. Short-term dispersal of kelp fauna to cleared (kelp-harvested) areas. Hydrobiologia, 503: 77-91					
	Walker, F. T. and Richardson, W. D. 1955. An ecological investigation of *Laminaria* cloustoni edm. (L.hyperborea Fosl.) around Scotland. Journal of Ecology, 43, 26-38.					
	Werner, A. & Kraan, S. 2004. Review of the potential mechanisation of kelp harvesting in Ireland. Marine Resource Series, Marine Institute, Dublin					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	Wilkinson, M. 1995. Information review on the impact of kelp harvesting. Scottish Natural Heritage Review. No.34 (1995)					
	Wilkinson, M., Scanlan, C.M. and Tittley, I. 1987. The attached algal flora of the estuary and Firth of Forth. Proceedings of the Royal Society of Edinburgh 93B: 343-354.					
Green Seaweed s						
Red Seaweed s	Environment and Resource Technology Ltd. (ERT) Undated. Littoral seaweed resource assessment and					

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
	management in the Western Isles. Condensed from the report produced by Environment and Resource Technology Ltd for the Minch Project. [Online] Available at: http://www.cne-siar.gov.uk/minch/seaweed/seaweed.htm#TopOfPage [Accessed 24/5/16]					
Maerl	Adey, W.H. and McKibbin, D.L., 1970. Studies on the maerl species Phymatolithon calcareum (Pallas) nov. comb. and Lithothamnion corallioides (Crouan) in the Ria de Vigo. Botanica Marina,	Hiscock, K., Sewell, J. and Oakley, J. 2005. Marine health check 2005. A report to gauge the health of the UK's sea-life.				Blunden, G., Binns, W.W. and Perks, F., 1975. Commercial collection and utilisation of maerl. Economic Botany, 29(2), pp.141-145.

	Biotope	Ecological Interactions	Food Web Dynamics	Production	Coastal Protection	Carbon Cycling
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Seagrasses	Cooke, A. and McMath, A. 2001. Sensitivity and mapping of inshore marine biotopes in the southern Irish Sea (SensMap): development of a protocol for assessing and mapping the sensitivity of marine species and benthos to maritime	Blanc, A. and Daguzan, J. 1998. Artificial surfaces for cuttlefish eggs (Sepia officianalis L.) in Morbihan Bay, France. Fisheries Research 38, 225-231.	D'Avack, E.A.S., Tyler-Walters, H. & Wilding, C., 2015. Zostera marina/angustifolia beds on lower shore or infralittoral clean or muddy sand. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information	Kirkman, H., and Kendrick, G.A., 1997. Ecological significant and commercial harvesting of drifting and beach-cast macro-algae and seagrasses in Australia: a review. Journal of Applied Phycology. 9: 311 - 326	Bos, A.R., Bouma, T.J., de Kort, G.L.J., van Katwijk, M.M. 2007. Ecosystem engineering by annual intertidal seagrass beds: Sediment accretion and modification. Estuarine Coastal and Shelf Science 74: 344–348.	Borum, J., Wium-Andersen, S. 1980. Biomass and production of epiphytes on eelgrass (Zostera marina L.) in the Oresund, Denmark. Ophelia Suppl 1:57-64

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	D'Avack, E.A.S., Tyler-Walters, H. & Wilding, C., 2015. Zostera marina/angustifolia beds on lower shore or infralittoral clean or muddy sand. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line][last accessed 24.02.16]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/habitat/detail/257	Heck Jnr, K.L., Hays, G. and Orth, R.J., 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. Marine Ecology Progress Series, 253, pp.123-136.	Ganter, B., 2000. Seagrass (Zostera spp.) as food for brent geese (Branta bernicla): an overview. Helgoland Marine Research, 54(2-3), pp.63-70.	Nybakken, J.W. 2001. Marine Biology: An Ecological Approach. Fifth Edition. Benjamin Cummings. 516pp	Christianen, M.J., van Belzen, J., Herman, P.M., van Katwijk, M.M., Lamers, L.P., van Leent, P.J. and Bouma, T.J., 2013. Low-canopy seagrass beds still provide important coastal protection services. PloS one, 8(5), p.e62413.	Burrows, M.T., Kamenos, N.A., Hughes, D.J., Stahl, H., Howe, J.A. and Tett, P., 2014. Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment. Review, 17, 101-161.

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	Giesen, W.B.J.T., Van Katwijk, M.M., Den Hartog, C., 1990. Eelgrass condition and turbidity in the Dutch Wadden Sea. Aquatic Botany 37, 71–85	Reed, B.J. and Hovel, K.A. 2006. Seagrass habitat disturbance: how loss and fragmentation of eelgrass Zostera marina influences epifaunal abundance and diversity. Marine Ecology Progress Series 326:133-143.	Peterken, C.J. and Conacher, C.A. 1997. Seed germination and recolonisation of Zostera capricorni after grazing by dugongs. Aquatic Botany, 59(3), pp.333-340.		Gambi, M.C., Nowell, A.R.M., Jumars, P.A. 1990. Flume observations on flow dynamics in Zostera marina (Eelgrass) beds. Marine Ecology-Progress Series 61: 159–169.	Koch, M., G. Bowes, C. Ross, and X.-H. Zhang. 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. Glob. Change Biol. 19:103–132.
	Han, Q., Bouma, T. J., Brun, G.G., Suykerbuyk, W. and van Katwijk, M.M. 2012. Resilience of Zostera noltii to burial or erosion disturbances. Marine Ecology Progress Series	Seitz, R. D., Wennhage, H., Bergstro¨m, U., Lipcius, R. N., and Ysebaert, T. 2013. Ecological value of coastal habitats for commercially and ecologically important	Preen, A., 1995. Impacts of dugong foraging on seagrass habitats: observational and experimental evidence for cultivation grazing. Marine Ecology Progress		Hemminga, M.A., Nieuwenhuize, J. 1990. Seagrass wrack-induced dune formation on a tropical coast (Banc d'Arguin, Mauritania). Estuarine Coastal and Shelf Science 31:499-502	Mellors, J., Marsh, H., Carruthers, T.J.B., Waycott, M. 2002. Testing the sediment trapping paradigm of seagrass: Do seagrasses influence nutrient status and

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	Hemminga, M.A., and Duarte, C.M. 2000. Seagrass Ecology. Cambridge University Press				Hendriks, I.E., Sintes, T., Bouma, T.J., Duarte, C.M. 2008. Experimental	Wium-Andersen, S., and Borum, J. 1984. Biomass variation and autotrophic production of an

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	Huntington, T.C., Roberts, H., Cousins, N., Pitta, V., Marchesi, N., Sanmamed, A., T. Hunter-Rowe, Fernandes, T.F., Tett, P., McCue, J. and Brockie, N. 2006. Some Aspects of the Environmental Impact of				Koch, E., Ackerman, J., Verduin, J., and Keulen, M.. 2006. Fluid dynamics in seagrass ecology: from molecules to ecosystems. In: Anthony W. D. Larkum RJOaCMD (ed) Seagrasses: Biology, Ecology	

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	Tillin, H.M., Hull, S.C., Tyler-Walters, H. 2010 . Development of a Sensitivity Matrix (pressures-MCZ/MPA features). Report to the Department of Environment, Food and Rural Affairs from ABPMer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. .Defra Contract No. MB0102 Task 3A, Report No. 22.				Orth, R.J., Carruthers, T.J., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S. and Short, F.T., 2006. A global crisis for seagrass ecosystems.Bioscience, 56(12), pp.987-996.	

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	Vonk, J.A., Christianen, M.J. and Stapel, J., 2010. Abundance, edge effect, and seasonality of fauna in mixed-species seagrass meadows in southwest Sulawesi, Indonesia. Marine				Ward, L.G., Kemp, W.M., Boynton, W.R. 1984. The influence of waves and seagrass communities on suspended particulates in an estuarine embayment. Marine Geology	

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	Zieman, J.C., Orth, R., Phillips, R.C., Thayer, G. & Thorhaug, A., 1984. The effects of oil on seagrass ecosystems. In Restoration of habitats impacted by oil spills (ed. J. Cairns & A.L. Buikema Jr.), pp. 37-64. Boston: Butterworth Publ.				Waycott, M., Duarte, C.M., Carruthers, T.J., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R. and Kendrick, G.A., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences, 106(30), pp.12377-12381.	

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Any enquiries regarding this publication should be sent to us at
The Scottish Government
St Andrew's House
Edinburgh
EH1 3DG

ISSN: 2043-7722 ISBN: 978-1-78652-622-9 (web only)

Published by The Scottish Government, November 2016

Produced for The Scottish Government by APS Group Scotland, 21 Tennant Street, Edinburgh EH6 5NA
PPDAS83958 (11/16)