Scottish Wildlife Trust

Natural Capital Assessment of the Orkney Marine Region Area

Final Report

October 2021

RSK ADAS

ADAS GENERAL NOTES

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Executive Summary

E0.1 The Scottish Wildlife Trust commissioned RSK ADAS Ltd (hereinafter ADAS) to undertake a desk-based natural capital assessment of the Orkney Islands Scottish Marine Region to identify the type, location, condition, importance and vulnerabilities of natural capital assets and associated ecosystem services that are of value to the Orkney community and potentially wider communities. The Marine Biological Association, who made up part of the wider consortium team for this project, provided the expert input and marine environment knowledge required to robustly undertake the ecosystem services and condition (sensitivity) assessments. RSK IPG Marine, Caloo Ecological Services, Dr Andrew Want and Dr Nova Mieszkowska also provided valuable contributions to project objectives requiring expertise in climate change, marine environments, seabirds and the Orkney Islands.

E0.2 The primary objectives of the study were to identify:

- The ecosystem services Orkney's marine natural capital assets provide;
- The location of the assets that provide these services;
- Which services are most beneficial to the Orkney community;
- Whether the benefits of these services are felt outside of the Orkney marine region;
- The natural capital assets that are most important for maintaining the ecosystem services;
- The condition of each natural capital asset and whether it is being used/managed sustainably;
- The natural capital assets that are most important for:
  - Environmental health
  - Society
  - Businesses
- The marine natural capital assets that are most valuable in fighting against climate change; and
- The marine natural capital assets that are most vulnerable to climate change.

E0.3 The importance of the natural capital assessment for informing marine spatial planning was also identified by the Trust as an important component of this study.

E0.4 To address the project objectives this study adopted a research approach that incorporated:

- A first stage rapid evidence assessment (REA) aimed at identifying the presence and extent of key habitats and species within the Orkney 12 nautical mile (nm) boundary from critically reviewed literature (Section 2).
- A review of marine planning legislation and associated documentation at a UK, Scottish and Orkney scale to help identify to what extent the existing marine planning approach incorporates natural capital and ecosystem services (Section 3).
- Broadscale habitat assessments using representative ecosystem service scores based on expert judgement and condition assessments for 10 agreed Orkney habitats. These also included assessments of the implications of condition for ecosystem service provision by the 10 habitats (Section 4).
- A review and assessment of climate change impacts on habitats including confidence scores to indicate the strength of the evidence base for impacts (Section 5).
- Three high level case studies designed to provide examples of how natural capital assessments could be used to inform marine planning. The marine natural capital assets selected were chosen because of their well-known ecological, cultural and socio-economic importance to the Orkney community, as well as their distribution across the whole of the Orkney Islands (Section 6).

E0.5 The natural capital assessment and case study evaluations provided in this report should be considered as providing a first stage assessment of ecosystem services by habitats within the Orkney Islands Scottish Marine Region. Ecosystem services and evidence for provision have been identified and compared for a number of habitats, including Priority Marine Features (PMF). The likely condition of these in relation to key seabed disturbing habitats in Orkney has also been evaluated using spatial datasets (as outlined in Section 4 of this report) to map and analyse distribution, sensitivity and intensity.

E0.6 To support the condition assessment the project used the broadscale habitat mapping outputs from UK SeaMap (2016 and 2018). These habitats are typically based on EUNIS classification levels 3 and 4 and are not resolved to the more detailed biological communities described by levels 4-6. This is a drawback, as provisioning services in particular can be species specific (e.g. species targeted by fisheries).

E0.7 Assessments of ecosystem service provision, presence and sensitivity are presented in Appendix 3 of this report. Confidence in the assessments is also provided as a High (3), Medium (2), Low (1) or variable (V) score, indicating our judgement of the strength of the evidence supporting the level of provision of each ecosystem service by each of the 10 habitats.

Evidence and key findings from the Natural Capital Assessment

E0.8 The marine habitats and species of the Orkney Islands currently deliver a range of provisioning, regulating and cultural services (see Table 2-2 in this report). Horse mussel reefs, for example, provide a number of beneficial ecosystem services including the provision of nursery grounds for commercial fisheries species. Sustaining fish populations is a key ecosystem service provided by a number of Orkney habitats, however there is very limited evidence to identify which ecological functions might best support the fish population.

E0.9 Key uncertainties in assessing habitat condition and potential to provide ecosystem services were identified for Orkney. All of these are issues which affect the capacity to manage marine environments and assess natural capital and ecosystem services in most regions and countries and are not specific to Orkney. There was little evidence for the location and extent of habitats, particularly at the level of the biological assemblage and for the level of ecosystem services likely to be provided by the habitats. This is particularly important where the component habitats may vary considerably in terms of the species that are characteristic and may therefore deliver different ecosystem services and vary in their sensitivity to impacts.

E0.10 The broadscale habitat macrophyte, for example, may have maerl beds, seaweed dominated mixed sediments (including kelps such as Laminaria saccharina and filamentous/foliose red and green algae) or seagrass beds present. The kelps may recover very rapidly whereas maerl is very slow growing and is considered a non-renewable resource. The evidence base for ecosystem service provision by habitats in the Orkney marine region varied between different types of service as can be seen in the ecosystem service matrix in Appendix 3 of this report.

E0.11 No direct evidence[1] for condition of species and habitats around Orkney was identified in the project timescale, although national and international reporting obligations to monitor progress towards policy targets (such as the UK Marine Strategy) may include Orkney. However, reviewing these indicators was outside the scope of the current project. It should be noted that the seabed disturbance metric used in the condition assessment is provided through the UK Marine Monitoring and Assessment Strategy and that the NMPi was checked for suitable indicators. Limited monitoring evidence to assess condition has been identified by previous projects (Tillin et al. 2018) as an issue for the coastal and marine environments. A lack of monitoring data is an issue for management of marine habitats and is likely to remain so in the near future, even with improvements and future investment in autonomous platforms and automated data processing.

E0.12 It should be noted that many of the ecosystem services are based on potential evidence, rather than actual evidence that the service is realised in Orkney, as the evidence base specific to Orkney is limited which in turn limits being able to assess the full extent of service provision .

E0.13 More evidence on ecosystem service provision and condition was available for **provisioning services** and there was higher confidence in these. There was stronger evidence for provisioning services as these relate to goods and services with an economic value and associated industries, for example, fisheries and aquaculture, that are managed and regulated.

E0.14 For **cultural services**, there was less information which reflects the inaccessibility of marine habitats and the lack of awareness of these habitats. Most subtidal habitats are visited only by snorkelers and divers and this inaccessibility also reduces public awareness and use so that cultural value is lower compared to terrestrial habitats. Some species, however, may be important to local communities such as species targeted for food or other uses. In Orkney, kelp was assessed as having a strong cultural value which was evidenced and supported by heritage and historical uses.

E0.15 **Intermediate (supporting) services** and services relating to regulation and maintenance are provided by all the assessed habitats. These services are largely derived from ecological processes and functions. While there was little direct evidence for these for Orkney (with the exception of carbon storage and sequestration), information from other examples of these habitats could be used to assess potential delivery.

Recommendations and Considerations

E0.16 To better understand the level of evidence available to support a natural capital approach to regional marine planning we would recommend undertaking a full systematic review of literature. Future natural capital assessments would benefit from a comprehensive systematic review, including the collation and synthesis of data and evidence from both academic and key organisations/agencies involved in marine systems research.

E0.17 Further research, as listed below, should also be considered:

- Exploration of wider UK regulatory hooks and how these have been implemented by practitioners across the UK including the 25 Year Environment Plan, associated lessons learnt and the implementation of key principles and objectives via the Marine Pioneer.
- A review of emerging marine plans across European Member States and associated lessons learned, to help draw on the experiences of others and prove the concept of wider application of a natural capital based marine plan.
- If recommendations of the Feasibility study for a marine natural capital asset index for Scotland are progressed and a Marine NCAI is developed, opportunities to embed the index into Scottish Marine Plans and associated policy drivers should be explored.

E0.18 Protecting and enhancing the marine ecosystem services and habitats identified through the natural capital assessment undertaken as part of this study will be key to ensuring the Orkney marine environment continues to provide vital benefits and

[1] Direct evidence for condition includes information on chemical, biological and ecological parameters.

remains sustainable and viable into the future. The following recommendations and considerations are therefore suggested as potential ways to help achieve this:

- Proposed marine Special Protection Areas (SPAs) be taken forward as classified SPAs engaging closely with Orkney Islands Council, local communities, and businesses. Consideration should be given to how these PMFs can be appropriately protected, managed and enhanced. Any management measures should be informed by an assessment of feature condition, pressures from development and activities and engagement with local stakeholders.
- Where potential adverse interactions have been identified between fishing activities and PMFs, consideration should be given to implementing appropriate fisheries management measures to protect sensitive areas such as biogenic reefs. Fisheries management measures have already been proposed to protect maerl beds from towed bottom-contacting gears in Orkney (The Scottish Government, n.d.).
- As part of future marine planning, consideration should also be given to identifying appropriate fisheries management actions aimed at minimising the impacts that different fishing activities (as discussed in Section 4 of this report) could have on key Orkney natural capital assets and ecosystem services.
- Where protected features are at risk, measures should be taken forward to improve water quality, involving collaboration with fish farms, terrestrial stakeholders and regulating authorities etc. This measure could particularly benefit Scapa Flow's biogenic habitats. The WFD water quality status of Scapa Flow is currently 'good' and the fish farms have not been identified as a significant issue in relation to nutrient enrichment (Orkney Islands Council, 2018).
- Investigating opportunities and potential for environmental and biodiversity net gain in the context of marine environments. While it is acknowledged that marine environments are complex systems and it is not yet clear how environmental or biodiversity net gain could be incorporated into marine planning, there are opportunities that may warrant further investigation. For instance, kelp-restoration practices could promote biodiversity, such as transplanting adult/juvenile kelp from donor sites, out-planting lab-cultured kelp and/or and installation of artificial reefs for kelp recruitment. Though these restoration methods are in their infancy, success has been achieved elsewhere, such as Operation Crayweed in Australia (Layton et al., 2020). These practices both protect ecosystem services provided by kelp and increase the level of provision by greater densities and coverage of kelp. Biogenic habitat restoration is also possible, and has been undertaken elsewhere in the UK, such as horse mussel bed restoration in Strangford Lough - restored by adding scallop shells to the seabed, showing higher benthic invertebrate density following restoration (Lemasson et al., 2020).
- Pelagic habitats provide valuable ecosystem services, therefore their inclusion in future natural capital assessments should be considered. Pelagic habitats have received little attention in the development of marine natural capital frameworks in the UK due to accessibility and extent of suitable data, however these habitats could be defined and assessed according to factors such as stratification, depth and salinity.

E0.19 Consider developing a detailed Orkney Marine Natural Capital Plan aimed at addressing local economic and strategic development needs within the context of the Orkney Islands Regional Marine Plan. A natural capital plan would identify and incorporate key policies and procedures that could support the protection of the identified marine natural capital assets and ecosystem services as well as detailing actions targeted at enhancing the resilience of marine habitats and ecosystem services to climate change, natural hazards and anthropogenic pressures.

E0.20 Participatory approaches that draw upon different value perspectives can be beneficial in promoting a holistic view of natural capital whilst helping to build the evidence base around the links between the generation of services and the associated beneficiaries. Any future natural capital plan or natural capital assessments of the Orkney marine region should look to engage key stakeholders (private, public and community representatives) to support a local place-based approach to marine planning and decision making.

E0.21 Investigate the establishment of a regular monitoring and evaluation process for Orkney marine natural capital. This could be incorporated into the detailed natural capital plan and include an Orkney marine natural capital account. Regular updates against the baseline account would provide ongoing understanding and evidence of the extent and condition of marine natural capital assets and ecosystem services. This process would also help identify key assets that continue to be threatened by anthropogenic pressures and help to develop the evidence base underpinning the targeted actions associated with the monitoring, protection or enhancement strategies outlined in the Orkney Marine Natural Capital Plan.

Contents

1 Introduction

1.1 Background

1.1.1 Marine Systems offer vital ecosystem services which, from an anthropocentric viewpoint, have values that are linked to the productive use of resources by humans (Picone et al., 2017). From a more ecological perspective the flow of ecosystem services from natural capital stocks provide other values that are not necessarily linked to their use by humans but instead to the role they play in supporting multiple species at different scales in the biosphere. Anthropogenic pressures continue to threaten the long-term sustainability and health of marine environments around the world, despite the growing acknowledgement that our natural environment underpins the health and well-being of our economy and the people in it. According to Constanza et al. (1997) marine and coastal environments contributed over 60% of the total economic value generated in the biosphere. However, de Groot et al. (2012) estimated the contribution of marine systems to be around 40%. This decline in value was attributed mainly to the large loss of coral reef area resulting from anthropogenic pressures.

1.1.2 The shifting balance between the value[2] (both monetary and non-monetary) of marine and terrestrial systems in the biosphere is concerning and this, in part, can be attributed to a skewed focus on terrestrial systems research. Marine studies in the ecosystem services and natural capital literature are few (<9% over time) yet the level of human dependence on marine and coastal systems, which has been estimated to approximate to around 75% of the world's population by 2025 (Townsend et al., 2018), is large. There is an urgent need to increase the evidence base, including spatial data, improved assessment techniques and better decision support tools, to enable hidden values to be captured and the complex, multidimensional nature of marine systems, and the interconnected ecosystem processes and services provided by them, to be better understood.

1.1.3 Natural capital assessments which reveal the hidden value of natural assets and the ecosystem services they provide are a robust mechanism by which communities, business and government can gain information on quantity, quality, vulnerabilities (i.e. current pressures and future risks) and physical flows of goods and services generated by natural capital assets. This information is vital for decision making across all levels if the concepts of natural capital and ecosystem services are to progress beyond theory and into the realm of practical tools. However, there is a need to ensure that the progress in different systems (e.g. marine and terrestrial) takes place through balanced research that will ensure the way we value the biosphere is not altered by a lack of adequate, robust evidence.

1.1.4 The concepts of natural capital and ecosystem services have developed significantly over the past decade, gaining traction globally as a robust means of linking the underlying functioning and ecology of ecosystems to multiple benefits enjoyed by society. With the emergence of nationally accepted metrics for assessing the ecosystem services derived from natural capital such as the IUCN Peatland Code, Biodiversity Net Gain Metric 3.0 and the Woodland Code, terrestrial assessments that make use of spatial patterns of land-use/land-cover (LULC) have, since the early 2000s, grown exponentially, not only in the UK but globally (Townsend et.al., 2018). The acceptance of the terminology and philosophy behind natural capital has come a long way since the launch of the Scottish Forum on Natural Capital in 2013 at the inaugural World Forum on Natural Capital. However, while terrestrial assessments continue to grow, aided by recent calls for the mainstreaming of natural capital and ecosystem services into decision making processes, marine assessments and studies, as previously mentioned, have lagged behind (Figure 2-2).

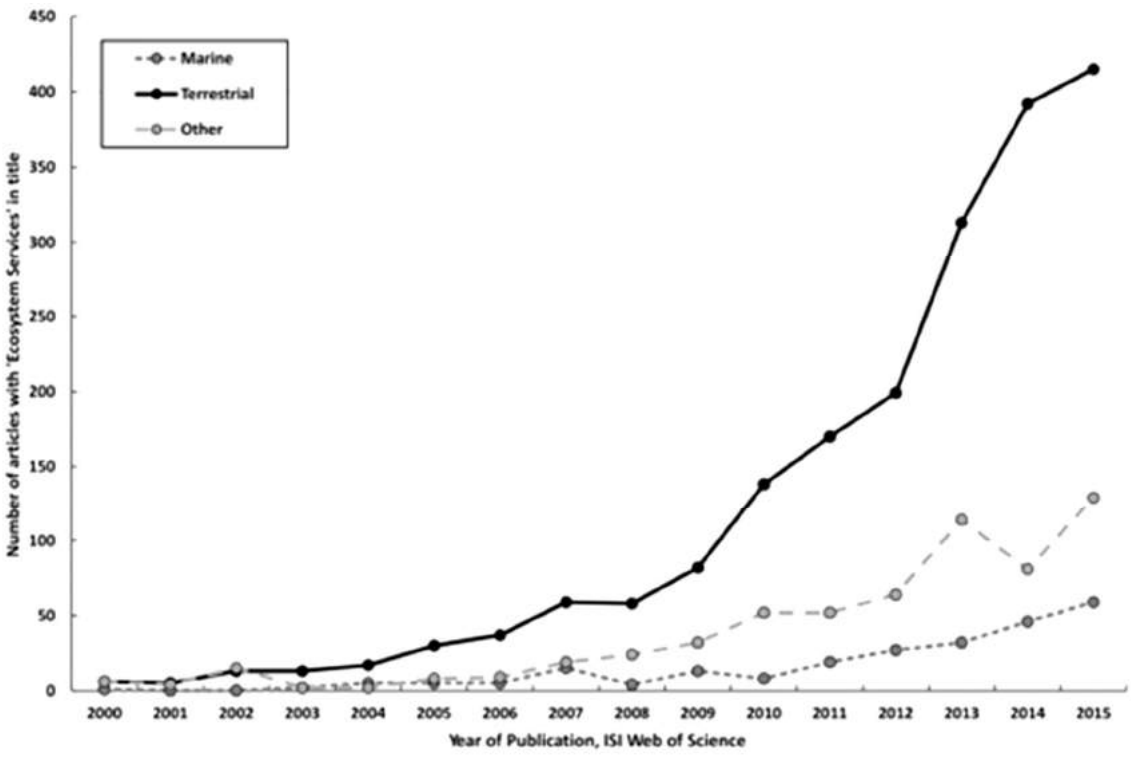

Figure 1-1: Terrestrial versus marine publication occurrences with "ecosystem service" in title. Source: Townsend et al (2018)

[2] It is important to distinguish between 'value' which is an attribute of a good or service and 'valuation' which is the process of quantifying that attribute. Value used here refers to the non-monetary attributes of natural capital and ecosystem services that provide benefits to society beyond those established through traditional markets. These include, for example, existence value, bequest value and indirect use values.

1.1.5 The Scottish Wildlife Trust (the Trust) have acknowledged the growing importance of capturing hidden values in the marine environment through their Oceans of Value (OoV) project. The OoV is looking to compare results from stakeholder engagement using the Community Voice Method to results from a natural capital assessment, utilising the Orkney Islands Scottish Marine Region. This report is concerned with the second part of this comparison; a natural capital assessment of the 'hidden values' provided by the marine area around Orkney.

1.2 Project Objectives

1.2.1 The Trust commissioned RSK ADAS Ltd (hereinafter referred to as ADAS) to undertake a desk-based natural capital assessment of the Orkney Islands Scottish Marine Region to identify the type, location, condition, importance and vulnerabilities of natural capital assets and associated ecosystem services that are of value to the Orkney community and potentially wider communities. The Marine Biological Association, who made up part of the wider consortium team for this project, provided the expert input and marine environment knowledge required to robustly undertake the ecosystem services and condition (sensitivity) assessments. RSK IPG Marine, Caloo Ecological Services, Dr Andrew Want and Dr Nova Mieszkowska also provided valuable contributions to project objectives requiring expertise in climate change, marine environments, seabirds and the Orkney Islands.

1.2.2 The primary objectives of the research were to identify:

- The ecosystem services Orkney's marine natural capital assets provide;
- The location of the assets that provide these services;
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- Whether the benefits of these services are felt outside of the Orkney marine region;
- The natural capital assets that are most important for maintaining the ecosystem services;
- The condition of each natural capital asset and whether it is being used/managed sustainably;
- The natural capital assets that are most important for:
  - Environmental health
  - Society
  - Businesses
- The marine natural capital assets that are most valuable in fighting against climate change; and
- The marine natural capital assets that are most vulnerable to climate change.

1.2.3 The importance of the natural capital assessment for informing marine spatial planning was also identified by the Trust as a key component of this project.

1.3 Marine Planning Framework

1.3.1 The Marine (Scotland) Act 2010 established a statutory marine planning framework for Scotland requiring Scottish Ministers to prepare and adopt a national marine plan for Scotland's marine area. A National Marine Plan for Scotland was adopted by the Scottish Government in 2015 setting out strategic policies for the sustainable use of Scotland's marine resources out to 200 nautical miles. Better management of the competing demands of Scotland's marine resources and associated users was key to the development of the Scottish National Marine Plan (2015). This National Marine Plan provides the wider context for planning within Scotland's Marine waters including what should be considered at a regional and local scale. The Act introduced a new era for the management of Scotland's seas including provision for local stakeholders to prepare statutory regional marine plans at the local level. A regional marine plan is the marine equivalent of a local development plan, containing statutory local policies and spatial plans to guide marine consenting and management decisions. Marine Planning Partnerships are to be established to enable local ownership of policy development and decision making taking account of local circumstances.

1.3.2 The Scottish National Marine Plan will be supported by 11 regional marine plans (RMP). Currently only two RMPs are in advanced stages of development, the Shetland and the Clyde. The regional plans will be led by a number of Marine Planning Partnerships, representing the economic, community, environmental and recreational interests within a local marine region.

1.3.3 The regional plan of relevance to this project is the Orkney Islands Regional Marine Plan developed by Orkney Island Council as part of the Orkney Islands Marine Planning Partnership. The focus area for the natural capital assessment includes Orkney coastal waters primarily bounded by the 12nm (nm) limit including the Loch of Stenness brackish water lagoon (see Figure 1-1). This area encompasses a coastline of approximately 1220 km and a sea area of some 7290 km2 along the Mean High-Water Spring mark, accounting for 8.1% of Scottish territorial waters (Porter et al., 2020).

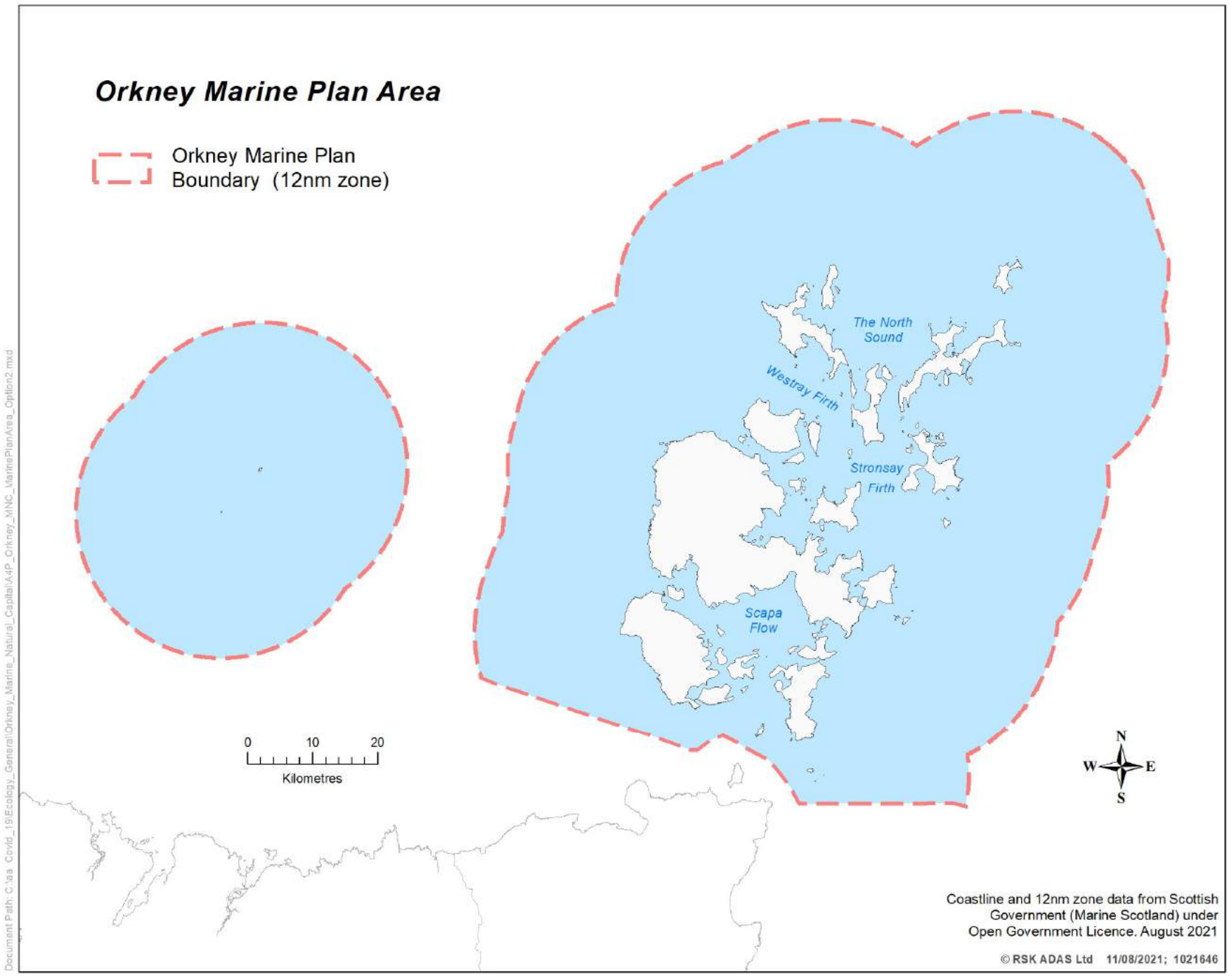


Figure 1-2: Orkney Regional Marine Plan Area bounded by the 12nm limit.

1.4 The Orkney Marine Environment

1.4.1 Orkney has a complex coastline with a diverse range of different geological features and biotopes which are influenced by physical factors including tidal flow regimes and wave exposure and the underlying geology. The North Sea to the east and the Atlantic Ocean to the west meet in the Orkney region producing a wide range of hydrodynamic conditions as large water masses pass through the narrow channels including the Pentland Firth, creating tidal surges and thus affecting tidal heights and times across the region. Major influences include the East Shetland Atlantic Inflow and Fair Isle Current, as described by Turrell et al. (1996).

1.4.2 The natural deep harbour of Scapa Flow also experiences a range of flow regimes from 3ms-1 at Holy Sound to <0.5 ms-1 in the more sheltered embankments. The west coast of Orkney also experiences wave heights of over 18m during storm events due to the 3000km maximum fetch, with reduced exposure in Scapa Flow and between the islands (EMEC, 2019). This gradient of wave exposure is the key component which influences the marine habitat type and extent (Want, 2017). Key geological habitats include bare rock, and a variety of mobile sediments including muds and sands to gravel and boulders. The associated biological habitats include maerl beds, kelp forests, seagrass (*Zostera*) beds, saltmarshes, horse mussel beds, flame shells, brittlestar beds, and bryozoan thickets.

1.5 Natural Capital and Ecosystem Services

1.5.1 **Natural capital** is the stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people that are commonly referred to as ecosystem services. The UK Natural Capital Committee (2017) define **Natural Capital** as:

"the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions."

1.5.2 A **natural capital approach** provides an understanding of these stocks and the natural processes upon which we depend (Figure 1-3). The benefits, services and goods we derive from nature underpin our assets, commerce, well-being and amenity and as such need to be taken into account alongside traditional financial measures and metrics. In Research Report No.1071 - 'Feasibility study for a Marine Natural Capital Asset Index for Scotland' carried out for Scotland Natural Heritage and Marine Scotland by the Marine Biological Association, it was concluded that natural capital condition assessments and the classification for marine natural capital assessments should follow a habitats-based approach, as developed for terrestrial systems, where habitats are the fundamental 'units' around which asset risk registers and accounts are developed.

1.5.3 The natural capital approach explicitly recognises the multiple trade-offs that arise from decisions involving human well-being and the environment. Translating these various effects into common units of value (both monetary and non-monetary) enables an approach to decision making which recognises the key challenges of allocating finite resources for a sustainable future.

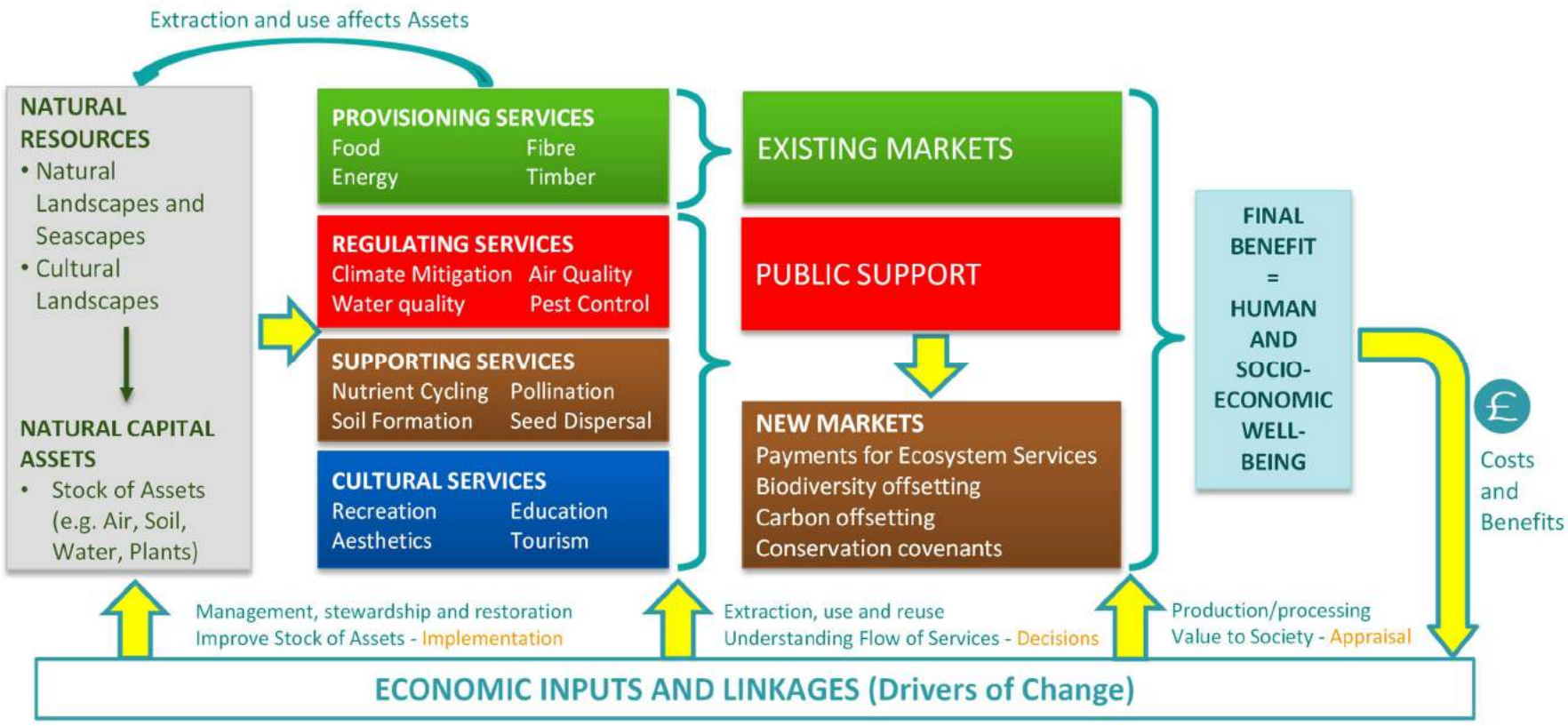


Figure 1-3: The flows and links between natural capital assets, ecosystem services and final benefits. The coloured (green, red, brown and dark blue) boxes show the different ecosystem service classifications and their links to existing or potential ecosystem markets. Examples for each service classification are also provided in the coloured boxes. Adapted from (Office of National Statistics, 2017).

1.5.4 The UK Natural Capital Committee (2017) further define **Ecosystem Services** as:

"functions and products from nature that can be turned into benefits with varying degrees of human input."

Benefits are the changes in human well-being or welfare that result from the consumption or use of goods and services or from knowing something exists. These benefits can be classified as:

- Provisioning services -> create benefits through the provision of products from nature such as food, water and raw materials.
- Regulating Services -> benefits arise through the moderation of natural phenomena, for example, sequestering carbon, removing pollutants from the air, regulating water flows.
- Cultural Services -> non-material, experiential benefits provided through interaction with nature, for example, recreation, tourism or aesthetic experiences.
- Supporting Services[3] -> cross cutting services which underpin the production of all other ecosystem services, for example, soil formation, nutrient cycling, provision of habitat, seed dispersal.

1.5.5 The concepts of natural capital and ecosystem services have developed significantly over the past decade, gaining traction globally as a robust means of linking the underlying functioning and ecology of ecosystems to multiple benefits enjoyed by society. In 2021, the partial asset value of UK marine natural capital assets was £211 billion[4]. In 2018, the natural economy in Scotland contributed £29.1 billion gross value added to the Scottish economy (just over a fifth of its total).

1.5.6 Natural capital and ecosystem markets[5] are now at the forefront of Scottish Government plans for a green post-COVID recovery and featured prominently in the 2020 update of Climate Change Plan 2018-2032, "Securing a Green Recovery on a Path to Net Zero"[6]. However, despite a recent proliferation in ecosystem markets and a rapid growth in demand for ecosystem services from the corporate sector, the ability for communities such as Orkney to benefit directly from these developments remains limited.

[3] Note: throughout this report the term 'intermediate services' is also used to refer to services which sit between the natural capital assets and the final goods and services. Intermediate services relate to ecological function and support final ecosystem services. This follows the terminology provided in Potts et al., (2014).

[4] See Marine Accounts, natural capital, UK: 2021 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/marineaccountsnaturalcapitaluk/2021

[5] Natural capital and ecosystem markets allow trading of property rights for natural resources (renewable and non-renewable) and the goods and services these resources provide. Some ecosystem services are more amenable to trading than others, for example, in a carbon market, carbon credits (which provide the right to emit carbon) are bought and sold. A business who is not able to reduce its own carbon emissions any further, for example, could instead buy credits from a seller who will sequester carbon equivalent to the buyer's emissions.

[6] See Securing a green recovery on a path to net zero https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/

Classifying Ecosystem Services in Marine Environments

1.5.7 Across terrestrial and marine ecosystems, ecosystem services are generally recognised as the flow of goods and services that provide societal benefits that extend beyond agricultural or other commercial value.

1.5.8 Version 5.1 of the Common International Classification of Ecosystem Services (CICES)[7] provides definitions for multiple types of ecosystem services, including those specific to marine environments (Figure 1-3).

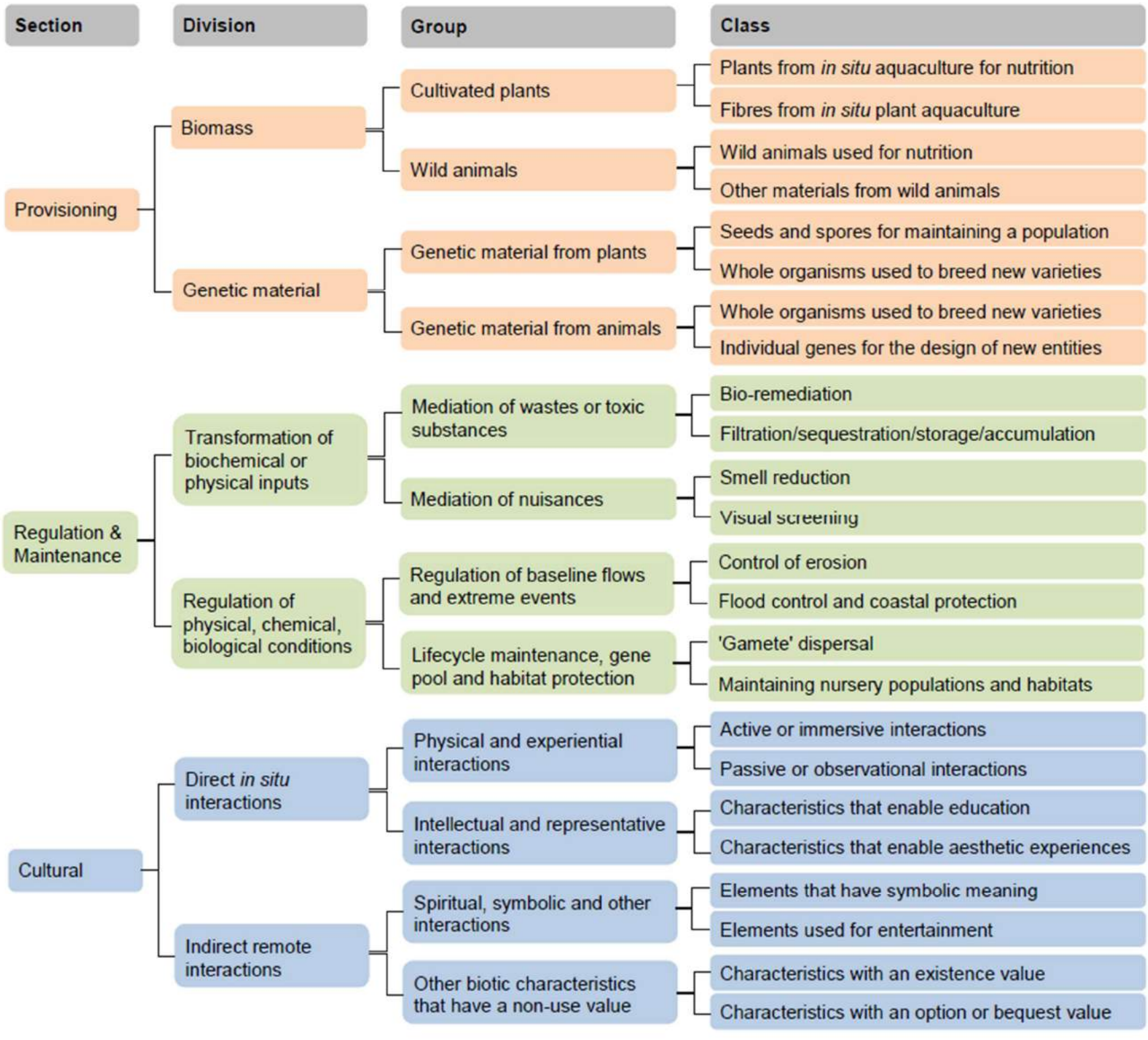


Figure 1-4: Hierarchical structure of marine ecosystem services within the CICES classification. Source: (Hooper, 2019)

1.5.9 The CICES framework has been adopted in this study for the assessment of the ecosystem services delivered by the marine natural capital assets identified in the Orkney Islands Scottish Marine Region (see Section 4 of this report). Table A3-1 in Appendix 3 of this report shows the CICES V5.1 ecosystem service classifications by division, group, class, and class type.

[7] See Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting https://cices.eu/resources/.

2 Rapid Evidence Assessment

2.1 Background and Method

2.1.1 Natural capital assessments are typically context-driven, and their design is influenced by the prevailing social, environmental, economic, and institutional conditions in the study area. The assessment is also often tailored to the specific ecosystem (in this case marine) under consideration. Identifying a strong robust evidence base that supports important marine areas and the ecosystem services they provide is helpful for researchers and practitioners who are involved in marine management and conservation and are interested in better understanding the location, extent and condition of habitats and species.

2.1.2 A Rapid Evidence Assessment (REA) approach of the current thinking, research and evidence on marine natural capital (habitats and species); ecosystem services and the use of spatial data to aid decision making in marine planning was undertaken as the first stage of a Natural Capital Assessment of the Orkney Islands Scottish Marine Region. REA offers a systematic and transparent basis to identify, critically appraise, and synthesise evidence that reduces the potential for bias. The approach uses a structured, step-wise methodology (Figure 2-1), following an a priori protocol to comprehensively collate, critically appraise and synthesise existing research evidence (traditional academic and grey literature[8]) (Collins, 2015; Dicks et al., 2017).

2.1.3 The purpose of the REA was to review and synthesise evaluated evidence on the provision of ecosystem services by marine features within the 12nm boundary surrounding the Orkney Islands. Evidence was identified using key search terms in academic databases including Science Direct, Google Scholar, and Web of Science and by following citations from key primary studies.

2.1.4 Search terms were developed from the key objectives outlined in Section 1.2.1, taking into consideration synonyms, similar concepts and specific terms related to the Orkney marine environment, natural capital and ecosystem services (e.g. seaweed, fisheries, blue carbon, kelp, seabirds, maerl beds etc).

2.1.5 Peer-reviewed and grey literature were included in the first stage search and a trial and error process was followed until search terms were optimised to return the most reliable overview of available evidence. Given the timeframe and resources available for the project the REA was constrained to a maximum of 50 papers, agreed in consultation with the Trust.

2.1.6 The evidence was collated into review summary matrices within an Excel spreadsheet (see Supplementary Material 1 – REA Matrix), supported by accompanying evidence tables to provide clear, fully referenced outputs that provide a transparent and audited information source. Critical appraisal templates were also setup and used in the REA to provide confidence scores for the reliability of evidence.

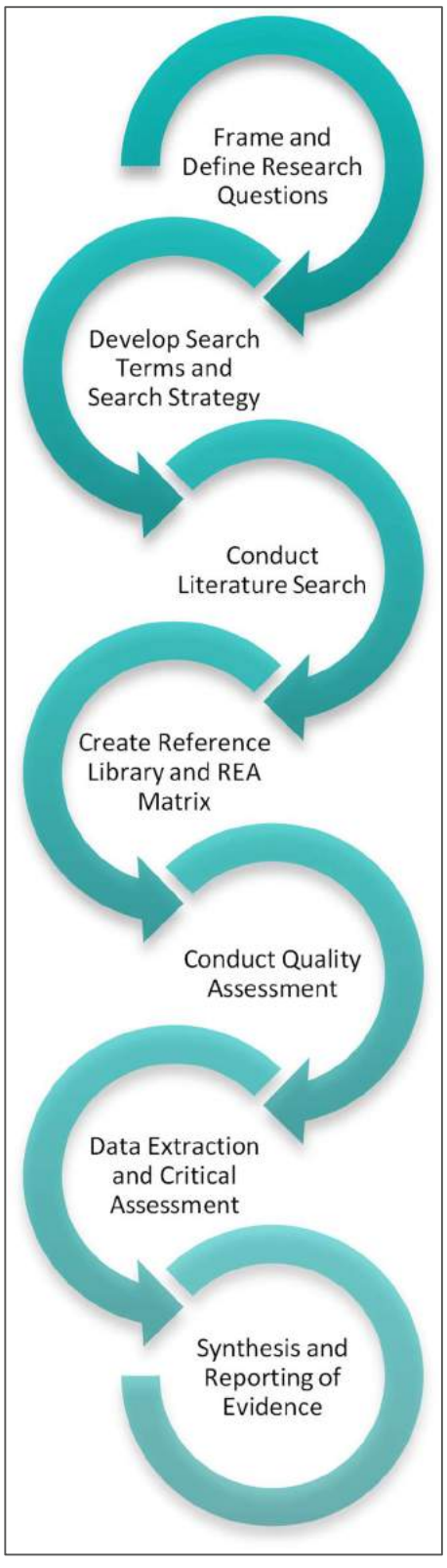


Figure 2-1: REA step-wise process

2.2 Overview of process and evidence

2.2.1 The REA sought to present a fair interpretation of the evidence base, however, as it was not a full systematic review, the evidence was not exhaustive and the number of final papers taken through for critical review was 46, split according to primary and secondary research questions and assessed following the search protocol and criteria detailed in Appendix 1. Due to shorter timeframes the level of data that is able to be extracted and reviewed in an REA is often restricted in comparison to a systematic review which has timeframes extending beyond six months.

2.2.2 The narrative reviews provided in sections 2.2 to 2.5 below are intended to give a snapshot of the evidence relating to certain habitats and species identified in the critically reviewed literature. It is not intended to be a comprehensive review of all habitats and species that may be present in the Orkney marine region or an assessment of the condition or extent of habitats and species.

2.2.3 The literature screening process that was undertaken to arrive at the final number of papers is shown in Figure 2-2. A total of 47,402 studies were identified through the initial database search. The top 200 hits for each individual search term were then assessed based on title, resulting in 1559 studies being identified as suitable. After duplicates were removed 421 studies were taken through to the first phase RAG (Red, Amber, Green) which assessed suitability/relevance based on title, year of publication and study location. After the first phase assessment 89 studies were taken through to the second phase RAG assessment which included a review of abstracts. At the end of the second phase 46 studies were identified as being suitable/relevant to take through to the critical review phase which involved reading and scoring the full study based on the criteria shown in Table A1-3, Appendix 1.

[8] Grey literature refers to research that is either unpublished or has been published in non-commercial form. Examples include government reports, policy statements, conference proceedings etc.

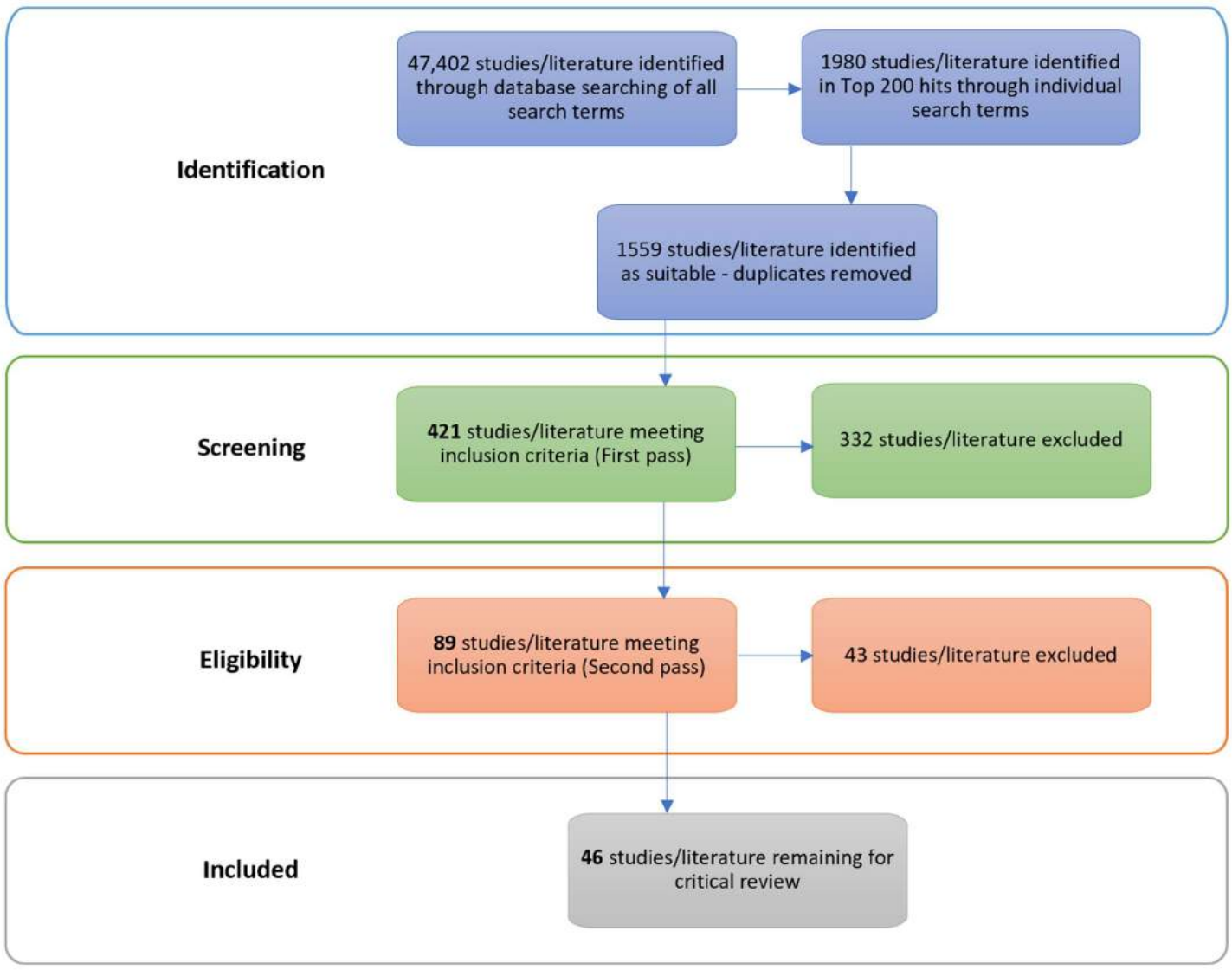


Figure 2-2: Literature screening process flow diagram

2.2.4 The final 46 studies examined in the critical review phase were largely peer-reviewed journal papers (43%) and grey literature government reports (39%). Eighteen papers (41%) were specifically related to the Orkney marine region and a further seventeen (37%) were more widely related to Scotland waters. Table 2-1 provides a breakdown of the literature by country/region and evidence type.

Table 2-1: Overview of study regions by literature type

Country/Region	Type of evidence		
	Journal	Government Report	Working Paper/Other
Orkney	6	10	2
Scotland	7	6	4
Wales	1	0	0
UK	5	2	1
EU/International	2	0	0
Total Studies/Papers Reviewed	**21**	**18**	**7**

2.2.5 Figure 2-3 shows the breakdown of marine features identified in the 46 critically reviewed papers. Seabirds and waterbirds featured strongly in the literature especially in papers specifically related to the Orkney Islands. The search of literature returned only a small number of papers related to marine mammals in the Orkney region (four studies) with only one of these studies including usage maps and spatial data that indicated the extent of seal populations within the 12nm boundary for the Orkney Islands.

2.2.6 Habitats such as Maerl Beds, Kelp and Horse mussel beds featured more prominently in wider geographical (UK, Scotland and Wales) studies. One study was found that related specifically to seagrass (*Zostera marina*) beds in Orkney and nine studies discussed multiple habitats and species. Two of these studies provided spatial data and mapping of extent and presence for specific marine habitats within the 12nm boundary for Orkney. A narrative review of the key habitats and species identified from the REA is provided in sections 2.4 and 2.5.

2.2.7 It should be noted that although the REA search related to marine habitats was focused on biogenic habitats, pelagic habitats also provide valuable ecosystem services. Phytoplankton organisms, for example, are the primary producers in all aquatic ecosystems and they can rapidly adapt to changes in environmental conditions (Durante et al., 2013). Evidence from Scotland's Marine Assessment 2020[9] shows increasing trends in life form abundances of large phytoplankton around Scapa Flow which will play an important role in the plankton community that forms the base of the marine food web.

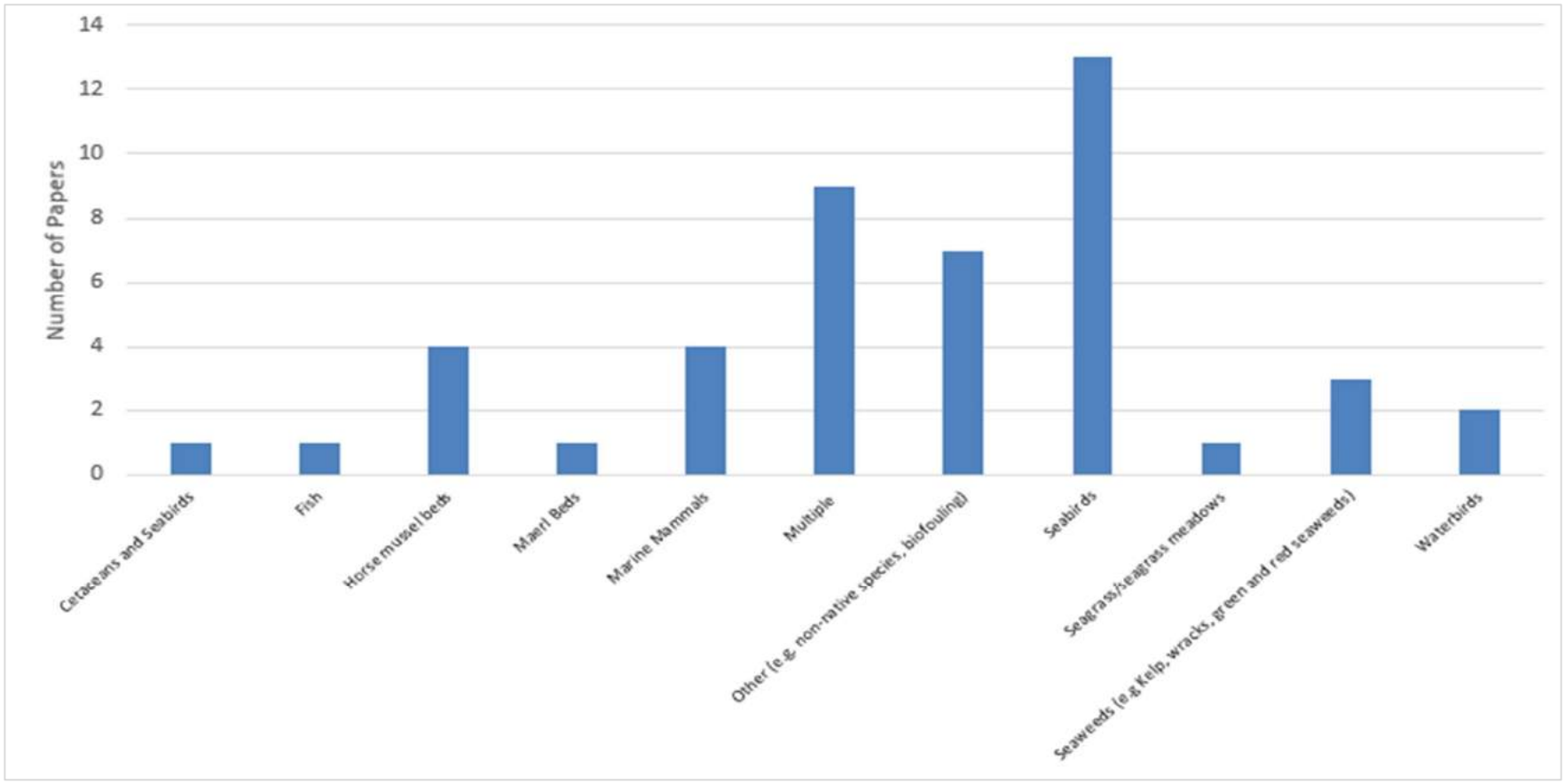


Figure 2-3: Marine features mentioned in the critically reviewed literature (N=46).

2.3 Key Findings

Habitats and Species

2.3.1 Analysis of the literature identified the following **biological habitats** as being present within the 12 nm boundary for the Orkney Islands:

- Circalittoral[10] coarse and mixed sediments[11]
- Circalittoral mud
- Burrowed Mud
- Intertidal boulder communities
- Intertidal mudflats
- Horse mussel beds (*Modiolus modiolus*)
- Brittlestar beds (*Ophiothrix fragilis*)
- Flame shell beds (*Limaria hians*)
- Maerl beds
- Blue mussel beds (*Mytilus edulis*)
- Native Oyster (*Ostrea edulis*)
- Seaweeds (including Kelps, Red, Green and wracks)
- Bryozoan thicket (*Flustra foliacea*)
- Saltmarshes
- Seagrass beds (*Zostera marina*)
- Rock
- Littoral caves and overhangs
- Sublittoral[12] wave surge gullies and caves

2.3.2 The following **species** were also identified in the literature as being present within the 12 nm boundary for the Orkney Islands:

- Black guillemot
- Common scoter (non-breeding)
- Eider (non-breeding)
- Great northern diver (non-breeding)
- Long-tailed duck (non-breeding)
- Black-throated diver (non-breeding)
- Common skate[13]
- Goldeneye (non-breeding)
- Guillemot (breeding)
- Puffin (breeding)
- Velvet scoter (non-breeding)
- Grey Seal (*Halichoerus grypus*)
- Harbour Seal (*Phoca vitulina*)
- Great Skua
- Arctic Skua

[9] See Scotland's Marine Assessment 2020 – Plankton https://marine.gov.scot/sma/assessment/plankton

[10] Circalittoral is the subzone of the rocky sublittoral below that dominated by algae (the infralittoral) which is dominated by animals. See https://www.marlin.ac.uk/glossarydefinition/verticalbiologicalzones for additional biological zone definitions.

[11] Circalittoral coarse and mixed sediments discussed in the literature included gravel, gravelly muddy sand, muddy sand, muddy sandy gravel, slightly gravelly sand, and slightly gravelly muddy sand.

[12] Sublittoral is the zone exposed to air at its upper limit by the lowest spring tides. See https://www.marlin.ac.uk/glossarydefinition/verticalbiologicalzones for additional biological zone definitions.

[13] According to the Orkney Skate Trust, the Common Skate (*Dipturis batis*) is now considered as two separate species, the Blue Skate (*Dipturis batis*) and the Flapper Skate (*Dipturis intermedius*) see: https://www.orkneyskatetrust.co.uk/flapper-skate/

- Red-breasted merganser (non-breeding)
- Shag (breeding)
- Shag (non-breeding)
- Red-throated diver (breeding)
- Scaup (non-breeding)
- Sandeels
- Sea Trout
- Slavonian grebe (non-breeding)
- Ocean quahog (aggregations)

2.3.3 Across the 46 studies reviewed the following key activities and associated pressures on habitats and species were identified (see Tables A1-7 and A1-8, Appendix 1 for detailed matrix of activities and pressures identified in the 46 critically reviewed papers):

Activities (Pressures) on Habitats

- Aquaculture (deposition of fish waste, chemical therapeutants used to treat caged fish, eutrophication)
- Climate Change (rising sea levels and temperatures)
- Energy production (renewable energy installations, shading from construction activities)
- Fishing (mobile fishing gear, dredging, trawling)
- Land-use change (reduced light penetration, sedimentation and siltation)
- Shipping (anchors and moorings)
- Tourism and recreation
- Other (pollution, disease, overgrazing of seaweeds, invasive species)

Activities (Pressures) on Species

- Aquaculture (bycatch, habitat loss/damage)
- Climate Change (ocean acidification, reduced food availability)
- Energy production (displacement, collision, barriers to movement)
- Fishing (bycatch, habitat loss, prey depletion, turbidity, entanglement)
- Land-use change (sedimentation, disturbance)
- Shipping (disturbance, collision)
- Tourism and recreation (disturbance)
- Other (pollution, contamination, predation, competition for food, invasive species)

Ecosystem Services

2.3.4 Table 2-2 highlights the ecosystem services provided by the habitats identified in the literature, classified according to the Common International Classification of Ecosystem Services (CICES)[14].

Table 2-2: CICES classification of ecosystem services identified in critically reviewed literature (Numbers in brackets represent literature identifier as referenced in Table A1-4 in Appendix 1.)

Provisioning		Regulating		Cultural	
CICES Group	**Ecosystem Service**	**CICES Group**	**Ecosystem Service**	**CICES Group**	**Ecosystem Service**
Reared aquatic animals for nutrition, materials or energy	**Biomass production** • Fish and Shellfish (10)	**Mediation of wastes or toxic substances of anthropogenic origin by living processes**	**Nutrient cycling** • Waste breakdown and detoxification of water and sediments • Improving water quality (7,21,22,40)	**Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting**	**Formation of seascape** • Watching/studying nature • Education • Socially valued places/seascapes • Aesthetic benefits • Tourism • Valued species (1,7,9,13,14,18,21,24,27,29, 31,36,38,39,41,43,44,45,46)
Wild plants (terrestrial and aquatic) for nutrition, materials or energy	**Biomass production** • Food supplements (40,42) • Phycocolloids-alginate, agars and carrageenans (40,42)	**Regulation of baseline flows and extreme events**	**Coastal protection and natural hazard protection** • Sediment stabilisation • Alleviating coastal erosion • Flood defence (7,21,22,40)		
Wild animals (terrestrial and aquatic) for nutrition, materials or energy	**Biomass production** • Fish and Shellfish (7,21)	**Lifecycle maintenance, habitat and gene pool protection**	**Formation of species habitat for other species and Larval/gamete supply** • Fish and Shellfish stocks • Protected bird species (7,21,24,29,30,31,40)		

[14] See Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting https://cices.eu/resources/.

Genetic material from plants, algae or fungi	**Formation of habitats for other species and Larval/gamete supply** • Fish and Shellfish stocks (7,21,40)	**Pest and disease control**	• Resilience to INN • Resilience to Disease (4,7)		
		Atmospheric composition and conditions	**Carbon sequestration** • Climate regulation and carbon stores and sinks (2,6,7,21,36,40)		

2.4 Orkney Marine Natural Capital – Habitats

2.4.1 The Orkney Islands marine environment includes a variety of sedimentary and biological habitats that contribute to the provision of a wide range of ecosystem services vital to the Orkney community and its economy. The full extent and presence, however, of some habitats (including carbonate sediments which are formed from the disintegration of benthic organism skeletons such as coralline algae, molluscs, etc.) are still unknown or require further ground truthing to establish additional area estimates (Porter et al., 2020; Burrows et al., 2017).

2.4.2 As stated previously, the purpose of this REA is to provide a snapshot of the available evidence that was identified and reviewed within the timeframe for this component of the project. The findings provide some basis for the Natural Capital Assessment but should not be interpreted as a comprehensive and exhaustive review of the extent and presence of all habitats that could be found within the Orkney Regional Marine Plan area. Table A1-5 in Appendix 1 shows the different habitats identified in the REA along with a RAG (red, amber, green) assessment of our confidence in the extent and presence of the habitats as evidenced in the literature.

2.4.3 Burrows et al. (2017) utilised habitat data obtained from the Scottish Natural Heritage (SNH) GeMs V2110 Geodatabase to identify and map a range of 'blue carbon'[15] habitats linked to specific inshore Marine Protected Areas (MPAs) and Special Area Conservation (SACs) locations around the Orkney Islands (Table 2-3).

Table 2-3: Inshore MPA and SAC network locations and habitats specific to the Orkney Islands.

Location and Description	Longitude and Latitude (Total Area Km^2)	Habitats (Area Km^2)
Loch of Stenness – SAC A large brackish lagoon connected to the sea, situated 2 miles northeast of the town of Stromness	58°59'45.00'N; 003°15'0.00'W (7.93 Km^2)	**Sedimentary (Geology):** Mud, rock, sand/mud and sand/mud/gravel (6.68 Km^2) **Biological:** Intertidal macroalgae (0.47 Km^2) Subcanopy algae (0.77 Km^2)
Papa Westray – MPA Encompasses the shallow coastal waters around the islands Papa Westray and the Holm of Papa Westray to the North.	59°22.121'N; 002°52.509'W (33 Km^2)	**Sedimentary (Geology):** Gravel/sand, sand/mud and rock (25.77 Km^2) **Biological:** Kelp beds (6.57Km^2) *Mytilus edulis* beds (0.82 Km^2)
Sanday – SAC A large, low lying island to the north east of the Orkney Islands	59°16'60.00' N; 002°30'0.00'W (110 Km^2)	**Sedimentary (Geology):** Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (35.42 Km^2) **Biological:** Intertidal macroalgae (0.37 Km^2) Kelp beds (72.76 Km^2) Subcanopy algae (0.32 Km^2)
Wyre and Rousay Sounds – MPA Situated where the Atlantic and North Sea meet off the Orkney Isles. Covers the waters between the islands of Rousay, Wyre and Egilsay	59°08.467'N; 002°57.952'W (16 Km^2)	**Sedimentary (Geology):** Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (5.59 Km^2) **Biological:** Intertidal macroalgae (0.03 Km^2) Kelp beds (3.89 Km^2) Maerl beds (7.09 Km^2)

Source: Burrows et al. (2017)

[15] 'Blue carbon' is used to refer to carbon stored in ocean ecosystems and is defined by Nellemann et al. (2009a) as '*carbon stored and sequestered in coastal and marine ecosystems, including tidal and estuarine saltmarshes, seagrass meadows, and mangrove forests.'* Blue carbon can also include the geological substrate on which the marine ecosystem is developed (Burrows et al, 2017).

2.4.4 Building on the work of Burrows et al. (2017), Porter et al. (2020), undertook a blue carbon audit of Orkney waters which involved mapping a number of biological habitats including kelp, maerl beds, seagrass beds (Zostera marina), saltmarshes, horse mussel beds (Modiolus modiolus), flame shell (Limaria hians), brittlestar beds (Ophiothrix fragilis) and bryozoan thicket (Flustra foliacea). The spatial distribution of different seabed sediments within the 12nm boundary limit for the Orkney Islands were also identified and mapped, including slightly gravelly muddy sand, muddy sand, sand, gravelly sand, slightly gravelly sand, gravelly muddy sand, muddy sandy gravel, gravel, sandy gravel and rock. The *Blue carbon audit of Orkney waters* is the most comprehensive regional audit of blue carbon resources in Scotland and has been used to inform the recent *Orkney Islands Marine Region: State of the Environment Assessment* (Porter et al., 2020; Orkney Islands Council., 2020). It should be noted that the *Blue Carbon audit of Orkney waters* excluded the waters surrounding Sule Stack and Sule Skerry and as such was not a full assessment of the entire Orkney marine region.

2.4.5 We provide below brief reviews of the extent and presence of selected biological habitats that we believe are important habitats in terms of 'hidden' natural capital value and ecosystem service provision for the Orkney Islands. We also highlight key anthropogenic activities and pressures that were identified in the reviewed literature.

Kelp

2.4.6 Kelp is the common term for the large brown seaweeds of the taxonomic order *Laminariales*. Kelp forests in Scottish waters are predominantly comprised of *Laminaria hyperborean* but other species such as *Laminaria digitata*, *Alaria esculenta*, *Saccharina latissimi* (formerly *Laminaria saccharina*) and *Saccorhiza polyschides* have also been identified and recorded (Porter et al., 2020; Burrows et al., 2017; Marine Scotland, 2016).

2.4.7 Porter et al. (2020) estimate around 48,710 hectares of Kelp forests within the 12nm boundary limit for the Orkney Islands (Table 2-4).

Table 2-4: Estimated area of different Kelp species in Orkney waters

Kelp Species	Habitat area (Hectares)
Alaria esculenta	730[a]
Laminaria digitata	520[b]
Saccorhiza polyschides	260[b]
Saccharina latissima	18,000[a]
Laminaria hyperborea	29,200[a]

Source: Porter et al. (2020). **Note:** [a] indicates presence of Kelp species is likely to be >50%, [b] indicates presence likely to be >10%.

2.4.8 The 'hidden' value and importance of Kelp in providing multiple ecosystem services to Orkney and wider communities is discussed further in Section 6.2.

Maerl beds

2.4.9 The collective term "Maerl" is used to describe the multiple species of coralline red algae that secrete a calcareous skeleton and grow as unattached nodules, often with a complex branching structure (Perry and Tyler Waters., 2018; Burrows et al., 2017). Beds of maerl are usually found in the tide-swept channels of marine inlets or the open coast with the predominant biotypes found in the waters surrounding the Orkney Islands being *Phymatolithon calcareum* and *Lithothamnion glaciale* (Figure 2-4).

2.4.10 Diver core samples taken at Wyre Sound in 2015 also identified a variety of maerl bed taxa including *Leptochiton cancellatus*, *Modiolus modiolus*, Nematoda spp., *Amphipholis squamata*, *Socarnes erythrophthalmus*, *Vaunthompsonia cristata*, *Uromunna petiti*, *Animoceradocus semiserratus* and *Caprella acanthifera* (which was recorded in 100% of the samples) (Allen, 2017).

2.4.11 Porter et al. (2020) highlight, with the exception of the Wyre Sound maerl beds, that there is very little information available to determine the deposit thickness of maerl beds in Orkney waters. They do, however, provide estimates of the areal extent (in hectares) of maerl bed habitats. Wyre sound maerl beds cover around 1120 hectares (which is ~44% of the total estimated area of maerl identified in Orkney waters). The remaining 2526 hectares of maerl are distributed across multiple locations within the Orkney 12nm boundary limit.

2.4.12 The importance of Orkney Maerl bed habitats as a potential refuge under climate change projections was highlighted in Simon-Nutbrown et al. (2020). Using a MaxEnt[16] species distribution model that focused on maerl-forming species, but also included crustose coralline algae associated with coralline algal beds, the authors were able to identify suitable areas for species presence that currently lack records of occurrence. Areas predicted to maintain non-geniculate coralline algal populations were also determined using climate projection datasets from Bio-ORACLE for Representative Concentration Pathway (RCP) scenarios 2.6, 4.5, 6.0, and 8.5 for the years 2050 and 2100 (Assis et al., 2018). Around Orkney, the modelling indicated a high probability (>0.7) of coralline algae occurrence being maintained by 2100, even under the highest climate projection scenario RCP 8.5.

[16] A MaxEnt model uses "*the principle of maximum entropy on species presence-only data to predict or estimate a group of functions that link environmental variables and habitat suitability in order to approximate the probable geographic distribution*" (Porter et al., 2020).

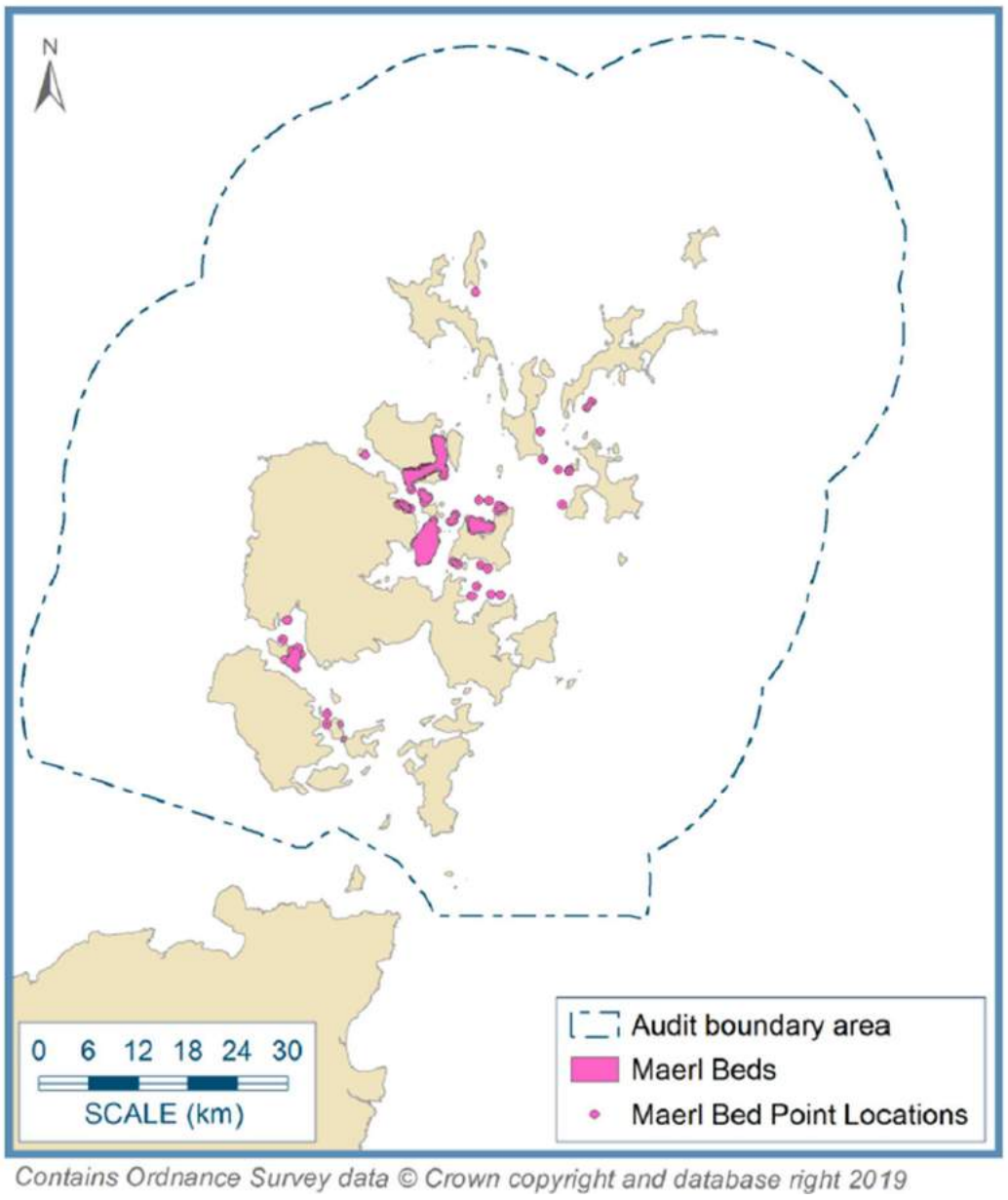


Figure 2-4: Extent and presence of Maerl bed habitats (*Phymatolithon calcareum* and *Lithothamnion glaciale*) in Orkney waters as bounded by the 12nm limit.

Source: Porter et al. (2020)

Seagrass beds (*Zostera marina*)

2.4.13 Commonly known as eel grasses, seagrasses (*Zostera marina*) develop on sands and muds in sheltered intertidal and shallow subtidal areas and are an important marine habitat that provides multiple ecosystem services (e.g. reducing coastal erosion, stabilising and binding sediments, and supporting biodiversity). According to Thomson et al. (2014) seagrasses are the only marine flowering plants found in Scotland and are an important nursery, spawning and feeding area for a variety of fish species. The leafy canopy and network of rhizomes and roots found in seagrass habitats also provide hiding places that allow other species, such as fish, to avoid predation.

2.4.14 Seagrass habitats are also an important sink for carbon with an estimated average net carbon sequestration rate of 83 g C $m^{-2}y^{-1}$ (Laffoley & Grimsditch, 2009). Porter et al. (2020) provide areal extent estimates for *Zostera marina* (1243 hectares) and *Zostera noltii* (180 hectares) in Orkney waters. These estimates were determined with the aid of a MaxEnt predictive model.

2.4.15 Thomson et al. (2014) also used a maxent predictive model and a Wave Exposure Model (WEMo)[17] to estimate seagrass distribution and habitat suitability around the Orkney Islands. Extensive seagrass beds were found in Deer Sound, Widewall and along the north shore of Wyre. Interestingly, Thomson et al. (2014) note that the seagrass in this area was associated with maerl beds and the seagrass was observed to be rooted in both areas of living and dead maerl.

[17] WEMo is an open source ArcGIS application that was developed by scientists from the Centre for Coastal Fisheries and Habitat Research at NOAA (National Oceanic and Atmospheric Administration) (see Fonesca et al., 2006).

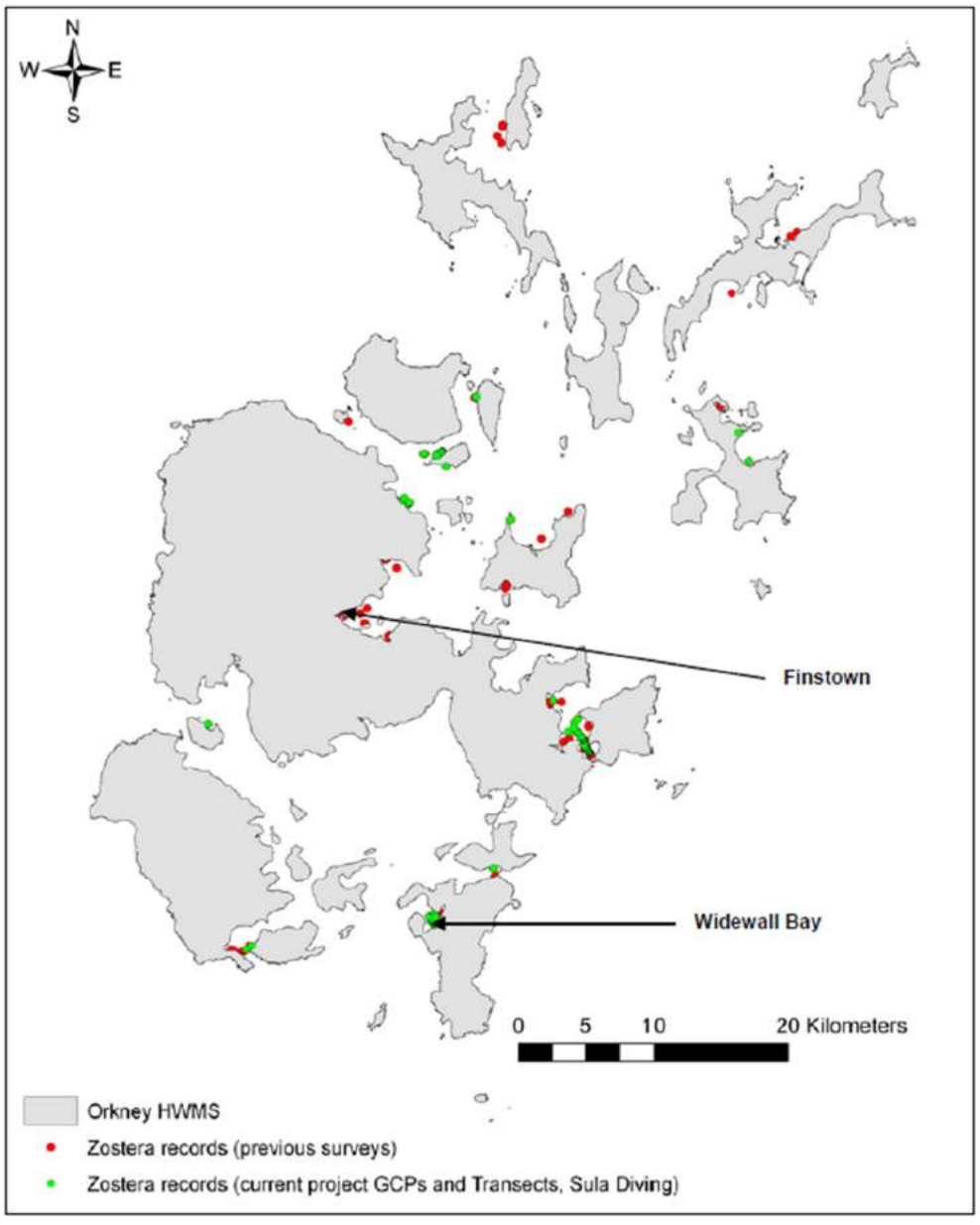


Figure 2-5: Map showing locations of Seagrass beds around Orkney derived from predictive modelling undertaken by Dr Emma Jackson in 2009/2010 and ground truthing by SULA diving in 2010. Source: Thomson et al. (2014)

Horse mussel (*Modiolus modiolus*) and Blue Mussel (*Mytilus edulis*) beds

2.4.16 A large bivalve with a robust shell, horse mussel (*Modiolus modiolus*) beds cover an estimated area of 3828 hectares within the Orkney 12nm boundary limit Porter et al. (2020) with the largest, continuous dense beds (~40ha) occurring off Copinsay (Marine Scotland, 2018). Other horse mussel beds were recorded by Sanderson et al. (2014) off the SMS Karlsruhe wreck and within Gutter Sound in Scapa Flow.

2.4.17 Horse mussel beds significantly modify sedimentary habitats and provide substrate, refuge and ecological niches for a wide variety of organisms. They also increase local biodiversity and may provide settling grounds for commercially important bivalves, such as queen scallops (Marine Scotland, 2018).

2.4.18 Blue mussel (*Mytilus edulis*), also known as the common mussel, are a medium-sized edible marine bivalve mollusc. The blue mussel is one of the most common and widespread shallow-water invertebrates of Scottish coastal waters (Burrows et al, 2017) however, evidence on the extent and presence of this bivalve within the 12nm boundary of Orkney is limited. Our rapid evidence assessment of the literature did not identify any evidence of the extent of Blue mussel beds in Orkney waters, although we note that the Orkney Local Biodiversity Action Plan 2018 does list them as being present.

Flame shell (*Limaria hians*) and Brittlestar beds (*Ophiothrix fragilis*)

2.4.19 Flame shell (*Limaria hians*) is an epifaunal bivalve that lives hidden in 'nests' on the seabed that are built from shells, stones, algae and other secreted materials. Often groups of nests combine to form a dense continuous reef-like structure that can help stabilise the seabed and provide a protective habitat for multiple different species. Porter et al. (2020) estimate the areal extent of flame shell in Orkney waters to be around 1799 hectares.

2.4.20 Brittlestars (*Ophiothrix fragilis*) dominate circalittoral sediment forming dense beds on boulder, gravel and sedimentary substrata. Extensive brittlestar beds are commonly found in Scottish inshore waters, including Orkney waters with Porter et al. (2020) estimating the areal extent of *Ophiothrix fragilis* within the 12nm boundary for Orkney to be around 4756 hectares. A large brittlestar bed has been surveyed north of Cava Island and a 25 m *in situ* diver transect of a brittlestar bed next to the Karlsruhe wreck was undertaken in 2019 (Porter et al. 2020). Brittlestar beds are an important habitat for blue carbon because of their endoskeleton of calcareous plates and their carbon storage potential (Porter et al. 2020; Burrows et al., 2017).

Evidence of anthropogenic activities and pressures on habitats

2.4.21 Biological and sedimentary habitats are highly exposed to physical changes due to anthropogenic activity such as dredging and trawling which can cause surface and subsurface abrasion (Marine Scotland, 2018; Burrows et al., 2017). Mobile fishing gears and boat moorings that are not fixed on the seabed also cause sediment resuspension and reduce carbon burial rates in sediments (Porter et al., 2020; Burrows et al., 2017).

2.4.22 Coastal marine sediments are also particularly vulnerable, where terrestrial and marine ecosystems meet, and as such are sensitive to changes in land use (e.g. increased eutrophication) and direct anthropogenic activity (e.g. tourism, recreation) (Burrows et al., 2017). Increases in terrestrial carbon input from land use practices could result in reduced light penetration and increased water turbidity which in turn will impact on the capacity of biological habitats to cycle and store carbon as well as lead to higher rates of sedimentation (Porter et al. 2020).

2.4.23 Perry and Tyler Waters (2018) assessed the sensitivity of a number of live maerl biotypes to climate related pressures. They found that *Phymatolithon calcareum* is likely to have a 'High' resistance to temperature increases at the benchmark level (2-5^{o}C) while the same level of temperature increase and sea surface warming may be detrimental to *Lithothamnion glaciale.* As such, their resilience was assessed as 'Very Low' and their sensitivity as 'Medium'. These are the two dominant maerl biotypes found in Orkney waters and they appear to be highly sensitive to, and have a 'Very Low' resilience to, de-oxygenation, local decreases in salinity, local water flow (tidal) changes and organic enrichment which is caused by build-up of organic waste from fish farms (Perry and Tyler Waters, 2018).

2.4.24 Ocean acidification is also a threat to the carbon stored in sediments and is one of the biggest impacts of climate change identified and discussed in several papers including Burrows et al. (2017) who describe ocean acidification as *"the process whereby the increasing concentration of atmospheric carbon dioxide exerts a higher partial pressure of carbon dioxide against sea water, increasing the rate at which carbon dioxide is naturally absorbed by sea water. This 'extra' carbon dioxide dissolves in sea water, altering the pH of coastal and oceanic surface waters. Carbon dioxide and sea water produce a weak carbonic acid, which quickly dissociates to form bicarbonate, releasing H+ ions into the sea water*."

2.4.25 Burrows et al. (2017) also highlight that Increasing ocean acidification reduces the availability of carbonate, in addition to increasing the rate at which calcium carbonate dissolves and the effects of ocean acidification on sediments is likely to be higher in protected areas that contain carbonate sediments, such as those found predominantly in Orkney.

2.4.26 Table A1-8 in Appendix 1 provides a matrix of activity/pressures identified in the literature as impacting on the specific habitats listed which were identified in the literature as being present in Orkney waters.

2.5 Orkney Marine Natural Capital – Species

2.5.1 Table A1-6 in Appendix 1 shows the different species identified in the REA along with a RAG (red, amber, green) assessment of our confidence in the extent and presence of the species as evidenced in the critically reviewed literature. We provide below brief reviews of selected species that we believe are important species in terms of Orkney natural capital and ecosystem service provision.

Sandeels

2.5.2 Sandeels are a small burrowing fish that tend to be found living within sandy sediments. Sandeels (family *Ammodytidae*) are important to the diets of many animals feeding in the North Sea, including seabirds and predatory fish. Sandeels are a priority marine feature in Scotland's seas and have recently been included within one of four additional Nature Conservation Marine Protected Area (MPA) proposals for designation to complete the Scottish MPA network. The population of Sandeels are heavily dependent on the major spawning areas north/west of Orkney, which are most significantly impacted by environmental conditions (Perkins et al., 2018). Our search of the literature did not provide any evidence of the extent, size and condition of Sandeel populations within the 12nm boundary for Orkney.

Seals

2.5.3 Seals are a charismatic species of cultural importance that help maintain a balance in the food web and through their movement help to cycle nutrients through the water column. Both Grey Seal (*Halichoerus grypus*) and Harbour Seal (*Phoca vitulina*) are species of 'least-concern'[18] and are found extensively across the north eastern Atlantic. Since 2000 the number of Harbour seals at Orkney have declined by approximately 75% (around 3.75% p.a.) from around 8,000 to just over 2,000 individuals. This decline may be linked to possible Grey seal predation among other things (Arso Civil et al. 2018; Marine Scotland, 2017). Arso Civil et al. (2018) also mention prey quality/availability, and the occurrence and exposure of seals to toxins from harmful algae as other reasons for declining Harbour seal numbers.

2.5.4 Grey seal numbers within the Orkney 12nm boundary are indicated to have peaked during 2000 with around 18-19,000 pups born each year within the numerous colonies. Since 2000 the numbers of grey seals has declined at a slower rate than Harbour seals (around 2% p.a.). Figure 2-6 shows seal count numbers in Orkney in August 2016 (aggregated by 1km squares).

[18] A least-concern species is a species that has been categorized by the International Union for Conservation of Nature (IUCN) as evaluated as not being a focus of species conservation. See: https://www.iucn.org/resources/conservation-tools/iucn-red-list-threatened-species

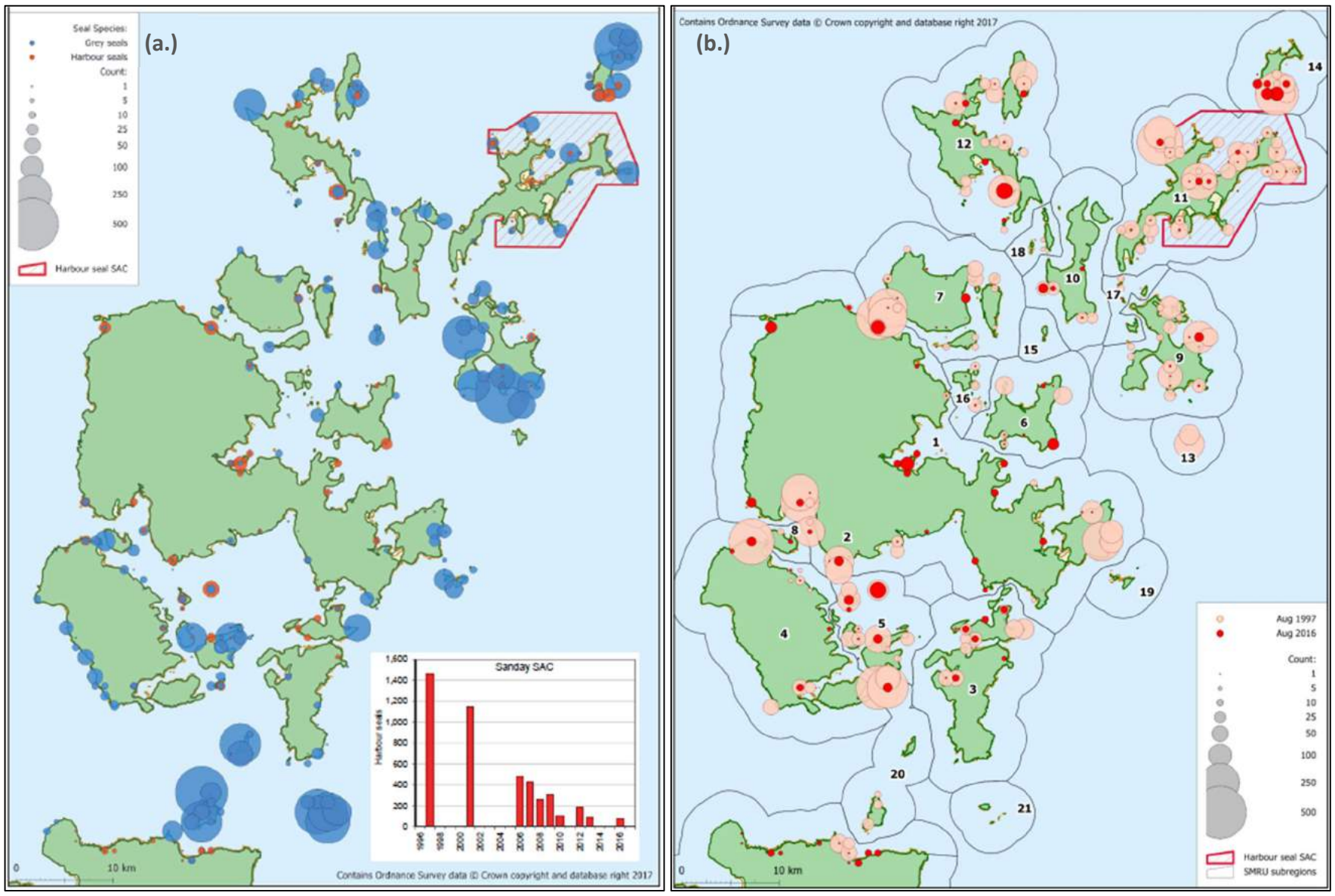


Figure 2-6: (a.) Distribution of Harbour and Grey seals in Orkney in 2016 and (b.) Harbour seals counted in Orkney in 2016 compared to 1997.

Source: Duck and Morris (2019)

Seabirds

2.5.5 Seabirds provide vital cultural services for visitors to Orkney. Bird watching of key species such as the Atlantic Puffin (*Fratercula arctica*) is one such example. Seabirds are also greatly appreciated by the local Orkney community, figuring largely in Orcadian music and literature. Orkney holds internationally important populations of both breeding and wintering seabirds, which attract many visitors. The 'hidden' value and importance of seabirds in providing multiple ecosystem services to Orkney and wider communities is discussed further in Section 4.4.

2.5.6 The sheltered waters between the islands of the Orkney archipelago also provide important wintering areas for seabirds. The Scapa Flow pSPA and the North Orkney pSPA (which includes the sheltered sounds and firths that lie between the Orkney Mainland and the neighbouring islands of Rousay, Egilsay, Shapinsay, Eynhallow, Wyre and Gairsay) have been proposed to protect the internationally important wintering populations of wintering seaduck, grebes, divers and shags in these two areas. Beyond these two proposed SPAs there is little high quality systematic survey data on the distribution and abundance of wintering seabirds. However, these two pSPAs alone are estimated to hold more than 30% of wintering great northern diver (*Gavia immer*), more than 20% of wintering Slavonian grebe (*Podiceps auritus*) and long tailed duck (*Clangula hyemalis*), more than 10% of wintering red-breasted merganser (*Mergus serrator*), more than 5% of wintering black-throated diver (*Gavia arctica*), velvet scoter (*Melanitta fusca*) and eider (*Somateria mollissima*), and more than 4% of wintering shag (*Phalacrocorax aristotelis*).

2.5.7 In 2016 the Atlantic Puffin population of Orkney was estimated to be 6,675 breeding pairs (based on the counts of apparently occupied burrows [AOB] where available, and assuming that one individual represented one breeding pair for the other sites) (Hughes et al., 2018). The true extent of seabirds in Orkney (and wider) waters is difficult to establish due the seasonal nesting nature of the different species. Burdon (2018) states that "*the number of species using UK marine waters varies seasonally: whilst there is a large influx of seaducks, divers and grebes in coastal waters in winter, a greater number of true marine seabirds use coastal areas/islands in the summer months to nest*".

Figure 2-7: Atlantic Puffin (*Fratercula arctica*), Photo ©Andrew Want

Flapper skate and Blue skate

2.5.8 The Orkney Islands and Northern Scotland are home to the largest skate species in European waters. Previously known as the Common Skate (*Dipturus batis*) but now considered to be two separate species, the Flapper Skate (*Dipturus intermedius*) and the Blue Skate (*Dipturus batis*). Skates tend to live on sandy, muddy and gravel bottoms from the coast down to 600m. The flapper skate is common in Orkney waters occurring from the shallow coastal areas around the North Isles and Scapa Flow to the deeper waters off the West Mainland coast. The blue skate (*Dipturus batis*) has a broader distribution across the North East Atlantic and overlaps in the Celtic Sea to northwest Scotland. The Orkney Islands are an important breeding ground for these Critically Endangered species with the largest flapper skate in Orkney being measured at 2.3m nose to tail and 1.8m across the wings. The extent and population size of both skate species in Orkney waters was not able to be determined through our search of the literature. However, a recently released paper by Phillips et al. (2021) provides evidence of Essential Fish Habitats (EFHs) for the critically endangered flapper skate in the waters surrounding Orkney (Figure 2-7). The evidence is based on citizen-science observation data provided by the Orkney Skate Trust.

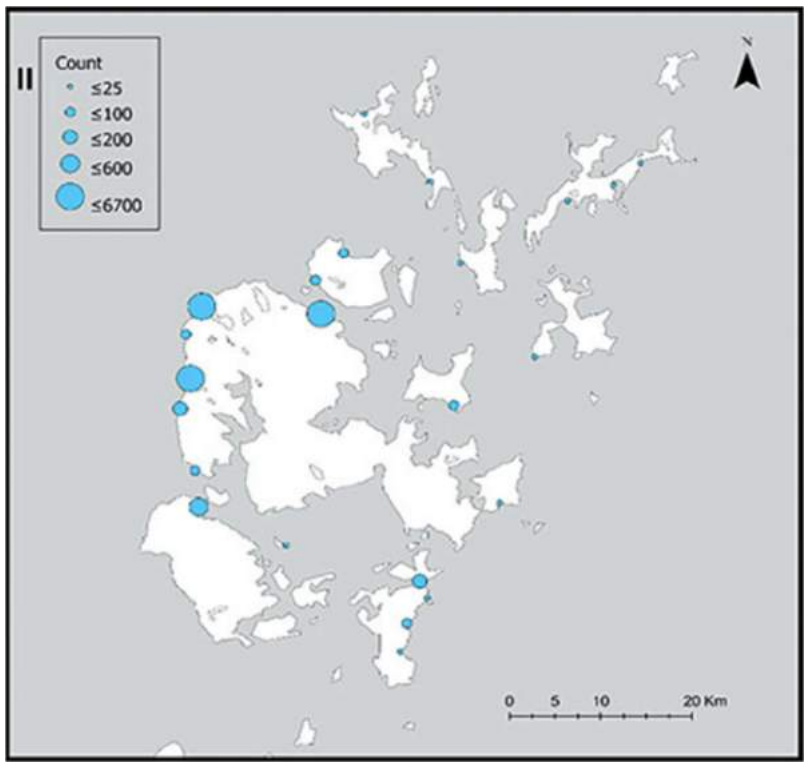


Figure 2-8: Flapper egg case records around Orkney Islands.

Source: Phillips et al. (2021)

Evidence of anthropogenic activities and pressures on species

2.5.9 Table A1-7 in Appendix 1 provides a matrix of activity/pressures identified in the literature as impacting on the specific habitats listed.

2.5.10 Harbour and grey seals are impacted by energy production through collisions with tidal turbines, net fishing activities through bycatch (especially pups), interactions with shipping vessels, the bioaccumulation of toxic compounds, noise pollution, competition for prey, infectious disease, nutritional stress, legal shooting, pollution, injuries from killer whales (Damseaux et al., 2020; Marine Scotland, 2017).

2.5.11 There are a number of anthropogenic pressures on the health and populations of seabirds, with many factors influencing species in different ways, subject to species behaviours and habitats. Activities such as energy production, and its associated infrastructure, has been found by Jarrett et al. (2017) to adversely affect seabirds through a variety of displacement, collision, and barrier effects. Fishing activities have exerted pressure through seabirds becoming bycatch, the depletion of prey and increased ocean turbidity (Thompson et al., 2016; Jarrett et al., 2017). Disturbance of many seabird species has also been reported in response to shipping activities, aquaculture, tourism and recreation (Thompson et al., 2016; Jarrett et al., 2017). Additional pressures of sedimentation from land-use change and soil erosion, and habitat pollution are common for many species (Jarrett et al., 2017).

2.5.12 Protecting access to the marine food sources upon which the livelihood of both adult birds and young chicks depend, both within and outside the SPA, must therefore be a priority to maintain and/or enhance seabird status through managing the intense competition for marine space and development pressures within the region (Burdon, 2018). Furness et al, (2012) indicates that tidal turbines, more so than wave energy devices, may affect seabird populations through collision mortality, disturbance and habitat loss due to imposed behavioural constraints. They identify black guillemot (*Cepphus grylle*), razorbill (*Alca torda*), European shag (*Phalacrocorax aristotelis*), common guillemot (*Uria aalge*), great cormorant (*Phalacrocorax carbo*), divers (*Gavia spp.*) and Atlantic puffin (*Fratercula arctica*) as the species most vulnerable to adverse effects from tidal turbines in Scottish waters. Supplementary Material 2 – Case Studies provides additional evidence and discussion on anthropogenic activities and pressures on seabirds.

2.5.13 Sandeel populations are being affected by anthropogenic pressures such as rising ocean temperatures due to climate change and ocean acidification, excessive extraction for human consumption (e.g. as food source for aquaculture), and disturbance from tourism and recreation activities (Perkins et al., 2018). Other factors include displacement due to energy production and infrastructure and targeted fishing (Thompson et al., 2016).

2.5.14 A serious anthropogenic pressure for skate is the activity of fishing which often impacts on skate numbers as bycatch and habit loss through seabed damage from fishing gear (Orkney's Biodiversity Steering Group, 2018). Activities such as energy production and its associated infrastructure (electrical/magnetic subsea equipment and cables), overfishing of skate and predation by seals also place significant pressure on skate populations (Orkney's Biodiversity Steering Group, 2018).

2.6 Ecosystem Services provided by the Orkney Marine Environment

2.6.1 The marine habitats and species of the Orkney Islands currently deliver a range of provisioning, regulating and cultural services (see Table 2-2). Horse mussel reefs, for example, provide a number of beneficial ecosystem services including the provision of nursery grounds for commercial fisheries species. Sustaining fish populations is a key ecosystem service provided by a number of Orkney Island habitats, however there is very limited evidence to identify which ecological functions might best support the fish population. According to Bakker et al, (2019) *"fishing as a practice has a strong history in which it has endured as a small but stable and resilient industry in Orkney. Its local importance relates directly to the salvation of these peripheral islands, where over decades and generations, fishing has provided jobs and income opportunities for the small island communities."*

Figure 2-9: Fishing Boat and Lobster Creels, Weddell Sound, Orkney. Photo © Becky Williamson (cc-by-sa/2.0)

2.6.2 Intermediate ecosystem services which are indirect and removed from human interaction provide the foundation for final ecosystem services (Potts et al., 2014). Key intermediate ecosystem services in the Orkney marine environment include carbon sequestration (which is provided by habitats such as seagrass beds that are vitally important in relation to coastal resilience to sea level rise, etc), natural hazard regulation, nutrient cycling and formation of seascape. Final ecosystem services identified in the literature as being provided by the habitats and species in the Orkney marine environment include, but are not limited to:

- Fish and shellfish
- Food supplements
- Phycocolloids - alginate, agars and carrageenans
- Aesthetics
- Tourism, recreation and watching/studying nature
- Wild Seaweed harvesting
- Energy from renewable and non-renewable sources

2.6.3 The REA provided the foundation for the natural capital assessment however we acknowledge that the evidence on habitat and species extent and presence related specifically to Orkney was somewhat limited. As such, additional spatial data and evidence was sourced, and expert judgement utilised, to confirm the presence or absence of key habitats and species prior to undertaking the ecosystem service and condition assessments.

3 Regional Marine Planning Review

3.1 Introduction to Marine Planning

3.1.1 Marine planning is in its relevant infancy when compared to terrestrial planning with an iterative process to plan development being employed across the UK. The Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and the EU Directive on Marine Spatial Planning 2014, established legislative drivers and associated frameworks for national marine plans. Since the introduction of these legislative drivers there has been significant development of marine plans and associated initiatives at a variety of geographic scales. This chapter undertakes to summarise the developments in marine spatial planning from a Scottish perspective and assess the opportunities to embed Natural Capital and Ecosystem Services at its heart. It reviews the emerging relevant marine plans and policies from a natural capital and ecosystem services perspective to help develop recommendations for the future Orkney Island Regional Marine Plan which will be developed by a Marine Planning Partnership currently being setup up by Orkney Islands Council via delegated powers received from Scottish Government on 27 November 2020.

3.1.2 This chapter reviews marine planning legislation and associated documentation at a UK, Scottish and Orkney island scale to help identify to what extent the existing marine planning approach incorporates natural capital and ecosystem services. As the Orkney Regional Marine Plan is in the early stages of development, it has not been possible to review any substantive Orkney Marine Planning material, with the exception of the Pilot Pentland Firth and Orkney Waters Marine Spatial Plan and State of the Environment Assessment - A baseline assessment of the Orkney Island Marine Region which will be used to inform the baseline of the regional marine plan. However, the review has strived to identify elements of the existing marine planning framework and overarching policies that the Orkney Regional Marine Plan could build upon to further embed natural capital at the heart of its marine planning process.

3.1.3 C.20 core marine planning documents which directly referenced natural capital 8 times and ecosystem services 44 times (excluding the Feasibility study for a marine natural capital asset index for Scotland report) were reviewed (see Table A2-1, Appendix 2). Additional indirect references to natural capital and ecosystem services are made throughout relevant planning documentation providing potential hooks and drivers to develop the Orkney regional marine plan with natural capital at its heart. These are discussed in more detail in sections 3.2, 3.3 and 3.4.

3.2 International and National Marine Planning

3.2.1 The European Commission introduced the Maritime Spatial Planning (MSP) Directive (Directive 2014/89/EU) in September 2014, with a requirement for all Member States to transpose the Directive into domestic legislation by September 2013. The Directive places a duty on Member States to develop MSPs by the 31st March 2021. It provides an outline framework for the development of MSPs with the aim of such plans to encourage the sustainable growth of marine economies alongside the sustainable development of marine areas and the sustainable use of marine resources. "*Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials.*" Article 5(2), Directive 2014/89/EU.

3.2.2 The Directive prescribes fundamental elements that must be included within Member State's marine plans which include the application of an ecosystem-based approach, spatial planning of marine resources, land-sea interactions, environmental, economic and social aspects, as well as safety and the promotion of the co-existence of relevant uses and activities. The EU's intention in the development of the MSP Directive was to create a planning framework within which all human activities at sea could fit. The MSP Directive therefore stated that it would contribute to a number of other EU Directives including the Water Framework Directive 2000/60/EC and the Marine Strategy Framework Directive 2008/56/EC, which recalled the Commission communication of 3 May 2011 entitled 'Our life insurance, our natural capital: an EU biodiversity strategy to 2020'.

3.2.3 In terms of building upon a natural capital approach, in addition to prescribing that MSPs must apply an ecosystem-based approach, paragraph 13 of the Directive states: "*In marine waters, ecosystems and marine resources are subject to significant pressures. Human activities, but also climate change effects, natural hazards and shoreline dynamics such as erosion and accretion, can have severe impacts on coastal economic development and growth, as well as on marine ecosystems, leading to deterioration of environmental status, loss of biodiversity and degradation of ecosystem services. Due regard should be had to these various pressures in the establishment of maritime spatial plans. Moreover, healthy marine ecosystems and their multiple services, if integrated in planning decisions, can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention.*" Although this is at an extremely high level, the intention of European Commission in developing MSPs in the spirit of a natural capital approach is clear.

3.2.4 The European Commission also acknowledge that some Member States already had considerable experience in the assessment and planning of marine resources. To this end, the UK is significantly ahead of the curve, with the prior introduction of the Marine and Coastal Access Act 2009 and Marine (Scotland) Act 2010. Due to the prior development of this domestic legislation and the high-level framework nature of the EU MSP Directive, we have not considered this legislation any further in the context of the review of regional marine planning in Scotland and the development of the Orkney Regional Marine Plan. However, the above references to ecosystem services should be noted and further research into Member States MSP progress at a local level could be beneficial in identifying transferable lessons learnt in terms of the implementation of MSP at a local scale and the extent to which Natural Capital and ecosystem services have been incorporated into, or driven, the process.

3.2.5 In addition to specific marine legislation, the EU's Biodiversity Strategy to 2030 aims to maintain and enhance ecosystem services across Europe (Target 2) protect nature and reverse the degradation of ecosystems by ensuring Europe's biodiversity is on a path to recovery by 2030. This builds upon the aim of the EU's Biodiversity Strategy to 2020, to maintain and enhance ecosystem services across Europe (Target 2). The Strategy to 2030 introduces several actions including establishing a larger EU-wide network of protected areas (which at sea could generate a return of 3 Euros to every Euro invested, Brander et. al, 2005), launching an EU nature restoration plan and introducing measures to enable transformation to tackle the global biodiversity challenge. In the marine environment, this specifically includes restoring good environmental status of marine ecosystem services (as set out in section 2.2.6 of the EU Biodiversity Strategy for 2030). Furthermore, the strategy supports legally binding agreements on marine biological diversity of areas beyond national jurisdiction through a new action plan to conserve fisheries resources and protect marine ecosystems by 2021. The Strategy firmly believes that the *"application of an ecosystem-based management approach under EU legislation will reduce the adverse impacts of fishing, extraction and other human activities, especially on sensitive species and seabed habitats. To support this, national maritime spatial plans, which Member States have to deliver in 2021, should aim at covering all maritime sectors and activities, as well as area-based conservation-management measures".*

3.2.6 The delivery of the aims and objectives of the EU Biodiversity Strategy to 2030 will be supported in the marine environment by the EC developed ecosystems knowledge base which includes ecosystem condition and capacity for environments to provide ecosystems services. This systematic approach could align with the Marine Strategy Framework Directive indicators and related UK marine assessments to help provide coherent mapping and assessment of ecosystem services to support both marine and terrestrial planning.

3.2.7 In the UK, the Marine and Coastal Access Act received Royal Assent on 12 November 2009. The act introduced powers to create a new marine planning system for England's inshore waters and the offshore waters around the UK. The new marine planning system aims to enable a more strategic approach to be taken to the management of our seas. Similarly, the Marine (Scotland) Act 2010, introduces powers for the development of marine planning in Scottish Inshore Waters.

3.2.8 Section 44 of the Marine and Coastal Access Act 2009 required the development of a Marine Policy Statement (MPS) to provide an agreed framework for preparing Marine Plans and taking decisions affecting the marine environment. The MPS was jointly adopted by the Secretary of State, Scottish Ministers, Welsh Ministers and the Department of the Environment in Northern Ireland and will contribute to the sustainable development of the United Kingdom's marine area. The MPS is therefore key in achieving the UK Administrations shared vision of having "clean, healthy, safe, productive and biologically diverse oceans and seas". As the new marine planning system is introduced through primary legislation across the UK and associated national and local marine plans are developed, the MPS provides a high level policy context to ensure appropriate consistency in marine planning across the UK marine area. The MPS sets out some conditions for the marine planning process across the UK, including that it must achieve integration between different elements; recognise that the demand for use of our seas and the associated pressures on them will increase; manage competing demands on the marine area, take an ecosystem-based approach; enable the co-existence of compatible activities where possible and; integrate with terrestrial planning. Although the MPS prescribes an ecosystem-based approach, it makes no direct reference to natural capital or ecosystem services.

3.2.9 The MPS facilitates and supports the formulation of Marine Plans, offering some consistency across the Devolved Administrations by introducing a number of high level marine objectives helping to ensure marine resources are used in a sustainable way, thereby:

- Promoting sustainable economic development;
- Enabling the UK's to move towards a low-carbon economy, in order to mitigate the causes of climate change and ocean acidification and adapt to their effects;
- Ensuring a sustainable marine environment which promotes healthy, functioning marine ecosystems and protects marine habitats, species and our heritage assets; and
- Contributing to the societal benefits of the marine area, including the sustainable use of marine resources to address local social and economic issues.

3.2.10 The MPS makes significant reference to the Marine Strategy Framework Directive and associated UK Marine Strategy, with particular reference to the ecosystem-based approach and associated definitions as follows: *"A practical interpretation of the ecosystem approach is set out in regulation 5 of the Marine Strategy Regulations 2010 which transpose the Marine Strategy Framework Directive. An ecosystem-based approach to the management of human activities means an approach which ensures that the collective pressure of human activities is kept within the levels compatible with the achievement of good environmental status; that does not compromise the capacity of marine ecosystems to respond to human-induced changes; and that enables the sustainable use of marine goods and services."*

3.2.11 The Scottish National Marine Plan and all Scottish regional marine plans discussed below, build upon the framework provided by the MPS and adopt the High Level Marine Objectives (HLMO) (See Appendix 2 for HLMO objectives).

3.2.12 Another core driver for marine planning across Europe and within the UK MPS and National Marine Plans are the principles of the Marine Strategy Framework Directive (MSFD). At its heart is a set of eleven Good Environmental Status (GES) descriptors, which the Scottish National Marine Plan adopts, (Figure 3-1) and member states strive towards achieving for their marine waters by 2020. Although not directly built around a natural capital approach, it is the first EU legislative instrument for the protection of marine biodiversity as illustrated by the regulatory objective that "biodiversity is maintained by 2020", delivering the cornerstone of GES. By its very nature, the Directive aims to enhance and protect the marine resource based upon which marine related economic and social activities depend. The MSFD therefore legislates a framework for an ecosystem approach to the management of the marine environment, integrating the concepts of environmental protection and management and human impacts and sustainable use.

3.2.13 As the Feasibility study for a marine natural capital asset index for Scotland notes: *"Many details of the MSFD and HLMOs can be clearly associated with the principles of the natural capital concept, as can specific National Marine Plan policies which seek to improve ecosystem status and function for the benefit of people".*

3.2.14 In addition to marine legislation, both Scotland's Economic Strategy and the Programme for Government, reference commitments to protecting and enhancing the environment and natural capital. The Scottish Biodiversity Strategy's 2020 Challenge also identifies an intention to develop a marine Natural Capital Asset Index which would support marine planning through the identification of key marine species, habitats and functions, better understanding of the pressures on these assets and identification of key areas for management to safeguard priority ecosystem services.

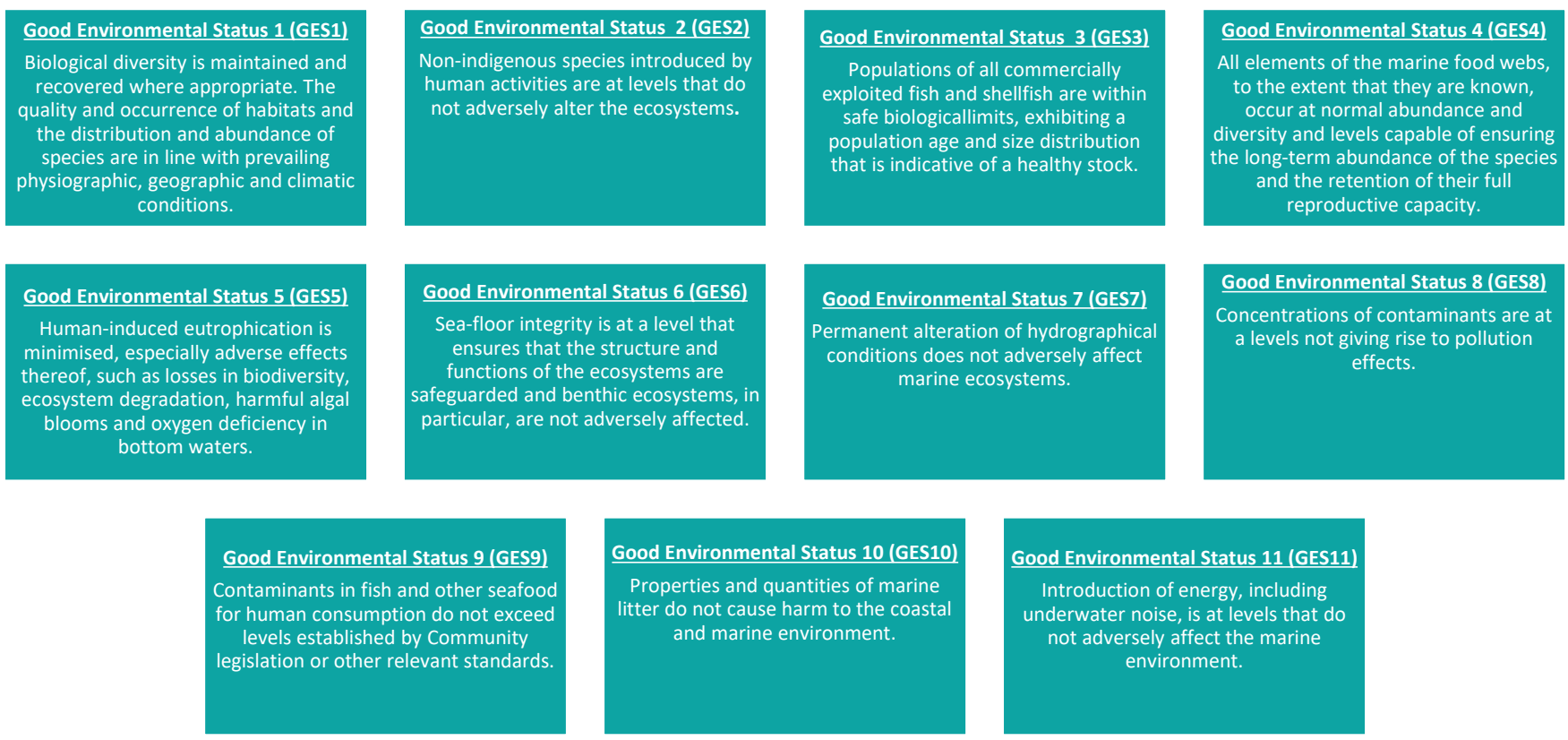


Figure 3-1: Marine Strategy Framework Directive Good Environmental Status Descriptors

3.3 Scottish National Marine Planning

3.3.1 The Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009 established a statutory marine planning framework for Scotland requiring Scottish Ministers to prepare and adopt a national marine plan for Scotland's inshore waters (out to 12nms) and offshore waters (12 to 200 nautical miles) respectively. The two Acts (referred to as the Marine Acts) establish a legislative framework for marine planning to enable demands on marine resources to be managed in a sustainable way across all of Scotland's seas.

3.3.2 A National Marine Plan for Scotland was adopted by Scottish Government in 2015 setting out strategic policies for the sustainable use of Scotland's marine resources out to 200 nautical miles. The Plan supports development and activity in Scotland's seas while incorporating environmental protection into marine decision making to achieve sustainable management of marine resources. This National Marine Plan provides the wider context for planning within Scotland's Marine waters including what should be considered at a regional and local scale. The Act introduced a new era for the management of Scotland's seas including provision for local stakeholders to prepare statutory regional marine plans at the local level.

3.3.3 The plan is built around the common vision within the Marine Policy Statement of clean, healthy, safe, productive and diverse seas, managed to meet the long terms needs of nature and people. It contributes to the delivery of this vision, alongside the High Level Marine Objectives, which are adopted by all UK Administrations (see Appendix 2). The adoption of these principles which run through all National Plans and set a framework for the regional plans, reflect a commitment to the five guiding principles of sustainability set out in the UK's 2005 sustainable development strategy. This is further supported by Scotland's commitment to the UN Sustainable Development Goals, with specific importance of Goal 14: "conserve and sustainably use the oceans, seas and marine resources".

3.3.4 The EU MSP Directive, the Marine and Coastal Access Act 2009, Marine (Scotland) Act 2010, the MPS and associated national marine plans are all centred around an ecosystem approach. The Marine Scotland Act states that *"this Plan promotes an ecosystem approach, putting the marine environment at the heart of the planning process to promote ecosystem health, resilience to human induced change and the ability to support sustainable development and use. This Plan adopts the guiding principles of sustainable development, which also ensures that any individual policy, plan or activity is carried out within environmental limits."* The Marine Act endorses an ecosystem approach to marine management, requiring a duty to keep relevant matters under review including the physical, environmental, social, cultural and economic characteristics of the Scottish marine area and the living resources which the area supports.

3.3.5 The Scottish National Marine Plan also stresses the importance of Scotland's marine ecosystems through strong reference to the number and diversity of designations set out to protect them at both international and national levels. These designations are incorporated into Scotland's Marine Protected Area Network which currently covers C. 20% of Scottish Seas and are incorporating into the marine planning

process through General Policy 9 (Natural Heritage). Detailed guidance on the development and management of Scotland's MPA network can be obtained from NatureScot. Appendix 2 also provides a summary of the most relevant objectives and policies within the Scottish National Marine Plan and associated regional and pilot marine plans.

3.4 Regional Marine Planning

Orkney Regional Marine Planning Area and Natural Capital

3.4.1 The Scottish National Marine Plan may be supported by up to 11 regional marine plans (RMP). A regional marine plan is the marine equivalent of a local development plan, containing statutory local policies and spatial plans to guide marine consenting and management decisions. Currently only 2 RMPs are in advanced stages of development, these are Shetland Islands Marine Spatial Plans and Clyde Regional Marine Plan. These plans are being developed by local Marine Planning Partnerships, representing the economic, community, environmental and recreational interests within a local marine region. As other RMPs are developed for the Scottish marine regions neighbouring Orkney, including the Shetland Islands, Moray Firth, West Highlands and North Coast, they should be reviewed and where appropriate accounted for in development of the Orkney RMP. This is due to the relevantly close geographic proximity of the RMPs and thus possible interactions and dependencies, especially in terms of mobile species and shared natural capital assets.

3.4.2 To this end, the Orkney Regional Marine Plan is to be developed by the Orkney Marine Planning Partnership, following the legal delegation of powers to Orkney Islands Council on 27 November 2020 to take this forward (as per the Orkney Marine Planning Update in December 2020). The Scottish Wildlife Trust has highlighted the opportunity for the regional marine plan to set out an ecosystem-based planning process which considers the value of Orkney's marine and coastal environment (Orkney Planning Update in September 2020 and the Development and implementation of Regional Marine Plans in Scotland: interim report (July 2020)).

3.4.3 The Orkney Regional Marine Plan should develop research and findings from previous reports on the provision of ecosystem services, natural capital and the ecosystem approach. The Orkney Regional Biodiversity Plan (completed in 2018) sets out goals for the protection of areas important for ecosystem service provision and for the restoration and safeguarding of ecosystem services (Strategic goals C and D, targets 11 and 14). Target 14 specifically states that *"by 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable".* The Biodiversity Plan also states that the marine and coastal environment delivers many additional benefits including*:*

- Dune and links systems, vegetated shingle and saltmarshes provide valuable coastal defence against the erosive forces of high tides and wave action during storms.
- Habitats such as Maerl beds, Flame shell beds, Kelp forests, Horse mussel reefs and Seagrass meadows have been found to be significant storage areas for carbon, commonly known as 'Blue Carbon'.
- The seas around Scotland provide a source of offshore renewable wave, tidal and wind energy.
- Coastal and marine environments are also valued for the recreational, educational and spiritual benefits that they provide.

3.4.4 The recent State of the Environment Assessment (SoEA)[19] undertaken by Orkney Islands Council in 2020 also makes a strong case for the importance of considering ecosystem services and natural capital, however it also notes that at the time of writing there was limited data and mapping available on Orkney's ecosystem services. The natural capital assessment undertaken in this study, supported by the Feasibility study for a marine natural capital asset index for Scotland, can help to fill a number of these data gaps. The SEA identifies a number of ecosystem services that benefit Orkney including:

- Water purification through soil processes and natural filtration and the marine nutrient cycle.
- Food production in the form of wild fish and shellfish and an environment which supports both wild stocks and aquaculture activity.
- Energy from renewable and non-renewable sources including electricity and fuels.
- Flood mitigation by peatlands, wetlands, saltmarsh and kelp beds.
- Coastal protection by dune systems, shingle/cobble beaches, saltmarsh, mudflats and kelp forests.
- Carbon sequestration and storage in for example, marine sediments, kelp forests and biogenic reefs.
- Landscape and seascape features and natural beauty provided by the diversity of landforms and vegetation cover.
- The health and well-being benefits people obtain from ecosystems through recreation, reflection, and spiritual enrichment.

3.4.5 The SoEA also states that "*the Ecosystems Services Approach to marine planning recognises the value of these services so that they can be fully considered within policy and decision making as well as 'on the ground' actions"* and highlights the need to consider human impacts on Orkney's ecosystem service provision, especially climate change impacts. Some of the benefits of regional marine planning listed in the SoEA include:

- Safeguarding the functioning of marine ecosystems whilst supporting economic activities;
- Policies, spatial allocations and data to improve certainty at the development consenting stage and support investment; and

[19] Orkney Islands Marine Region: State of the Environment Assessment (2020). https://www.orkney.gov.uk/Service-Directory/D/orkney-islands-marine-region-state-of-the-environment-assessment.htm

- Regional marine planning will allow the national interest to be interpreted at the local level in a way that is appropriate to local circumstances.

3.4.6 The adoption of a natural capital approach would support the findings of the SoEA through the recognition and identification of impacts and dependencies associated with human activities and by assigning a value to Orkney's marine natural capital stocks and associated ecosystem services.

3.4.7 The Orkney Regional Marine Plan can also build on the ecosystem approach set out in other Scottish regional plans. The Shetland Islands Marine Spatial Plan (2015, fourth edition) takes an ecosystem approach (based on the 2010 Marine Act) and considers the importance of ecosystem services such as provisioning and regulating services, and the cultural and spiritual role that the marine environment has. It states that *"an ecosystems approach provides a framework for looking at whole ecosystems in decision making, and for valuing the ecosystem services they provide, to ensure that society can maintain a healthy and resilient natural environment now and for future generations".*

3.4.8 The Clyde Regional Marine Plan Pre-Consultation Draft (2019) also takes an ecosystem-based approach building on the Marine (Scotland) Act 2010 and associated national marine plan. It recognises the importance of a healthy marine environment to support the provision of ecosystem services we depend on, stating that *"the good health and condition of species and habitats contributes to the provision of many ecosystem services with benefits that we rely on, such as food provision, flood/storm protection, nutrient cycling and breakdown of waste. There are also other benefits, such as recreation, a sense of place and cultural heritage which contribute to our own wellbeing and provide opportunities for tourism".*

3.4.9 The Pilot Pentland Firth and Orkney Waters Marine Spatial Plan (published in 2016) also takes an ecosystem-based approach for management and includes the importance of conserving the marine and coastal environment for the cultural and social wellbeing of local communities. The Orkney Local Development Plan (2017) for land-based planning does not include a significant focus on ecosystem services but does state that all development proposals should ensure that healthy ecosystems can be maintained, and thus continue to provide ecosystem services. It is imperative for the sustainable management of Orkney as a whole, that the Local Development Plan and Regional Marine Plan work together across the land-sea interface and share common policies as appropriate. The application of a natural capital approach across both plans would help to facilitate this transparency and cohesive management at the land-sea interface, whilst allowing local environmental features to shape the plans.

4 Natural Capital and Ecosystem Services Assessments

4.1 Introduction

4.1.1 Ecosystem services in marine environments are spatially complex and are usually not delivered or generated uniformly. A key first step therefore in marine natural capital assessments is obtaining suitable spatial data to enable mapping of biologically and ecologically important areas (Burdon et al., 2019). The Natural Capital Committee (2014) acknowledge the difficulty of including certain habitats (such as saltmarshes, seagrass, bivalve reefs, and littoral and sublittoral mudflats) in natural capital assessments due to a general lack of baseline information on extent and condition. This section describes the process (including the use of appropriate spatial datasets) undertaken to enable the assessment of the extent and condition of 10 Orkney habitats and the associated ecosystem services these habitats provide.

4.2 Methodology

4.2.1 Figure 4-1 below outlines the methodology used to assess the condition of Orkney habitats and the implications of condition for ecosystem service provision by habitats.

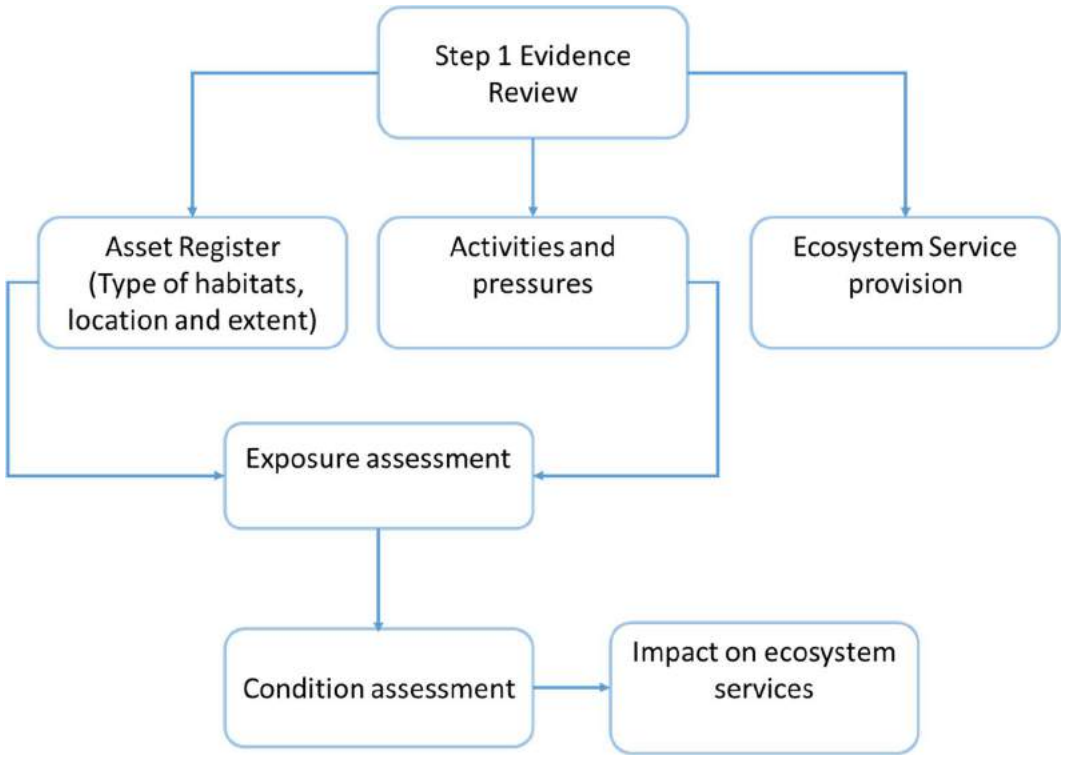


Figure 4-1: Outline of the ecosystem service and condition assessment methodology.

4.2.2 This phase of the project was underpinned by the Rapid Evidence Assessment (REA). As outlined in Section 2, the scope of search for the REA was broad and covered a range of habitats identified in the 46 critically reviewed papers, therefore a number of references in the REA were not relevant to the final ES sensitivity and pressure assessments. Table 4-1 below indicates the number of applicable references from the REA and the aspect these addressed (ES, sensitivity and pressure) for each feature. Some of the references were relatively generic, that is not specific to Orkney and provided general information on habitat type. All relevant feature information from the REA was reviewed and added to the ES spreadsheet (see Supplementary Materials – Orkney NC Workbook).

4.2.3 It can be seen that overall there were significant gaps from the literature evidence available to develop a condition assessment for the Orkney marine region. These gaps meant that alternative approaches were required to source suitable data and create the condition assessment.

Table 4-1: REA Summary of number of applicable references with evidence to support condition assessment.

	Ecosystem Service	Sensitivity	Pressure
Brittlestar beds	2	0	0
Burrowed mud	0	0	0
Circalittoral mud	0	0	0
Flame shell beds	3	0	0
Horse mussel beds	4	0	0
Kelp	5	1 (generic)	1 (generic)
Maerl	3	1 (generic)	0
Seagrass	4	0	2 (generic)
Seaweeds	2	0	0
Saltmarsh	3	1 (generic)	1 (generic)

Additional spatial data searches to support condition assessment

4.2.4 To address the evidence gaps the MBA project team undertook an additional rapid review of data (including methodological literature and spatial datasets) available on ecosystem services. Recent reviews were firstly incorporated (e.g. Tillin et al., 2020; Tillin et al., 2019a and b). If there were no assessments of ecosystem service reviews for a particular habitat, then the evidence base supporting older reviews were then considered (e.g. Potts et al., 2014; Fletcher et al., 2010). In addition, information on the underlying processes, habitat components and wider ecology was considered e.g. MarLIN reviews, literature searches.

4.2.5 The spatial data and other data used in the condition assessment comes from Scotland's National Marine Plan interactive (NMPi). NMPi is a web based spatial data tool that hosts information at a national level, to support the Scotland's National Marine Plan, but also hosts data for each of the eleven Scottish Marine Regions. These data are continuously updated. Checks on evidence likely to be of relevance to the project within the NMPi identified 140 resources of relevance to Orkney. A review of NMPi data layers is provided in Table 5-2 below.

Table 4-2: Number of relevant data sources from NMPi.

	Condition	Natural capital stock	Ecosystem service	Pressure	Pressure/Condition or Pressure/ecosystem, service
No of data layers, other evidence	4	39	15	44	15

4.3 Orkney Natural Capital Assets

4.3.1 A key step to develop natural capital assessments is the development of an inventory of natural capital stocks. An asset register has been defined as "an inventory of the natural assets in an area and their condition", with suggestions that assets could be defined according to their type, area and quality, and represented spatially where possible using maps and GIS layers (Natural Capital Committee, 2017). The marine habitats present in Orkney were identified from the REA exercise, with further information on extent and location sourced for Priority Marine Features (PMF) from the NMPi and seabed habitats classified according to the European Nature Information System (EUNIS) as broadscale habitats from UK SeaMap (2018). The EUNIS habitat classification is a pan-European, comprehensive and widely accepted classification of all habitat types.

Feature selection for asset register

4.3.2 Marine habitats, as classified by EUNIS, are those that occur below spring high tide limit (or below mean water level in non-tidal waters) and include enclosed coastal saline or brackish waters, without a permanent surface connection to the sea but either with intermittent surface or sub-surface connections (as in lagoons). Marine habitats include those that are fully saline, brackish or almost fresh. Waterlogged littoral saltmarshes and associated saline or brackish pools above the mean water level in non-tidal waters or above the spring high tide limit in tidal waters are included with marine habitats.

4.3.3 Previous work by Tillin et al. (2018) found that differences in ecosystem service provision between PMF and their respective parent broadscale habitats shows a clear pattern. The largest differences in ecosystem service provision are found in the habitats with key ecosystem engineering species that mediate the ecosystem service flow. Examples include algal dominated habitats e.g. Tide-swept algal communities but also biogenic reef communities such as horse mussel beds and native oyster beds. In all of these cases, PMF habitats scored higher indicating disproportionately high contributions of ecosystem services and therefore that these habitats are of particular interest for service delivery. It was decided to focus the assessment of ecosystem services on key PMF for Orkney.

4.3.4 Table 4-3 below shows the PMF and other habitats selected for the project and the EUNIS habitat codes that correlate with these. Spatial data sources are identified. Only the PMF features were assessed.

Table 4-3: Key PMF and other habitats selected for Orkney, EUNIS codes and spatial data source

Feature	PMF	EUNIS Codes	Orkney Spatial data
Burrowed mud	Yes	A5.361, A5.362	NMPi
Flame shell beds	Yes	A5.434	NMPi
Horse mussel beds	Yes	A5.621, A5.622, A5.623, A5.624	NMPi
Maerl	Yes	A5.51	NMPi
Kelp	Yes	A3.113, A3.115, A3.212,	NMPi
Seagrass	Yes	A2.61, A5.53	NMPi
Seaweeds (Kelp and seaweed communities on sublittoral sediment, Tide-swept algal communities)	Yes	A1.15; A5.52 (and others)	NMPi
Circalittoral mud	No	A5.35, A5.36 and A5.37	UK SeaMap (2018)
Brittlestar beds	No	A5.445	None

Inclusion of species with no or limited mobility within features

4.3.5 Many benthic invertebrates are sessile, or have low mobility, are closely linked to benthic habitats and frequently have very specific habitat-species associations. Marine benthic invertebrates (like terrestrial invertebrates) are important for ecosystem function and delivery of services. They are therefore considered an integral part of habitat assets and their contribution to ecosystem service delivery is captured through service classes such as 'Mediation of wastes or toxic substances of anthropogenic origin by living processes'.

Distribution of priority habitats in Orkney

4.3.6 All PMF habitats selected were mapped using data layers from the NMPi with the exception of brittlestar beds as there was no information found on the location and extent of these beds. While species records are available from a number of sources, the brittlestars are common species and the presence of individuals does not signify that dense beds are present. Examples of PMF distribution maps are shown below (Figure 4-2) and in Section 6 (Figure 6-1). Further maps are provided as Supplementary Material.

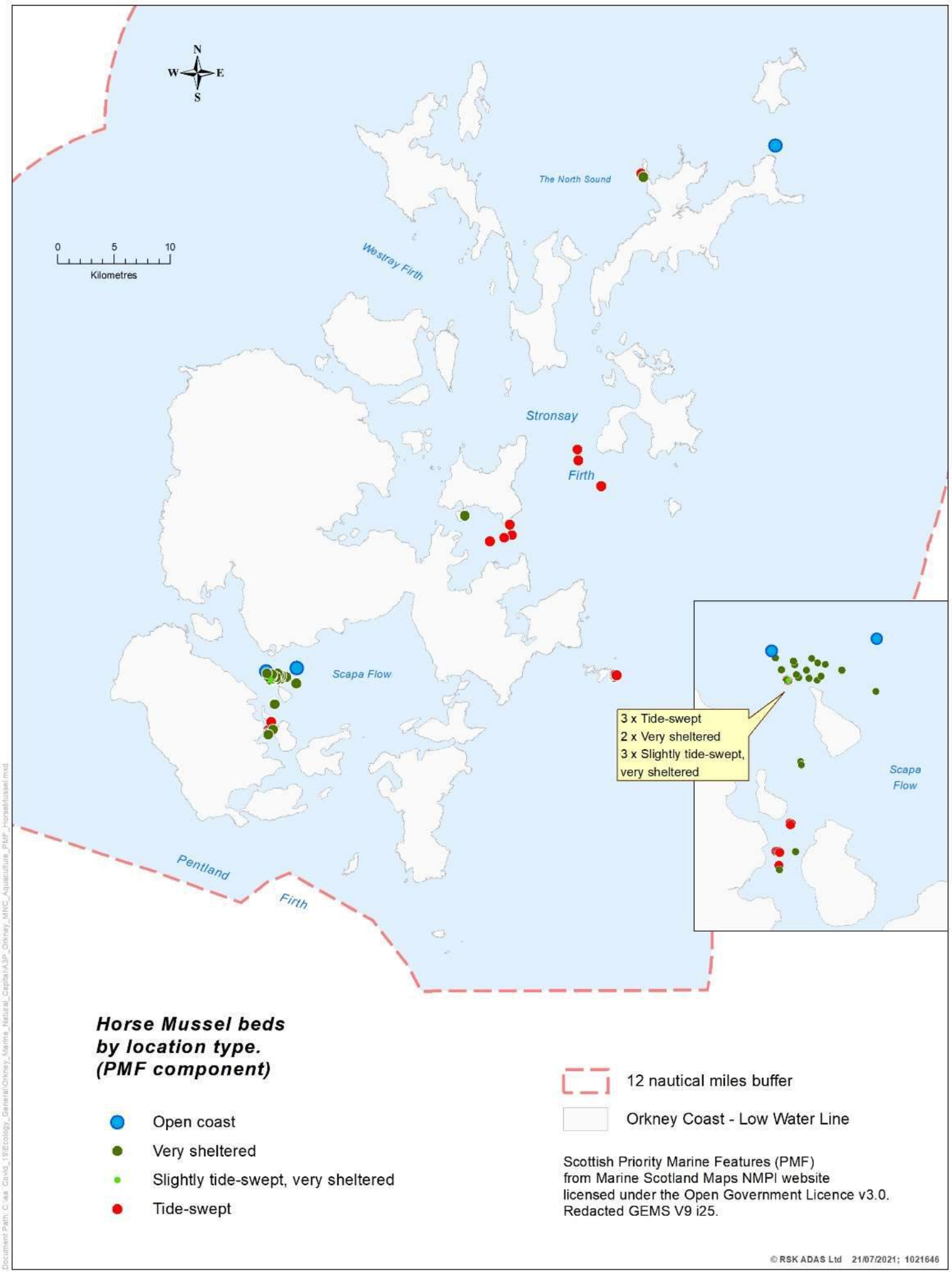


Figure 4-2: Distribution of horse mussel beds around Orkney (Data layer NMPi)

4.4 Ecosystem Service Provision

4.4.1 To assess the ecosystem services delivered by the natural capital assets, we adopted the Common International Classification of Ecosystem Services (CICES)[20]. The CICES framework assesses final ecosystem services, classified into three groups, provisioning, regulating and maintenance and cultural. Currently there are over 70 marine relevant ecosystem service classes in CICES V5.1 (Haines-Young & Potschin, 2018). It was considered that a sub-set of these would suffice to capture delivery of the key ecosystem services and the following steps were undertaken to develop the final list of assessed ecosystem services.

Ecosystem service rationalisation:

Step 1. Exclude CICES marine relevant ecosystem services that are considered to be marine relevant but not utilised in Scotland e.g. abstraction of sea water for drinking water.

Step 2. Removal of services delivered by the abiotic habitat, e.g. noise attenuation (see below for further detail)

Step 3. Remove ecosystem services for which there is limited information. This step was included in this assessment to remove blank cells from the scoring. We acknowledge that some of these ecosystem services, over time, may have new data and so further assessment should be undertaken as and when this data becomes available or improvements in data collection occur.

4.4.2 Services that were delivered entirely by the abiotic environment, without biotic components, were removed (step 2) on the basis that these were independent of condition or human pressures and would therefore be unchanged and only marine relevant ones were included. CICES was developed to support accounting systems and as such is focussed on final ecosystem services. Due to the complex nature of the marine system, some key elements of the breadth of ecosystem services supported by marine habitats are not included, so two additional categories of intermediate services were also added to capture this (based on regulating and supporting services after Potts et al. (2014). These were nutrient cycling/secondary production and primary production.

Rapid Evidence Assessment results for condition assessment

4.4.3 In order to link seabed habitats with their relative flow of ecosystem services, it is necessary to understand how different habitats deliver particular components of natural capital flows. The evidence base used to support the assessment of ecosystem service provision for the 10 habitats came from a variety of sources. The full review is provided in the ES spreadsheet (see Supplementary Materials – Orkney NC Workbook) which provides details of the evidence base supporting each relationship that was used to assign both the ecosystem service provision score and the confidence, together with the literature sources that were referred to. A summary table of this information is given in Table 4-4.

4.4.4 Within the project resources PMF habitats were prioritised. However, it became apparent from the review that disturbance from fisheries was widespread. In order to incorporate the large extents of marine habitats affected, a rapid ecosystem service assessment was undertaken for the broadscale habitats. The ES matrix was populated from work undertaken by the project team for JNCC and used with permission. The JNCC project was based on conceptual ecosystem models (for representative example see Alexander et al., 2015) and assessed the contribution of individual components to ES.

4.4.5 To create broadscale habitat assessments for Orkney we created representative ES scores for the habitat based on expert judgement. These were translated as follows:

- A3.2 was based on the PMF kelp assessment;
- A5.5 includes, kelp, seagrass and maerl the kelp score was used as this tended to represent high levels of service, but confidence was set to 1 for all assessments;
- A3.1 and A3.2 based on seaweeds PMF;
- A4.1, A4.2 4.3 circalittoral rock- based on the rock assessment by JNCC without the primary producer; and
- A3.3/A4.2 based on highest score for each with confidence lowered to represent uncertainty where the service was only delivered by one habitat.

[20] https://cices.eu/

Table 4-4: Summary table of ecosystem services with marine relevance used in the assessment. Note: for consistency, ecosystem service terminology has been based on the cited references. Appendix 3, Table A9-1 provides additional detail.

Section	Class	Source
Intermediate	Nutrient cycling/ Secondary production	Potts et al. 2014
Intermediate	Primary production	Potts et al. 2014
Provisioning	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	CICES v5.1
Provisioning	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	CICES v5.1
Provisioning	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	CICES v5.1
Provisioning	Wild animals (terrestrial and aquatic) used for nutritional purposes	CICES v5.1
Provisioning	Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)	CICES v5.1
Provisioning	Seeds, spores and other plant materials collected for maintaining or establishing a population	CICES v5.1
Provisioning	Higher and lower plants (whole organisms) used to breed new strains or varieties	CICES v5.1
Provisioning	Individual genes extracted from higher and lower plants for the design and construction of new biological entities	CICES v5.1
Provisioning	Animal material collected for the purposes of maintaining or establishing a population	CICES v5.1
Provisioning	Wild animals (whole organisms) used to breed new strains or varieties	CICES v5.1
Provisioning	Individual genes extracted from organisms for the design and construction of new biological entities	CICES v5.1
Regulation & Maintenance	Bio-remediation by micro-organisms, algae, plants, and animals	CICES v5.1
Regulation & Maintenance	Filtration/sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	CICES v5.1
Regulation & Maintenance	Control of erosion rates	CICES v5.1
Regulation & Maintenance	Buffering and attenuation of mass movement	CICES v5.1
Regulation & Maintenance	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	CICES v5.1
Regulation & Maintenance	Pollination (or 'gamete' dispersal in a marine context)	CICES v5.1
Regulation & Maintenance	Seed dispersal	CICES v5.1
Regulation & Maintenance	Maintaining nursery populations and habitats (Including gene pool protection)	CICES v5.1
Regulation & Maintenance	Pest control (including invasive species)	CICES v5.1
Regulation & Maintenance	Disease control	CICES v5.1
Regulation & Maintenance	Regulation of the chemical condition of salt waters by living processes	CICES v5.1
Regulation & Maintenance	Regulation of chemical composition of atmosphere and oceans	CICES v5.1
Cultural	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions e.g. Recreational activities, scuba diving.	CICES v5.1
Cultural	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions e.g. passive, cliff top cafes, walking along	CICES v5.1
Cultural	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	CICES v5.1
Cultural	Characteristics of living systems that enable education and training e.g., rockpooling, school visits, fieldtrips	CICES v5.1

Section	Class	Source
Cultural	Characteristics of living systems that are resonant in terms of culture or heritage e.g. oyster festivals, kelp harvesting in Orkney, language associated kelp harvesting.	CICES v5.1
Cultural	Characteristics of living systems that enable aesthetic experiences e.g. photography, artists.	CICES v5.1
Cultural	Elements of living systems that have symbolic meaning e.g. poetry, artworks.	CICES v5.1
Cultural	Elements of living systems that have sacred or religious meaning	CICES v5.1
Cultural	Elements of living systems used for entertainment or representation	CICES v5.1
Cultural	Characteristics or features of living systems that have an existence value	CICES v5.1
Cultural	Characteristics or features of living systems that have an option or bequest value	CICES v5.1

4.4.6 The provision of each ecosystem service by each of the 10 habitats was assessed and scored relative to other marine habitats, together with our confidence in the evidence supporting this association. Ecosystem service scores were assessed using a five point scale: significant contribution, moderate contribution, low contribution, no or negligible contribution, and not assessed (after Potts et al. 2014). Confidence was scored on a four point scale as shown below (Table 4-5).

Table 4-5: Confidence score categories used in the assessment of ecosystem service provision by habitats.

Confidence score	Description
High (3)	There is a good understanding of the habitat-ecosystem service relationship and/or the assessment is well supported by evidence. There is consensus among experts
Medium (2)	While there is an understanding of the habitat-ecosystem service relationship, this may be based on limited evidence and/or proxy information. There is a majority agreement between experts; but conflicting evidence/opposing views exist.
Low (1)	There is limited or low understanding of the habitat-ecosystem service relationship and/or the assessment is not well supported by evidence. There is no clear agreement amongst experts.
Variable	The habitat-ecosystem service relationship is highly variable in space and/or time.

4.5 Condition Assessments Based On Pressures From Activities

4.5.1 Data that can be used as direct indicators of 'condition' of marine habitats is largely limited in the marine environment to small spatial scales. Direct assessments of condition can be based on biological, chemical and physical parameters, such as assessments of population characteristics, the presence of contaminants or measures of variables such as oxygen and salinity or substratum condition. Condition assessments are undertaken by the statutory agencies as part of legislative reporting obligations. Other surveys that may provide information vary in scope from Seasearch (carried out by volunteer divers), studies undertaken to support development proposals, dedicated PMF validation surveys (e.g. 2012 SNH/MSS Shetland benthic camera survey) and academic research (e.g. Heriot-Watt University surveys). For many benthic habitats there may be some data on extent but annual data on condition are rare. No direct assessments of habitat condition were identified from the literature reviewed as part of the initial REA.

4.5.2 Where data based on direct monitoring of condition of habitat assets is absent an alternative is to use proxy measures to assess condition based on exposure to pressures (European Environment Agency, 2015). Assessments that combine evidence for exposure to pressures with an assessment of the sensitivity or impact on receptors may sometimes be referred to as a risk assessment or vulnerability assessment. Key pressures resulting from human activities for Orkney were identified from Scotland's Marine Assessment (2020) (Moffat et al., 2021).

Selecting and prioritising pressures for condition assessment

4.5.3 Selection of pressures to support condition assessment was informed by Scotland's Marine Atlas (Moffat et al., 2021). This is an assessment of the condition of Scotland's seas, based on scientific evidence from data and analysis, supported by expert judgement.

4.5.4 Scotland's Marine Assessment 2020 presents details of the process which was conducted to identify the key pressures in each region and any trends in the pressures over the period 1 January 2014 to 31 December 2018 together with the outcomes from the process. The assessment of pressures only considers those human activities that directly have an impact on the marine environment. Indirect pressures were not assessed, such as the effect of CO_2 emissions into the atmosphere, as well as other greenhouse gases, which can indirectly influence the marine environment through climate change and ocean acidification.

4.5.5 Pressures on the marine environment of Orkney are considered low relative to other Scottish Marine Regions. In this context, removal of target shellfish and fish species by inshore fisheries is identified as the most important pressure (Table 4-6), but this does not imply fishing beyond biological limits. Faeces and waste food from salmon aquaculture is the main (and increasing) source of organic enrichment, but agricultural run-off can occur at a local scale and is intense where it occurs.

4.5.6 A small scallop dredge fishery exists in the region, accounting for sub-surface abrasion and penetration of shallow subtidal sediments. Surface abrasion is likely to occur through weather-related dragging of traps and ropes from creeling and potting activity which is widespread but at low intensity in the region. Creeling and potting may also affect non-target species through ghost fishing of lost gear and risk of entanglement in ropes.

4.5.7 The ranking of the pressures in terms of impact is a relative exercise within each region and is not a statement of their absolute impact.

4.5.8 After consideration of the pressure prioritisation, it was decided that the condition assessment should focus on the two main activities (fishing and finfish aquaculture) and the five associated pressures with further assessments undertaken if data was available.

Table 4-6: Prioritised pressures for the Orkney region (Scotland's Marine Assessment, 2020)

Pressure	Component affected	Main contributing FEAST activity
Removal of target species	Commercial fish and shellfish	Fishing - Creeling and potting Fishing - Dive fisheries (not including hydraulic dredging) Fishing - Pelagic trawling & purse seining Fishing - Scallop dredging
Organic enrichment	Predicted extent of physical disturbance to seafloor	Aquaculture - Finfish Industrial and agricultural liquid discharges
Subsurface abrasion/penetration	Predicted extent of physical disturbance to seafloor Commercial shellfish	Fishing - Scallop dredging
Surface abrasion	Predicted extent of physical disturbance to seafloor Commercial fish Commercial shellfish Wider fish community	Fishing - Creeling and potting Fishing - Scallop dredging
Removal of non-target species	Predicted extent of physical disturbance to seafloor Seals Cetaceans Commercial fish Wider fish community	Fishing - Creeling and potting Fishing - Recreational Fishing Fishing - Scallop dredging

Sensitivity assessment sources

4.5.9 Condition assessments based on exposure require that the response to a pressure by the components of the habitat that deliver the services is understood. This project used, as a starting point, the habitat sensitivity assessment databases FeAST[21] and MarLIN[22].

4.5.10 The FeAST online tool uses a Marine Protected Area 'feature' approach (e.g. habitat or species) and provides sensitivity assessments for Scotland's Priority Marine Features (including benthic habitats and species, seabirds, fish and mammals). The assessments have been made tailored for Scottish waters and evidence for the sensitivity assessments and a full bibliography are available to view within FeAST.

4.5.11 MarLIN provides information to support marine conservation, management and planning. The resources are based on available scientific evidence and designed for all stakeholders, from government agencies and industry to naturalists and the public. MarLIN hosts the largest review of the effects of human activities and natural events on marine species and habitats yet undertaken.

4.5.12 Sensitivity information from these sources was used as a starting point to understand the response of the components of the habitat that deliver ecosystem services to pressures. This information is captured in the supplied spreadsheets.

[21] FeAST – Feature Activity Sensitivity Tool. See: http://www.marine.scotland.gov.uk/feast/

[22] MarLIN – The Marine Life Information Network. See: http://www.marlin.ac.uk

4.6 Results of Natural Capital Assessment

Orkney Natural Capital Assets

4.6.1 Habitats identified from UK SeaMAP and used in the Extent of physical damage indicator are shown below in Table 4-7 (total area is rounded). The predominant habitats in Orkney are sublittoral coarse sediments and sands followed by large extents of infralittoral and circalittoral rock.

Table 4-7: EUNIS Broadscale habitats and total area (hectares) in the Orkney region bounded by the 12nm limit.

EUNIS	Mainland	Western Isles	Total Area
A3.1 High energy infralittoral rock	26,643	145	26,787
A3.2 Moderate energy infralittoral rock	27,062	0	27,062
A3.3 Low energy infralittoral rock	9,272	0	9,272
A4.1 High energy circalittoral rock	40,176	8,864	49,040
A4.2 Moderate energy circalittoral rock	53,831	11,002	64,833
A4.3 Low energy circalittoral rock	10,403	131	10,534
A5.1 Sublittoral coarse sediment	375,389	101,716	477,105
A5.2 Sublittoral sand	151,630	67,830	219,459
A5.3 Sublittoral mud	6,764	0	6,764
A5.4 Sublittoral mixed	13,161	0	13,161
A5.5 Sublittoral macrophyte dominated	431	0	431
A3.2/A4.2 Moderate energy infralittoral/circalittoral rock	0	7,632	7,632
Total	**714,762**	**197,320**	**912,080**

Presence of Priority Marine Features

4.6.2 For most PMFs the available evidence is for data points indicating presence and not polygon (area) data. Table 4-8 below summarises the number of data points for each PMF. There are high numbers of records for kelp and seaweed PMF and maerl. As these are not habitat extents, evidence is lacking for areal coverage. For some PMFs polygon data was available (Table 4-9). This shows that circalittoral mud was the most extensive of these habitats.

Table 4-8: PMF by number of data points

PMF	Total
Burrowed mud	4
Flame shell beds	15
Horse mussel beds	55
Kelp and seaweed communities on sublittoral sediment	142
Kelp beds	282
Maerl beds	163
Seagrass beds	42
Tide-swept algal communities	18
Tide-swept algal communities and Kelp beds	84

Table 4-9: PMF by area (hectares)

PMF	Total area
Circalittoral mud	5,707
Flameshell beds	508
Kelp and seaweed communities on sublittoral sediment	468
Maerl beds	537
Saltmarsh	58

Ecosystem service provision

4.6.3 No evidence was found for the following services and these are not shown in the summary Table A3-2 in Appendix 3.

- Wild animals used to breed new strains or varieties
- Passive or observational interactions e.g. cliff top cafes, walking along coastal paths
- Elements of living systems that have symbolic meaning e.g. poetry, artworks
- Elements of living systems that have sacred or religious meaning
- Elements of living systems used for entertainment or representation
- Characteristics or features of living systems that have an existence value
- Characteristics or features of living systems that have an option or bequest value

4.6.4 The intermediate [23]services nutrient cycling and primary and/or secondary production were supported by all habitats and underpin the delivery of other services through food webs.

4.6.5 Many of the ecosystem services are based on potential evidence, rather than actual evidence that the service is realised in Orkney, as the evidence base was too limited to assess service provision.

Provisioning services.

4.6.6 Services associated with plants were restricted to habitats dominated by seagrass, seaweeds and kelp. Many of the sublittoral habitats were too deep and/or too mobile to support attached plants and therefore these do not support ecosystem services provided by plants.

4.6.7 All habitats, with the exception of brittlestar beds, were considered to provide wild animal species (shellfish and crustaceans predominantly) that were targeted by commercial fisheries.

4.6.8 Provisioning services, for which there was little evidence, are the use of wild animals and plants for purposes other than food, such as fibres and other materials or to produce energy, exploitation of genetic resources and development of new strains. Fibres and other materials from wild animals for direct use or processing, were limited to sandeels that have been harvested as aquaculture feed stock and horse mussels which are occasionally collected for bait and which have been suggested to offer opportunities for novel pharmaceutical compounds. No evidence was found for exploitation of genetic resources from species around Orkney. Typically this service does not require large amounts of material and in general there is little information to link development of new products etc. to the habitats from which they came.

4.6.9 Animal material collected to maintain or establish a population was limited to horse mussels which are sometimes collected to establish new populations as part of habitat restoration efforts. Similarly, seagrass seeds may be collected to restore seabed habitats.

Regulating services

4.6.10 Regulation of the environment by marine habitats and associated species was supported by most habitats. Most seabed habitats were assessed as having the capacity to process and store wastes, with habitats that support reefs of filter feeders (horse mussels and brittlestars) considered to provide a significant contribution. Marine algae and sediments with at least some mud content were considered to provide a moderate contribution. Circalittoral rock habitats and well-flushed sands and coarse sediments were considered to have a lower capacity to process and store wastes.

4.6.11 Most habitats were considered to have the capacity to reduce erosion and regulate water flows, either through the presence of rock substratum that reduce erosion or through the presence of animals and plants or sediments that can dampen wave action and trap sediments. Rock habitats were also considered to act as a buffer against mass movement with sedimentary habitats having a lower capacity to provide this service.

4.6.12 Carbon capture and storage (Regulation of chemical composition of atmosphere and oceans) and maintenance of nursery habitats for commercial species were services that were assessed as provided by most habitats.

4.6.13 Most habitats were considered to provide some regulation of pest species through the presence of native species that can occupy space therefore reducing colonisation or consume propagules or predate on pests. Confidence was low as there was little specific evidence to assess this service. There is limited evidence available to assess disease control by habitats so this service was largely not assessed across habitats.

Cultural services

4.6.14 Habitats that were considered to be accessible or that were characterised by plants and animals present on the surface were considered to be more attractive to divers and snorkelers and to provide opportunities for active interactions. These habitats were also considered to offer opportunities to undertake scientific research and other educational activities.

[23] The term intermediate is used here to refer to services which sit between the natural capital assets and the final goods and services. Intermediate services relate to ecological function and support final ecosystem services. This follows the terminology provided in Potts et al., (2014).

4.6.15 Only kelp habitats were identified as having particular cultural significance based on historical harvesting and traditions with activities such as festivals commemorating this heritage.

4.7 Ecosystem Services Weighted by Habitat Area

4.7.1 The summary table (Table A3-2) of ecosystem services was used to weight the provision of service by habitat area in order to evaluate the contribution of different habitats to ES provision (Table A3-3). This assessment could only be undertaken for habitats for which there was information on extent, therefore, burrowed mud, horse mussel beds, flameshell beds and seagrass were excluded. The ecosystem area was estimated based on PMF polygon data or habitat area based on the UK SeaMap areas from the BH3 indicator assessments for each of the habitats in hectares (10,000 m²).

4.7.2 The potential value of each ecosystem service from the ES potential matrix is converted to a proportional value (ecosystem service potential divided by maximum possible potential). The re-weighting of the potential ecosystem service delivery from 0-1 in this step by dividing by 3 (the maximum potential delivery weighting) prevents the ES value exceeding the extent of the habitat. An ecosystem service that is fully realised, i.e. delivered at full potential, is weighted as the area of habitat for that service. Table (A3-3) identifies the degree to which habitats potentially provide each ecosystem service as a proportion of the total provision of that service.

4.7.3 The formula for assessing ecosystem potential, weighted by area is:

$$Area\ ('000\ hectares) \times \frac{Potential\ ES\ delivery}{Maximum\ ES\ Delivery\ (5)} = ES\ Potential\ base$$

4.7.4 The weighted scores were then recalculated as percentage contribution of each habitat to that service, to aid interpretation of condition assessments and implications for ecosystem service provision. This weighted table is provided in Appendix 3.

4.7.5 During the assessment process a large number of uncertainties arose related to evidence gaps for habitat spatial resolution, sensitivity, ES provision and impact footprint. To help address some of these uncertainties, the approach above was adopted to provide a standardised way of weighting that allowed comparison based on spatial area which removes the incidence of high delivery of ES by very spatially restricted habitats to appear to dominate ES services in Orkney compared to extensive habitats.

4.7.6 The evidence to model the shape of ES service delivery by area through, for example, density dependent functions has not currently been developed and is not applicable across habitats, therefore, interpretation of outputs should be treated with caution.

4.8 Fishing Condition Assessment

4.8.1 Evidence to assess the condition of Orkney seabed habitats based on exposure to fishing pressures was provided by two different evidence sources. Fishing by vessels >12m was assessed using data collated as part of the BH3 abrasion indicator 'Extent of Physical Damage' developed for international reporting obligations. The BH3 abrasion indicator does not capture activity by smaller inshore vessels and therefore evidence on the number of fishing vessels produced by the ScotMAP project was used as an indicator of how fishing effort may be distributed between habitats.

4.8.2 Data on fish catches is available on NMPi but these are reported as ICES statistical rectangles and are not resolved to certain areas/habitats. There is also ScotMap information related to the value of fish catches but again these data are not resolved to habitat types.

4.8.3 The key pressures assessed were surface and subsurface abrasion from fisheries that use mobile gears.

Extent of physical damage based on vessels >12m

4.8.4 The BH3 abrasion indicator developed for use in OSPAR and UK Marine Strategy assessments (known as 'Extent of Physical Damage' indicator (OSPAR, 2017), predicts the spatial extent and level of physical disturbance by mapping areas where pressures overlap with sensitive habitats. Currently, it only considers disturbance from surface and sub-surface abrasion caused by vessels over 12 m in length using Vessel Monitoring System (VMS) (reporting vessels) fishing with bottom contacting gears. 'Extent of Physical Damage to Predominant and Special Habitats (BH3)'.

4.8.5 The Coordinated Environmental Monitoring Programme (CEMP) guideline is published as OSPAR Other Agreement 2017-09. The aim of this indicator is to evaluate to what extent the sea floor and its associated ecology, species and habitats are being damaged by human activities. The indicator uses a combination of spatial analyses to extrapolate data and knowledge from local studies to larger areas, and therefore it is regarded as particularly useful for assessing large sea areas where currently only limited data are available.

4.8.6 The indicator builds upon two types of underlying information:

i) The distribution and sensitivity of habitats (resilience and resistance), and

ii) The distribution and intensity of mobile bottom gear fisheries, sediment extraction and offshore constructions (based on the area swept by fishing gears).

4.8.7 These two sources of information (pressure and sensitivity) are combined to calculate the potential damage to a given seafloor habitat, and the trends across the six-year period. Table 4-10 below shows the pressure categories and Table 4-11 how these are combined with ranked sensitivity scores to develop the disturbance indicator.

4.8.8 The focus of the habitat data available is the EUNIS broadscale (level 3) classification. The corresponding pressure maps produced using these data aggregate pressure across a large grid cell. It is assumed that fishing occurs evenly across the whole grid cell which may not be the case.

4.8.9 The indicator categorises disturbance at the seabed from 0 (none) to 9 (very high). Categories 5 to 9 represent higher levels of disturbance (Table 4-11). Areas with a score of 5 and above are considered highly disturbed and, therefore, potentially in poor condition. Habitats may have a high disturbance score if they are heavily fished or if they are fished less frequently but are highly particularly sensitive to the associated pressures.

Table 4-10: The pressure categories used in the disturbance assessment based on area swept by combined fishing gears in each grid cell.

None	0	0
Very Low	1	>0.00 – ≤0.33
Low	2	>0.33 - ≤0.66
Medium	3	<0.66-≤1.00
High	4	>1.00- ≤3
Very high	5	> 3

Table 4-11: Disturbance matrix combining extent of pressure and habitat sensitivity

		Habitat sensitivity				
		1	2	3	4	5
Extent of pressure	1	1	2	3	4	6
	2	1	2	4	6	7
	3	1	3	5	7	9
	4	1	4	6	8	9
	5	2	4	7	9	9

Inshore fisheries ScotMap

4.8.10 To improve knowledge of the distribution of fishing activity and the value of fisheries in inshore waters, Marine Scotland carried out a fisheries mapping study known as ScotMap. ScotMap provides spatial information on the fishing activity of Scottish registered commercial fishing vessels under 15 m in overall length (Kafas et al., 2014). The data were collected during face-to-face interviews with individual vessel owners and operators and relate to fishing activity for the period 2007 to 2011. Interviewees were asked to identify the areas in which they fish, and to provide associated information on their fishing vessel, species targeted, fishing gear used and income from fishing. While ScotMap data does not provide quantitative information on fishing intensity and frequency, this dataset represented the 'best available evidence' on inshore fisheries at the time of this assessment.

4.8.11 ScotMap data layers used in the condition assessment were:

- Combined (all vessels) number of vessels;
- Pots and creels, number of vessels;
- Trawls (not Nephrops) number of vessels;
- Trawls (Nephrops) number of vessels; and
- Towed dredges number of vessels.

4.8.12 The results of the assessment of the extent of physical damage disturbance, PMF exposure to surface abrasion and the inshore fisheries ScotMap assessment are tabulated in Appendix 3. Figure 4-3 highlights the PMF exposure to surface pressure abrasion.

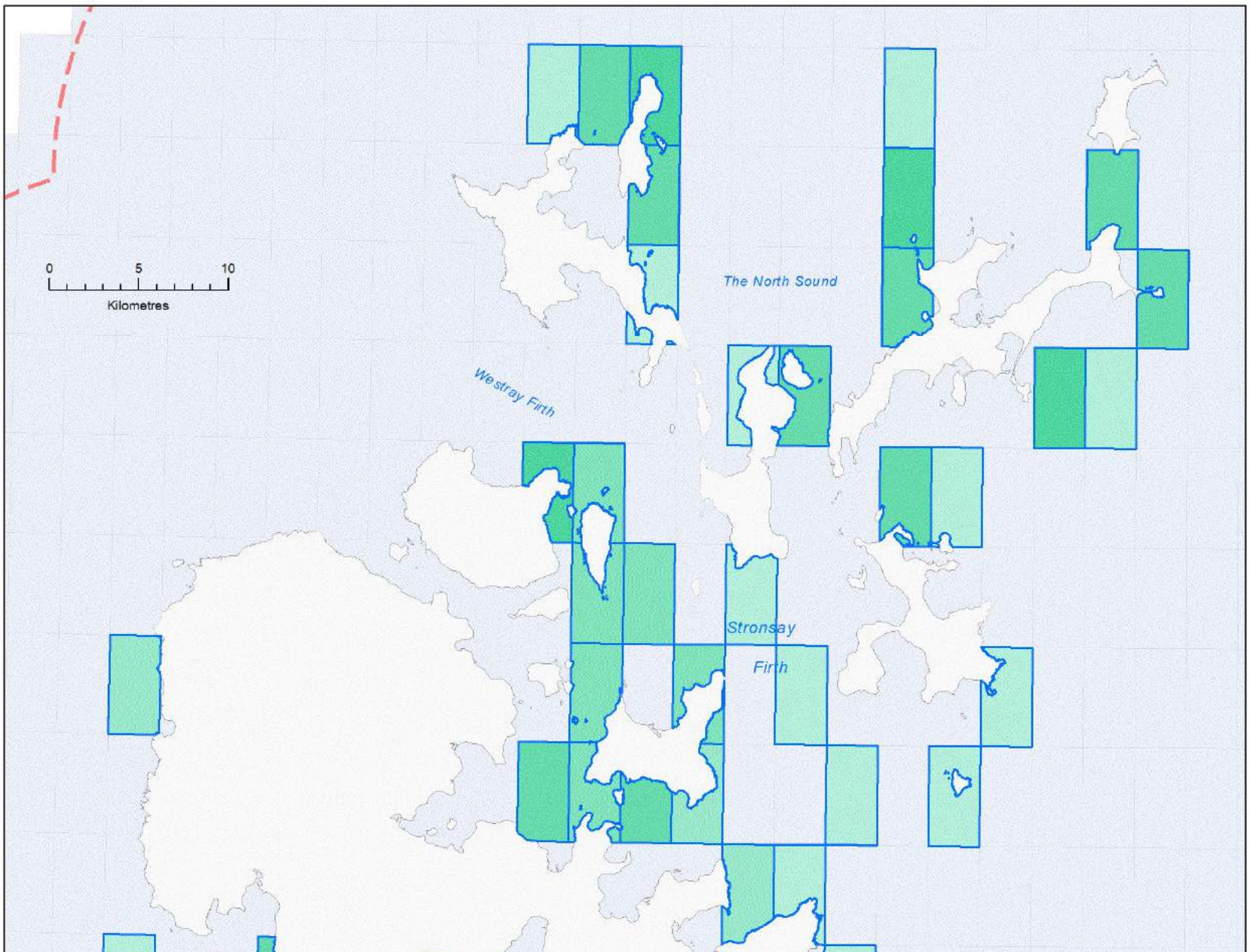


Figure 4-3: Surface pressure abrasion and PMF count. Grid cell edging indicates disturbance see Table 4-7 for pressure categories.

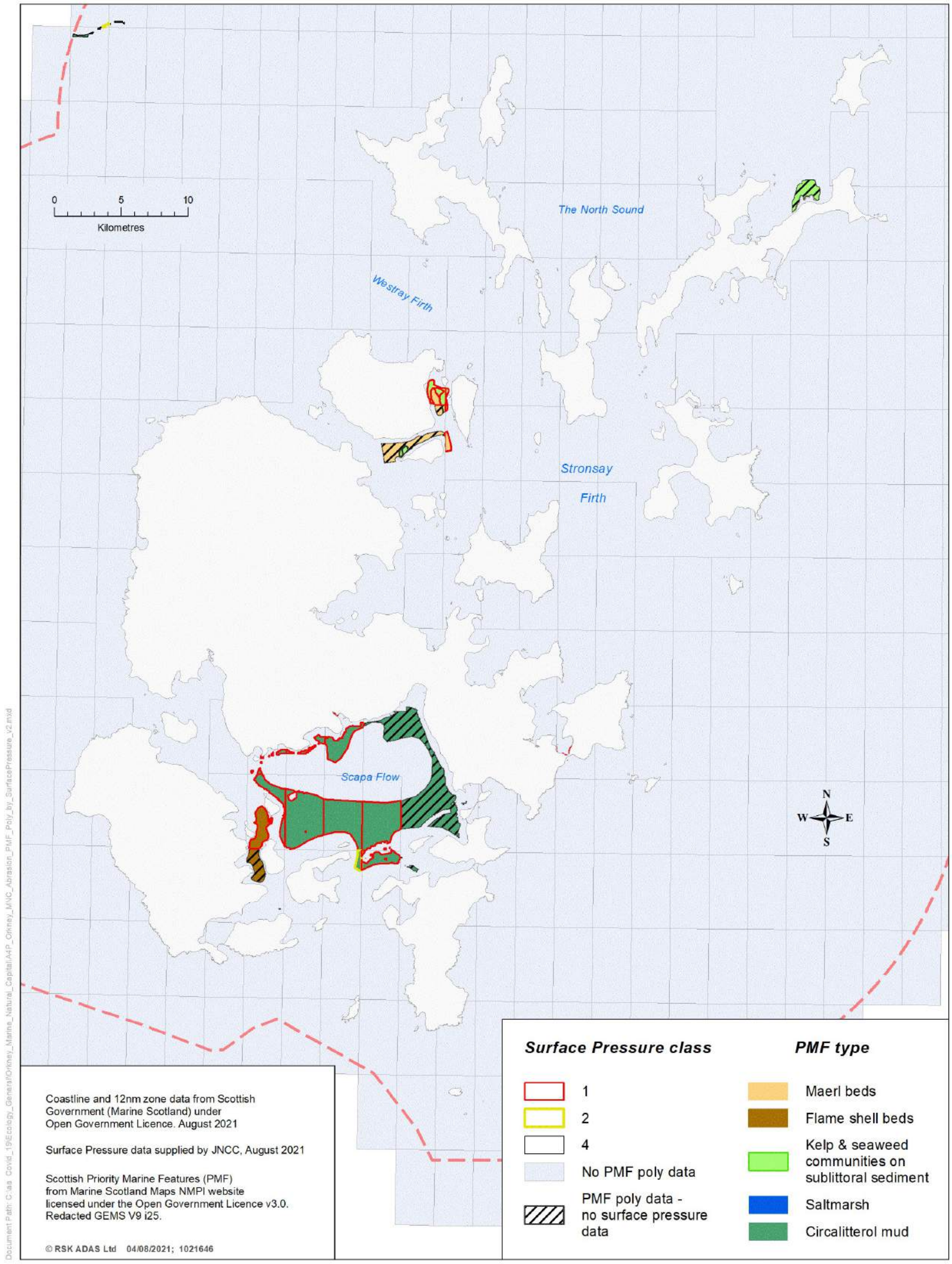


Figure 4-4: Surface abrasion (pressure) by PMF habitat polygon. See Table 4-7 for pressure categories.

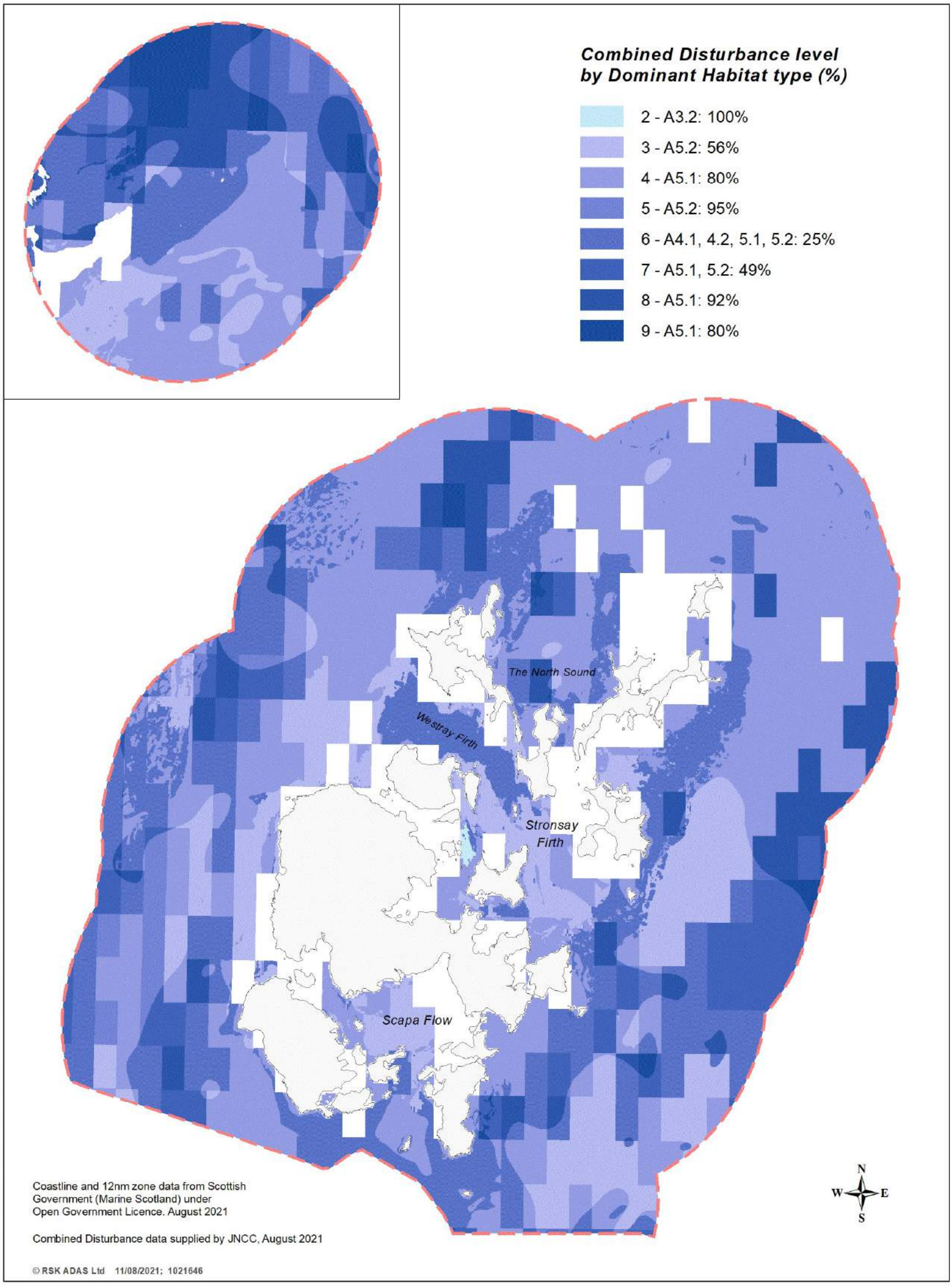


Figure 4-5: Combined disturbance by habitat area

Figure 4-6: Location of fish farms in Orkney waters bounded by the 12nm limit.

4.9 Aquaculture Condition Assessment

4.9.1 The key pressure of concern that has been identified with finfish aquaculture within the Orkney Marine Area is organic enrichment (Orkney Islands Council, 2020). Organic enrichment results from the degraded remains of dead biota and microbiota, faecal matter from finfish stocks, flocculated colloidal organic matter and the degraded remains of feedstuffs. Aquaculture is a source of organic matter together with sewage discharges and terrestrial/agricultural runoff. Organic enrichment may lead to eutrophication through nutrient enrichment. Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

4.9.2 The benchmark within MarLIN/MarESA is a deposit of 100gC $m^{-2}yr^{-1}$ of organic material resulting from degraded remains of dead biota and microbiota, faecal matter from finfish stocks, flocculated colloidal organic matter and the degraded remains of feedstuffs. Sensitivity assessments of each feature were collated from MarLIN/MarESA to understand how the 10 seabed habitats would be affected by organic enrichment, and then using this information plus the evidence base for the provision of ecosystem services, an assessment of the sensitivity of the ecosystem service to organic enrichment was conducted.

4.9.3 A 150m buffer was used to identify habitats adjacent to finfish farms. This was selected on the basis of work on organic enrichment by Hall-Spencer et al. (2006) who examined maerl beds in the vicinity of fish farms in strongly tidal areas. They noted a build-up of waste organic materials up to 100 m from the farms examined and a 10-100 fold increase in scavenging fauna (e.g. crabs).

4.9.4 There are 27 active finfish farms in the Orkney marine region, all of which farm salmon. Their locations are given in Figure 4-6 and the site names are in Table 4-12. The key pressure assessed was organic enrichment from salmon aquaculture.

Table 4-12: Site name and location of finfish farms

Site No.	Site Name	Management Area	OS grid Ref
FS0645	Kirk Noust	8b - Central Orkney	HY449291
FS0054	Lyrawa Bay	8c - Scapa Flow	ND299989
FS0597	Meil Bay	8b - Central Orkney	HY485123
FS0823	Noust Geo	8b - Central Orkney	HY570306
FS1340	Mill Bay	8b - Central Orkney	HY678271
FS1349	Bay of Holland	8b - Central Orkney	HY640224
FS1209	Ouseness	8a - Westray	HY465497
FS0860	Shapinsay	8b - Central Orkney	HY501213
FS1312	Skelwick Skerry	8a - Westray	HY524450
FS0122	Bay of Ham	8b - Central Orkney	HY448319
FS1198	South Cava	8c - Scapa Flow	ND333989
FS1023	Bring Head	8c - Scapa Flow	HY273022
FS0390	Carness Bay	8b - Central Orkney	HY469139
FS0993	Chalmers Hope	8c - Scapa Flow	HY288009
FS0031	Pegal Bay	8c - Scapa Flow	ND302976
FS0813	Puldrite	8b - Central Orkney	HY425185
FS0908	Quanterness	8b - Central Orkney	HY432140
FS1210	Vestness	8a - Westray	HY480493
FS1305	Westerbister	8c - Scapa Flow	HY453025
FS1331	Lober Rock (SMH)	8c - Scapa Flow	ND434946
FS1337	Hunda	8c - Scapa Flow	ND445977
FS1294	Wyre	8b - Central Orkney	HY456253
FS1080	Bay of Cleat (North)	8a - Westray	HY473475
FS0595	Bay of Cleat (South)	8a - Westray	HY470471
FS1020	Bay of Vady	8b - Central Orkney	HY465278
FS1017	Fara West	8c - Scapa Flow	ND321953
FS1024	Toyness	8c - Scapa Flow	HY354037

4.9.5 Sensitivity of features to organic enrichment, the key pressure identified from finfish aquaculture, was identified based on MarLIN. These assessments were then evaluated for applicability to ecosystem services based on the habitat component that supports the service. The rationale for PMFs can be found in the attached spreadsheet.

4.9.6 Distribution of finfish farms was plotted against PMF data points and polygons to assess likely overlaps (see Figure 4-8 and Figure 4-9).

4.9.7 While the data do not support a full condition assessment, it is possible to make some inference solely on the presence of PMF records within a 1km buffer around finfish farms.

Table 13: Number of PMF records within 1km buffer around finfish farms

PMF	Buffer zone around finfish farms (radius, m)				Total	% within 1Km buffer
	150	150-500	500-1000	All		
Burrowed mud			1	1	4	25
Flame shell beds			3	3	15	20
Horse mussel beds				0	55	0
Kelp and seaweed communities on sublittoral sediment	2	2	17	21	142	14.79
Kelp beds		2	3	5	282	1.77
Maerl beds	1	5	9	15	163	9.20
Seagrass beds			1	1	42	2.38
Tide-swept algal communities			4	4	18	22.22
Tide-swept algal communities and Kelp beds				0	84	0
Total	3	9	38	50	805	

4.9.8 While the actual impact to features will be strongly influenced by local hydrodynamics, it is possible to identify which features have a higher proportion of records within 1km of a finfish farm and so could be at risk.

4.9.9 This study suggests that the three PMFs with the most records within 1km of a finfish farm and thus potentially exposed to organic enrichment are: Burrowed mud (25% of records), Flame shell beds (20% of records) and Tide-swept algal communities (22% of records).

4.9.10 The sensitivity of PMFs to organic enrichment varies greatly (See Appendix 3, Table A3-4). This suggests that the ecosystem services associated with burrowed mud have medium sensitivity to organic enrichment, similarly for tide-swept algal communities but there are no data to support the impact of organic enrichment on the ecosystem service provision from Flame shell beds as no feature sensitivity information is available to base an ecosystem service assessment on. The feature with the most sensitivity ecosystem service provision is maerl, so while only 9% of maerl beds are within a 1km buffer of a finfish farm, the impact on their ecosystem services may be disproportionate.

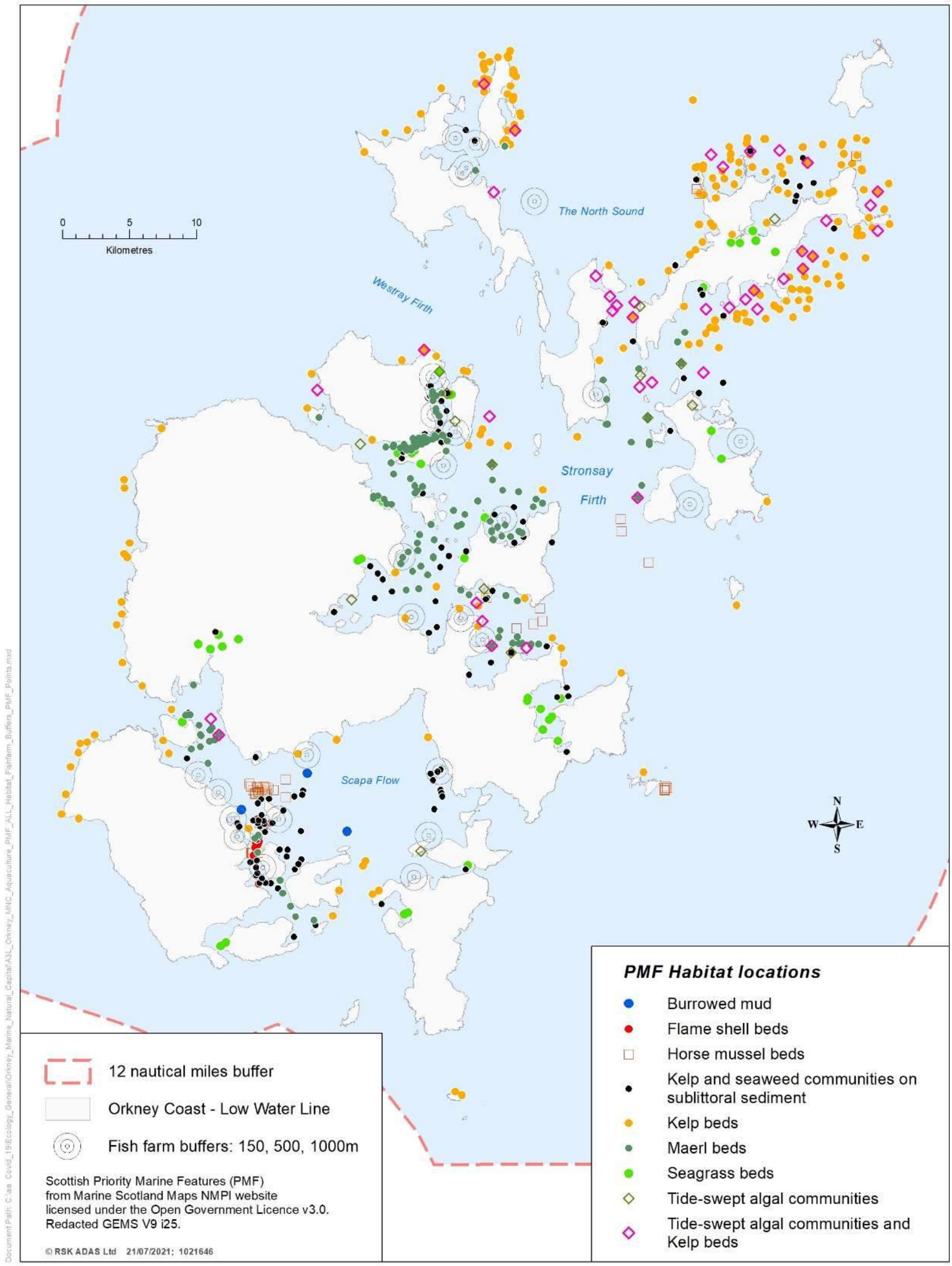


Figure 4-7: PMF data points shown with 150, 500 and 1000m buffers to support the organic enrichment condition assessment.

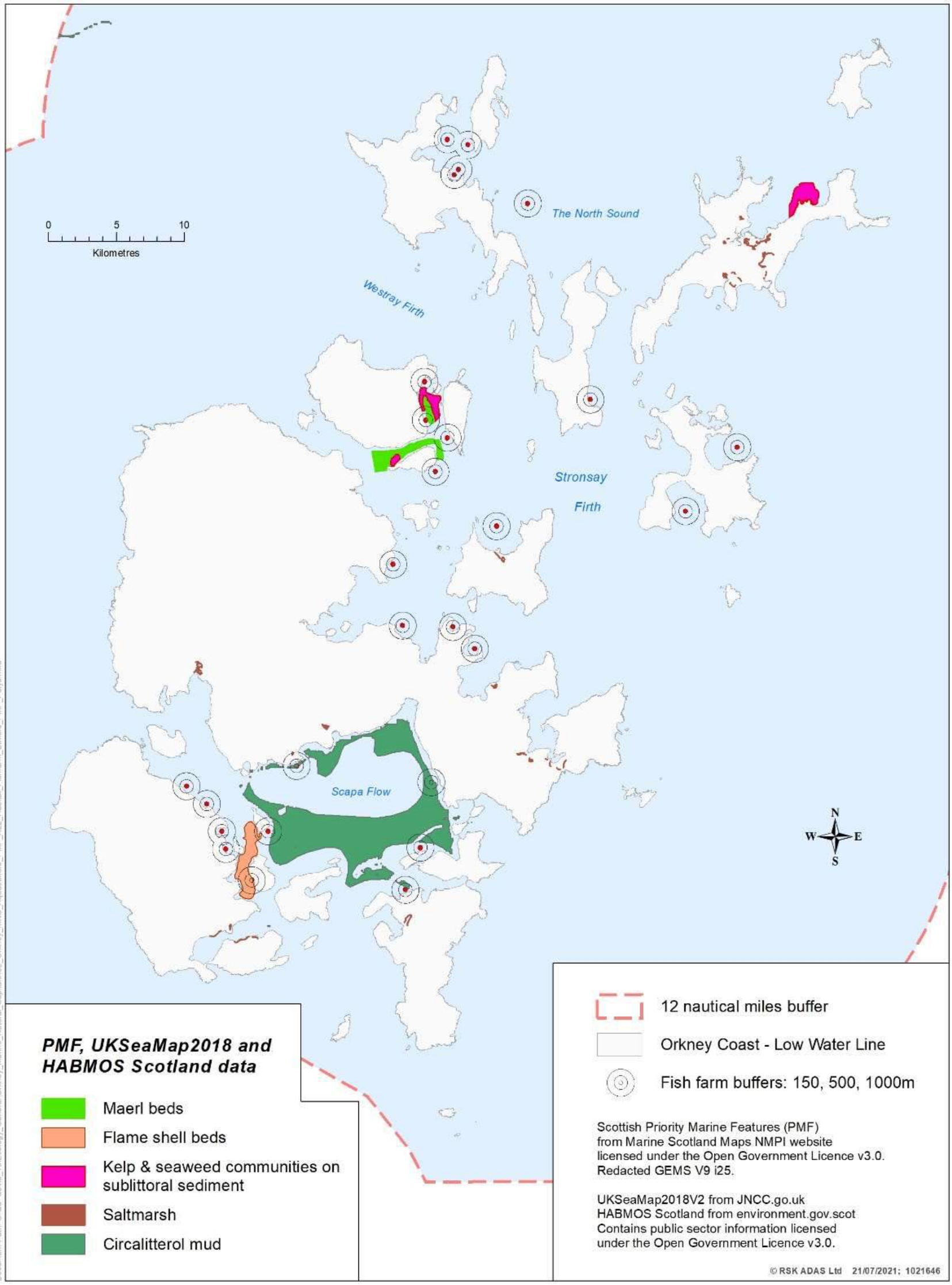


Figure 4-8: PMF polygons shown with 150, 500 and 1000m buffers to support the organic enrichment condition assessment.

Discussion

4.9.11 No direct evidence was found to assess the condition of Orkney's marine natural capital assets. Direct evidence for condition would include information on chemical, biological and ecological parameters. For example, condition assessments could include information such as the population structure (age structure, abundance and biomass) of key species compared to unimpacted habitats, the amount of contaminants in sediments and the response of the biological community such as incidence of tumours and malformations or the presence, extent and quality of habitats. Conditions assessments may track variables over time and space to provide information to support assessments.

4.9.12 Where information on condition is available assumptions may also be required to link the delivery of ecosystem service to condition. The link between delivery of ecosystem services and habitat condition will vary between services and the level of certainty will likewise vary. For example, rock habitats may protect coastlines through armouring regardless of the species present, bioturbation may be supported by a suite of species but those species may vary considerably between habitats, conversely the value of nursery habitats or provision of target species for fisheries is linked to specific commercially valued species. Due the lack of direct evidence, the project therefore made an explicit assumption that the capacity of marine habitats to deliver ecosystem services is dependent upon the condition of one or more ecosystem components from which that service is derived and assumes that the condition of a particular ecosystem component is a good indication of that capacity.

4.9.13 A lack of monitoring data is an issue for management of marine habitats and is likely to remain so even with improvements in autonomous platforms and automated data processing. We have identified the issue above (i.e. no direct evidence to aid condition assessment) and have proposed and tested a methodology (condition assessments based on pressure exposure and habitat sensitivity) to address this. We acknowledge and draw attention to these limitations, but also note that even for well-resourced projects such as the OSPAR/MSFD assessments of seabed disturbance this type of approach had to be developed and used due to evidence limitations. Weighting delivery by extent to allow comparison between habitats, which we acknowledge is not ideal, is however supported by previous research that has utilised this approach.

4.9.14 Key uncertainties were identified around the assessments, particularly around the spatial resolution of pressure and habitat data and the assumption that fishing effort is homogenous across a grid cell. The ScotMap does not indicate the frequency of activities but does suggest which habitats are targeted and where. With a concentration of activity between the mainland, Rousay and Shapinsay. Potting appears to be the most common fishing activity and this has less impact on the condition of the seabed than the use of mobile gears.

4.9.15 While the ScotMap and physical damage indicator show that some areas are frequently fished and disturbed, overall fishing effort appears relatively low for all habitats that are undisturbed or have low disturbance. Fishing represents the realisation of a provisioning ecosystem service that is also supported by regulation and maintenance services in the CICES framework, such as larval and gamete supply and the maintenance of nursery habitats as well as ecological processes (intermediate or supporting services, secondary production and nutrient cycling). Habitat areas that are subject to high levels of disturbance are assumed to be in poorer condition with a reduction in ecosystem service provision. Regulating and maintenance services that depend on the biota are likely to be the most affected as cultural services are not in general supported by seabed habitats to the same degree.

4.9.16 Ecosystem services that are likely to be sensitive to fishing pressures include bioremediation and storage of wastes although, given the high water quality in the Orkney region this service may not be realised (due to the low level of wastes and contamination). Even in areas of low disturbance, mobile gears may disturb the sediment disrupting carbon storage although other regulating service such as control of erosion rates that are supported by the abiotic habitat (sediment and rock) are likely to be unaffected. As large areas of the broadscale habitats that support services are exposed to low or no fishing effort, ecosystem services are considered to be provided and sustained around Orkney. Habitats of key concern would include biogenic features that are highly sensitive to damage with low recovery.

5 Climate Change Assessment

5.1 Introduction

5.1.1 The balance and maintenance of the chemical composition of the atmosphere and the oceans by marine living organisms is vitally important for a healthy climate. A key ecosystem service in this process is the sequestration of carbon. Plant based blue carbon resources such as kelp forests, maerl, seaweed and seagrass capture carbon through photosynthesis. Activities and pressures which prevent photosynthesis from occurring such as resuspension of sediments from dredging, increased sedimentation from land-based activities, flooding and erosion could potentially reduce the capacity of these plant based blue carbon resources to capture carbon. Physical loss of habitats and damage to the physical integrity of marine habitats will also impact on long-term storage capacity (Porter et al., 2020). This section provides a review and assessment of climate change impacts, highlighting the marine habitats that are valuable in fighting against climate change and those that are vulnerable to climate change.

5.2 Method

5.2.1 Data, predictions, and additional relevant information were provided from research carried out by project experts A. Want and N. Mieszkowska, and sourced from the primary literature, grey literature reports, scientific websites, and governmental websites.

5.2.2 Each species/habitat was evaluated for:

a) climate change impact on habitat, and

b) confidence in evidence base of impact. Climate change impacts were assigned scores of 'negligible', 'low', 'moderate' or 'significant' based upon existing evidence. Confidence of each climate change impact was scored 0-3 based upon a qualitative assessment of the available literature. Scores of 3 were reserved for habitats with considerable supporting evidence, specialised to the habitat and region. Lower scores were assigned to impact assessments with less supporting evidence or less specialised to habitat and region.

5.2.3 Species/habitats were assessed based on direct impacts associated with changes in sea surface temperature (SST) / near bottom temperature (NBT), ocean acidification (OA), and sea level rise (SLR). Knowledge gaps exist concerning indirect impacts of climate change on certain ecosystem services.

5.2.4 Climate change scenarios for SST / NBT, OA, and SLR were obtained from the MarLIN website (MarLIN, 2021), and RCP scenarios 2.6 and 8.5 from the Technical Summary of the IPCC Special Report on Ocean and Cryosphere in a Changing Climate (SROCC) (IPCC, 2019).

5.2.5 Ecosystem services potentially provided by each habitat were evaluated for the expected impact, and confidence in this evaluation, following the IPCC RCP 8.5 climate change scenario. Scores were assigned based on the greater expected impact and lower confidence from changes expected in the habitat in response to changes in SST and OA.

5.3 Review of habitat vulnerabilities to climate change

5.3.1 For marine species that cannot adjust their depth, e.g. littoral species, coping with global temperature change may be limited to latitudinal range shifts into suitable habitats (Burrows et al., 2011). Current distribution range temperature tolerances have been used to establish thermal safety margins for individual species (Sunday et al., 2014). Thermal safety margins can be used to predict future latitudinal distribution patterns along thermobars in response to temperature change, typically seen as poleward shifts. Sensitivity to increased sea surface temperature may be estimated in relationship to the optimal temperature range for species at any given location, i.e. populations in increasingly suboptimal temperature regions will be expected to be more negatively impacted as temperature shifts.

5.3.2 Elevated levels of atmospheric carbon dioxide increase the formation of carbonic acid and dissociated hydrogen ions in the marine environment. This process is known as ocean acidification and is recorded as decreases in pH. Plants and animals with 'skeletons' composed of calcium carbonate will have a reduction in the ability to produce a calcified skeleton as the pH of seawater decreases (Form and Riebesell, 2012). Organisms produce calcium carbonate in two polymorphs, aragonite and calcite, the latter being more robust against the dissolving effects of acidification. The ratio between these two forms varies between species resulting in greater sensitivity to changes in pH seen in predominantly aragonite-producing organisms. In contrast, calcitic organisms tend to be more resistant to the effects of ocean acidification.

5.3.3 The effects of sea level rise are expected to be most apparent in littoral and sublittoral habitats were relatively narrow vertical zones available to certain species may become 'squeezed' against incompatible habitats above. This may be especially important in coastal areas where the population of upper shore species may be reduced or lost if they are unable to move higher up the shore owing to a lack of suitable habitat.

Burrowed mud

5.3.4 Predicted loss of ecosystem engineers such as the burrowing shrimps *Callianassa subterranea* and *C. macandreae*, and the sea urchin *Brissopsis lyrifera* could alter community structure and ecosystem functioning (Weinert et al., 2016, Durkin & Tyler-Walters 2017). Changes in the distribution and abundance of benthic communities may alter trophodynamics and competition (Kirby et al., 2007), however, both acute heatwave events and chronic increases in sea temperature are considered unlikely to adversely affect this biotope as the key species can potentially adapt to a wide range of temperatures (Durkin & Tyler-Walters, 2017).

Flame Shell beds

5.3.5 The thin aragonitic shells of *Limaria* are considered to be sensitive to ocean acidification. According to Porter et al. (2020), however, *Limaria* nests in Orkney are not sensitive to increases in sea surface temperature.

Horse Mussel beds

5.3.6 Modiolus shells are thick and are less sensitive to ocean acidification when compared with other bivalves, such as *Limaria*, owing to an increased ratio of calcite to aragonite. In Orkney waters, *Modiolus* is highly sensitive to increased sea temperature (Porter et al., 2020)

Maerl

5.3.7 Maerl beds are expected to be corroded in a warming world (Brodie et al., 2014) and described as 'especially vulnerable' to ocean warming and acidification (Martin & Hall-Spencer, 2017). In the OBCA (Porter et al., 2020) the maerl bed habitat in Orkney was assessed as of 'medium' sensitivity to increases in sea temperature. Maerl beds in boreal latitudes are expected to be lost owing to lowered aragonite saturation, dissolving their skeletons (Brodie et al., 2014).

Kelp

5.3.8 Kelp forests are among the most productive ecosystems in the world (Dasgupta 2021). *Laminaria hyperborea* and *Saccharina latissima* are expected to persist in Orkney owing to thermal maxima of around 15.5C; Other kelp species, such as *Alaria esculenta* with more northerly distributions might be expected to become absent in Orkney with projected warming of seas (Mieszkowska et al., 2006). Distribution changes are being seen as retractions in lower latitudes (Wernberg et al., 2013).

5.3.9 By 2050, it is likely that Scottish populations of *Laminaria hyperborea* and *Saccharina latissima* will also have experienced a reduction in abundance, however, this species is likely to persist in Scotland beyond the end of the century (Raybaud et al.,2013).

5.3.10 Intertidal and shallow subtidal kelp beds are already showing signs of bleaching due to warmer springs and summers, and in response to heatwave events. This is likely to continue and exacerbate as the climate continues to warm (Mieszkowska et al., 2006).

5.3.11 Ecological Niche Models based on two climate models (AOGCM and MIROC5) and two climate change scenarios (RCP2.6 and 8.5) predicted by 2090–2100 that the warm-water kelp *L. ochroleuca*, expand through south-west England and Wales under RCP 2.6 and throughout the entire UK where suitable habitat exists (including the Orkney and Shetland Islands) under RCP8.5 (Assis et al.,2018).

5.3.12 In contrast to temperature-related distribution changes, increased carbon availability associated with ocean acidification may benefit kelp productivity (Koch et al., 2013; Brodie et al., 2014; Martin & Hall-Spencer, 2017).

Seagrass

5.3.13 Increased carbon availability associated with ocean acidification may benefit seagrass productivity (Koch et al., 2013; Kroeker et al., 2013; Brodie et al., 2014; Martin & Hall-Spencer, 2017). Seagrass meadows in Orkney are not considered to be sensitive to sea temperature increases (Porter et al., 2020).

Seaweeds

5.3.14 Climate change responses are dependent on thermal evolutionary origins and biogeographic distributions of the range of seaweed species occurring on Orkney. Many are boreal species and so will shift biogeographic distributions to higher latitudes as sea and air temperatures warm, with contractions of trailing range edges. *Lusitanian* species will also undergo a poleward shift, with leading range edges expanding as sea and air temperatures warm sufficiently to allow survival and reproduction. Invasive non-native species are mostly showing increasing invasion success as environmental temperatures increase as they mostly come from warmer climatic origins (Burrows et al., 2020).

5.3.15 Intertidal macroalgae are already showing signs of bleaching and/or other symptoms of heat damage due to warmer springs and summers, and in response to heatwave events. This is likely to continue and exacerbate as the climate continues to warm (Mieszkowska et al., 2021).

5.3.16 In contrast to calcareous seaweeds (e.g. maerl), 'fleshy' algae (e.g. fucoids) may benefit from increased concentrations of carbon dissolved in seawater (Martin & Hall-Spencer, 2017). In boreal waters, fucoids are not expected to be adversely impacted by ocean acidification (Brodie et al., 2014). Distribution changes in fucoids are being seen as retractions in lower latitudes (Nicastro et al., 2013; Wernberg et al., 2013).

5.3.17 Sea level rise may 'squeeze' vertical habitats forcing a reduction or loss in high shore species as they are unable to move higher up the shore if there is a lack of suitable habitat.

Circalittoral mud

5.3.18 A greater number of infaunal species are expected to shift their distribution in a more-expected northward direction (77%). Shifts of 60 km or more were predicted for the bivalves *Nucula nitidosa* (60 km) and *Ennucula tenuis* (76 km), the brittle star *Acrocnida brachiate* (60 km), the amphipod *Harpinia antennaria* (75 km) and the mollusc *Chaetoderma nitidulum* (88 km). Overall, 60% of species were predicted to shift ranges by 10–50 km towards the north. Only 9% of infaunal species were predicted to shift range towards the south

(Weinert et al., 2016). The brittlestar *Amphiura filiformis* has already been recorded as decreasing in abundance in the North Sea due increased SST (Krönke et al., 2011).

5.3.19 Sediments have a high pH buffering capacity (Andersson et al. 2003) which may lessen the impact of ocean acidification on infaunal sediment communities (Widdicombe et al. 2016), although the lack of experimental data raises concerns as to the applicability of comparisons across infaunal species.

Brittlestar beds

5.3.20 Brittlestars and other echinoderms secrete high-magnesium carbonate skeletal components (>4% mol MgCO3). As such these organisms are more vulnerable to OA, with respect to both increased susceptibility to dissolution and inhibition of skeletal element production, than those with skeletons consisting primarily of aragonite or calcite (Dupont et al., 2008; McClintock et al., 2011).

5.3.21 MCCIP report from 2020 states that *Ophiothrix fragilis* will undergo a northerly range shift in the North Sea of up to 109 km (Moore & Smale, 2020). Although, according to the Orkney Blue Carbon Audit (Porter et al., 2020), brittlestars are not sensitive to changes in sea temperature. Note: this assessment was based on *Ophiothrix fragilis* and/or *Ophiocomina nigra*.

Plankton

5.3.22 The Continuous Plankton Recorder (CPR) Survey has been collecting data on both phytoplankton and zooplankton since 1931. Changes in biogeographic distribution of several species in response to climate change have been recorded across the last few decades (https://www.mba.ac.uk/fellows/cpr-survey#b7).

5.4 Climate Change Assessment

5.4.1 Following the method described above in section 5.2 an assessment of climate change impacts on the key habitats and ecosystem services provided by these habitats was undertaken. Table 5-1 shows the outcomes from the climate change assessment for intermediate, regulating and cultural services.

Table 5-1: Summary of climate change scenario scores by habitat together with confidence in the evidence base supporting the relationships.

ES Classification	Climate Change Scenario	Burrowed mud	Flame shell beds	Horse mussel beds	Maerl	Kelp	Seagrass	Seaweeds	Circalittoral mud	Brittlestar beds
	↑SST/NBT (middle: 3°C) (MarLIN)	2	1	2	2	2	2	V	2	1
	↑SST/NBT (high: 4°C) (MarLIN)	2	1	2	2	2	2	V	2	1
	↑SST/NBT (extreme: 5°C) (MarLIN)	2	1	1	1	1	1	V	2	1
	↓pH (middle: 0.15) (MarLIN)	1	1	2	3	3	3	V	1	3
	↓pH (high: 0.35) (MarLIN)	1	1	2	3	3	3	V	1	3
	↑SLR (middle: 50 cm) (MarLIN)	1	3	3	3	3	2	V	1	3
	↑SLR (high: 70 cm) (MarLIN)	1	3	3	3	3	2	V	1	3
	↑SLR (extreme: 107 cm) (MarLIN)	1	3	3	2	3	2	V	1	3
	↑SST (RCP2.6); 0.9°C (2050); 1.0°C (2100) (IPCC)	1	2	3	3	3	3	V	2	2
	↑SST (RCP8.5) 1.3°C (2050); 3.7°C (2100) (IPCC)	1	1	2	2	2	2	V	2	1
	↓pH (RCP2.6); 0.072 (2050); 0.065 (2100) (IPCC)	1	1	2	3	3	3	V	1	3
	↓pH (RCP8.5); 0.108 (2050); 0.315 (2100) (IPCC)	1	1	2	3	3	3	V	1	3
Ecosystem Services										
Intermediate	Nutrient cycling/ Secondary production	1	1	2	2	2	2	V	1	1
	Primary production	NR	NR	NR	2	2	2	V	NR	NR
Regulating	Bio-remediation by micro-organisms, algae, plants, and animals	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Filtration/sequestration/storage/accumulation by living organisms	1	1	2	2	2	2	V	1	1
	Control of erosion rates	NR	NR	NR	NR	2	2	V	NR	NR
	Pest control (including invasive species)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Disease control	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cultural	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Characteristics of living systems that enable education and training	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Characteristics of living systems that enable aesthetic experiences	NA	NA	NA	NA	NA	NA	NA	NA	NA

Scale for climate change impact on habitat	
Significant impact	#
Moderate impact	#
Low impact	#
None/negligible impact	#
Not assessed	NA
Not relevant	NR

Scale for confidence in evidence base	
High	3
Medium	2
Low	1
Variable	V

SST: sea surface temperature
NBT: near bottom temperature
SLR: sea level rise

5.4.2 Our assessment highlights that all habitats, with the exception of seaweeds, are vulnerable to an extreme (5°C) increase in both sea surface and near bottom temperatures. The impact of this change is expected to be significant on burrowed mud, horse mussel beds, maerl, kelp and circalittoral mud habitats. For flame shell beds, seagrass and brittlestar beds the impact is expected to be moderate, although our confidence in the evidence base for these is low.

5.4.3 Maerl and brittlestar beds are also expected to be impacted significantly by decreases in pH (High: 0.35) levels and our confidence in the evidence base for this is high. Likewise flame shell beds are expected to by impacted significantly by decreases in pH levels but our confidence in the evidence base for this is low.

6 Case Studies

6.1 Introduction

6.1.1 Orkney's environment is rich in marine natural capital, providing numerous ecosystem services with economic, social and environmental benefits. Following on from the Rapid Evidence Assessment and Ecosystem Service Matrices, and supplemented by additional desktop research, three high level case studies were developed to provide examples of how natural capital assessments could be used to inform marine planning. The marine natural capital assets selected were chosen because of their well-known ecological, cultural and socio-economic importance to the Orkney community, as well as their distribution across the whole of the islands. These included kelp beds (predominantly *Laminaria hyperborea*) as the species focussed case study, Scapa Flow's biogenic habitats – horse mussel beds (*Modiolus modiolus*), flame shell beds (*Limaria hians*) and maerl beds as the habitat focussed case study, and Orkney's seabirds as the population focussed case study. The three assets also support each other in the provision of ecosystem services, for example, kelp forests indirectly provide a food source for seabirds and protect more fragile biogenic habitats from storm damage. A brief overview of the case studies assessment is provided in this section. The case studies have been appraised against the context of the wider ecosystem service assessment and regional marine spatial planning framework. The full case studies assessment table, with methodology stated and a full description of each case study and outputs, is provided as Supplementary Material to this report (see Supplementary Material 2 - Case Studies).

6.1.2 Each of the case study assets were assessed using the following steps:

1. The completed ecosystem service provision workbook was first assessed to identify the ecosystem services provided by each case study natural capital asset, with the level of provision and confidence noted. Any ecosystem services provided with a negligible level of provision were excluded.
2. For each ecosystem service provision, the available literature and spatial data from the Rapid Evidence Assessment was reviewed, and additional evidence was identified for each case study.
3. Links between each case study were made and assessed.
4. Evidence on the threats to each case study asset was assessed.

6.1.3 The results from the case study assessments could help inform the Orkney Regional Marine Plan and act as a template to allow an ecosystem services and natural capital based approach to be tested and further developed over time. Research and findings from other previous work on ecosystem services and natural capital in Orkney could also be used to supplement and provide an updated and relevant approach to these case studies.

6.1.4 The following recommendations, relating to the case study areas, have already been identified from Scotland's National Marine Plan Policy guidance (The Scottish Government, 2015 a):

- '*Regional marine plans should: Identify significant natural carbon sinks and seek to avoid colocation with potentially damaging activity; then; Assess the acceptability of any proposed partial loss or damage to natural carbon sinks (including any compensatory measures) through licensing or management of marine activities, balanced with priorities presented in the Plan and respective regional marine plans*.' This could be applied to Scapa Flow's biogenic habitats, highlighting the need to identify and protect these assets in the marine planning process.
- '*Using relevant guidance and data sources to identify, where appropriate, areas that are sensitive to specific types of development or other activity; Particular regard should be given to protected sites, protected species and Priority Marine Features. Spatial policies should take account of the sensitivities identified; Developing policies that contribute to the achievement of Conservation Objectives for designated sites within the MPA network; Recognising the role of habitats and species in providing and supporting ecosystem services and consider opportunities to enhance these services*.' This guidance can be applied to all case studies, highlighting the need for consideration of protected features, both for their intrinsic value, and the ecosystem services that they provide.
- '*Regional marine plans should consider the potential for sustainable growth of aquaculture in their region, taking into account the policies set out above, and working in close partnership with terrestrial planners, SEPA, Marine Scotland, SNH (now NatureScot) and other regulators*.' This guidance can be applied to kelp, highlighting the potential for development of kelp aquaculture in Orkney, which could be supported in the Regional Marine Plan and planning process.
- '*Regional marine plans should consider: Identifying thematic links to other regions and acknowledging the different methods of travel across Scotland, e.g. Great Glen route; Identifying important areas for protection, provisions and improvements to access and facilities to support the sector; Promoting/ensuring better engagement between sectors and other marine users, e.g. Inshore Fisheries Groups and sea anglers; Aligning with Tourism Development Areas within Local Development Plans and promote marine based development strategies; Promoting education and the use of codes of conduct and good practice guidance, including signage; Supporting sustainable tourism including sustainable transport and green tourism*.' This guidance can be applied to all case studies, with emphasis made to develop sustainable eco-tourism offerings to enjoy kelp forests, Scapa Flow and Orkney's seabirds.

6.2 Case Study 1: Kelp Beds

Background

6.2.1 Kelp beds (*L. hyperborea*) were identified as a habitat of interest, as the beds provide ecosystem services that regulate and maintain the condition of ecosystems and also directly and indirectly support the provision of goods and benefits (e.g. nutrient cycling). There is a wide range of evidence for ecosystem services, commercial interests and the sensitivity of kelp beds to a range of pressures, which include harvesting (see section 2). Historical interest relates to the burning of kelp, washed ashore in gales for potash and soda, and carried out from the 18th century until the early 19th. In recent years, there has been gathering interest in commercial harvesting of seaweed, including sourcing of alginate and the use of seaweed as a source of animal feed.

Ecosystem services provision

6.2.2 The main ecosystem services provided by kelp beds were identified using the ecosystem services workbook (see Supplementary Materials 3 – Orkney NC Workbook). The services identified to have a high level of provision by kelp beds include the following:

- The shedding of kelp, with detritus (waste organic material) entering the water column provides a nutrient cycling and secondary production service (Smale et al., 2013).
- A primary production service, with kelp being a photosynthesising organism.
- A provisioning service via the use of kelp as a food for humans (and also for animals, such as the famous North Ronaldsay sheep) (The Orkney Sheep Foundation, 2021 a).
- A provisioning service via the use of kelp's fibres for extraction of alginates, with a high level of provision and high confidence in this level. Alginate extraction in Scotland was an important historical industry, though in recent years there has been an interest in large scale harvesting of kelps for the alginate.
- A provisioning service with kelp as a food source for various other marine species, supporting diverse and abundant community assemblages. Kelp habitats are described by Scottish Natural Heritage as a Scottish version of tropical coral reefs (Morrison, 2018).
- A regulating service through the filtration and bioremediation of excess inorganic nutrients in the water column by kelp.
- Kelp providing a habitat to support nursery populations and a diverse marine community, as well as protecting gene pools.
- A regulatory service through fixation of carbon through primary production.
- A cultural service through kelp's importance to the Orkney community for heritage.

6.2.3 Additional services are provided by kelp habitats in Orkney, but with low to medium levels of provision. These varied services bring socioeconomic, cultural and nature conservation benefits to the community, including reaching beyond Orkney, and helping to combat and withstand climate change. See Supplementary Material 2 - Case Studies for the full assessment, including an evaluation of the ecosystem services provided and vulnerabilities to climate change and other stressors.

Location

6.2.4 In terms of the location of the kelp beds, Figure 6-1 illustrates the distribution of kelp beds in Orkney. Figure 6-2 illustrates the distribution of kelp and seaweed communities in Orkney. Figures are based on the NMPI database (Marine Scotland, 2021).

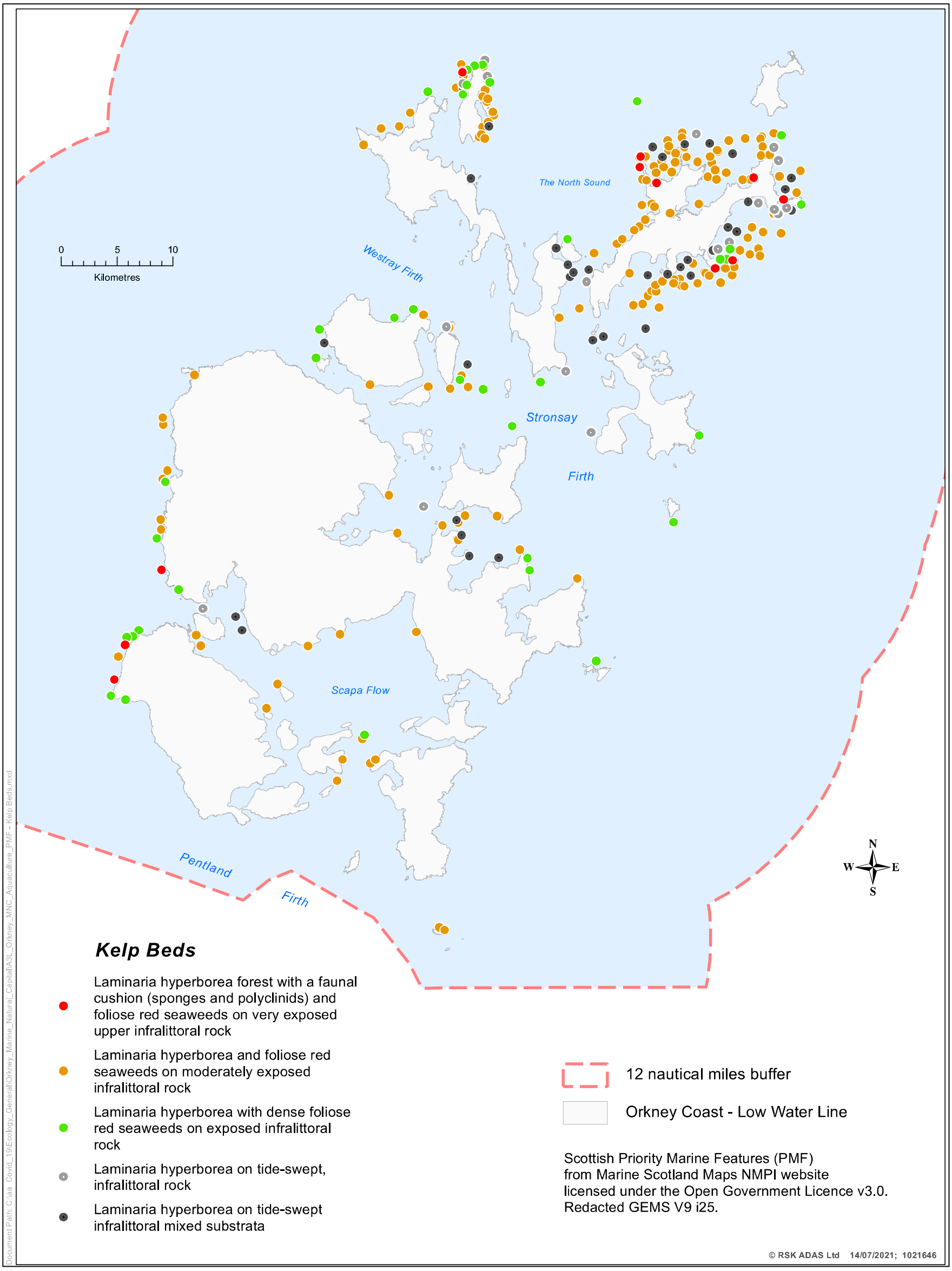


Figure 6-1: Kelp bed distribution in Orkney

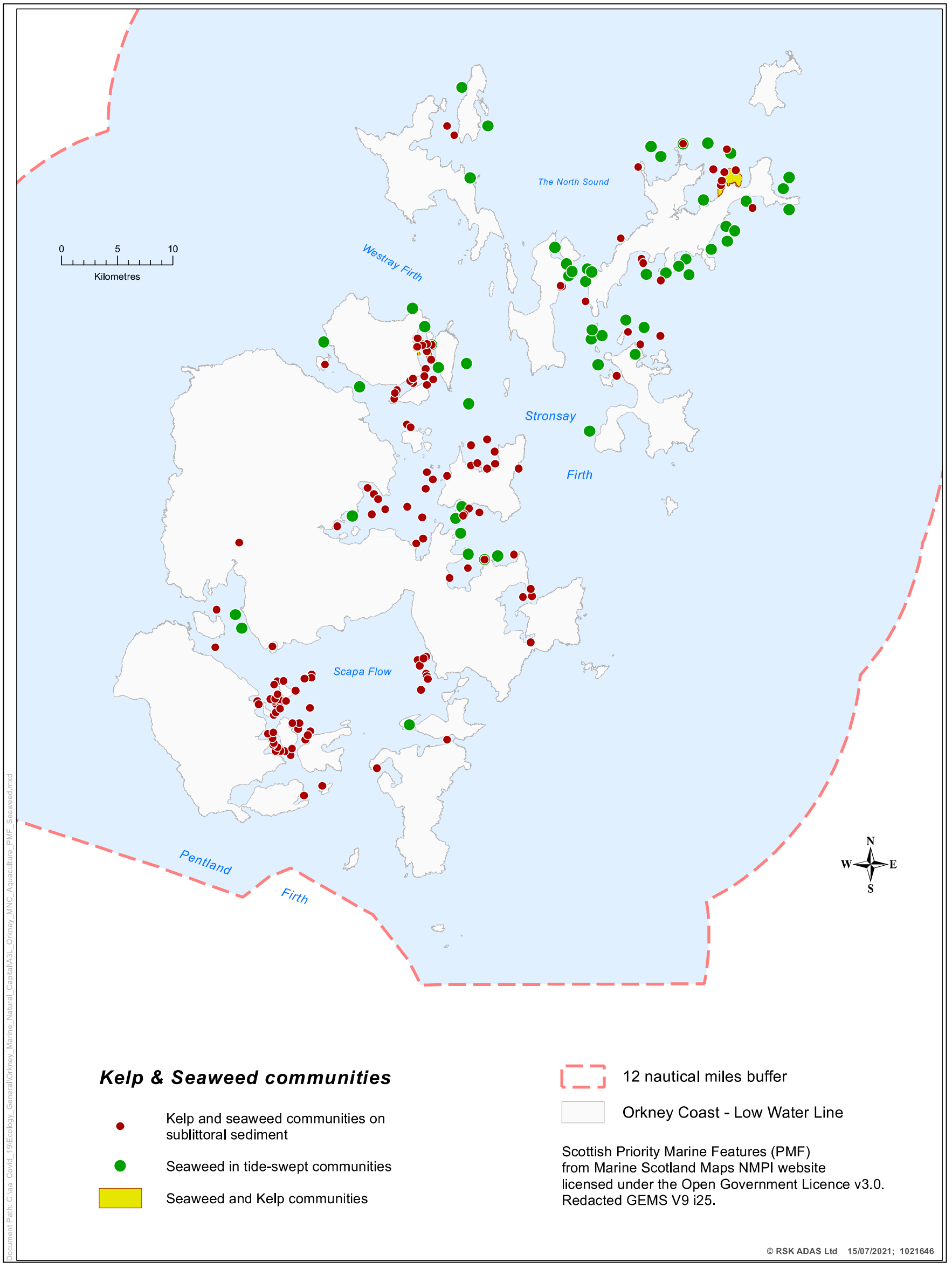


Figure 6-2. Distribution of kelp and seaweed communities in Orkney

6.3 Case Study 2: Scapa Flow Biogenic Habitats

Background

6.3.1 Scapa Flow is an enclosed bay in Orkney. The western part of Scapa Flow is particularly interesting from an ecological and a commercial fisheries perspective. Found within this relatively small area are beds of the calcareous algae maerl, biogenic reefs formed by horse mussels, nests created by flame shells, and in shallow embayments, seagrass meadows. Habitats created by horse mussels and flame shells increase local biodiversity. Maerl beds create nursery habitats for commercially important scallop fisheries and are recognised as an important source of 'blue carbon'. The presence of wrecks used for recreational diving may relieve some of the pressures on these vulnerable habitats from fishing vessels which tend to avoid these areas owing to entanglement risks. Assessment of the impact of the proposed deep-water quay at Scapa Flow as part of the Orkney Islands Council harbour infrastructure masterplan will also be important in order to ensure a long-term sustainable future for these communities.

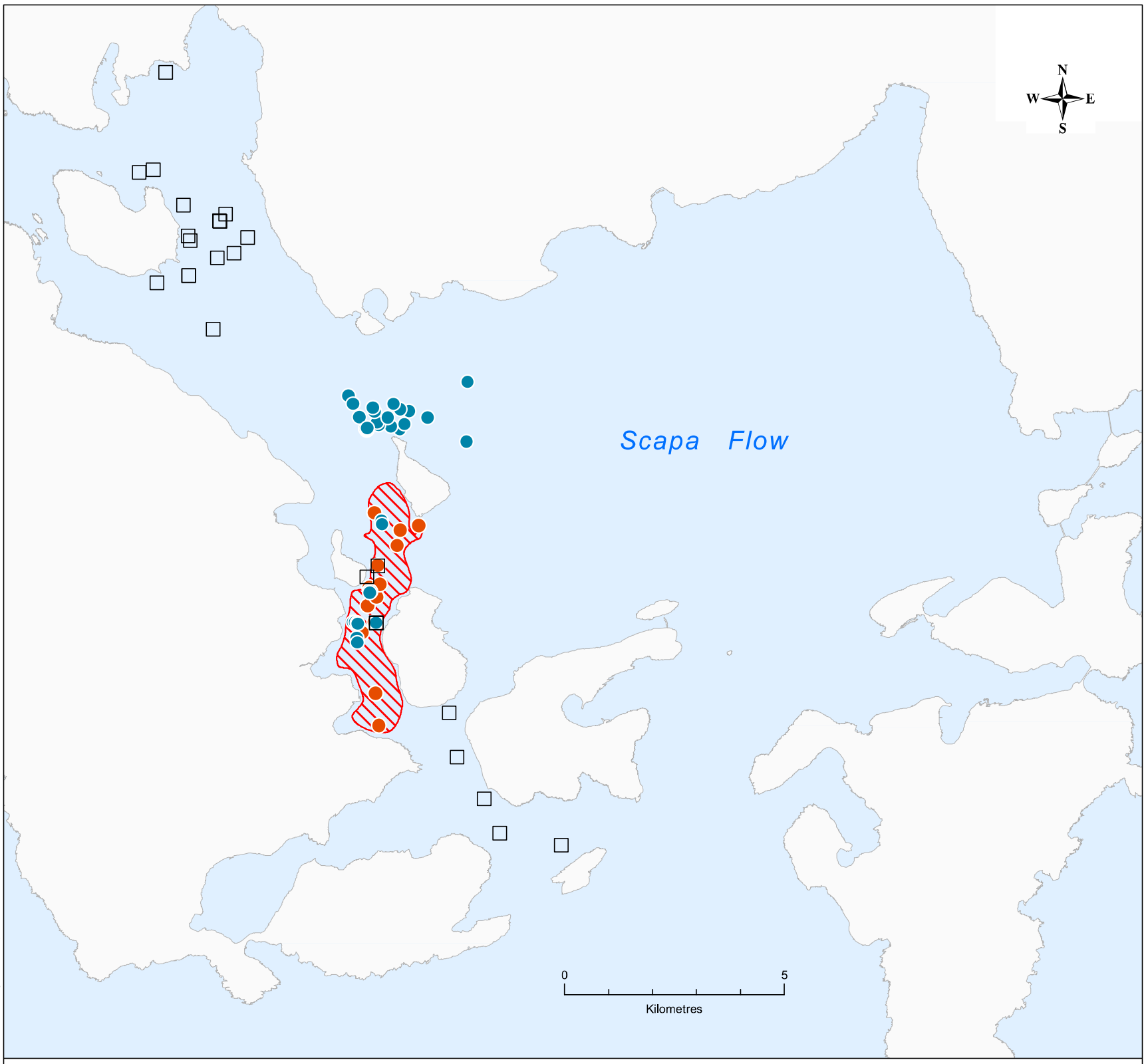
Ecosystem services provision

6.3.2 The main ecosystem services provided by Scapa Flow's biogenic habitats were identified using the ecosystem services workbook (see Supplementary Materials 3 – Orkney NC Workbook). The services identified to have a high level of provision by biogenic habitats include the following:

- Horse mussel beds provide an intermediate nutrient cycling service (provisioning), transferring organic matter to the benthos, as well as providing a structure for other species, which themselves contribute to nutrient cycling.
- Horse mussel beds provide a provisioning service as they support Queen scallop (*Aequipecten opercularis)*, Great scallop (*Pecten maximus)*, the common whelk (*Buccinum undatum)*, spider crabs (*Maja brachydactyla, Hyas araneus*), razor clams (*Ensis ensis*) and fish. These are all wild animals used for nutritional purposes. The scallop fishery is particularly important in Scapa Flow.
- *Modiolus modiolus* (horse mussels) as filter feeders, provide a bio-remediation service (regulating).
- The flame shell and horse mussel beds in Scapa provide an important gamete dispersal service (regulating) for the rest of Scotland's rare flame shell and horse mussel populations.
- Flame shell beds, horse mussel beds and maerl beds in Scapa provide an important regulating and maintenance service by creating a habitat for nursery populations of both non-commercial and commercial fish and shellfish species, also providing shelter and a food source for juveniles. Species associated with biogenic habitats in Scapa include scallops, edible crab and other shellfish.
- Maerl beds play a role in regulation of chemical composition of the ocean, via the storage of carbon in their living tissues and in maerl deposits.

Location

6.3.3 Figure 6-3 illustrates the distribution of biogenic habitats in Scapa Flow, based on the data provided in the NMPI database (Marine Scotland, 2021).



Biogenic Habitats in Scapa Flow

- Maerl beds
- Horse Mussel beds
- Flame Shell beds
- General extent of Flame Shell beds

Orkney Coast - Low Water Line

Scottish Priority Marine Features (PMF)
from Marine Scotland Maps NMPI website
licensed under the Open Government Licence v3.0.
Redacted GEMS V9 i25.

Figure 6-3. Distribution of biogenic habitats in Scapa Flow

6.4 Case Study 3: Seabirds

Background

6.4.1 The waters around Orkney support internationally important numbers of seabirds. For breeding seabirds, data from the most recent complete censuses (1998-2002 for most species, 2006 for red-throated diver (*Gavia stellata*), 2013-2014 for gannet (*Morus bassanus*)), suggests that nearly 400,000 pairs of seabirds from 22 species breed in Orkney. If juveniles and non-breeding adults are also included, there may be over a million individual seabirds in Orkney waters each summer. For ten species, over 10% of the British population breeds in Orkney. For Arctic skua (*Stercorarius parasiticus*), Great black-backed gull (*Larus marinus*), Arctic tern (*Sterna paradisaea*), common gull (*Larus canus*), and Great skua (*Stercorarius skua*), over a fifth of the British populations breed in Orkney. In world terms, the population of Great skua is particularly significant, representing 13.8% of the global population. The importance of Orkney for breeding seabirds is reflected in the classification of eleven Special Protection Areas (SPAs) (internationally important sites designated under European legislation and now protected under domestic legislation) in the county, for which breeding seabirds provide some or all of the qualifying interests (terrestrial sites with marine extensions). In addition, breeding red-throated divers are also qualifying interests for both the North Orkney and Scapa Flow Proposed Marine Special Protection Areas – areas that are still under consideration.

6.4.2 This case study focuses on those birds that forage at sea beyond the intertidal zone. As well as breeding seabirds, this includes wintering divers, grebes and seaduck. It does not include waders and wildlfowl (e.g. wigeon, teal) that feed along the shore in the intertidal zone. However, important populations of these intertidal species winter along the Orkney coastline and are dependent on the marine environment beyond the shore. Many waders and dabbling ducks (e.g. wigeon, teal and mallard) and gulls feed on the invertebrates found in rotting kelp and other seaweeds, deposited on the shore by storms.

6.4.3 Some of the diving seabirds that use Orkney waters (e.g. breeding cormorants (*Phalacrocorax carbo*), shags (*Phalacrocorax aristotelis*), black guillemots (*Cepphus grylle*) and red-throated diver, wintering seaduck including eider (*Somateria mollissima*) and long-tailed duck (*Clangula hyemalis*) feed almost exclusively on the seabed and are strongly associated with particular seabed habitats. Their foraging habitats include the biogenic habitats and subtidal sediments previously assessed in the ecosystem service assessment and sensitivity matrix. Other seabird species feed at oceanographic features, which are not associated with particular seabed habitats, e.g. shelf-edge fronts, upwelling and tidal-mixing fronts, offshore banks and internal waves (Cox et al. 2018). This results in foraging habitats across a huge range of spatial and temporal scales. Some species (e.g. European Storm Petrel (*Hydrobates pelagicus*) and Leach's Petrel (*Oceanodroma leucorhoa*)) feed exclusively at large scale oceanographic features and are not associated with particular seabed habitats. However, the majority of species, both surface feeders and diving species, tend to exploit both foraging locations associated with particular seabed habitats, and those associated with oceanographic features. The ecological consequences of seabirds foraging at oceanographic features will not be the same as when they are feeding in seabed habitats. This means that the ecosystem service assessment and sensitivity analyses for them must include these oceanographic habitats, as well as their seabed habitats.

6.4.4 Surface feeders (e.g. kittiwakes (*Rissa tridactyla*) and other gulls, skuas, terns, fulmar (*Fulmarus glacialis*) and storm petrels (*Hydrobates pelagicus*)) and plunge divers (e.g. gannet, manx shearwater (*Puffinus puffinus*)) must feed on or near the surface. Where birds are feeding in the water column above a particular seabed habitat, they are usually feeding on prey originating within the seabed habitat beneath. For example, kittiwakes and puffins (*Fratercula arctica*) feed on juvenile sandeels above a sandbank.

Ecosystem service provision

6.4.5 As seabirds were not included in the ecosystem services workbook, data on associated habitats and additional literature was used to determine ecosystem services provided by the birds. The full case study assessment has been included in Supplementary Material 2 - Case Studies. The following ecosystem services were identified:

- Seabirds provide a nutrient cycling/secondary production service (intermediate service based on regulating and supporting services as outlined in Potts et al. (2014)) - concentrating nutrients and transporting them to land.
- Seabirds provide a scientific service through ecosystem monitoring of other harder to study species.
- Orkney's seabirds provide a scientific interest service through interest in the natural world.
- Orkney's seabirds provide a cultural service through tourism.
- Orkney's seabirds provide a cultural service through heritage and cultural significance.
- Orkney's seabirds provide an important nature conservation scientific interest, both for their support of other marine species and habitats, and for the interest in the birds themselves.

Location

6.4.6 Seabirds are found across the whole area of Orkney, including the islands Sule Skerry and Sule Stack. There are various Sites of Special Scientific Interest (SSSIs) and proposed Special Protection Areas (pSPAs) in Orkney that are protected for birds. These sites are provided in Appendix 1 of Supplementary Material 2. Supplementary Material 2 also presents the population numbers of Orkney's breeding seabirds, wintering populations. Results from an assessment of distribution, abundance and ecosystem provision of Orkney's seabirds, and the methodology for the assessment, are provided in the appendices of Supplementary Material 2. Total breeding population numbers equalled 438,270 and 780,930 adults (Mitchell et al., 2004; Murray et al., 2015). Seabird data is based on the seabird census 2015 to 2020 and other seabird studies in Orkney (JNCC, 2021).

7 Key Findings and Limitations

7.1 Future Evidence Assessments

7.1.1 The Rapid Evidence Assessment (section 2) highlighted a number of habitats and species that were identified in the critically reviewed literature as being present within the 12nm boundary for Orkney. However, while the REA provided the foundation for the natural capital assessment we acknowledge that the evidence on habitat and species extent and condition related specifically to Orkney was somewhat limited. As such, additional spatial data and evidence was sourced, and expert judgement utilised, to confirm the presence or absence of key habitats and species prior to undertaking the ecosystem service and condition assessments.

7.2 Marine Planning

7.2.1 The review of current marine planning legislation and associated drivers identified a significant number of supporting policies and political direction to enable the embedding of a Natural Capital approach into the heart of future regional marine plans. These, along with the findings of the natural capital assessment, provide an important ecosystem services viewpoint for the preparation of the Orkney regional marine plan. Coupled with the results of the Community Voice Method component of the Oceans of Value (OoV) project, the findings from this study create a unique opportunity for Orkney to develop a natural capital framework for regional marine plans to allow a standardised approach, that meets the requirements of the Marine Acts and Scottish National Marine Plan while supporting natural capital assets for future generations and providing marine sectors with the security they require to thrive. As per UK Government guidance, a natural capital framework sets out a standardised approach to identify the quantity, quality and location of ecosystem (natural capital) assets, determine the ecosystem services and subsequent benefits provided by these assets, and manage pressures on these assets and measures to manage pressures, e.g. via economic inputs or management interventions (UK Government, 2021). The Orkney Regional Marine Plan can incorporate a natural capital framework into its RMP approach to create a blueprint for future regional marine planning in Scotland, improving consistency while allowing local flexibility.

7.2.2 Applying the knowledge gained through this natural capital assessment to regional marine planning in Orkney would allow natural capital assets to be recognised, evaluated, communicated and valued by the public with relevant policies developed to support future decision making to protect and enhance these shared assets. This could include prioritising certain assets/habitats that provide significant ecosystem services, particularly if that asset, habitat or service is limited or declining and sensitive to pressures that have potential to occur in that area.

7.2.3 A Natural Capital based approach would allow a regional marine plan to focus on local assets, pressures and opportunities, addressing Orkney Island Councils concerns voiced through the Development and Implementation of Regional Marine Plans in Scotland: interim report (July 2020) that if deviation from the National Marine Plan is not possible to allow a more localised approach then there would be no point in developing Regional Marine Plans. The proposed natural capital approach to marine planning would allow this local flexibility in a standardised way, keeping structure and line of sight to the national marine plan, which would allow sectors to clearly identify policies affecting them while enabling the plan to be developed based on the local environment and associated unique natural capital assets.

7.2.4 As illustrated earlier in Section 3, the marine planning legislation already allows for an ecosystem-based approach and many emerging plans are starting to incorporate ecosystem services, but in an ad hoc manner. A regional marine plan framework built around natural capital would remove this ad hoc nature, provide more standardisation whilst allowing the local natural environment to shape policies in conjunction with social, economic and marine sector drivers. This approach would very much support the vision of the EU MSP Directive which states *"healthy marine ecosystems and their multiple services, if integrated in planning decisions, can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention."*

7.2.5 The development and implementation of such policies within marine plans are only as good as the evidence they are built on. With the Marine Planning Framework in the UK taking an ecosystem-based approach with strong references to the UK Marine Strategy and the attainment of Good Environmental Status, it is imperative regional marine plans develop a robust, local evidence base. We believe that the current marine planning framework and associated legislative drivers present significant opportunity to develop the Orkney Regional Marine Plan with a natural capital approach at its core, with evidence being drawn from a number of existing resources including the Orkney Local Biodiversity Action Plan, State of the Environment Report and this Natural Capital Assessment. We believe this approach, can incorporate all marine planning requirements and be compatible with existing plans, whilst offering a whole system based template for future regional marine plans.

7.2.6 We acknowledge that it is important to ensure some consistency in approach and useability of Scottish regional marine plans for users in multiple regions. This also includes the consistency in use of data to ensure the replicability of the plans over time, and consistency between the different areas. A natural capital approach to regional marine planning can focus on the unique assets and ecosystem services of Orkney, while retaining the sector specific policies that have proved beneficial and popular with specific sectors throughout UK Marine Plan Development.

7.2.7 Appendix 2 summarises a number of existing objectives, policies and guidance principles within the Scottish National Marine Plan and emerging pilot and regional marine plans which could support embedding a Natural Capital and Ecosystem Services approach at the heart of future regional marine plans. The most significant of these are based around the following themes:

- **Natural Heritage** including geodiversity, protected sites, protected species and Priority Marine Features which provide numerous ecosystem services society rely upon. The role of habitats and species in providing and supporting ecosystem services should be

recognised and consideration given to opportunities to enhance these services. As many of these natural heritage features are present in Orkney (see section 6 on specific case studies) their protection is of importance.

- **Recreation and tourism** especially sustainable and green tourism and the value (and protection for future generations) of the natural capital assets that draw tourists to certain areas and form part of the community's recreational pursuits. This is of specific relevance to Orkney as eco-tourism plays a large role in the socio-economic make-up of the island. Key tourist activities include scuba diving in Scapa Flow and bird-watching across Orkney (see section 6).
- **Sustainable development** policies that encourage enhancement of natural heritage assets. On Orkney these include kelp beds and biogenic habitats (see section 6).
- **Climate change** including Blue Carbon initiatives, identification of carbon sinks etc. - For instance, biogenic habitats in Orkney are identified as carbon sinks (see section 5).
- **Fisheries** especially sustainable management of fish stocks and associated habitats. This is addressed on Orkney via the Inshore Fisheries Management Plan with which the Orkney RMP will align.
- **Aquaculture** where aquaculture sites are designed to minimise environmental impact and provide socio-economic benefits to the local community, e.g. Scapa Flow in Orkney (see section 6).
- **Protection of Wild Salmon and Diadromous Fish** – though most salmon for food in Orkney is farmed.
- **Safeguarding of marine aggregate resources** in line with broader environmental considerations – though as of the State of the Environment Assessment (SoEA, 2020), there were no licences for aggregate extraction in Orkney.

7.2.8 The SoEA - A baseline assessment of the Orkney Islands Marine Region, identifies that "detailed information on Orkney's ecosystems services is not currently available, therefore this has been identified as a data gap in Table 33." (SoEA, 2020). It is therefore suggested that the recommendations and associated data of this natural capital assessment be shared with the Orkney Islands Council and the Marine Planning Partnership.

7.2.9 The adoption of a natural capital approach would support the findings of the SoEA through the recognition and identification of impacts and dependencies associated with human activities and by assigning a value to Orkney's marine natural capital stocks and associated ecosystem services.

7.3 Natural Capital Assessment

Key Findings

- Across the four types of ecosystem services – intermediate, provisioning, regulation and maintenance and cultural, the most complete evidence for and the most important are the provision of regulating services by seabed habitats;
- Maintaining nursery populations and habitats is a key ecosystem service that many of these structured, biogenic or vegetated habitats provide;
- Of the provisioning categories, the most important is the role of seabed habitats in supporting wild capture fisheries;
- Many habitats reviewed here are circalittoral and as such do not include a strong plant/algal component so many of the provisioning categories are not relevant;
- Relating cultural services to seabed habitats remains a huge challenge especially for the more esoteric categories such as symbolic or religious meaning, and also existence or bequest value which could be argued applies to all living things.
- The natural capital assessment supports comparison of potential contribution but the results should be interpreted critically as discussed below. Services, particularly provisioning and cultural services, may not be consistently provided or realised from habitats as demand for these may vary across the habitat extent. Service level may also vary across habitats due to biological or environmental factors.

Ecosystem service provision weighted by habitat area

7.3.1 Weighting the level of ecosystem service provision by habitat extent and calculating as a proportion of overall contribution to services allows comparison between habitat types (see Appendix 3). We caveat that this analysis is biased by habitat area, however the results are particularly important for regulation and maintenance services that support the wider ecosystem. These are likely to be produced more consistently across the extent than those services that are dependent on direct human interaction for realisation. Even low levels of service, if they are generated across large areas should be considered to be of importance. The spatially extensive habitats, A5.1 (Sublittoral coarse sediment) and A5.2 (Sublittoral sand) have the potential to contribute a high proportion of ecosystem services generally in the Orkney marine region, with the exception of services that are supported by seagrass and seaweeds/kelps. For plant-based services, the infralittoral rock habitats A3.1 (High energy infralittoral rock), A3.2 (Moderate energy infralittoral rock) and A3.3 (Low energy infralittoral rock) provided a high proportion of the overall service contribution due to their extent.

Extent of physical damage based on vessels >12m

7.3.2 The proportion of each broadscale habitat exposed to physical disturbance from mobile fishing gears is variable. For some habitat types more than half of the habitat extent was not exposed to mobile gears and, where exposed the disturbance was considered to be very low. Habitats that are relatively unimpacted by mobile gears in the Orkney mainland region are infralittoral rock and low energy circalittoral rock, sublittoral muds and macrophyte-dominated sediments (85% undisturbed or subject to low disturbance). High and

moderate energy circalittoral rock was exposed to high level of disturbance (>80% of habitat highly disturbed) with sublittoral coarse and sand sediments moderately disturbed (32% and 48% respectively).

7.3.3 In the western island region, a similar pattern was recorded with the infralittoral rock habitat A3.1 subject to low disturbance, while infralittoral rock (including a habitat that could not be assigned to infralittoral or circalittoral (A3.2/A4.2) was exposed to high levels of disturbance. Sublittoral coarse and sand sediments were highly disturbed across 49% and 60% of extent respectively.

7.3.4 The high level of disturbance to rock habitats was surprising as these habitats are generally less suitable for mobile gears. It is possible that these results are artefacts of either the predictive habitat layer (habitats classified as rock that are in fact sediment or overlain by sediment), or that vessels were steaming rather than fishing over these habitats or that the recorded gear type is incorrect. However, as fishing effort is recorded as evenly distributed across a grid cell it is also likely that fishing occurs on the fringe of rock habitats in grid cells that contain both rock and sediment habitats. The indicator guidance notes that there is a likely overestimation of the results in some areas due to the assumption that fishing effort is the same across a grid cell.

7.3.5 In circalittoral rock habitats and coarse and sand sediments, the species that deliver ecosystem services are found on or buried within the sediment. It is likely that surface abrasion and sub-surface damage (and associated removal of target and non-target species) in highly disturbed areas will reduce the level of ecosystem service potential through damage and removal of biota.

7.3.6 For the PMFs, none were assessed (through datapoint or polygon data) to be exposed to high levels of disturbance (disturbance category 5 or greater), however the spatial analysis suggested all types of PMF were subject to low levels of exposure. Habitats that are highly sensitive to surface abrasion and that recover slowly may be degraded by even low levels of pressure. This is particularly of concern for biogenic habits where degradation may reduce habitat suitability for other species. Given the low recovery rates of horse-mussel, maerl, seagrass and flame shell beds and the sensitivity to physical disturbance these seemed to be the habitats most likely to be in poor condition based on surface abrasion from mobile gears.

7.3.7 Other impacted PMFs such as circalittoral mud, tide-swept habitats and kelp habitats may not be in poor condition as these may contain more infaunal species (mud) and are characterised by species that generally recover within a few years. It is acknowledged that the assumption of equal effort across a grid cell may be misleading and the beds may not be directly impacted.

Inshore fisheries ScotMap: Output tables

7.3.8 The ScotMap data suggests that all habitats around the Orkney mainland support fisheries. The numbers of vessels habitats were used by varied. In general at least half of each habitat was used by 6-15 vessels (see Appendix 3). Effort was assumed to be homogenous across the reporting grid cells, therefore this analysis cannot account for fisheries that target specific types of habitats within grid cells.

7.3.9 All habitats appeared to be targeted by fishers that use pots (although caveats around effort across grid cells apply). For most habitats around half of the extent was used by 6-10 vessels a year. With potting occurring on both rock and sediment. The footprint of surface abrasion from potting and other static gears is relatively low compared to mobile gears, although if gear drags this can create a bigger impact footprint. Potting will also remove target species.

7.3.10 Fewer vessels fish with towed dredges, the maximum number of vessels operating towed dredges in any habitat was 5. Towed dredges were used in rock habitats which was unexpected, these may be fitted with rockhopper gear or result from the low level of habitat and activity resolution described above. Habitats with low levels of exposure include muds (A5.3) and mixed sediments (A5.4) and low energy circalittoral rock. Habitats where more than 40% of the habitat was exposed to three or more vessels with towed dredges were infralittoral rock and coarse and sand sediments. Due to differences in habitat area, sublittoral coarse and sand sediments are suggested to be most important to towed dredges. For the majority of habitats, more than half of extent was not exposed to dredges. This suggests that these areas are likely to be in good condition although we caveat that it is not clear if they were targeted by vessels >12m or other types of fishing.

7.3.11 Trawl fishing appears limited in Orkney with the majority of the area of each habitat not exposed to trawling, The maximum number of vessels operating in a grid cell was 3. Habitats exposed to the highest level of trawling were circalittoral coarse sands and sediments with nearly 39% of deep circalittoral sands exposed to trawling. Overall the number of vessels operating trawls was low and the majority of all habitats were not exposed, suggesting that these were in good condition.

7.3.12 The Nephrops fishery was suggested to operate at low intensities across a range of habitats, that are not considered suitable for this species, indicating the underlying issue with ScotMap data and lack of resolution of fishing activity to habitat type. Most effort was focussed on muds (A5.35 and A5.37) and mixed sediments (A5.44) that can overlay mud. Few vessels undertook this activity with 3-4 vessels operating in the fished grid cells. For all other habitats effort was low with <10% of habitat extent exposed and, this is probably an artefact of the grids rather than reflecting fishing activity in these habitats.

Removal of target species: an ecosystem service and a pressure

7.3.13 The Scottish Marine Atlas noted that removal of target species was a key pressure in the Orkney marine region. The condition assessment also indicates the habitats where this service is being realised via fishing with mobile gears. It is clear that sand and coarse sediments support the >12m vessel fisheries using mobile gears and that circalittoral rock habitats may also be important areas where fishing gears operate either over or close to reef areas that support target species. Removal of target species will reduce the services provided by these, however, this study focussed on services provided by the biological assemblage and did not identify any services other than provisioning of food and nutrition (and sandeels extraction for aquaculture) that were delivered only by commercially targeted species.

7.3.14 While target species may support a range of services such as secondary production, nutrient cycling and waste remediation these services are supported by a range of species within the biological assemblage. Removal of target species that form biogenic habitat such as oysters, mussels and horse mussels would have a disproportionate affect as these form the habitat itself and support a wider community. There was no evidence from the condition assessment or the REA that these species are being targeted in Orkney.

Limitations

7.3.15 For some services there was little information and assigning a level of service provision and discriminating between habitats was difficult. Some services are less understood as they have not been the subject of research focus and linkages to habitats and species and their potential level is poorly understood. For example, there is little evidence for disease control in the literature and disease control was only linked to two habitats (flame shell beds and brittlestar beds). Pest control was assessed as likely to be higher for filter feeding communities that also occupy space, preventing colonisation but confidence is low and reflects the underlying uncertainty.

7.3.16 As linkages between features and ecosystem services are highly uncertain, or variable, depending on the specific conditions, they are hard to elaborate across larger scales with high levels of confidence. Provision of ecosystem service is likely to be influenced by a number of factors and is likely to vary over time and space. These aspects have received little attention for most habitats. The assessment of ecosystem services in this study was therefore generic rather than location specific and it was assumed that delivery was homogenous over a habitat extent.

7.3.17 Assessment of provision was categorical (none/negligible, low, medium, high). The assessments largely consider the potential to provide services rather than the level to which the service is realised. For example, habitats and associated species may support the sequestration or breakdown of wastes and contaminants but where water quality is high and these are absent, the service potential is not realised. Similarly, if target species are not fished from a habitat then the habitat is not providing that service, although it may of course support this indirectly through migration of adults and juveniles, propagule supply or nursery functions.

7.3.18 Further examples of services that are difficult to link to specific locations and which are only partially realised are the collection of seaweed propagules to seed aquaculture operations. Fertile material may be collected directly in-situ or propagules may be obtained from the water column rather than directly from the providing habitat. Only a proportion of those produced are collected and contribution of each km2 of habitat to this service is likely to be highly variable.

7.3.19 Due to time and data limitations, we were not able to assess potential trade-offs. For example, if a habitat provides target species, realisation of the service (removal of the species) may reduce the supply of other services associated with the species such as larval and gamete supply, waste remediation etc. Removal of target species was identified as a key pressure affecting Orkney seabed habitats, so the realisation of this service is also a pressure on the marine environment. It should be noted from the assessment that most seabed habitats were subject to relatively low levels of disturbance from mobile gears and that large areas of the key targeted sand and coarse sediments were not fished.

7.3.20 Monitoring of condition for marine habitats is costly and requires expensive equipment which limits the collection of direct evidence for condition assessments. The use of human activities and associated pressures as a proxy measure has been widely adopted in the marine environment but there are limitations around characterising the spatial distribution of pressures, their frequency and intensity. The approach also relies on assumptions around impact and recovery times.

7.3.21 While the natural capital assessment undertaken as part of this study provides an indicator of likely condition there are inherent assumptions and limitations, as outlined above. It should be noted, however, that there is increasing evidence available about the relationship between pressures and condition but little work to date has successfully assessed changes in ecosystem service provision to pressures and resulting changes in condition. Better understanding of these relationships and key thresholds would greatly inform future assessments of ecosystem services and natural capital in marine environments.

7.4 Case Studies Findings and Limitations

7.4.1 The ecosystem services provided by the three case study assets are varied and numerous. Vital regulating and supporting services are provided, such as bio-remediation and nutrient cycling, as well as provisioning services that provide a source of food for the surrounding ecosystem and community. The case studies provide a useful way to illustrate the ecosystem service approach and can support decision making as an important communication tool. More detail on the three case studies can be found in Supplementary Material 2 - Case Studies.

7.4.2 All of the case study assets support a vibrant and thriving community in Orkney and attract tourists from around the world. As climate change brings warmer oceans, acidification and increased storm intensity, some of these services provided will be essential for Orkney's resilience. For instance, the wave attenuation service provided by kelp beds will help to reduce wave action related damage to Orkney's coastline and more vulnerable habitats – e.g. seagrass beds. The bio-remediation and filtration services provided by Scapa Flow's biogenic habitats will help to maintain a healthy water column as warmer waters increase the risk of pollution incidents and eutrophication.

7.4.3 The level of services that these assets may provide however, is also threatened by climate change, in addition to other anthropogenic actions such as fishing. Though there is a chance kelp forests may benefit from increased carbon dioxide concentrations in the water column, the warmer temperatures will likely impact this cold water species. Biogenic habitats will be threatened by ocean acidification and storms, while seabirds will be impacted by warmer temperatures, storms and changing food availability. Protection and enhancement of these marine natural capital assets, as well as numerous others not assessed in the case studies, should be viewed as a priority action moving forward.

7.4.4 The three case study assets are also found to be linked and support each other to provide a number of ecosystem services. For example, kelp forests indirectly provide a food source for seabirds, and kelp forests protecting more fragile biogenic habitats from storm damage.

Kelp

7.4.5 The kelp bed habitats identified within the Orkney marine region (as highlighted in Figure 6-1 above) have been found to provide at least nineteen ecosystem services at a level of provision above negligible. The kelp habitats are also vital for combating climate change threats.

Scapa Flow's biogenic habitats

7.4.6 The biogenic habitats identified around Scapa Flow (as highlighted in Figure 6-3 above) have been found to provide at least thirteen ecosystem services at a level of provision above negligible.

Seabirds

7.4.7 Seabirds are incredibly important both culturally and as an ecotourism draw for Orkney. In the 2019 Orkney Visitor survey, the two main reasons given by leisure visitors for visiting Orkney were scenery and landscape (62%) followed by history and culture (57%), with over half of visitors engaging in wildlife and bird watching and/or visiting wildlife sites.

Importance of the case study natural capital assets for society

7.4.8 **Environmental health:** Scapa Flow's biogenic habitats are assessed to be important for environmental health in Orkney, due to the nutrient/carbon cycling, bio-remediation and chemical composition regulating services they provide. Flame shells and horse mussels are filter feeding bivalves, so the level of supporting and regulating services that these provide, are likely to be high around Scapa Flow. As bio-carbonate is stored in both their shells and living tissues, these organisms also provide a high level of the biocarbonate accumulation service, which helps to regulate chemical composition in the ocean. Though maerl provides a lower level of these services, it is considered an important component of the natural capital assets provided by biogenic habitats in Scapa. As climate change worsens, together with likely greater anthropogenic inputs, the role of Scapa's biogenic habitats in preserving marine environmental health will become increasingly important.

7.4.9 **Society:** Though kelp forests, biogenic habitats and seabirds all hold cultural value to the Orkney community, seabirds are assessed to be the most valued, mainly as they can be passively observed from above the ocean. Kelp beds and biogenic habitats require scuba diving or snorkelling to view, study and enjoy. The seabirds also attract many visitors to Orkney, which in turn supports the Orkney community via the tourist industry. As the impacts of climate change intensify and many seabird populations in more southerly parts of the UK shift northwards, Orkney's seabird populations may become even more respected, as one of the last strongholds of some species. Due to a widespread interest in birds, Orkney's seabirds provide an important scientific ecosystem service, through their value in nature conservation based ecological research. The Orkney community as well as the bird-watching community worldwide have historically and currently put great value on Orkney's seabirds, and wish to protect them for generations to come.

7.4.10 **Business:** As discussed in section 6, seabirds are important to many tourism businesses in Orkney. However, as kelp habitats also provide the potential to be harvested and/or cultivated as a food source, as well as attracting divers and snorkellers, they are assessed to hold greater value to businesses. In addition, by providing a food source for many commercially fished species, kelp habitats support the historically important fishing industry in Orkney.

Marine natural capital assets review

7.4.11 The ecosystem services provided by these assets are varied and numerous. Vital ecosystem regulating and maintenance services are provided, such as bio-remediation and nutrient cycling, as well as provisioning services supporting the surrounding ecosystem and community. All of the assets support a vibrant and thriving community in Orkney and attract tourists from around the world. As climate change brings warmer oceans, acidification and increased storm intensity, some of these services provided will be essential for Orkney's resilience. For instance, the wave attenuation service provided by kelp beds will help to reduce wave action related damage to Orkney's coastline and more vulnerable habitats – e.g. seagrass beds. The bio-remediation and filtration services provided by Scapa Flow's biogenic habitats will help to maintain a healthy water column as warmer waters increase the risk of pollution incidents and eutrophication. Yet, the level of services that these assets may provide is also threatened by climate change, in addition to other anthropogenic actions such as fishing. Though there is a chance kelp forests may benefit from increased carbon dioxide concentrations in the water column, the warmer temperatures will likely impact this cold water species. Biogenic habitats will be threatened by ocean acidification and storms, whilst seabirds will be impacted by warmer temperatures, storms and changing food availability. Protection and enhancement of these marine natural capital assets, as well as numerous others not assessed, must be made a priority.

Integration of case studies into the regional marine planning framework

7.4.12 Given the significant potential benefits of many of the ecosystem services provided by the marine natural capital assets discussed, protecting and enhancing these assets is essential. As discussed in the regional marine planning review (see section 3), we recommend that a natural capital framework for regional marine plans is developed to allow a standardised approach, into which the findings from this case study assessment could be incorporated (section 3 defines 'natural capital framework').

7.4.13 The Orkney Regional Marine Plan should also take research and findings from previous work on ecosystem services and natural capital in Orkney, to provide an updated and relevant approach to these case studies and others. The following recommendations, relating to the case study areas, have already been identified from Scotland's National Marine Plan Policy guidance (The Scottish Government, 2015a): '*Regional marine plans should: Identify significant natural carbon sinks and seek to avoid colocation with potentially damaging activity; then; Assess the acceptability of any proposed partial loss or damage to natural carbon sinks (including any compensatory measures) through licensing or management of marine activities, balanced with priorities presented in the Plan and respective regional marine plans*.' This could be applied to Scapa Flow's biogenic habitats, highlighting the need to identify and protect these assets in the marine planning process. '*Using relevant guidance and data sources to identify, where appropriate, areas that are sensitive to specific types of development or other activity; Particular regard should be given to protected sites, protected species and Priority Marine Features. Spatial policies should take account of the sensitivities identified; Developing policies that contribute to the achievement of Conservation Objectives for designated sites within the MPA network; Recognising the role of habitats and species in providing and supporting ecosystem services and consider opportunities to enhance these services*.' This guidance can be applied to all case studies, highlighting the need for consideration of protected features, both for their intrinsic value, and the ecosystem services that they provide.

Limitations

7.4.14 In completing the case study assessments, the following limitations were identified:

- There was limited evidence available on the full extent and condition status of kelp (L.hyperborea) habitats in the Orkney marine region, and limited evidence on the potential long-term impacts of various developing industries and changing climates.
- There was also limited data on flame shell beds in Scapa Flow, as they have only recently been recorded by Seasearch.
- The most recent Orkney bird census has been postponed due to COVID-19. The bird census for Scotland 2021 has been postponed to 2022, with the last full census being 2011.
- As this was a desktop study, there was limited public involvement. Stakeholder responses and the views of the Orkney community were not assessed using primary data. This may present difficulties when applying the approach to both the Orkney area and other areas, as stakeholder and community views should ideally be incorporated into the assessment to both provide further information and highlight their concerns. To overcome this challenge for Orkney specifically, the results of the Community Voice method could be reviewed and incorporated into a developing ecosystem based approach.
- Other barriers identified include a lack of a standardised method for identifying and quantifying ecosystem services in marine environments and limited current consideration of marine natural capital and ecosystem services in Scottish legislation.
- Due to a lack of empirical evidence for all marine natural capital assets in Orkney specifically, and their associated ecosystem services, evidence from other areas (with similar climate) has been extrapolated for Orkney. As ecosystem services and marine natural capital are fairly new areas of research, it is likely that other marine regions also lack specific evidence and information.

Appendix 1: REA Methodology

Rapid Evidence Review Protocol

Title of Review: Rapid evidence assessment of natural capital assets and ecosystem services in marine environments with specific reference to the Orkney Marine Region Area

Project Title: Natural Capital Assessment of the Orkney Marine Region Area

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Background to Review

Marine Systems offer vital ecosystem services which, from an anthropocentric viewpoint, have values that are linked to the productive use of resources by humans (Picone et al., 2017). From a more ecological perspective the flow of ecosystem services from natural capital stocks provide other values that are not necessarily linked to their use by humans but instead to the role they play in supporting multiple species at different scales in the biosphere. Anthropogenic pressures continue to threaten the long-term sustainability and health of marine environments around the world, despite the growing acknowledgement that our natural environment underpins the health and well-being of our economy and the people in it. According to Constanza et al. (1997) marine and coastal environments contributed over 60% of the total economic value generated in the biosphere. However, de Groot et al. (2012) estimated the contribution of marine systems to be around 40%. This decline in value was attributed mainly to the large loss of coral reef area resulting from anthropogenic pressures.

The shifting balance between the value (both monetary and non-monetary) of marine and terrestrial systems in the biosphere is concerning and this, in part, can be attributed to a skewed focus on terrestrial systems research. Marine studies in the ecosystem services and natural capital literature are few (<9% over time) yet the level of human dependence on marine and coastal systems is large; Townsend et al. (2018) estimated this dependence to relate to approximately 75% of the world's population by 2025. There is an urgent need to increase the evidence base, including spatial data, improve assessment techniques and decision support tools, to enable hidden values to be captured and to better understand the complex, multidimensional nature of marine systems and their associated interconnected ecosystem services and processes.

The Scottish Wildlife Trust (the Trust) have acknowledged the growing importance of capturing hidden values in the marine environment through their Oceans of Value project. This project is looking to compare results from stakeholder engagement using the Community Voice Method against results from a natural capital assessment, utilising the same Orkney Regional Marine Plan (RMP) area. It is our understanding that the Trust is seeking a natural capital assessment of the Orkney marine region that will identify the type, location, condition, importance and vulnerabilities of natural capital assets and associated ecosystem services that are of value to the Orkney community and potentially wider communities. We also appreciate that in doing so the Orkney RMP may well set the standard for the completion of the other remaining RMPs.

The purpose of the Rapid Evidence Assessment (REA) is to review and synthesise current thinking, research and evidence on: marine natural capital assessments; ecosystem services in marine environments; and to enable the use of spatial data to aid decision making in marine planning at the onset of the project. REA offers a systematic and transparent basis to identify, critically appraise, and synthesise evidence that reduces the potential for bias. The approach uses a structured, step-wise methodology, following an a priori protocol to comprehensively collate, critically appraise and synthesise existing research evidence (traditional academic and grey literature) (Dicks et al., 2017). In addition to collated evidence, a range of literature on provision of ecosystem services by marine features will be reviewed and criteria scores will be developed.

Review Questions

Primary Question: **What is known in the literature about the ecosystem services provided by marine natural capital?**	
Population (Area of study)	Orkney Regional Marine Plan (RMP)area
Focus	Location and extent of marine Natural Capital assets (species and habitats) within the Orkney RMP area (bounded by 12nm limit including the Loch of Stenness brackish water lagoon)
Outcomes	Habitats, species, pressures, condition and beneficiaries of ecosystem services provided by identified natural capital assets in the Orkney RMP area. Climate change vulnerabilities and impacts.
Secondary Questions: Which marine natural capital assets are most important for maintaining the ecosystem services? What is known about who benefits from the ecosystem services provided by marine natural capital assets? What is known about the impact of climate change on marine natural capital assets?	

Inclusion and Exclusion Criteria

	Include	Exclude
Study Type	Primary and secondary research that assesses ecosystem services provided by marine natural capital.	Studies related to terrestrial natural capital, coastal habitats (e.g. dunes) outside RMP, economic valuation studies
Date	Published between 2010 to 2020	Pre 2010
Population /Geographical	Literature that investigates marine natural capital in the UK. Initial search to start with Orkney Islands and Scotland.	International studies
Outcomes	Natural Capital assets (including intertidal habitats), Ecosystem service benefits, spatial data, climate change vulnerabilities and impacts.	

Search Methods

Search Engines/Platforms/Databases	Google Scholar, Microsoft Academic Search, Wiley Online Library, Science Direct
Other Methods used for identifying relevant research	Reference lists from included studies, grey literature, organisation/government websites (e.g.

Methods of Review

Initial screening of literature	ADAS and RSK REA team will screen citations against the inclusion and exclusion criteria. All literature deemed eligible by initial reviewers will be independently assessed for inclusion by second reviewers.
Literature search and data extraction	The type of information extracted will include year of publication, first author, title, study type, study scale, Habitat type, ES pressure, country/region, outcome measure, main findings, limitations.
RAG of title and abstract and quality assessment	First reviewers will perform RAG screening and quality assessment based on title and abstract. Critical appraisal templates will be setup and used by second reviewers to provide scores and comments for criteria based on transparency, appropriateness, validity, reliability and cogency of evidence. Cross-validation of evidence using expert experience and judgement will also be undertaken.
Narrative review	A narrative review will be based on thematic analysis of extracted data related to habitats, species and ecosystem services.

Presentation of results

Additional material	Protocol Flow diagram showing search and selection process Excel workbook with matrix of extracted data
Outputs of review	Section included within Final Report

Search Terms and evidence screening

Boolean search terms were used to develop searches that combined key words. After the hits were downloaded for each search term, the first phase screening ranked the publication title using a relevancy RAG approach. Red (R) represented titles that were 'clearly not relevant', Amber (A) represented titles which were 'uncertain' and would be taken through to the second phase screening and Green (G) were 'clearly relevant' titles.

Second phase screening involved reading the abstract or the first paragraph of the 'clearly relevant' and 'uncertain' publications. Evidence that was clearly relevant was then critically reviewed and scored according to the criteria in Table A1. Those papers scoring highly (>3) were obtained in full and used as the basis for the narrative review.

Table A1-1: Boolean search term explanation

Operator	Search example	Result
AND	Orkney AND marine	Results will contain both the words 'Orkney' and 'marine'.
OR	Orkney OR Scotland	Results will contain one or more of the words 'Orkney' or 'Scotland'
Phrase	'Ecosystem services'	Results will contain the exact phrase 'Ecosystem services'
Multiple character	Fish*	Results will contain words that start with fish e.g. 'fishing', 'fished', 'fishers', 'fishery'

Table A1-2: Boolean search operators and search terms applied in literature search.

	Key search words (AND)						
Synonyms (OR)	**ORKNEY**	**Habitat***	**Marine***	**"Ecosystem Services"**	**"Priority Marine Features"**	**"Marine Species"**	**"Climate Change"**
	"ORKNEY ISLANDS"	"Biogenic habitat"	Intertidal	"Ecological Services"	Marine plan	"Marine Mammals"	"Climate vulnerability"
	SCOTLAND	Littoral	Water*	Fisheries	"Marine conservations zone"	Seal*	"Climate pressure"
		Pelagic*	Ocean*	Tourism	"Regional marine plan area"	Seabird*	"Climate impacts"
		Saltmarsh	Sea*	Education	"MPA"	Fish*	"Blue carbon"
		Kelp	lagoon	Cultural	"Special area of conservation"	Skua	
		"Kelp forest"	"marine assets"	"Primary production"		"Sea Trout"	
		Maerl		Energy		Puffin	
		"Maerl Bed"		"Seaweed harvesting"			
		Seagrass*		Recreation			
		"Flame shell beds"					

Search Term: ***Orkney*** *OR "Orkney Islands" OR Scotland AND* ***Habitat**** *OR "biogenic habitat" OR littoral OR pelagic* OR saltmarsh OR kelp Or "kelp forest" OR maerl OR "maerl beds" OR seagrass AND* ***Marine**** *OR intertidal OR water* OR ocean* OR sea* OR lagoon OR "marine assets" AND* ***"Ecosystem Services"*** *OR "ecological services" OR fisheries OR tourism OR education OR cultural OR "primary production" OR energy OR "Seaweed harvesting" OR Recreation AND* ***"Priority Marine Features"*** *OR marine plan OR "Marine conservations zone" OR "regional marine plan area" OR "MPA" OR "special area of conservation" AND* ***"Marine Species"*** *OR "marine mammals" OR seal* OR seabird* OR fish* OR Skua OR "sea trout" OR Puffin AND* ***"Climate Change"*** *OR "climate vulnerability OR climate pressures OR "blue carbon"*

Table A1-3: Critical Review Scoring Guide

Criteria	Description	Score (1 low, 5 high)					Description
Transparency	Biased literature to serve interests of funding body	1	2	3	4	5	Full disclosure on data, theory and methodology which informs literature
Appropriateness	Irrelevant to Research Questions	1	2	3	4	5	Fully relevant argument that is relevant to Research Questions
Validity	Illogical article that does not provide a sound evidence base	1	2	3	4	5	Logically or factually sound conclusions reached from the primary or secondary evidence discussed
Reliability	Unsubstantiated article	1	2	3	4	5	Provides consistent findings that are accurate and trustworthy
Cogency	Vague and unclear, no clear argument	1	2	3	4	5	Clear, logical argument backed up with robust methodology

Table A1-4: List of critically reviewed papers

ID	First Author	Title	Year	Web Link	ID	First Author	Title	Year	Web Link
1	Jones, E.	Fine-scale harbour seal at-sea usage mapping around Orkney and the North coast of Scotland.	2016	https://data.marine.gov.scot/dataset/fine-scale-harbour-seal-sea-usage-mapping-around-orkney-and-north-coast-scotland	**24**	Perkins, A.	Combined bottom-up and top-down pressures drive catastrophic population declines of Arctic skuas in Scotland.	2018	https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2656.12890
2	Porter, J.	Blue carbon audit of Orkney waters	2020	https://data.marine.gov.scot/dataset/blue-carbon-audit-orkney-waters	**25**	Johnson, K.	Innovation in the approach to integrating fisheries with MSP in Scotland.	2015	https://www.ices.dk/sites/pub/ASCExtendedAbstracts/Shared%20Documents/O%20-%20Marine%20spatial%20planning%20and%20fisheries.%20A%20stock-take%20on%20approaches,%20examples%20and%20future%20needs/O0815.pdf
3	Kent, A, E, F.	Horse mussel reef ecosystem services: evidence for a whelk nursery habitat supporting a shellfishery.	2016	https://www.tandfonline.com/doi/full/10.1080/21513732.2016.1188330	**26**	Angus, S.	Scottish saline lagoons: Impacts and challenges of climate change.	2017	https://www.sciencedirect.com/science/article/pii/S0272771416302438
4	Kakkonen J, E.	The value of regular monitoring and diverse sampling techniques to assess aquatic non-native species: a case study from Orkney	2019	https://www.researchgate.net/publication/329391439_The_value_of_regular_monitoring_and_diverse_sampling_techniques_to_assess_aquatic_non-native_species_a_case_study_from_Orkney	**27**	Burden, A.	Impacts of climate change on coastal habitats, relevant to the coastal and marine environment around the UK	2020	https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/19428/11_coastal_habitats_2020.pdf?sequence=1&isAllowed=y
5	Want, A.	Biodiversity characterisation and hydrodynamic consequences of marine fouling communities on marine renewable energy infrastructure in the Orkney Islands Archipelago.	2017	https://www.tandfonline.com/doi/full/10.1080/08927014.2017.1336229	**28**	Brash, M, J.	The demographics and morphometries of biogenic reefs: important considerations in conservation management	2017	https://www.cambridge.org/core/journals/journal-of-the-marine-biological-association-of-the-united-kingdom/article/demographics-and-morphometries-of-biogenic-reefs-important-considerations-in-conservation-management/6B4646C84C19FB38ABEB0D9DAA9222D8
6	Burrows, M, T.	Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network.	2017	https://www.researchgate.net/publication/313368535_Assessment_of_Blue_Carbon_Resources_in_Scotland's_Inshore_Marine_Protected_Area_Network	**29**	Philip, E.	North Orkney Proposed Special Protection Area (pSPA) NO. UK9020314 SPA Site Selection Document: Summary of the scientific case for site selection	2016	https://www.nature.scot/sites/default/files/2017-11/Marine%20Protected%20Area%20%28Proposed%29%20-%20Site%20selection%20document%20%20-%20North%20Orkney.pdf
7	Marine Scotland	Review of PMFs outside the Scottish MPA network - Horse mussel beds.	2018	https://consult.gov.scot/marine-scotland/priority-marine-features/supporting_documents/Review%20of%20PMFs%20outside%20the%20Scottish%20MPA%20network%20%20FINAL%20%20Horse%20mussel%20beds.pdf	**30**	Thompson, K	North Orkney proposed Special Protection Area (pSPA) Advice to Support Management	2016	https://www.nature.scot/sites/default/files/2017-11/Marine%20Protected%20Area%20%28Proposed%29%20-%20Advice%20to%20support%20management%20%20-%20%20North%20Orkney.pdf
8	Howson, C, M.	Identification of Priority Marine Features in Scottish territorial waters.	2012	https://www.nature.scot/sites/default/files/2017-08/Publication%202012%20-%20SNH%20Commissioned%20Report%20388%20-%20Identification%20of%20Priority%20Marine%20Features%20in%20Scottish%20territorial%20waters.pdf	**31**	Burdon, D.	The matrix revisited: A bird's-eye view of marine ecosystem service provision.	2017	https://www.sciencedirect.com/science/article/abs/pii/S0308597X16306650
9	Pollard, E.	Insights from archaeological analysis and interpretation of marine data sets to inform marine cultural heritage management and	2014	https://www.sciencedirect.com/science/article/abs/pii/S0964569114001604	**32**	Furness, R. W.	Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices.	2012	https://academic.oup.com/icesjms/article/69/8/1466/704765

		planning of wave and tidal energy development for Orkney Waters and the Pentland Firth, NE Scotland.							
10	McLay, A.	Mapping inshore fishing activity to inform marine planning in Scotland: A pilot project using stakeholder data in the Pentland Firth and Orkney waters	2012	http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2012/I/I0712.pdf	**33**	Gallego, A.	Bio-physical connectivity patterns of benthic marine species used in the designation of Scottish nature conservation marine protected areas.	2017	https://academic.oup.com/icesjms/article/74/6/1797/2726868
11	Potts, T.	Do marine protected areas deliver flows of ecosystem services to support human welfare?	2014	https://www.sciencedirect.com/science/article/pii/S0308597X13001656	**34**	Kober, K.	An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs	2010	https://data.jncc.gov.uk/data/7db38547-5074-4136-8973-fd7d97666120/JNCC-Report-431-Full-FINAL-WEB.pdf
12	Owen, E.	Black guillemot (*Cepphus grylle*) tracking in Orkney, 2013 and 2014	2015	https://www.researchgate.net/profile/Ellie_Owen2/publication/293825798_Black_guillemot_Cepphus_grylle_tracking_in_Orkney_2013_and_2014/links/56bc8ea808ae08d7a6bc1d52.pdf	**35**	Murray, S.	The status of the gannet in Scotland in 2013-14.	2015	http://nora.nerc.ac.uk/id/eprint/510050/
13	Moore, C. G.	An assessment of the conservation importance of species and habitats identified during a series of recent research cruises around Scotland	2011	https://tethys.pnnl.gov/sites/default/files/publications/More_and_Roberts_2011.pdf	**36**	Waggitt J.	Distribution maps of cetacean and seabird populations in the North-East Atlantic	2019	https://www.researchgate.net/profile/Kevin_Robinson2/publication/336834551_Distribution_maps_of_cetacean_and_seabird_populations_in_the_North-East_Atlantic/links/5e3ad456a6fdccd9658a6ae5/Distribution-maps-of-cetacean-and-seabird-populations-in-the-North-East-Atlantic.pdf
14	Wade, M, H.	GPS tracking of great skuas Stercorarius skua to investigate interactions with fisheries and marine renewable energy developments	2013	http://www.ices.dk/sites/pub/CM%20Doccuments/CM-2013/Theme%20Session%20I%20contributions/I1413.pdf	**37**	Thomson, M.	NatureScot Commissioned Report 765: Seagrass (Zostera) beds in Orkney	2014	https://media.nature.scot/record/~39175ff05d
15	Scottish Natural Heritage	Coastal character assessment: Orkney and North Caithness	2016	https://www.nature.scot/sites/default/files/2018-11/Coastal%20Character%20Assessment%20-%20Orkney%20and%20North%20Caithness.pdf	**38**	Jarrett, D	Short-Term Behavioural Responses of Wintering Waterbirds to Marine Activity: Appendix 2	2017	https://data.marine.gov.scot/sites/default/files/SMFS%200907%20-Appendix%202.pdf
16	McMurdo Hamilton, T.	Commissioned Report No. 703 Breeding success of cliff nesting seabirds in Mainland Orkney in 2013 and initial review of Orkney seabird monitoring	2016	https://www.nature.scot/sites/default/files/Publication%202016%20-%20SNH%20Commissioned%20Report%20703%20-%20Breeding%20success%20of%20cliff%20nesting%20seabirds%20in%20Mainland%20Orkney%20in%202013%20and%20initial%20review%20of%20Orkney%20seabird%20monitoring.pdf	**39**	Philip, E.	Final advice and recommendations on a network of proposed marine Special Protection Areas	2018	https://www.nature.scot/sites/default/files/2019-03/Marine%20Special%20Protection%20Areas%20-%20Final%20advice%20to%20Scottish%20Government.pdf
17	Upton, A.G.	North Orkney proposed Special Protection Area (pSPA) – inshore wintering waterfowl survey 2017/18	2018	https://www.nature.scot/sites/default/files/2018-12/Publication%202018%20-%20SNH%20Research%20Report%201074%20-%20North%20Orkney%20proposed%20Special%20Protection%20Area%20%28pSPA%29%20-%20inshore%20wintering%20waterfowl%20survey%202017_18.pdf	**40**	Marine Scotland	Wild seaweed harvesting: strategic environmental assessment - environmental report	2016	https://www.gov.scot/publications/wild-seaweed-harvesting-strategic-environmental-assessment-environmental-report/
18	Duck, C.D.	Aerial survey of harbour (Phoca vitulina) and grey seals (Halichoerus grypus) in Scotland in 2016: Orkney and the North Coast, the Moray Firth and part of East Scotland	2019	https://www.nature.scot/sites/default/files/2019-09/Publication%202019%20-%20SNH%20Research%20Report%201005%20-%20Aerial%20survey%20of%20harbour%20and%20grey%20seals%20in%20Scotland%20in%202016.pdf	**41**	Allen, J, H.	Infaunal and PSA analyses of benthic samples collected from around the Isle of Arran, Loch Fyne and Orkney in July and August 2015	2017	https://www.nature.scot/sites/default/files/Publication%202017%20-%20SNH%20Commissioned%20Report%20945%20-%20Infaunal%20and%20PSA%20analyses%20of%20benthic%20samples%20collected%20from%20around%20the%20Isle%2

									0of%20Arran%2C%20Loch%20Fyne%20and%20Orkney%20in%20July%20and%20August%202015.pdf
19	Smale, A, D.	Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective.	2013	https://www.researchgate.net/publication/258337958_Threats_and_knowledge_gaps_for_ecosystem_services_provided_by_kelp_forests_A_northeast_Atlantic_perspective	**42**	Burrows, M	Wild seaweed harvesting as a diversification opportunity for fishermen	2018	https://www.researchgate.net/publication/328354001_Wild_seaweed_harvesting_as_a_diversification_opportunity_for_fishermen/link/5d0b48e192851cfcc62531bc/download
20	Mackenzie, C	Orkney's shipwreck graveyard is bursting with life	2018	https://theconversation.com/orkneys-shipwreck-graveyard-is-bursting-with-life-95179	**43**	Orkney's Biodiversity Steering Group	The Orkney Local Biodiversity Action Plan	2018	https://www.orkney.gov.uk/Files/Planning/Biodiversity/Orkney_LBAP_2018_2022_FINAL_Oct_2018.pdf
21	Kent, A, E, F.	Commercially important species associated with horse mussel (Modiolus modiolus) biogenic reefs: A priority habitat for nature conservation and fisheries benefits	2017	https://pureapps2.hw.ac.uk/ws/portalfiles/portal/15470344/Kent_et_al_megafauna_25_Nov_2016_3_.pdf	**44**	Marine Scotland	Regional differences in the abundance trends amongst harbour seal populations	2017	https://www.gov.scot/binaries/content/documents/govscot/publications/factsheet/2019/11/marine-scotland-topic-sheets-marine-mammals/documents/regional-differences-in-the-abundance-trends-amongst-harbour-seal-populations-updated-march-2017/regional-differences-in-the-abundance-trends-amongst-harbour-seal-populations-updated-march-2017/govscot%3Adocument/harbour-seal-populations.pdf
22	Perry, F	Maerl beds.	2020	https://www.marlin.ac.uk/habitats/detail/255/maerl_beds#citation	**45**	Damseaux, F	Habitat and resource segregation of two sympatric seals in the North Sea	2020	https://www.sciencedirect.com/science/article/pii/S0048969720363725
23	Bakker, W, Y.	Resilience and social capital: The engagement of fisheries communities in marine spatial planning.	2019	https://www.sciencedirect.com/science/article/abs/pii/S0308597X18301441	**46**	Hughes, Robert	A census of Atlantic Puffins on Orkney	2018	https://www.researchgate.net/publication/332298796_A_census_of_Atlantic_Puffins_on_Orkney_UK

Table A1-5: Habitats identified in REA

Common Habitat name (*Scientific name*)	Confidence in Presence (within Orkney 12 nm zone)	Confidence in Extent (within Orkney 12 nm zone)	Number of critically reviewed papers that directly mention habitat
Blue mussel beds (*Mytilus edulis*)	2	2	2
Brittlestar beds (*Ophiothrix fragilis*)	3	3	5
Bryozoan thicket (*Flustra foliacea*)	3	2	4
Burrowed Mud	2	1	1
Circalittoral mud	2	1	1
Flame shell beds (*Limaria hians*)	3	3	4
Gravel	3	2	4
Gravelly muddy sand	3	2	4
Gravelly sand	3	2	4
Horse mussel beds (*Modiolus modiolus*)	3	3	6
Intertidal boulder communities	2	1	3
Intertidal mudflats	2	1	1
Littoral caves and overhangs	2	1	1
Maerl beds	3	3	6
Muddy sand	3	2	6
Native Oyster (*Ostrea edulis*)	1	1	1
Muddy sandy gravel	3	2	4
Rock	3	2	3
Saltmarshes	3	2	4
Sand	3	2	5
Sandy gravel	3	2	4
Seaweeds:			
Kelps	3	2	6
Red Seaweeds	2	2	5
Green Seaweeds	2	2	4
Wracks	2	2	4
Seagrass beds (*Zostera marina*)	3	3	7
Slightly gravelly muddy sand	3	2	3
Slightly gravelly sand	3	2	3
Sublittoral Wave surge gullies and caves	2	1	1

Confidence in Habitat Presence	Confidence in Habitat Extent	Score
Orkney related, peer-reviewed literature or mapped	Strong evidence of habitat extent	3
Grey literature, Scotland/UK or strong evidence of habitat presence (e.g. aerial photos or videos)	The habitat exists, but no strong evidence of extent	2
Expert opinion/judgement	Unknown	1
No evidence of presence		0

Table A1-6: Species identified in REA

Species Name - FeAST [24]	Description - FeAST	Confidence in Presence (within Orkney 12 nm zone)	Confidence in Extent (within Orkney 12 nm zone)	Number of critically reviewed papers that directly mention species
Black guillemot	Members of the auk family, black guillemot are a resident non-migratory species that generally remain close inshore. They nest along cliffs and offshore islands and generally feed in kelp forests.	2	2	1
Black-throated diver (non-breeding)	Black-throated diver is an elegant and distinctive species that typically uses sheltered coastal waters during the non-breeding season. Feeds predominantly upon fish, alongside other prey groups.	2	2	1
Common scoter (non-breeding)	Common scoter is a non-breeding visitor to Scotland that typically feeds and roosts far offshore. Forages on benthic species, mainly molluscs.	2	2	1
Common skate	Studies have shown that common skate are in fact two species - the blue skate and the flapper skate. It is the flapper skate that is predominantly recorded in Scottish waters. This skate is the largest in European waters and tends to live on sandy, muddy and gravel bottoms from the coast down to 600m.	3	2	2
Eider (non-breeding)	The largest duck species found in Scotland. Eider is a seaduck which dives to the seabed to forage on benthic molluscs and crustaceans, primarily selecting mussels.	3	3	6
Goldeneye (non-breeding)	Goldeneye is a medium-size duck species occurring in highest numbers during the non-breeding season, although a small population does breed in Scotland. Goldeneye dive to forage for food, mainly molluscs and	3	2	1

[24] Marine Scotland: FeAST – Feature Activity Sensitivity Tool https://www.marine.scotland.gov.uk/FEAST/FeatureReport.aspx#0

	crustaceans, but fish and plant material can also make up a small part of their diet.			
Great northern diver (non-breeding)	The largest diver species. Spends its winters in a range of coastal habitats, preferring shallow inshore waters. Feeds on a mix of freshwater and marine prey, mainly fish.	3	3	4
Guillemot (breeding)	Members of the auk family, guillemot are a migratory species that generally breed on coastal cliffs and spend the rest of the year at sea. They generally feed on fish.	3	2	5
Long-tailed duck (non-breeding)	Long-tailed duck is a gregarious seaduck that forms large non-breeding flocks. Long-tailed duck dives to the seabed to forage on a range of prey including benthic molluscs, crustaceans, and small fish.	3	2	5
Northern featherstar aggregations on mixed substrata	Feather stars are a relative of the starfish. They use their branching arms to catch passing plankton and suspended organic particles. Feather stars are commonly found on sediment, shell, gravel or bedrock. In areas of low wave action and good water flow, feather stars can form dense aggregations making up a significant component of the seabed community.	2	1	1
Ocean quahog (aggregations)	Aggregations or individual examples of the long-lived mollusc Arctica islandica. The species tends to live within sandy seabed sediments	2	1	1
Puffin (breeding)	Members of the auk family, puffin are a migratory species that generally breed in burrows on offshore islands and spend the rest of the year at sea. They generally feed on fish; crustaceans may also form part of their diet.	3	2	5
Red-breasted merganser (non-breeding)	Red-breasted merganser is a diving duck, gregarious and seen in large groups during the non-breeding season. It feeds primarily on small fish along with small amounts of vegetation and aquatic invertebrates.	3	2	6
Red-throated diver (breeding)	The smallest of Scotland's diver species. Typically breeds on inland water bodies in open moorland or blanket bog landscapes. Feeds on a mix of freshwater and marine prey, mainly fish.	3	2	4
Sandeels	A small burrowing fish that tends to be found living within sandy sediments. Sandeels are very important to the diets of many animals feeding in the North Sea	3	1	5
Scaup (non-breeding)	Scaup is a gregarious winter visitor to Scotland. An omnivorous diving forager that mostly feeds upon benthic molluscs.	2	1	1
Shag (breeding)	Shag is resident in Scotland and is a species that shows high nesting site fidelity at its coastal colonies. A diving pursuit feeder mainly preying on sandeels.	2	2	4
Shag (non-breeding)	Shag is resident in Scotland, and in non-breeding season typically remains within 100-200km from its breeding colony site. A diving pursuit feeder mainly preying on sandeels.	3	3	7
Slavonian grebe (non-breeding)	Slavonian grebe is a migratory species seen in the seas around Scotland in the non-breeding season. A strong swimmer and diver that feeds mainly on fish and crustaceans.	3	2	6
Velvet scoter (non-breeding)	Velvet scoter is a non-breeding visitor to Scotland that typically feeds and roosts far offshore, often in association with common scoter. Forages on benthic species, mainly molluscs.	3	2	5

OTHER SPECIES (*Scientific name*)	**Confidence in Presence (within Orkney 12 nm zone)**	**Confidence in Extent (within Orkney 12 nm zone)**	**Number of critically reviewed papers that directly mention species**
Grey Seal (*Halichoerus grypus*)	3	2	5
Harbour Seal (*Phoca vitulina*)	3	3	7
Sea Trout	2	1	2
Great Skua	2	2	3
Arctic Skua	3	2	1

Confidence in Species Presence	Confidence in Species Extent	Score
Orkney related, peer-reviewed literature or mapped	Strong evidence of species extent	3
Grey literature, Scotland/UK or strong evidence of species presence (e.g. aerial photos or videos)	The species exists, but no strong evidence of extent	2
Expert opinion/judgement	Unknown	1
No evidence of presence		0

Table A1-7: Matrix of Activities and pressures identified in literature as impacting on specific Habitats within the Orkney 12 mile nautical boundary

	Activity/Pressure									
HABITAT	**Aquaculture**	**Climate Change**	**Energy production and associated infrastructure**	**Extraction**	**Fishing**	**Land-use change/erosion**	**Seaweed harvesting**	**Shipping**	**Tourism and recreation**	**Other**
Blue mussel beds (Mytilus edulis)			Shading from construction activities (6)			Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6)				
Brittlestar beds (Ophiothrix fragilis)		Increase in temperature and ocean acidification (2,6) Increased storminess (2)	Shading from construction activities (2,6)		Dredging (2,6)	Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6)				Pollution in the form of organ-metallic compounds such as TBT (2)
Bryozoan thicket (Flustra foliacea)		Increase in temperature and ocean acidification (2,6) Increased storminess (2) Rising sea levels (8)	Shading from construction activities (2,6)		Dredging (2,6)	Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6)				Pollution in the form of organ-metallic compounds such as TBT (2) Invasive non-native species (4)
Flame shell beds (Limaria hians)	Deposition of fish wastes and surplus feed from aquaculture cages Chemical therapeutants used to treat caged fish (43)	Increase in temperature and ocean acidification (2,6) Increased storminess (2)	Shading from construction activities (2,6)		Dredging (2,6) Scallop dredging (43)			Anchors and moorings (43)		
Circalittoral mixed and coarse sediments			Renewable energy installations (6)		Mobile fishing gear (6)	Sedimentation (2,6)		Moorings (6)	Direct anthropogenic activity (6)	
Horse mussel beds (Modiolus modiolus)		Increase in temperature and ocean acidification (2,6,7) Increased storminess (2,7)	Shading from construction activities (2,6) Tidal flow changes (13)	Substrate loss (13)	Scallop dredging (2,6,8,21) Trawling (7,21)	Sedimentation (2,6,13) Siltation (7)				Pollution in the form of organ-metallic compounds such as TBT (2) Competition from Flame shells (7)
Intertidal mudflats		Rising sea levels (8)		Shellfish extraction (8)	Mobile fishing gear (6)	Coastal development (8)			Recreational activities (8)	Pollution (8)
Maerl Beds	Deposition of fish wastes and surplus feed from aquaculture cages, Chemical therapeutants used to treat caged fish (43) Eutrophication from aquaculture (22)	Increase in temperature and ocean acidification (2,6,22,27) Increased storminess (6,22)	Shading from construction activities (2,6) Wave and tidal flow changes (22) Renewable energy infrastructure (6)	Removal of substratum (8,22)	Scallop dredging (2,6,8,22,43) Demersal trawling (22) Suction dredging (22,43)	Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6) Sedimentation (2,6,22,43)	Trawling, dredging Mechanical 'hedge' cutting Hand cutting (40)	Anchors and moorings (43)		Pollution in the form of organ-metallic compounds such as TBT (2) Sea defences (43)

Saltmarshes		increase in temperature and ocean acidification (2,6) Increased storminess (2) Rising sea levels (8,27)			Dredging (2,6)	Sedimentation (2,6)			Direct anthropogenic activity (6)	Pollution in the form of organ-metallic compounds such as TBT (2)
Sand, Sandy gravel			Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion from renewable energy cable laying (9)			Sedimentation (2,6)			Direct anthropogenic activity (6)	
Kelp		and ocean acidification (2,6) Increased storminess (2) Rising sea levels (8)	Shading from construction activities (2,6)		Dredging (2,6) Demersal fishing (8)	Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6,42)	Trawling, dredging Mechanical 'hedge' cutting Hand cutting (40,42)	Shipping (42)		Pollution in the form of organ-metallic compounds such as TBT (2) Sewage (42) Disease (42) Overgrazing (42) Chemical/pharmaceutical application (42)
Seaweeds		Rising sea levels (8)				Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6) Coastal development (8)	Trawling, dredging Mechanical 'hedge' cutting Hand cutting (40,42)	Shipping (42)		Pollution in the form of organ-metallic compounds such as TBT (2) Sewage (42) Disease (42) Invasive non-native species (4) Overgrazing (42) Chemical/pharmaceutical application (42)
Seagrass beds (*Zostera marina*)		increase in temperature and ocean acidification (2,6) Elevated sea temperature (43) Rainfall extremes (43) Long-term cycles in oceanic circulation (43) Rising sea levels (27)	Shading from construction activities (2,6)		Dredging (2,6) Bottom trawling (43) Physical disturbance (37)	Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration (2,6) Increased turbidity (37)	Trawling, dredging Mechanical 'hedge' cutting Hand cutting (40,42)	Anchors (43)		Pollution in the form of organ-metallic compounds such as TBT (2) Nutrient enrichment and pollution (37) Introduced species (37)

Note: numbers in brackets represent literature identifier as referenced in Table A1-4 above

Table A1-8: Matrix of Activities and pressures identified in critically reviewed literature as impacting on specific Species within the Orkney 12 mile nautical boundary.

	Activity/Pressure								
Species	**Aquaculture**	**Climate Change**	**Energy production and associated infrastructure**	**Extraction**	**Fishing**	**Land-use change/erosion**	**Shipping**	**Tourism and recreation**	**Other**
Black guillemot			Displacement, collision, barrier effects (38)		Bycatch (38)		Disturbance (38)		Pollution (38)
Black-throated diver (non-breeding)			Displacement, collision, barrier effects (38)						Pollution (38)
Common scoter (non-breeding)			Displacement, barrier effects (38)		Bycatch, prey depletion (38)				Pollution (38)
Common skate			electrical/magnetic subsea equipment and cables (43)	Overfishing (43)	Bycatch, loss of habitat from seabed damage from fishing gear (43)				Predation by seals (43)
Eider (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Bycatch, Prey depletion, Turbidity (38, 30)	sedimentation (38)	Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Goldeneye (non-breeding)			Displacement, collision, barrier effects (38, 30)		Bycatch (38)				Pollution (38)
Great northern diver (non-breeding)	bycatch, loss/damage of habitat (30)				Bycatch, Prey depletion, Turbidity (38, 30)		Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Long-tailed duck (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Bycatch, Prey depletion, Disturbance, Turbidity (38, 30)	sedimentation (38)	Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Northern featherstar aggregations on mixed substrata					demersal fishing (8)				
Ocean quahog (aggregations)					deepwater trawling (8)				
Puffin (breeding)		impact of climate change on food availability (46)	interactions with renewable energy devices (46)		changing fisheries practices (46)				Pollution, predators, prey reduction (36,46)
Red-breasted merganser (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Bycatch (38, 30)		Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Red-throated diver (breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Bycatch, Turbidity (38,30)	sedimentation (38)	Disturbance (38,30)		Pollution (38)
Sandeels		rising temperatures and ocean acidification (24)	Displacement (30)	Human take (24)	targeted fishing (30)			Disturbance (24, 38, 30)	Predatory fish (24)
Shag (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Turbidity, Prey depletion (38, 30)	sedimentation (38)	Disturbance (38,30)	Disturbance (38, 30)	Pollution, contamination (38)

Slavonian grebe (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Turbidity, Prey depletion (38, 30)	sedimentation (38)	Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Velvet scoter (non-breeding)	bycatch, loss/damage of habitat (30)		Displacement, collision, barrier effects (38, 30)		Bycatch, habitat loss, prey depletion, Turbidity (38, 30)	sedimentation (38)	Disturbance (38,30)	Disturbance (38, 30)	Pollution (38)
Harbour Seal (Phoca vitulina)			collisions with tidal turbines (1)		bycatch (44)		interactions with vessels (44)		Bioaccumulation of toxic compounds, noise pollution (8) Competition for prey, infectious disease, nutritional stress, legal shooting, pollution, injuries from grey seals and killer whales (44,45)
Sea Trout	habitat degradation (43)	rising temperatures and ocean acidification (43)		Over abstraction, overfishing (43)					Predation and introduced species, sea lice (43)
Great Skua			renewable energy development (14)						
Arctic Skua									Great Skua predation, shortages of feed for chicks (e.g. sandeels) (24)

Note: numbers in brackets represent literature identifier as referenced in Table A1-4 above

Appendix 2: High-level Marine Objectives

Table A2-1: Summary of the core planning documents reviewed during the development of this chapter

Marine Planning Publication	Geographic Scale	Year of Publication	Publishing Authority	Summary	Direct References to Natural Capital	Direct References to Ecosystem Services
DIRECTIVE 2014/89/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 July 2014 Establishing a framework for maritime spatial planning	European Union	2016	European Union	This Directive introduces a framework for marine spatial planning and places a duty on Member States to produce Marine Spatial Plans by 31st March 2021.	1	1
UK Marine Policy Statement	UK	2011	HM Government, Northern Ireland Executive, Scottish Government, Welsh Assembly Government	The Marine Policy Statement (MPS) is the framework for preparing Marine Plans and taking decisions affecting the marine environment across the UK. It will contribute to the achievement of sustainable development and has been prepared and adopted for the purposes of section 44 of the Marine and Coastal Access Act 2009.	0	0
Scotland's National Marine Plan	Scotland	Mar 2015	The Scottish Government	The National marine plan for Scotland, published in March 2015 covering both Scottish inshore waters (out to 12nms) and offshore waters (12 to 200 nautical miles).	1	8 (excluding glossary)
Scotland's National Marine Plan Review	Scotland	March 2018	The Scottish Government	Three Year Report on the implementation of Scotland's National Marine Plan for period encompassing 26th March 2015 – 25th March 2018. This report fulfils the commitment to review and report on the implementation of the marine plan after 3 years of adoption.	0	0
Scotland's National Marine Plan - Modifications Report	Scotland	2015	The Scottish Government	The modifications report sets out the modifications that were made to the draft marine plan following an independent investigation by Planning Aid Scotland. The report contains 22 recommendations including focus on ecosystem services in the context of Climate Change (General Policy 5), a broadening of policies to include other ecosystem services in addition to natural protection and carbon sinks and the proactive enhancement of ecosystem services.	0	4
Lessons Learned Report for Scotland's first National Marine Plan	Scotland	March 2016	The Scottish Government	This document provides information about the lessons learned from the process of developing Scotland's first National Marine Plan. This includes acknowledgement of "a notable tension between a sectoral focus and a broader ecosystem focus presented by the draft Plan".	0	0

Marine Planning Publication	Geographic Scale	Year of Publication	Publishing Authority	Summary	Direct References to Natural Capital	Direct References to Ecosystem Services
Development and implementation of Regional Marine Plans in Scotland: interim report (July 2020)	Scotland	2020	Environment, Climate Change and Land Reform Committee - Scottish Parliament	This report summarises information gathered by the Committee to support their examination of the experience of developing and implementing Regional Marine Plans in Scotland. This included comments from Scottish Wildlife Trust that regional marine plans "provide the required mechanism to deliver an ecosystem-based approach and should consider a natural capital approach to marine planning" and comments from Orkney Island Council stating that they wish to "deviate from the National Marine Plan for a more localised approach, otherwise there was no point in developing an RMP."	1	0
Pilot Pentland Firth and Orkney Waters Marine Spatial Plan	Pentland Firth and Orkney	2016	Marine Scotland - Pilot Pentland Firth and Orkney Waters working group	A working group consisting of Marine Scotland, Orkney Islands Council and Highland Council developed this pilot Pentland Firth and Orkney Waters Marine Spatial Plan. The Plan sets out an integrated planning policy framework to guide marine development, activities and management decisions, whilst ensuring the quality of the marine environment is protected. The working group undertook the pilot to put in place a planning policy framework in advance of statutory regional marine planning.	0	5
Pilot Pentland Firth & Orkney Waters Marine Spatial Plan - Lessons Learned	Pentland Firth and Orkney	2016	7.4.15 Marine Scotland - Pilot Pentland Firth and Orkney Waters working group	This document outlines the "Lessons Learned" from the process of developing a non-statutory pilot marine spatial plan for the Pentland Firth and Orkney Waters. There were no specific lessons learnt in relation to natural capital or ecosystem services although reference is made to Ehler, D. & Douvere, F. (2009) Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO.	0	0
Shetland Islands Marine Spatial Plans (SIMSP)	Shetland	2015 (4th edition)	Shetland Island's Council, Marine Spatial Planning Team at the NAFC Marine Centre	Based on an ecosystem approach to marine planning, the SIMSP ensures that the use of the marine environment is spatially planned where practical, facilitates climate change mitigation and requires current and future marine related activities to address and include provision for the impacts of climate change.	0	3
Clyde Regional Marine Plan - pre consultation draft	Clyde	Mar 2019	Clyde Marine Planning Partnership	Draft regional marine plan, following Marine Scotland Framework, based around an ecosystems approach with a 20 year vision for the marine and coastal environment of the Clyde Marine Region. This vision (based on the UK	1	2

Marine Planning Publication	Geographic Scale	Year of Publication	Publishing Authority	Summary	Direct References to Natural Capital	Direct References to Ecosystem Services
				MPS vision) is for clean, healthy, safe, productive, biologically diverse seas that are accessible for all and managed sustainably to support productive and thriving coastal communities, allowing nature to flourish.		
The Orkney Local Biodiversity Action Plan	Orkney	2018	Orkney's Biodiversity Steering Group for the Orkney Environment Partnership	The Orkney Local Biodiversity Action Plan 2018-2022 (LBAP) is the third in a series of focused revisions of the original Orkney LBAP (2002). The Audit and Habitat Action Plans from the 2002 Plan provide much of the context to the current Plan and will continue to be relevant to the protection and enrichment of biodiversity in the Orkney Isles. The BAP provides information on marine biodiversity and the associated ecosystem services which will provide an important baseline for the development of regional marine plans, alongside the State of the Environment Report. The BAP also includes Strategic Goal D which strives to "Enhance the benefits to all from biodiversity and ecosystem services".	3	7
Orkney Local Development Plan	Orkney	2017	Orkney Islands Council	The Orkney Local Development Plan 2017 sets out a vision and spatial strategy for the development of land in Orkney over the next ten to twenty years. The Plan contains the land use planning policies which Orkney Islands Council will use for determining applications. As per guidance within the Scottish National Marine Plan and UK MPS, it is imperative that the development of the Orkney Regional Marine Plan integrates cohesively with the Orkney Local Development Plan. RSK believes there is opportunity to achieve this by embedding a Natural Capital approach at the heart of both plans, allowing a common "golden thread" to help stakeholders and decision makers to make robust system wide choices.	0	0
Orkney Island Marine Planning Updates x4	Orkney	Dec 2020, Sept 2020, 2019 & 2018	Orkney Islands Council	A series of updates from Orkney Islands Council for Orkney's coastal and marine stakeholders on the development of local marine planning and resource management initiatives including the creation of a marine planning partnership and commencement of development of a statutory regional marine plan.	0	0
State of the Environment Assessment - A baseline assessment of the Orkney Island Marine Region	Orkney	2020	Orkney Islands Council	This assessment presents a summary of the environmental pressures and impacts of human activities affecting the Orkney Islands marine region. It includes ecological, social and economic factors and presents associated pressures and trends. It provides a snapshot in time of the current issues facing Orkney's marine environment, as of November 2020, and the current status of the key economic sectors. The assessment will form a critical part of the	1	14

Marine Planning Publication	Geographic Scale	Year of Publication	Publishing Authority	Summary	Direct References to Natural Capital	Direct References to Ecosystem Services
				baseline in the development of the Orkney regional marine plan and provides numerous references to ecosystem services.		
Offshore Wind Energy in Scottish Waters - Regional Locational Guidance	Scottish	Oct 2020	Scottish Government	This report builds on the Scottish Government's plan for future commercial scale offshore wind development in Scottish waters in the period to 2050. It provides regional locational guidance (building on existing marine planning process and associated data) to identify potential areas for development of conventional fixed bottom and deep water wind technologies. This information will inform the development of the Orkney regional marine plan.	0	0
Feasibility study for a marine natural capital asset index for Scotland	Scottish	2019	NatureScot & Marine Scotland	This report produced by the Marine Biological Association on behalf of NatureScot and Marine Scotland provides the findings of a desk-based study which examined whether a marine version of the Natural Capital Asset Index (NCAI) for Scotland is now feasible for development given the recent advances in marine biodiversity indicators and associated underpinning data. The report concludes that *"it is technically feasible for a marine NCAI for Scottish Seas to be developed. Limitations in available data and indicators would mean that a national-scale index is coarse, but likely to be useful in tracking broad trends in the condition of marine natural capital."*	125	166
					This document makes 8 references to the planning system.	

Table A2-2: High-level Marine Objectives:

High Level Marine Objective	Aims of / guidance for marine objective
Achieving a sustainable marine economy	Infrastructure is in place to support and promote safe, profitable and efficient marine businesses (HLMO1)
	The marine environment and its resources are used to maximise sustainable activity, prosperity and opportunities for all, now and in the future (HLMO2)
	Marine businesses are taking long-term strategic decisions and managing risks effectively. They are competitive and operating efficiently (HLMO3)
	Marine businesses are acting in a way which respects environmental limits and is socially responsible. This is rewarded in the marketplace (HLMO4)
Ensuring a strong, healthy and just society	People appreciate the diversity of the marine environment, its seascapes, its natural and cultural heritage and its resources and act responsibly (HLMO5)
	The use of the marine environment is benefiting society as a whole, contributing to resilient and cohesive communities that can adapt to coastal erosion and flood risk, as well as contributing to physical and mental wellbeing (HLMO6)
	The coast, seas, oceans and their resources are safe to use (HLMO7)
	The marine environment plays an important role in mitigating climate change (HLMO8)
	There is equitable access for those who want to use and enjoy the coast, seas and their wide range of resources and assets and recognition that for some island and peripheral communities the sea plays a significant role in their community (HLMO9)
	Use of the marine environment will recognise, and integrate with, defence priorities, including the strengthening of international peace and stability and the defence of the UK and its interests (HLMO10)
Living within environmental limits	Biodiversity is protected, conserved and where appropriate recovered and loss has been halted (HLMO11)
	Healthy marine and coastal habitats occur across their natural range and are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems (HLMO12)
	Our oceans support viable populations of representative, rare, vulnerable, and valued species (HLMO13)
Promoting good governance	All those who have a stake in the marine environment have an input into associated decision-making (HLMO14)
	Marine, land and water management mechanisms are responsive and work effectively together, for example through integrated coastal zone management and river basin management plans (HLMO15)
	Marine management in the UK takes account of different management systems that are in place because of administrative, political or international boundaries (HLMO16)
	Marine businesses are subject to clear, timely, proportionate and, where appropriate, planned regulation (HLMO17)
	The use of the marine environment is spatially planned where appropriate and based on an ecosystems approach which takes account of climate change and recognises the protection and management needs of marine cultural heritage according to its significance (HLMO18)
Using sound science responsibly	Our understanding of the marine environment continues to develop through new scientific and socio-economic research and data collection (HLMO19)
	Sound evidence and monitoring underpins effective marine management and policy development (HLMO20)
	The precautionary principle is applied consistently in accordance with the UK Government and Devolved Administrations' sustainable development policy (HLMO21)

Table A2-3: Summary of policies within the Scottish National and existing regional and pilot marine plans supporting a natural capital / ecosystem services approach

Scotland's National Marine Plan	Scotland's National Marine Plan Regional Policy Guidance	Shetland Islands Marine Plan	Clyde Regional Marine Plan (pre-consultation draft)	Pentland Firth and Orkney Waters Pilot
General Policies:				
GEN 1 General planning principle: There is a presumption in favour of sustainable development and use of the marine environment when consistent with the policies and objectives of the Plan.				**General Policy 1A: Sustainable development:** Development(s) and/or activities will be supported by this Plan when it can be demonstrated that: • they will not have significant adverse direct, indirect, or cumulative social, environmental or economic effects • they will maintain and, where possible, enhance, existing built, natural and cultural heritage resources • the protection and, where appropriate, enhancement of the health of the marine area • maximise opportunities for lasting social, environmental and economic benefits balancing these considerations through the consenting process
GEN 2 Economic benefit: Sustainable development and use which provides economic benefit to Scottish communities is encouraged when consistent with the objectives and policies of the Plan.				**General Policy 1B: Supporting sustainable social and economic benefits:** Development(s) and/or activities will be supported by this Plan when the proposal can demonstrate: • that any adverse social, economic, and operational effects on existing activities have been avoided, or where avoidance is not possible, adverse effects have been appropriately mitigated
GEN 3 Social benefit: Sustainable development and use which provides social benefits is encouraged when consistent with the objectives and policies of the Plan.				
GEN 5 Climate Change: Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.	Regional marine plans should: Identify significant natural carbon sinks and seek to avoid colocation with potentially damaging activity; then Assess the acceptability of any proposed partial loss or damage to natural carbon sinks (including any compensatory measures) through licensing or management of marine activities, balanced with priorities presented in the Plan and respective regional marine plans. Explain how they have taken into account future climate change in terms of climate change adaptation.	**Policy MSP CLIM2: Climate Change Adaptation** Applications for marine-related developments should demonstrate that the impacts of climate change over the lifetime of the development have been considered and minimised as part of the overall development proposal.	**Objective CC 1:** Coastal zone and marine development(s) and activities minimise emissions of greenhouse gases and are resilient to the impacts of climate change. **Objective CC 2:** Natural carbon sinks and the associated benefits and services they provide are maintained and/or where possible enhanced in the Clyde Marine Region.	**General Policy 3: Climate Change** Development(s) and/or activities will be supported by the Plan where the proposal can demonstrate appropriate: • measures to mitigate the effects of climate change • measures taken to adapt to climate change

GEN 7 Landscape/seascape: Marine planners and decision makers should ensure that development and use of the marine environment take seascape, landscape and visual impacts into account**.**	Regional marine plans should consider identifying the landscape character types and protected landscapes within the Marine Region and setting out policies to safeguard their special qualities	**Policy MSP HER9: Safeguarding National Scenic Areas (NSAs) and Local Landscape Areas (LLAs)** Developments that affect an NSA or LLA will only be permitted where: a) it will not adversely affect the integrity of the area or the qualities or protected features for which it has been designated, or b) any such adverse effects are clearly outweighed by social, environmental or economic benefits of national importance for NSAs and local importance for LLAs.	Nationally and locally important landscape/seascape character of the Clyde Marine Region is protected, and where appropriate enhanced, at both a wider and a local level to contribute to the quality of life and wellbeing of local communities and visitors.	**General Policy 4D: Landscape and seascape:** The siting and design of any proposed development(s) and/or activities should demonstrate how the proposal takes into account visual impact and existing character and quality of landscape and seascape.
GEN 8 Coastal process and flooding: Developments and activities in the marine environment should be resilient to coastal change and flooding, and not have unacceptable adverse impact on coastal processes or contribute to coastal flooding.	Regional marine plans should be aligned with terrestrial development plans and reflect coastal areas likely to be suitable for development, taking into account the most recent flood risk and flood hazard maps, and forthcoming coastal erosion vulnerability mapping. Where relevant, regional marine plans should also reflect areas where managed realignment of coast may be appropriate, setting out the potential benefits such as habitat creation and new recreation opportunities.	**Policy MSP CD1: Coastal Defence Construction** … Where coastal defence is deemed necessary, there should be an overall presumption in favour of soft rather than hard defences. The use of managed realignment of coastal defences where appropriate will be promoted. **Policy MSP CD2: Coastal Defence Demolition** When considering the demolition of coastal defence structures, the following should be taken account of: e) value to species and habitats, such as providing a substrate for an important rocky shore habitat, or shelter for otters.	**Objective CP 1:** Current and new coastal zone and marine development(s) and activities, and land-based development(s) and activities near the coast, are resilient to the dynamic nature of the coast, including the impacts of climate change, using natural assets and soft engineering where possible.	
GEN 9 Natural heritage: Development and use of the marine environment must: (a) Comply with legal requirements for protected areas and protected species. (b) Not result in significant impact on the national status of Priority Marine Features. (c) Protect and, where appropriate, enhance the health of the marine area. Geodiversity particularly, provides many ecosystem services, such as a diversity of seabed habitats and physical features necessary for the existence of important marine life, the basis for energy development and the attenuation of erosive forces close to shore. Marine planning should consider opportunities to protect important features and prevent deterioration or enhance where appropriate. Where	**Regional marine plans should consider:** Using relevant guidance and data sources to identify, where appropriate, areas that are sensitive to specific types of development or other activity. Particular regard should be given to protected sites, protected species and Priority Marine Features. Spatial policies should take account of the sensitivities identified. Developing policies that contribute to the achievement of Conservation Objectives for designated sites within the MPA network. Recognising the role of habitats and species in providing and supporting ecosystem services and consider opportunities to enhance these services.	**Policy MSP HER1: Developments in or near Sites of International Interest (SACs, SPAs and Ramsar)** Developments that might affect a site designated or proposed to be designated as a SPA, SAC (collectively known as Natura 2000 sites) require competent authorities to carry out a Habitat Regulations Appraisal. **Policy MSP HER2: Developments in or near SSSIs** Development likely to have an effect on a Site of Special Scientific Interest (SSSIs) will only be permitted where there is no adverse effect or where there is no reasonable alternative. **Policy MSP HER3: Nature Conservation Marine Protected Areas** Development capable of affecting any Nature Conservation MPA will only be permitted where it has been adequately demonstrated that there will be no significant risk of hindering the conservation objectives of the Nature Conservation MPA. **Policy MSP HER7: Priority Marine Features** Developments or activities likely to have a significant effect on a Priority Marine Feature (PMF) will only be permitted where it can be demonstrated that there will be no adverse effect, mitigation measures are included or there is no reasonable alternative and	**Objective NH 1** The health of the marine and coastal natural heritage of the Clyde Marine Region is protected and, where appropriate, enhanced. **Objective NH 2** Development and use of the coastal and marine environment do not have significant negative impact on biodiversity, the Marine Protected Area network, other protected habitats and species and Priority Marine Features in line with the relevant conservation objectives and, where possible, contributes to their maintenance and/or enhancement. **Objective NH 3** Knowledge and data on marine and coastal natural features within the Clyde	**General Policy 1C: Safeguarding the marine ecosystem** The Plan will support proposed development(s) and/or activities when they: • safeguard the integrity of coastal and marine ecosystems • contribute towards the Marine Strategy Framework Directive objectives to promote enhancement or improvement of the environmental status of the marine environment • demonstrate how any significant disturbance and degradation of coastal and marine ecosystems has been avoided or appropriately mitigated **General Policy 4A: Nature conservation designations:** The Plan will support development(s) and/or activities where due regard is given to the importance of international, national and locally designated nature conservation sites. **General Policy 4B: Protected species:** The Plan will not support development(s) and/or activities that would be likely to have an adverse

features are qualifying or protected features of designated sites, activities must be managed accordingly under the relevant legislation.		the reasons for the development clearly outweigh the value of the feature. **Policy MSP HER8: Safeguarding Marine Geodiversity** Development will only be permitted where appropriate measures are taken to protect and/or enhance important marine geological and geomorphological resources and sites.	Marine Region are improved to identify opportunities for their enhancement, to inform sustainable development, and to identify climate change adaptation options. **Objective NH 4** The experience and knowledge of local people and visitors about the coastal and marine environment is enhanced through improved awareness of the natural heritage of the Clyde Marine Region.	effect on a European Protected Species unless certain conditions are met. **General Policy 4C: Wider biodiversity:** The Plan will not support development(s) and/or activities that result in a significant impact on the national status of Priority Marine Features. **General Policy 4E: Geodiversity:** Development and/or activities will only be supported by this Plan where they: • do not have a significant adverse effect on geodiversity interests of international, national and regional/local importance • provide mitigation to minimise any adverse effects on such features
GEN 10 Invasive non-native species: Opportunities to reduce the introduction of invasive non-native species to a minimum or proactively improve the practice of existing activity should be taken when decisions are being made		**Policy MSP INNS1: Reducing the Spread of Invasive Non-Native Species** Applications for marine-related developments should demonstrate that the potential risks of spreading INNS have been adequately considered in their proposal, particularly when moving equipment, boats or livestock (e.g. fish and shellfish) from one water body to another or introducing structures suitable for settlement of INNS. Development proposals in areas where INNS are known to exist must include mitigation measures or a contingency plan approved by the local authority that seeks to minimise the risk of spreading the INNS or identifies ways to eradicate the organisms and set up a scheme to prevent reintroduction.	**Objective NNS 1** The risk of introduction and spread of non-native species is reduced in the Clyde Marine Region through improved management of the main pathways. The impacts of non-native species on both the ecosystem and the economy are minimised.	**General Policy 9: Invasive non-native species:** All developers and users of the marine environment should take into account the risk of introducing and spreading non-native species and put in place biosecurity and management measures to minimise this risk.
GEN 12 Water quality and resource: Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive, Marine Strategy Framework Directive or other related Directives apply.		**Policy MSP WAT1: Water Ecology** Development shall not cause any water body to deteriorate in ecological status nor prevent the achievement of established objectives set out in the Scotland River Basin Management Plan and Orkney and Shetland Area Management Plan. Development adjacent to a water body must be accompanied by sufficient information to enable a full assessment of the likely effects including cumulative effects. **Policy MSP WAT2: Improving Water Quality and Ecology** Where possible, development will contribute towards objectives to improve the ecological status of coastal water bodies and the environmental status of marine waters.		**General Policy 5A: Water environment** The Plan will support development(s) and/or activities in the marine environment when the proposal: • does not cause any water body to deteriorate in status nor prevent the achievement of established objectives set out in the River Basin Management Plan for the Scotland river basin district • contributes, where possible, towards objectives to improve the ecological status of coastal water bodies and the environmental status of marine waters • does not cause deterioration in the standard of waters designated under European Commission Directives and national legislation

GEN 14 Air quality: Development and use of the marine environment should not result in the deterioration of air quality and should not breach any statutory air quality limits.				
GEN 15 Planning alignment A: Marine and terrestrial plans should align to support marine and land-based components required by development and seek to facilitate appropriate access to the shore and sea.	Regional marine plans are required to be compatible with the plans for any adjoining marine region.			
GEN 16 Planning alignment B: Marine plans should align and comply where possible with other statutory plans and should consider objectives and policies of relevant non-statutory plans where appropriate to do so.	Regional marine plans should consider relevant non statutory plans or strategies to allow for integration of policies of local relevance to be included for consultation. Examples include, but are not restricted to, shoreline management plans and integrated coastal zone management plans.			
GEN 17 Fairness: All marine interests will be treated with fairness and in a transparent manner when decisions are being made in the marine environment.	The concept of the marine environment and its resources being managed for current and future generations and for the benefit of the nation as a whole is integral to marine planning. The marine planning system therefore operates in the long-term public interest. Marine planning has a role to play balancing competing demands for marine resources and resolution of planning issues will not be able to satisfy all interests all of the time. However, it is fundamental that all interests should be able to participate on an equal basis in the planning and decision-making process and that decisions should be taken in a transparent manner.			
GEN 19 Sound evidence: Decision making in the marine environment will be based on sound scientific and socio–economic evidence.				
GEN 21 Cumulative impacts: Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation.	Cumulative impact on a resource and ecosystem service may occur because of a series of developments or activities of the same type or from the combined effects of a mix of different types of activities.			
Fisheries				
FISHERIES 1: Taking account of the EU's Common Fisheries Policy, Habitats Directive, Birds Directive and Marine Strategy Framework Directive, marine planners and decision makers should aim to ensure: • **An ecosystem-based approach to the management of fishing which ensures sustainable and resilient fish stocks and avoids damage to fragile habitats.** • **Protection for vulnerable stocks (in particular for**	Regional marine plans should consider: • Whether they require to undertake further work on any data gaps in relation to fishing activity within their region. • The potential socio-economic impacts for the local fishing industry (and parts of the industry using their area) of any proposed activity or conservation measure. • How to include local Inshore Fisheries Groups as a key part of their planning process. • The potential consequences and impacts for other marine regions, and for	**Policy MSP FISH1: Safeguarding Fishing Opportunities** Developments will only be permitted where it can be demonstrated that: a) there will be no significant damage or permanent obstruction to an important fishing area. b) there will be no damage to a known/designated spawning or nursery area for commercially exploited species of fish. c) it will not cause an unsafe navigational hazard for commercial fishermen; or d) there is no reasonable alternative and any such adverse effects are clearly outweighed by social, environmental or economic benefits of national importance.	**Objective FISH 1** The long-term objective is a sustainable, diverse and resilient marine ecosystem which supports a wide range of sustainable fishing opportunities supplying both local and other markets. Sustainable fisheries operating at or below Maximum Sustainable Yield ensures optimisation of the socio-economic contribution of the fishing industry and supply chain.	**Sectoral Policy 1: Commercial fisheries** Taking account of the relevant EU policies and Directives marine planners and decision makers should aim to ensure: • an ecosystem-based approach to the management of fishing which ensures the sustainability of fish stocks and avoids damage to fragile habitats has been implemented • consideration has been given to protection for vulnerable commercial stocks (in particular for juvenile and spawning stocks through continuation of sea area closures, where appropriate) • other sectors take into account the need to protect fish stocks and sustain healthy

juvenile and spawning stocks through continuation of sea area closures where appropriate). • **Improved protection of the seabed and historical and archaeological remains requiring protection through effective identification of high-risk areas and management measures to mitigate the impacts of fishing, where appropriate.** • **That other sectors take into account the need to protect fish stocks and sustain healthy fisheries for both economic and conservation reasons.** • **Mechanisms for managing conflicts between fishermen and/or between the fishing sector and other users of the marine environment.**	offshore regions of their approach to planning for fisheries. • Taking account of ongoing local initiatives, such as Clyde 2020, which may be relevant to their work.		**Objective FISH 2** Improve spatial data on areas of importance to fisheries activities and ensure that interactions with other marine users are well managed.	fisheries for both economic and conservation reasons • the cultural and economic importance of fishing, in particular to vulnerable coastal and island communities • the environmental impact on fishing grounds (such as nursery, spawning areas), commercially fished species, habitats and species more generally • the potential effect of displacement on: fish stocks; the wider environment; use of fuel; socio-economic costs to fishers and their communities and other marine users
Aquaculture				
AQUACULTURE 2: Marine and terrestrial development plans should jointly identify areas which are potentially suitable and sensitive areas which are unlikely to be appropriate for such development, reflecting Scottish Planning Policy and any Scottish Government guidance. There is a continuing presumption against further marine finfish farm developments on the north and east coasts to safeguard migratory fish species.	Regional marine plans should consider the potential for sustainable growth of aquaculture in their region, taking into account the policies set out above, and working in close partnership with terrestrial planners, SEPA, Marine Scotland, SNH and other regulators.	**Policy MSP AQ3: Aquaculture Development Management Plans** Area wide aquaculture development management plan proposals will be supported and encouraged where they aim to: c) reduce overall environmental impacts and/ or reduce potential impact on protected species or habitats. e) produce community benefits i.e. reduced visual impact, noise or impact on recreation/ access; and f) increase socio-economic benefit i.e. from job creation or increased economic viability. Subsequent developments which reverse the gains made by a management plan may not be permitted. **Policy MSP AQ4: Seaweed Cultivation** Applications for the development of seaweed cultivation will be considered favourably where the following is demonstrated: b) only seaweed species native to Shetland will be grown.	**Objective AQUA 1** Enable the sustainable development and diversification of the aquaculture sector within the carrying capacity of the Clyde Marine Region, providing socio-economic benefits to rural areas and islands and supporting the wider supply chain in Scotland. **Objective AQUA 2** Aquaculture sites in the Clyde Marine Region contribute to research & development initiatives which support sustainable development of the sector and aim to contribute to the	
AQUACULTURE 4: There is a presumption that further sustainable expansion of shellfish farms should be located in designated shellfish waters if these have sufficient capacity to support such development.				

AQUACULTURE 8: Guidance on harassment at designated seal haul out sites should be taken into account and seal conservation areas should also be taken into account in site selection and operation. Seal licences will only be granted where other management options are precluded or have proven unsuccessful in deterrence.		d) there is no artificial enrichment of the marine environment to aid production.	protection and enhancement of the marine environment.	
Wild Salmon and Diadromous Fish				
WILD FISH 1: The impact of development and use of the marine environment on diadromous fish species should be considered in marine planning and decision making processes. Where evidence of impacts on salmon and other diadromous species is inconclusive, mitigation should be adopted where possible and information on impacts on diadromous species from monitoring of developments should be used to inform subsequent marine decision making.				
Oil and Gas				
OIL & GAS 1: The Scottish Government will work with DECC, the new Oil and Gas Authority and the industry to maximise and prolong oil and gas exploration and production whilst ensuring that the level of environmental risks associated with these activities are regulated. Consideration will be given to key environmental risks including the impacts of noise, oil and chemical contamination and habitat change.	Regional marine plans should consider: The positive and negative impacts of any oil and gas activity in their area and the implications for other development and use. The implications of the transition to a low carbon economy for their area including the longer-term reduction of oil and gas activity, but also incorporating opportunities to re-use existing infrastructure and promote skills transfer to support emerging industries such as renewables and CCS.	**Policy MSP OAG1: Oil and Gas Proposals** Exploration and extraction for oil and gas within 12-nautical miles of the coast will only be permitted where it has: d) included an appropriate monitoring programme and detailed restoration and maintenance proposals.		**Sectoral Policy 3: Oil and gas** Exploration and production of oil and gas will be supported by this Plan, working with DECC, the Oil and Gas Authority and Competent Authority when: • connections to shore base and associated infrastructure take into account environmental and socio-economic constraints • appropriate monitoring programmes and detailed restoration and maintenance proposals based on standard best practice are in place • re-use of oil and gas infrastructure is considered and, where not practicable, decommissioning takes place in line with standard practice, and as allowed by international obligations
Offshore Wind and Marine Renewable Energy				
RENEWABLES 1: Proposals for commercial scale offshore wind and marine renewable energy development should be sited in the Plan Option areas identified through the Sectoral Marine Plan process.	Regional marine plans should consider: Further assessing Plan Options areas against local/updated data knowledge to identify development potential, interactions and compatibility.	**Policy MSP NRG1: Exploratory, Appraisal or Prototype Renewable Energy Proposals** Exploratory, appraisal or prototype energy proposals will be considered favourably where they have:	**Objective ENCA 1** The Clyde Marine Region enables the reduction in reliance on fossil fuels and the increased use of marine	**Sectoral Policy 4: Renewable energy generation** All proposals for offshore wind and marine renewable energy development are subject to licensing and consenting processes. The Plan will support proposals when:

Plan Options are considered the preferred strategic locations for the sustainable development of offshore wind and marine renewables. This preference should be taken into account by marine planners and decision makers if alternative development or use of these areas is being considered. Proposals are subject to licensing and consenting processes. **RENEWABLES 2:** Sites with agreements for lease for wave and tidal energy development in the Pentland Firth Strategic Area must be taken into account by marine planners and decision makers if alternative use of these areas, or use which would affect access to these areas, is being considered. Proposals are subject to licensing and consenting processes. Regional Locational Guidance and the Pentland Firth and Orkney Waters Marine Spatial Plans should also be taken into account when reaching decisions.	Co-ordinating and developing a better understanding of the interactions between the sector and the environment and other users. Ensuring better alignment between marine and terrestrial planning. Links to relevant terrestrial plans. Grid requirements and onshore infrastructures for grid. Links to strategic grid initiatives and engagement with these, e.g. the North Sea Countries Offshore Grid Initiative could also be supported by regional marine planning. Co-ordinating with the Crown Estate on leasing rounds.	c) included an appropriate monitoring programme and detailed restoration proposals. **Policy MSP NRG2: Renewable Energy Development Proposals** Renewable energy developments will be considered favourably where they have: c) demonstrated that the development will not cause significant harm to the safety or amenity of any sensitive receptors. d) demonstrated an appropriate monitoring programme specific to the design, scale and type. **Policy MSP NRG3: Wave and Tidal Development Proposals** Prior to submitting an application, developers should consult the Regional Locational Guidance for Wave and Tidal Energy in the Shetland Islands (RLG) which identifies potential constraints to development. Applications for the development of wave and tidal devices will be considered favourably where: c) in areas of medium-very high constraint, the development has incorporated design and operational measures which avoid potential adverse effects on Natura 2000 sites, and other important (natural and historic) sites, features and other sea users.	wind, wave and tidal renewable energy sources in line with national Sectoral Marine Plans.	• due regard has been paid to relevant factors in Regional Locational Guidance • any adverse impacts are satisfactorily mitigated
Recreation and Tourism				
REC & TOURISM 1: Opportunities to promote sustainable development of marine recreation and tourism should be supported. **REC & TOURISM 2:** The following key factors should be taken into account when deciding on uses of the marine environment and the potential impact on recreation and tourism: • **The extent to which any proposal interferes with access to and along the shore, to the water, use of the resource for recreation or tourism purposes and existing navigational routes or navigational safety.** **REC & TOURISM 3:** Regional marine plans should identify areas that are of recreational and tourism value and identify where prospects for significant development exist, including opportunities to link to the National Long Distance Walking and	Regional marine plans should consider: Identifying thematic links to other regions and acknowledging the different methods of travel across Scotland, e.g. Great Glen route. Identifying important areas for protection, provisions and improvements to access and facilities to support the sector. Promoting/ensuring better engagement between sectors and other marine users, e.g. Inshore Fisheries Groups and sea anglers. Aligning with Tourism Development Areas within Local Development Plans and promote marine based development strategies. Promoting education and the use of codes of conduct and good practice guidance, including signage. Supporting sustainable tourism including sustainable transport and green tourism.	**Policy MSP REC1: Safeguarding Marine Recreation** Developments that are likely to result in the reduction or loss of a marine recreational amenity will only be considered where it can be demonstrated that the proposal is necessary in order to deliver social, economic or environmental benefits that outweigh the reduction or loss. Developments should ensure that continued access rights to the marine and coastal resource for recreational use is maintained where reasonable and practical. **Policy MSP TR1: Tourism and Leisure Developments** Proposals for marine-related tourism and leisure development that promote employment opportunities, community benefits and rural diversification in a sustainable manner will be considered favourably where they comply with all policies included in Policy Framework Section 5(a) and 5(b) and Policy MSP DEV1.	**Objective SRT 1** The Clyde Marine Region provides world class sustainable sport, recreation and tourism experiences for local people and visitors. The social benefits, including health and wellbeing, and the economic benefits generated by this sector are protected and spread across residents, local communities and beyond. **Objective SRT 2** Ingress to and egress from the sea is improved, along with supporting infrastructure and facilities. **Objective SRT3**	**Sectoral Policy 5: Recreation, sport, leisure and tourism** The Plan will support the sustainable development of marine recreation, sport, leisure and tourism. The Plan will support proposals for recreation, sport, leisure and tourism development(s) and/or activities where: • they do not adversely affect the natural and historic environment which is the resource that recreation, sport, leisure and tourism rely upon • codes of best practice and guidance such as those for biosecurity planning, non-native species and Marine Wildlife Watching are complied with

Cycle Routes, and more localised and/or bespoke recreational opportunities and visitor attractions. **REC & TOURISM 5:** Marine planners and decision makers should support enhancement to the aesthetic qualities, coastal character and wildlife experience of Scotland's marine and coastal areas, to the mutual benefit of the natural environment, human quality of life and the recreation and tourism sectors. **REC & TOURISM 6:** Codes of practice for invasive non-native species and Marine Wildlife Watching should be complied with.			The increasing use of the Clyde Marine Region for sport, recreation and tourism does not have a significant adverse effect on the natural and historic/cultural environment on which it depends, nor does it reduce local socioeconomic wellbeing. Sustainable and responsible use of the area improves people's knowledge and enjoyment of the natural environment, their sense of place and their health & wellbeing.	
Submarine Cables				
CABLES 1: When making proposals, cable and network owners and marine users should evidence that they have taken a joined-up approach to development and activity to minimise impacts, where possible, on the marine historic and natural environment, the assets, infrastructures and other users. Appropriate and proportionate environmental consideration and risk assessments should be provided which may include cable protection measures and mitigation plans.			**Objective ENCA 2** The laying, replacement and maintenance of important subsea cables and pipelines is undertaken with due consideration of all marine users.	**Sectoral Policy 8: Pipelines, electricity and telecommunications infrastructure** Developers should ensure that they have engaged with other developers and decision makers at an early planning stage and taken a joined-up approach to minimise impacts on the marine historic and natural environment, the assets, infrastructures and other marine users. Appropriate and proportionate environmental consideration and risk assessments should be provided which may include cable protection measures and mitigation plans.
Aggregates				
AGGREGATES 1: Where an interaction between aggregate dredging and other uses is identified, consideration should be given to whether there are permissions for aggregate or mineral extraction and whether they require safeguarding. **AGGREGATES 2: A**ll necessary environmental issues are considered, and safeguards are in place when determining whether marine aggregate dredging is considered to be environmentally acceptable and is in accordance with the other policies and objectives of the Plan.	Regional marine plans should consider if areas of aggregate or mineral resource require any degree of safeguarding.	**Policy MSP EX1: Extraction of Sand, Gravel and Shingle** Proposals for the extraction of sand, gravel or shingle from beaches and dunes and below the Mean High-Water Spring (MHWS), including coastal quarrying, will be considered favourably, where the application meets the criteria set out within this policy.	**Objective AGG 1** Safeguard marine aggregate resources in the Clyde Marine Region and ensure any future exploitation is in line with regulations, in particular regarding potential environmental impact.	**Sectoral Policy 9: Marine Aggregates** Proposals for new marine aggregate extraction sites should ensure they do not compromise existing activities. Decision makers should ensure marine environmental issues are considered and appropriately safeguarded. Any marine development should consider any impacts on existing or potential marine aggregate resources.

Appendix 3: Ecosystem Service Assessments

Ecosystem services classification

Table A3-1: CICES v5.1 Classification

Section	Division	Group	Class	Code	Class type	Source
Intermediate			Nutrient cycling/ Secondary production			Potts et al. 2014
Intermediate			Primary production			Potts et al. 2014
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	1.1.5.1	*Plants, algae by amount, type*	CICES v5.1
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	1.1.5.2	*Plants, algae by amount, type*	CICES v5.1
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	1.1.5.3	*Material by type/source*	CICES v5.1
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used for nutritional purposes	1.1.6.1	*Animals by amount, type*	CICES v5.1
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)	1.1.6.2	*Material by type/source*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population	1.2.1.1	*By species or varieties*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from plants, algae or fungi	Higher and lower plants (whole organisms) used to breed new strains or varieties	1.2.1.2	*By species or varieties*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from plants, algae or fungi	Individual genes extracted from higher and lower plants for the design and construction of new biological entities	1.2.1.3	*Material by type*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population	1.2.2.1	*By species or varieties*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from animals	Wild animals (whole organisms) used to breed new strains or varieties	1.2.2.2	*By species or varieties*	CICES v5.1
Provisioning (Biotic)	Genetic material from all biota	Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities	1.2.2.3	*Material by type*	CICES v5.1
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals	2.1.1.1	*By type of living system or by waste or subsistence type*	CICES v5.1
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Filtration/sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	2.1.1.2	*By type of living system, or by water or substance type*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates	2.2.1.1	*By reduction in risk, area protected*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Buffering and attenuation of mass movement	2.2.1.2	*By reduction in risk, area protected*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	2.2.1.3	*By depth/volumes*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)	2.2.2.1	*By amount and pollinator*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Seed dispersal	2.2.2.2	*By amount and dispersal agent*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (Including gene pool protection)	2.2.2.3	*By amount and source*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Pest control (including invasive species)	2.2.3.1	*By reduction in incidence, risk, area protected by type of living system*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Disease control	2.2.3.2	*By reduction in incidence, risk, area protected by type of living system*	CICES v5.1
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of salt waters by living processes	2.2.5.2	*By type of living system*	CICES v5.1

Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans	2.2.6.1	*By contribution of type of living system to amount, concentration or climatic parameter*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions e.g. Recreational activities, scuba diving.	3.1.1.1	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions e.g. passive, cliff top cafes, walking along	3.1.1.2	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	3.1.2.1	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable education and training e.g. Rockpooling, school visits, fieldtrips	3.1.2.2	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage e.g. oyster festivals, kelp harvesting in Orkney, language associated kelp harvesting.	3.1.2.3	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences e.g. photography, artists.	3.1.2.4	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning e.g. poetry, artworks.	3.2.1.1	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have sacred or religious meaning	3.2.1.2	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation	3.2.1.3	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value	3.2.2.1	*By type of living system or environmental setting*	CICES v5.1
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an option or bequest value	3.2.2.2	*By type of living system or environmental setting*	CICES v5.1

Ecosystem service provision and confidence

Table A3-2: Summary of ecosystem service provision scores by habitat together with confidence in the evidence base supporting the relationships.

Ecosystem service		Burrowed mud	Flame shell beds	Horse mussel beds	Maerl	Kelp	Seagrass	Seaweeds	Circalittoral mud	Brittlestar beds	A3.1 High energy infralittoral rock	A3.2 Moderate energy infralittoral rock	A3.3 Low energy infralittoral rock	A4.1 High energy circalittoral rock	A4.2 Moderate energy circalittoral rock	A4.3 Low energy circalittoral rock	A5.1 Sublittoral coarse sediment	A5.2 Sublittoral sand	A5.3 Sublittoral mud	A5.4 Sublittoral mixed	A5.5 Sublittoral macrophyte dominated	A3.2/A4.2 Moderate energy infralittoral/circalittoral rock
Inter-mediate	Nutrient cycling/ Secondary production	3	1	3	3	3	2	3	3	2	3	3	3	3	3	3	1	1	3	2	1	2
	Primary production	1	1	2	3	3	2	3	1	1	3	3	3	1	1	1	1	1	2	1	1	2
Provisioning	Wild plants used for nutrition	3	3	3	1	3	3	3	1	1	3	3	3	3	3	3	3	3	3	3	1	2
	Fibres and other materials from wild plants for direct use or processing	3	3	3	1	3	1	3	1	1	3	3	3	3	3	3	3	3	3	3	1	2
	Wild plants used as a source of energy	3	3	3	3	3	1	3	1	1	3	3	3	3	3	3	3	3	3	3	1	2
	Wild animals used for nutritional purposes	2	1	3	3	3	3	3	3	2	3	3	3	2	2	2	3	3	3	3	1	2
	Fibres and other materials from wild animals for direct use or processing		1	3														3	1	1		
	Seeds etc. collected for maintaining or establishing a population	3	3	2		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	2
	Higher and lower plants used to breed new strains or varieties	3	3	2		3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	1	2
	Individual genes extracted from plants for new biological entities	3	3	2			1	1	3	3	1		1	3	3	3	3	3	3	3		
	Animal material collected to maintain or establish a population			1																		
	Individual genes extracted for constructing new biological entities																					
Regulating	Bio-remediation by micro-organisms, algae, plants, and animals	1	1	3		3	2	3	1	3	3	3	3	1	1	1	1	1	1	1	1	2
	Filtration/sequestration/storage/accumulation by living organisms	2	1	3		3	2	3	2	1	3	3	3	1	1	1	1	1	2	1	1	2
	Control of erosion rates	3	2	3	1	2	1	2	3	2	3	3	3	3	3	3	2	2	3	2	1	3
	Buffering and attenuation of mass movement										3	3	3	3	3	3	1	1	1	1	1	3
	Hydrological cycle and water flow regulation (flood control, coastal protection)	V	1	3	1	3	2	2		1	2	3	2	V	V	V	V	V	V	V	V	2
	Pollination ('gamete' dispersal in a marine context)	2	1	3	3				2	1		2		2	2	2	2	2	2	2		2
	Seed dispersal	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
	Maintaining nursery populations and habitats (Including gene pool protection)	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	2	3	3	1	2
	Pest control (including invasive species)	1			1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Disease control				1					1												
	Regulation of chemical composition of atmosphere and oceans	3	1	3	3	3	2	3	3	2	3	3	3	1	1	1	1	1	3	2	1	2
Cultural	Active or immersive interactions e.g. Recreational activities, scuba diving.		1	1		2	1	2			2	2	2	1	1	1	1	1	1	1	1	1
	Scientific investigation or the creation of traditional ecological knowledge	2		1	3	2		2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
	Education and training e.g. rockpooling, school visits, fieldtrips	2	1	1		2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
	Culture or heritage e.g. oyster festivals, kelp harvesting and associated language		1	1		3	1	3				3									1	
	Aesthetic experiences e.g. photography, artists	2	1	1	1	1	1	1	2	2	1	1	1								1	

Scale for ecosystem service provision	
Significant contribution	#
Moderate contribution	#
Low contribution	#
None/negligible contribution	#
Not assessed/no evidence from REA	

Scale for confidence in evidence base	
High	3
Medium	2
Low	1
Variable	V
Not assessed/no evidence from REA	

Weighted ecosystem service potential by habitat

Table A3-3: Ecosystem service provided or supported by each habitat as a % of total provision of that service

	Ecosystem service	Flame shell beds	Maerl	Kelp and seaweed	Circalittoral mud	A3.1 High energy infralittoral rock	A3.2 Moderate energy infralittoral rock	A3.3 Low energy infralittoral rock	A4.1 High energy circalittoral rock	A4.2 Moderate energy circalittoral rock	A4.3 Low energy circalittoral rock	A5.1 Sublittoral coarse sediment	A5.2 Sublittoral sand	A5.3 Sublittoral mud	A5.4 Sublittoral mixed	A5.5 Sublittoral macrophyte dominated	A3.2/A4.2 Moderate energy infralittoral/circalittoral rock
Intermediate	Nutrient cycling/ Secondary production	0.1	0	0	1	7	7	2	8	11	2	39	18	1	2	0	2
	Primary production	0.0	0	0	0	9	9	3	0	0	0	51	24	1	1	0	2
Provisioning	Wild plants used for nutrition	0	0	0	0	0	77	0	0	0	0	0	0	0	0	1	22
	Fibres and other materials from wild plants for direct use or processing	0	0	0	0	38	38	13	0	0	0	0	0	0	0	1	11
	Wild plants used as a source of energy	0	0	0	0	38	38	13	0	0	0	0	0	0	0	1	11
	Wild animals used for nutritional purposes	0	0	0	1	4	4	1	7	6	1	43	30	1	2	0	1
	Fibres and other materials from wild animals for direct use or processing	0	0	0	0	0	0	0	0	0	0	0	98	0	2	0	0
	Seeds etc. collected for maintaining or establishing a population	0	0	0	0	38	38	13	0	0	0	0	0	0	0	1	11
	Higher and lower plants used to breed new strains or varieties	0	0	0	0	38	38	13	0	0	0	0	0	0	0	1	11
	Individual genes extracted from plants for new biological entities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Animal material collected to maintain or establish a population	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wild animals used to breed new strains or varieties	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Individual genes extracted for constructing new biological entities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Regulating	Bio-remediation by micro-organisms, algae, plants, and animals	0	0	0	1	5	5	2	5	6	1	47	22	1	3	0	2
	Filtration/sequestration/storage/accumulation by living organisms	0	0	0	0	5	5	2	5	6	1	48	22	1	3	0	2
	Control of erosion rates	0	0	0	0	4	4	1	7	10	2	48	22	0	1	0	1
	Buffering and attenuation of mass movement	0	0	0	0	6	6	2	11	15	2	37	17	1	1	0	2
	Hydrological cycle and water flow regulation (flood control, coastal protection)	0	0	0	0	5	5	2	5	7	1	48	22	1	1	0	2
	Pollination ('gamete' dispersal in a marine context)	0	0	0	1	0	3	0	6	7	1	54	25	1	1	0	1
	Seed dispersal	0	0	0	0	0	84	0	0	0	0	0	0	0	0	0	16
	Maintaining nursery populations and habitats (Including gene pool protection)	0	0	0	1	5	5	2	8	7	2	55	13	1	2	0	1
	Pest control (including invasive species)	0	0	0	1	5	5	2	9	11	2	42	19	1	2	0	1
	Disease control	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Regulation of chemical composition of atmosphere and oceans	0	0	0	1	8	8	3	5	6	1	45	21	1	1	0	1
Cultural	Active or immersive interactions e.g. Recreational activities, scuba diving.	0	0	0	0	14	14	5	25	33	5	0	0	0	0	0	4
	Passive or observational interactions e.g. cliff top cafes, walking along coastal paths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scientific investigation or the creation of traditional ecological knowledge	0	0	0	1	3	3	1	5	7	1	52	24	1	1	0	1
	Education and training e.g. rockpooling, school visits, field trips	0	0	0	1	3	3	1	5	7	1	52	24	1	1	0	1
	Culture or heritage e.g. oyster festivals, kelp harvesting and associated language	0	0	0	0	0	98	0	0	0	0	0	0	0	0	2	0
	Aesthetic experiences e.g. photography, artists	0	1	0	4	40	40	14	0	0	0	0	0	0	0	1	0

Table A3-4. Sensitivity of ecosystem services provided by PMFs to organic enrichment from finfish farms.

Ecosystem service	Burrowed mud	Flame shell beds	Horse mussel beds	Maerl	Kelp	Seagrass	Tide swept algal	Circalittoral mud	Brittlestar beds
Nutrient cycling/ Secondary production	2	NR	1	3	2	2	3	2	2
Primary production	NR	NR	1	3	2	2	3	NR	NR
Wild plants used for nutrition	NR	NR	NR	NR	2	NR	NR	NR	NR
Fibres and other materials from wild plants for direct use or processing	NR	NR	NR	3	2	NR	3	NR	NR
Wild plants used as a source of energy	NR	NR	NR	NR	2	NR	3	NR	NR
Wild animals used for nutritional purposes	2	NR	1	3	2	2	3	NR	NR
Fibres and other materials from wild animals for direct use or processing	NR	NR	1	NR	NR	NR	NR	NR	NR
Seeds etc. collected for maintaining or establishing a population	NR	NR	NR	NR	2	2	3	NR	NR
Higher and lower plants used to breed new strains or varieties	NR	NR	NR	NR	2	NR	3	NR	NR
Individual genes extracted from plants for new biological entities	NR	NR	NR	NR	NR	NR	NR	NR	NR
Individual genes extracted from plants for new biological entities	NR	NR	NR	NR	NR	NR	NR	NR	NR
Animal material collected to maintain or establish a population	NR	NR	1	NR	NR	NR	NR	NR	NR
Wild animals used to breed new strains or varieties	NR	NR	NR	NR	NR	NR	NR	NR	NR
Individual genes extracted for constructing new biological entities	NR	NR	NR	NR	NR	NR	NR	NR	NR
Bio-remediation by micro-organisms, algae, plants, and animals	1	NR	1	NR	2	2	3	2	2
Filtration/sequestration/storage/accumulation by living organisms	1	NR	1	NR	2	2	3	1	2
Control of erosion rates	NR	NR	1	NR	2	1	2	NR	2
Buffering and attenuation of mass movement	NR	NR	NR	NR	NR	NR	NR	NR	NR
Hydrological cycle and water flow regulation (flood control, coastal protection)	1	NR	NR	NR	2	2	2	NR	NR
Pollination ('gamete' dispersal in a marine context)	2	NR	1	3	NR	NR	NR	2	NR
Seed dispersal	NR	NR	NR	NR	NR	1	NR	NR	NR
Maintaining nursery populations and habitats (Including gene pool protection)	2	NR	1	3	2	2	2	2	NR
Pest control (including invasive species)	2	NR	NR	1	1	2	2	1	1
Disease control	NR	NR	NR	NR	NR	NR	NR	NR	1
Regulation of chemical composition of atmosphere and oceans	2	NR	1	3	2	2	2	2	NR
Active or immersive interactions e.g. Recreational activities, scuba diving.	NR	NR	1	NR	1	1	2	NR	NR
Passive or observational interactions e.g. cliff top cafes, walking along coastal paths	NR	NR	NR	NR	NR	NR	NR	NR	NR
Scientific investigation or the creation of traditional ecological knowledge	2	NR	1	3	2	NR	2	2	2
Education and training e.g. rockpooling, school visits, fieldtrips	2	NR	NR	NR	2	1	2	2	2
Culture or heritage e.g. oyster festivals, kelp harvesting and associated language	NR	NR	NR	NR	2	NR	2	NR	NR
Aesthetic experiences e.g. photography, artists	2	NR	NR	1	1	NR	1	2	NR
Elements of living systems that have symbolic meaning e.g. poetry, artworks	NR	NR	NR	NR	NR	NR	NR	NR	NR
Elements of living systems that have sacred or religious meaning	NR	NR	NR	NR	NR	NR	NR	NR	NR
Elements of living systems used for entertainment or representation	NR	NR	NR	NR	NR	NR	NR	NR	NR
Characteristics or features of living systems that have an existence value	NR	NR	NR	NR	NR	NR	NR	NR	NR
Characteristics or features of living systems that have an option or bequest value	NR	NR	NR	NR	NR	NR	NR	NR	NR

Scale for ecosystem service sensitivity	
High	#
Medium	#
Low	#
Not sensitive	#
Not assessed/no evidence from REA to support ES provision	

Scale for confidence in evidence base	
High	**3**
Medium	**2**
Low	**1**
Variable	**V**
Not relevant as not assessed	**NR**

Extent of physical damage based on vessels >12m: Output tables

Table A3-5: Proportion (%) of each habitat type in the Orkney mainland for each disturbance category.

Habitat	Disturbance category										Total % area low	Total % High
EUNIS	0	1	2	3	4	5	6	7	8	9		
A3.1	64			9	28		<1				37	<1
A3.2	46		2	21	30		<1		<1		51	<2
A3.3	56			<1	43		<1				44	<1
A4.1	19						79	<1	1	<1%		82
A4.2	7			7	<1		78	1	6	1	8	86
A4.3	8			63	19	6	4	<1			82	11
A5.1	6			5	58		13	6	12	1	63	32
A5.2	2			36	18	7	24	24			54	48
A5.3	42			49	8		<1				99	1
A5.4	21			21	47		11	<1			89	12
A5.5	100										100	

Table A3-6: Proportion (%) of each habitat type in the Western Isles for each disturbance category.

Habitat	Disturbance category										Total % area low	Total % High
EUNIS	0	1	2	3	4	5	6	7	8	9		
A3.1					100		<1				100	<1
A4.1							89		11	<1		100
A4.2						1	76	4	12	7		100
A4.3							3	97				100
A5.1	1				50		6	4	23	16	50	49
A5.2	1			29	11	9	43	8			40	60
A3.2/A4.2	12			<1	7		68	2	6	6	8	82

Table A3-7: PMF data points in each class of surface abrasion pressure, see Table 4-7 for pressure category

PMF	0	1	2
Burrowed mud	1	3	
Flame shell beds	6	9	
Horse mussel beds	7	42	6
Kelp and seaweed communities on sublittoral sediment	70	72	
Kelp beds	130	149	3
Maerl beds	114	49	
Seagrass beds	36	6	
Tide-swept algal communities	11	7	
Tide-swept algal communities and Kelp beds	44	40	

Table A3-8: PMF area (hectares) affected by abrasion (rounded to hectares) see Table 4-7 for pressure category

PMF	0	1	2	3	4
Circalittoral mud	2,070	3,551	59	0	27
Flameshell beds	234	274	0	0	0
Kelp and seaweed communities on sublittoral sediment	319	149	0	0	0
Maerl beds	402	135	0	0	0
Saltmarsh	55	3	0	0	0

Table A3-9: No of vessels fishing with all types of gears over each habitat type shown as proportion (%) of each habitat type.

	Number of vessels							
Habitat	**0**	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**
A3.1	<1	3	47	43	5	3	<1	<1
A3.2	<1	1	4<1	21	17	13	6	1
A3.3	1	2	17	31	20	6	10	14
A4.1		7	59	30	4			
A4.12		<1	83	17	<1			
A4.2	<1	23	54	16	5	<1	<1	
A4.27	13	71	12	5	<1	<1	<1	
A4.3	5	16	51	22	6	<1	1	<1
A4.33	40	58	<1	<1	1	<1	<1	<1
A5	3	6	54	18	11	5	2	1
A5.13	<1	6	<1	30	18	5	<1	
A5.14		24	54	17	5		<1	
A5.15	15	59	23	3	<1			
A5.23 or A5.24	5	17	53	13	<1	12		
A5.25 or A5.26		4	69	19	5	4		
A5.27	17	41	41	1	<1			
A5.33		17	55	28	<1			
A5.35			33	46	21			
A5.37	17		18	62	3			
A5.43	<1	1	21	34	42			
A5.44			50	29	21			
A5.45	24		66	9	1			

Table A3-10: No of vessels fishing with pots over each habitat type shown as proportion (%) of each habitat type. Categories with >20% of fishing vessels for that habitat are highlighted in orange.

	Number of vessels							
Habitat	**0**	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-25**
A3.1	0.1	9.37	57.74	27.85	2.73	2.14	0.03	
A3.2	0.1	1.93	47.64	16.66	13.62	12.61	6.26	1.14
A3.3	0.9	1.66	23.33	26.95	17.72	5.59	9.92	13.94
A4.1	1.1	33	37	25	4			
A4.12		0.55	83	16				
A4.2	1.5	59.52	26.35	7.98	3.92	0.28	0.43	
A4.27	13.6	82.54	4	0.07	0.01	0.07		
A4.3	4.5	15.88	56.67	18.44	3.47	0.26	0.61	0.17
A4.33	40.5	58.15	0.18	0.74		0.08	0.29	0.07
A5	4.0	8.83	55.84	14.03	8.86	5.19	2.43	0.78
A5.13	0.2	7.35	48.29	29.99	11.63	2.28	0.29	
A5.14	2.6	50.41	36.53	8.48	1.91		0.08	
A5.15	30.2	63.64	5.81	0.37	0.00			
A5.23 or A5.24	4.6	17.40	52.99	12.77	12.28			
A5.25 or A5.26	4.4	23.43	59.69	4.17	8.33			
A5.27	41.5	57.39	1.14	0.00	0.01			
A5.33		17.08	68.15	14.77				
A5.35			63.94	25.26	10.80			
A5.37	17.4		79.69	2.89				
A5.43	0.4	1.38	24.84	44.48	28.86			
A5.44			71.69	21.66	6.65		0.00	
A5.45	24.1	0.00	67.16	8.24	0.53		0.00	

Table A3-11: No of vessels fishing with towed dredges over each habitat type shown as proportion (%) of each habitat type. Categories with >20% of fishing vessels for that habitat are highlighted in orange.

	Number of vessels				
Habitat	**0***	**3**	**4**	**5**	**Total %**
A3.1	51.64	48.15	0.18	0.02	100
A3.2	66.33	33.15	0.22	0.30	100
A3.3	98.25	1.75			100
A4.1	58.54	40.17	0.68	0.60	100
A4.12	99.00	1.00			100
A4.2	38.84	57.97	2.68	0.50	100
A4.27	82.44	12.80	4.56	0.20	100
A4.3	94.50	5.50			100
A4.33	99.32	0.44	0.25		100
A5	79.80	19.61	0.39	0.21	100
A5.13	65.08	34.35		0.57	100
A5.14	49.64	45.01	0.88	4.47	100
A5.15	77.05	17.98	3.32	1.65	100
A5.23 or A5.24	70.52	29.48			100
A5.25 or A5.26	45.50	43.03	11.48		100
A5.27	48.93	42.68	7.14	1.25	100
A5.33	100.00				100
A5.35	99.70	0.30			100
A5.37	100.00				100
A5.43	93.16	6.84			100
A5.44	89.43	10.57			100
A5.45	82.69	17.31			100
Na	88.10	11.90			100

Table A3-12: No of vessels fishing with trawls (not Nephrops) over each habitat type shown as proportion (%) of each habitat type. Categories with >20% of fishing vessels for that habitat are highlighted in orange.

Trawls not NEP	Number of vessels		
EUNIS Comb	**0**	**3**	**Total %**
A3.1	96.97	3.03	100
A3.2	97.00	3.00	100
A3.3	99.99	0.01	100
A4.1	96.10	3.90	100
A4.12	99.15	0.85	100
A4.2	89.36	10.64	100
A4.27	91.46	8.54	100
A4.3	100.00		100
A4.33	99.75	0.25	100
A5	96.77	3.23	100
A5.13	90.22	9.78	100
A5.14	91.64	8.36	100
A5.15	81.88	18.12	100
A5.23 or A5.24	100.00		100
A5.25 or A5.26	88.23	11.77	100
A5.27	61.27	38.73	100
A5.33	100.00		100
A5.35	100.00		100
A5.37	100.00		100
A5.43	100.00		100
A5.44	100.00		100
A5.45	100.00		100

Table A3-13: No of vessels fishing with Nephrops trawls over each habitat type shown as proportion (%) of each habitat type. Categories with >20% of fishing vessels for that habitat are highlighted in orange.

Trawls NEP	Number of vessels			
EUNIS Comb	0*	3	4	Total %
A3.1	100.00			100
A3.2	98.87	1.03	0.10	100
A3.3	87.15	9.25	3.60	100
A4.1	100.00			100
A4.12	100.00			100
A4.2	99.66	0.34		100
A4.27	99.99	0.01		100
A4.3	88.70	8.33	2.97	100
A4.33	99.72	0.16	0.12	100
A5	99.16	0.79	0.06	100
A5.13	99.84	0.16		100
A5.14	99.55	0.45		100
A5.15	99.98	0.02		100
A5.23 or A5.24	98.46	1.54		100
A5.25 or A5.26	100.00			100
A5.27	100.00			100
A5.33	78.55	15.49	5.96	100
A5.35	4.42	51.84	43.73	100
A5.37	18.94	56.38	24.69	100
A5.43	72.85	23.37	3.78	100
A5.44	20.78	31.59	47.63	100
A5.45	96.54	0.37	3.09	100

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