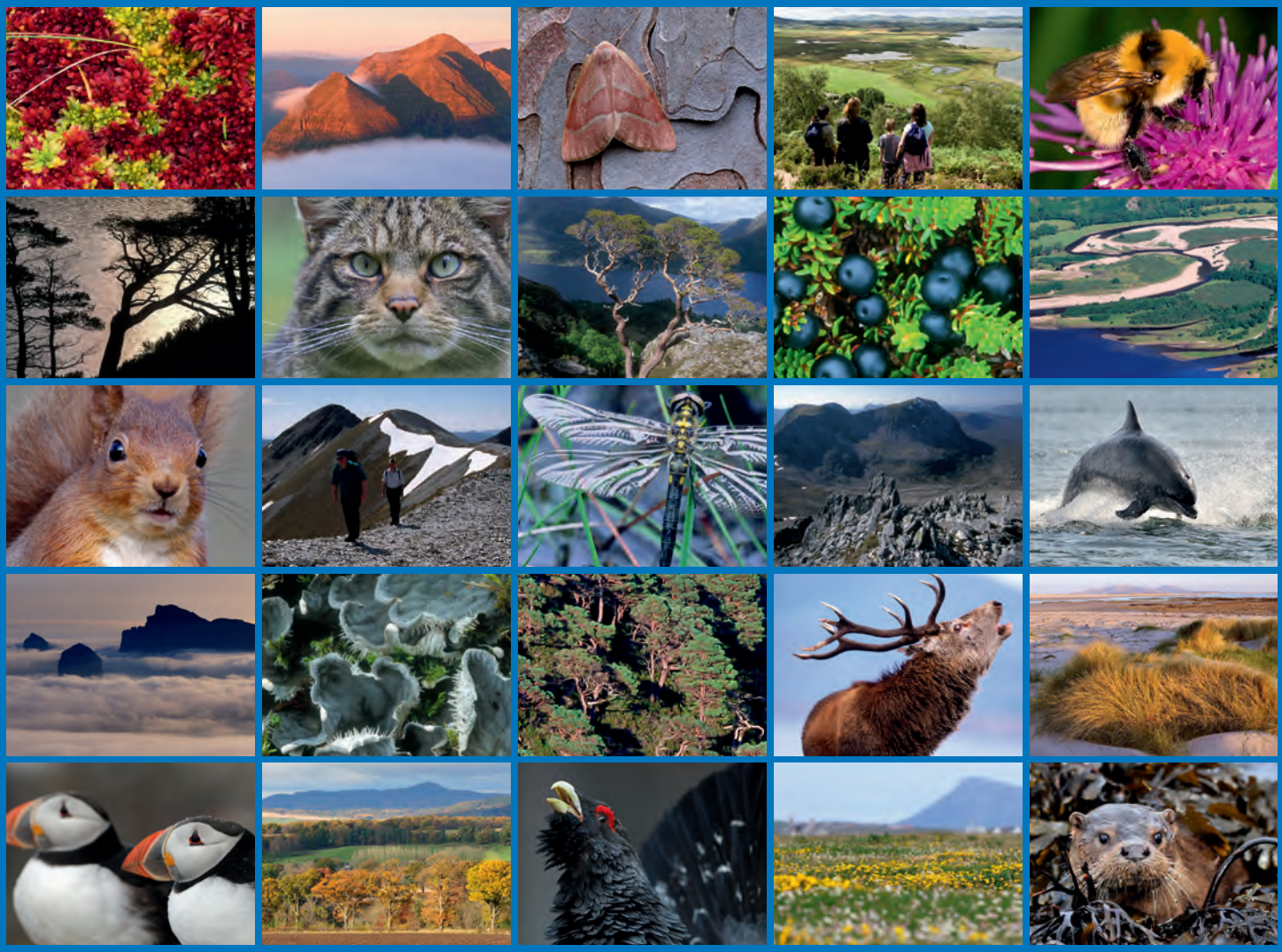
Scottish Natural Heritage
Commissioned Report No. 957

Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network



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COMMISSIONED REPORT

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Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network

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COMMISSIONED REPORT

Summary

Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network

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Keywords

Blue carbon; inorganic carbon; organic carbon; storage; sequestration; stocks.

Background

In this study, the blue carbon resources in each Nature Conservation Marine Protected Area (NC MPA) and Special Area of Conservation (SAC) in Scotland's inshore waters are estimated from the i) contributions of biological material to fixation of carbon, also referred to as production, and ii) contributions of geological sediments to blue carbon storage, following on from shelf-wide estimates in an earlier study (Burrows *et al.*, 2014). The methodology has been developed here to allow local-scale estimation of habitat extent and provides estimates of blue carbon associated with habitats and surface sediments.

Main Findings

- Combined, the SACs and NC MPAs (subsequently referred to as inshore MPAs) considered in this study cover 11 350 km^2. Stocks of carbon within the habitats and surface sediments of inshore MPAs are estimated at 9.4 million tonnes (Mt) organic carbon and 47.8 Mt inorganic carbon; 1.6% of the estimated total of 592 Mt organic carbon (revised Burrows *et al*., (2014) value) and 2.7% of the total 1 739 Mt inorganic carbon across Scotland's seas.
- Blue carbon habitats in the inshore MPA network are estimated to produce 248 000 t organic carbon and 36 000 t inorganic carbon per year, while sediment stores in the inshore MPAs accumulate 126 000 t organic carbon and 348 000 t inorganic carbon per year. Blue carbon production by seabed habitats is estimated to represent 0.6% of the total organic carbon assimilated, or 14% of the total produced by attached plants (including maerl).
- Sediment stores in inshore MPAs sequester 1.8% of total organic carbon across Scotland's seas. The estimate of the total amount of inorganic carbon production in inshore MPAs is less reliable but represents a much larger proportion of the total, than for organic carbon production. This is because of the focus of inshore MPAs on areas of carbonate production such as maerl beds and cold water coral reefs.
- Threats to organic carbon stores are from physical disturbance, moorings, coastal developments, and renewable energy) of the sea bed, causing breakdown of previously buried material. Ocean acidification may pose a threat to inorganic carbon in sediments stored as carbonate but the mechanisms whereby that threat may be realised are as yet

unclear. Ocean acidification also may have a direct negative effect on the capacity of calcareous reef builders and maerl to build carbonate skeletons, but algae such as kelp may benefit through enhanced photosynthesis due to higher CO_2 levels.

- There are limitations in the estimates produced. Much of the information used in this assessment of blue carbon stocks is based on legacy data, some from older, published sources. Spatial extents of blue carbon habitats at the scales required for this report are poorly constrained. Finally, the science of understanding the effects of climate change on these systems is very much in its infancy and new developments will allow a much better informed outlook for the fate of these stocks and flows in a changing world. By establishing a methodology that integrates existing knowledge and understanding of blue carbon it should be possible to update reports such as this as new information emerges.
- This report aims to provide a starting point and a methodology for the examination of blue carbon storage in an MPA network. It is clear throughout the report that there is paucity within the data set. Despite these difficulties, and the uncertainty around accurate values of estimates, the general conclusions are unlikely to change with more detailed information. Therefore, the authors believe that enough information exists to begin to make conclusions about the importance of blue carbon stocks in the marine environment, both within Scotland and globally if the methods used are employed elsewhere. Variable and limited data will be a common feature of MPA networks throughout the world. The methodology proposed allows conclusions to be made on incomplete data, providing the beginnings of a management tool to aid protection of blue carbon in the marine environment.

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Executive Summary for Policymakers

Marine protected areas (MPAs) provide valuable protection to marine habitats and species, and promote sustainable use of marine resources whilst maintaining key ecosystem services. A significant component of the better management of MPA networks involves understanding the services provided by these protected habitats, particularly in relation to the growing awareness and concern over the implications of global climate change. Marine habitats contain large stocks of carbon, accumulated over long timescales through natural processes. This is known as 'blue carbon' (carbon stored in marine ecosystems). Oceans are the largest natural sink for carbon, and sequestration rates (i.e. the process of capture and addition of carbon to the standing stock) of this carbon differs between habitats.

Increasing carbon emissions, which contribute to global climate change, are directly impacting on the natural processes that remove carbon from the atmosphere and store it in the ocean. As atmospheric carbon dioxide (CO_2) continues to increase, the capacity for the ocean to absorb this excess decreases, impacting on the global carbon cycle and, ultimately, marine carbon sequestration. In addition, the rate at which carbon is captured and stored by these natural systems mediates the mitigation of increasing anthropogenic CO_2 emissions. Thus as the ocean absorbs more carbon due to rising CO_2, its ability to take up further extra CO_2 is reduced.

Blue carbon storage and sequestration varies between habitats, and although some of the carbon is stored in biological components, such as plants (kelp forests, seagrass beds, seaweed) or animals (coral structures, including cold-water corals, molluscs), the carbon stored in marine sediments (geological stores; often underlying these biological stores) is sequestered over much longer timescales, and contains considerably larger stocks of carbon. Coastal marine habitats (i.e. those habitats in the area extending from the shore to the continental shelf break) alone are estimated to sequester over 50% of total marine carbon (Borges, 2005).

Present understanding of how blue carbon is captured and stored is currently limited, with the exception of a few relatively well-studied ecosystems, such as mangroves, tidal salt marshes and seagrass beds. In Scotland, even less is known about the blue carbon status of marine habitats, and this report attempts to assess the blue carbon stored within the the habitats and surface sediments of the Scottish inshore MPA network.

One of the difficulties in assessing blue carbon is the lack of clear terminology, and the differences in timescales when discussing carbon sequestration. In this report, 'blue carbon' refers to carbon stored in marine systems, including biological and geological storage, and timescales ranging from short term 'transient' storages (from days, to weeks or seasonal) to 'long term' storage (from over a year to decades, or hundreds or thousands of years in geological storage within sediments and biogenic structures).

The blue carbon estimates provided in this report are based on limited knowledge and understanding of the natural ability of these habitats to capture and sequester carbon. Many challenges need to be addressed in order to more accurately estimate the blue carbon within individual habitats. Despite these difficulties, and uncertainty around accurate values of estimates, the general conclusions are unlikely to change with more detailed information, with the majority of the blue carbon stored in geological habitats in inorganic form, such as in sediments which account for nearly 90% of the total stock of inorganic carbon. The methodology proposed in this report allows conclusions to be made on incomplete data (which is likely to be the case for all global MPA networks), providing the start of a management tool to aid protection of blue carbon in the marine environment.

The most important biological stores of inorganic carbon in Scotland are the maerl beds, with Scotland home to many of the most extensive maerl beds in Europe. Most organic carbon sequestration occurs in seabed sediments through burial / accumulation of biological material (e.g. algal detritus).

The SACs and NC MPAs considered in this study covers over 11 000 km^2, protecting 12% of the area in territorial waters. This inshore MPA network is estimated to hold over 55 million tonnes (Mt) of blue carbon (9.4 Mt of organic carbon and 47.8 Mt of inorganic carbon). This is based on assessing blue carbon within the top 10cm of the seabed sediments and the assumption that maerl beds are 60cm deep. To put this into context, the total blue carbon within the inshore MPA network equates to 210.8 Mt CO_2e (carbon dioxide equivalent) which is equivalent to four years of Scotland's annual greenhouse gas emission estimated at 53 Mt CO_2e (Scottish Government, 2015).

When compared to terrestrial stocks such as Scottish peatlands which hold 1620 Mt carbon (Chapman *et al.,* 2013) and forestry stores (biomass) which hold an estimated 85.15 Mt carbon (Forestry Commission, 2016a) the quantities of carbon held within the habitats and surface sediments of the inshore MPA network are relatively low.

To truly compare these stocks we must take into account the different aerial coverage of each stock; the peatlands cover an area of 17 270 km^2 (Chapman *et al*., 2013) and Scotland's forest occupy an area of 14 360 km^2 (Forestry Commission, 2016b). Therefore a per area unit measure must be used to directly compare the stocks; on this basis the MPA network stores 0.0050 Mt carbon km^{-2} in comparison to 0.094 Mt carbon km^{-2} and 0.0058 Mt carbon km^{-2} for Scottish peatlands and forest carbon stores. When these figures are compared the MPA network on a per unit area basis stores a comparable amount to Scotland's forest but significantly less than the peatlands. However, it must be remembered that the quantities of carbon estimated for each individual MPA is conservative as it only considers the top 10 cm of the sediment and the top 60cm of any mearl bed. When the full volume of sediment in Loch Sunart was considered (Smeaton *et al*., 2016) it demonstrated that the loch stored significantly more carbon on a per unit area basis than Scottish peatlands; it is the belief that if the full volume of sediment in each MPA was considered that they would match or outperform Scottish peatlands on a per area unit basis.

The main threat to organic carbon stores is physical disturbance, for example from demersal fishing activities, deployment of moorings and installation of renewable energy platforms. Climate change, specifically ocean acidification, is likely to have mixed effects on blue carbon capture and storage, negatively impacting on calcareous organisms (that build carbonate skeletons, e.g. cold water corals, horse mussel beds, maerl, etc.) and carbonate sediments, but potentially benefitting photosynthetic species (such as kelp or other seaweed).

Integrating the carbon value of marine habitats, such as those found in MPAs, into decisions relating to marine management would potentially improve the protection provided to these habitats and enhance their capacity to provide a carbon sink. In some cases, where an MPA supports important blue carbon habitats, management measures that have the specific objective of protecting these stocks should be implemented. To support this, it is recommended that specific research is prioritised, to better understand the carbon sequestration processes in key habitats, including natural variability (both temporal and spatial). This should be more closely integrated with existing research that focuses on key species/habitats (e.g. biodiversity hotspots or biogenic reefs) that are largely protected for their biodiversity value and not for their blue carbon capacities.

Priority areas for future research include:

- **'Ground-truth' of current estimated data** in this blue carbon report (particularly in the sedimentary habitats, where data used for estimates were either dated or based on geographical locations outside of the UK).
- **Differentiation of sedimentary habitats** – some of the MPAs around the larger island groups (e.g. Orkney, Shetland, Outer Hebrides) contain 'carbonate' sediment, which has a higher carbon content that 'non-carbonate' sediments. This report has assumed all sediments within the inshore MPA network are 'non-carbonate', due to the limited data on carbonate sediment estimates although it is recognised thast there are some important carbonate stores within the network. Robust data on carbonate sediments is likely to increase the blue carbon budget estimates for these habitats.
- **Lack of understanding of natural carbon capture and sequestration processes** – ecosystems exist as a series of varied habitats, and the carbon flows between these habitats (for example, carbon moves from capture in the kelp to eventual storage in the sediment), but there is a huge degree of uncertainty on the details of these processes.
- **Future environmental change** – rising temperatures, increasing ocean acidification (due to elevated atmospheric CO_2), and increasing occurrence of hypoxia are likely to have individual and interactive effects on many of the carbon cycle processes. Current understanding suggests these effects may be negative, but collection of baseline data (to encompass natural variability) is essential in identifying changes in trends due to anthropogenic activity.

For a robust understanding of blue carbon, both in Scotland and on a larger global scale, it is essential that a research framework is developed, based on these suggestions, and tied in to marine policy objectives. This will feed directly into management plans, assisting in the effective monitoring and maintenance of marine resources, and ensure Scotland's blue carbon contribution remains viable and secure in an uncertain environmental future.

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1. INTRODUCTION

1.1 Project background

The establishment of a network of Marine Protected Areas (MPAs) across Scottish Waters has provided a way to support and manage activities in the marine environment, helping to protect important marine habitats, species and to deliver other benefits such as supporting coastal communities, helping to sustain marine industries, and providing for recreational uses. The development of a MPA network in Scotland is part of a wider strategy to achieve the Government's commitment to a 'clean, healthy, safe, productive and biologically diverse marine and coastal environment that meets the long term needs of people and nature' (SNH, 2016). The focus of this report is on a subset of inshore MPAs (i.e. NC MPAs and SACs designated for their habitat and species features), those mostly within UK territorial waters less than 12 nautical miles from the coast. Territorial waters comprise 18% (86 000km^2) of the total area of 470 000 km^2 of Scotland's seas. Inshore MPAs protect 10 400 km^2, or 12.1%, of the total area within 12 nautical miles.

The ocean is the largest global carbon sink, and thus plays a vital role in the global carbon cycle. Describing the dynamics of the ocean carbon sink is complex and requires clarity with respect to particular terminology. In this report, stores of solid carbon in living material are called **standing stocks**, stores of solid carbon in sediments are called **stocks,** the addition of solid carbon to these long-term stocks is referred to as **sequestration**, the conversion of carbon dioxide to solid carbon in living material is referred to as **fixation** (or sometimes capture), and the process of creation of a particular kind of solid carbon is referred to as **production**.

Over half of global carbon sequestration occurs through fixation during oceanic photosynthesis and long-term storage of produced dead material (Nellemann *et al*., 2009a). In addition to carbon being sequestered within the oceanic sea bed, a significant stock is stored within living marine organisms. These organisms include taxa that possess calcium carbonate skeletons and shells such as coral and molluscs, with other carbon captured and stored in photosynthetic habitats such as seagrass beds and kelp forests and maerl. The identification, protection and management of such carbon resources are potentially very important in helping Scotland meet its climate change mitigation targets. In order for these ecosystems to continue to act as carbon sinks it is important that they are protected from degradation. Best practice management of these ecosystems, using systems such as the MPA network and wider regional marine planning measures, could help to maintain and potentially enhance their capacity as carbon sinks, whilst at the same time helping to conserve the communities of animals and plants associated with these ecosystems.

The increasing need to quantify the services that ecosystems provide has resulted in the identification of 'different colours' of carbon from different ecosystems (e.g. green carbon is stored in terrestrial ecosystems). This makes it easier to attribute a value to each ecosystem, based on the amount of carbon sequestered. Consequently, '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 salt marshes, seagrass meadows, and mangrove forests*'. For the purposes of this study, this definition has been extended to include the geological substrate on which the marine ecosystem has developed. This study incorporates differing timescales of 'blue carbon' accumulation, including seasonal changes (e.g. biological stocks in seaweeds, kelp and seagrass) to long term geological stores in the sediments (decades to thousands of years).

There is a growing awareness and body of research concerned with how global climate change may impact the marine environment, through processes such as ocean acidification and rising ambient seawater temperatures. In order to fully understand the threats that global

climate change poses to the marine environment of Scotland, a fuller understanding of the habitats in terms of their carbon resources is required.

The rate at which carbon is sequestered by natural systems is a critical factor in mitigating anthropogenic release of carbon dioxide (CO_2) from fossil fuel combustion. The oceans absorb between 30 – 50% of atmospheric CO_2 (Doney *et al*., 2009). Any increase in atmospheric CO_2 concentrations will impact the global carbon cycle, particularly in the oceans, with resulting effects on natural carbon sequestration. However, before the effects of environmental change can be predicted in marine ecosystems, it is important that the natural ability of different habitats to capture and sequester carbon is fully understood. The first step is to ascertain the differences between habitats, and quantify the amount of carbon that is sequestered. Coastal marine habitats are particularly important, as over 50% of marine carbon sequestration occurs in coastal zones (Borges, 2005).

A previous study (Burrows *et al.,* 2014) identified that up to 7.7 million tonnes (Mt) of carbon per year (C yr^{-1}) may be sequestered over an area of 470 000 km^2 across Scotland's seas, but the study did not attempt to partition this total at the scale of areas of conservation importance and current protection.

This study therefore aims to estimate the blue carbon stocks and carbon sequestration capacity of Scotland's inshore MPA network which for the purposes of this study includes Nature Conservation Marine Protected Areas (from now on referred to as just MPAs) and Special Areas of Conservation (SACs). The inshore MPA network in Scotland covers a range of biological habitats and geological features, many of which (such as biogenic reefs) lend themselves to high carbon sequestration rates through the retention of carbon in shell material, as well as the burial of organic carbon in the underlying sediments.

By its nature, the inshore MPA network in Scotland has a large geographical spread of locations, ranging from the Solway Firth in the south-west, through to the Shetland Islands in the north-east. The large geographic range is matched by a variety of different biotopes and geological features found in the network. Habitats include features such as biogenic reefs, muddy and coarse sediments, and kelp forests, whilst the geological features include bare rock and current mobile sand sediments, through to deep, organic rich sediments with a high input of terrestrial carbon in sheltered sea lochs.

1.2 Project objectives

This study follows on from Burrows *et al.* (2014), which looked at the overall blue carbon budget of Scotland. As such, a similar methodology was adopted, which has been further developed to allow local scale estimation of the extent of habitats important for blue carbon generation and storage. In addition, this study is restricted to the inshore MPA network in order to determine how the various protected areas within the network contribute both individually and as a whole to Scotland's blue carbon sequestration potential.

The current study will calculate the blue carbon resource represented by each MPA and SAC in Scotland's inshore waters. The relative contribution of biological material and geological substrate to blue carbon storage will be determined from a review of current scientific literature. The resultant blue carbon values will also be ranked in various ways, providing potential knowledge on protected areas that should be a focus for future investigations.

A collective assessment of the scale and nature of any threats to these blue carbon resources and any future management implications and opportunities for their blue carbon potential will be undertaken. This will allow effective targeting of monitoring and management resources to ensure that the protected habitats are given the priority required

to ensure Scotland's blue carbon contribution is maintained into the future. The potential for changing global climate to impact the blue carbon resource represented by Scotland's inshore MPA network will then be assessed, with advice given to aid effective management of such sites as changes in local climate progress.

Finally the study will highlight current knowledge gaps and outline priority research areas and considerations for the future. This will include an assessment of the blue carbon inventory process and recommendations on key data requirements, the level of confidence in current assessments and the best practice on how this can be rolled out on a wider scale, both domestically and internationally.

2. METHODOLOGY

This study aims to produce a quantitative assessment of the contribution made by the inshore MPA network to Scotland's blue carbon reserves, and give estimates of the blue carbon value of MPAs and SACs on the basis of current knowledge of the ecology and geology of existing habitats and data available on their presence and extent. The approach used in this report builds on the methodology used by Burrows *et al*. (2014), taking a tiered approach to data used to assess the contribution that each MPA or SAC from the network makes to the net and gross blue carbon budget of Scotland's coastal waters, previously estimated as sequestering up to 7.7 Mt C yr^{-1} across 470 000 km^2. The following sections detail the steps taken to achieve this.

2.1 Data review and rationalisation

At the initiation of this study Scottish Natural Heritage (SNH) supplied the authors with existing habitat data in the form of a GIS database (GeMS V2i10 Geodatabase) for all Scotland seas, including MPAs and SACs. These data included both point records and habitats mapped as polygons. After assessing the quality of data available for the study, a list of 48 MPA network locations regarded as 'inshore' were agreed with SNH (see Table 2.1 and Figure 2.1). This list included two currently proposed MPAs (pMPAs): North-east Lewis and Southern Trench. The full list of 48 locations will be henceforth referred to as the inshore MPA network within this report

Two areas were classified as both MPAs and SACs, since the areas had similar boundaries. These were Loch Creran MPA and Loch Creran SAC, where both designations have identical boundaries, and Loch Sunart MPA and Sunart SAC, where the marine environment of the latter matches the boundary of the former.

Data were extracted from the GIS shape files provided by SNH for the entire inshore MPA network in R, using the "data.table", "rgdal" and "sp" packages. These data were then collated into an excel.xlsx file, listing available biotope information and location.

The existing datasets were then examined and biological and geological habitats listed as present in the 48 inshore MPAs. A first look revealed that whilst a few MPAs and SACs had mapped habitat polygons with attendant spatial data, the majority of MPAs and SACs had point survey data only. A robust extrapolation method was needed to be developed and applied to estimate the extent of habitats in a consistent way across all MPAs and SACs.

The biotope data provided were categorised (EUNIS habitat classification system Level 3, developed by the Joint Nature Conservation Committee Marine Nature Conservation Review) into a range of blue-carbon habitats using relevant experts (see biographies). This reclassification of biotopes into blue carbon categories is available as an additional source if required.

The data contained over 500 different biotopes classified under the Marine Habitat Classification of Britain & Ireland that had been identified throughout the inshore MPA network; almost all of which were present in more than one protected area. Any attempt to assign net and gross carbon values to each biotope would far exceed the specificity of the available data on carbon values for these biotopes. Carbon values described in scientific literature are typically assigned for a particular broad habitat, substrate type or geographical area rather than a specific biotope. Allocating such broad values to particular biotopes would overstate the certainty of the resulting calculations for this study.

Table 2.1 – A list of the 48 inshore MPA network locations investigated within this study (in alphabetical order)

Number	Name	SAC/MPA
1	Berwickshire and North Northumberland Coast	SAC
2	Clyde Sea Sill	MPA
3	Dornoch Firth and Morrich More	SAC
4	East Caithness Cliffs	MPA
5	East Mingulay	SAC
6	Fetlar to Haroldswick	MPA
7	Firth of Lorn	SAC
8	Firth of Tay and Eden Estuary	SAC
9	Isle of May	SAC
10	Loch Creran	SAC/MPA
11	Loch Laxford	SAC
12	Loch Moidart and Loch Shiel Woods	SAC
13	Loch nam Madadh	SAC
14	Loch of Stenness	SAC
15	Loch Roag Lagoons	SAC
16	Loch Sunart to the Sound of Jura	MPA
17	Loch Sween	MPA
18	Lochs Duich, Long and Alsh	MPA
19	Lochs Duich, Long and Alsh Reefs	SAC
20	Luce Bay and Sands	SAC
21	Moine Mhor	SAC
22	Monach Islands	SAC
23	Monach Isles	MPA
24	Moray Firth	SAC
25	Mousa	SAC
26	Mousa to Boddam	MPA
27	North Rona	SAC
28	Noss Head	MPA
29	Obain Loch Euphoirt	SAC
30	Papa Stour	SAC
31	Papa Westray	MPA
32	Sanday	SAC
33	Small Isles	MPA
34	Solway Firth	SAC
35	Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	SAC
36	Sound of Barra	SAC
37	South Arran	MPA
38	South Uist Machair	SAC
39	St Kilda	SAC
40	Sullom Voe	SAC
41	Sunart/Loch Sunart	SAC/MPA
42	The Vadills	SAC
43	Treshnish Isles	SAC
44	Upper Loch Fyne and Loch Goil	MPA
45	Wester Ross	MPA
46	Wyre and Rousay Sounds	MPA
47	North-east Lewis	pMPA
48	Southern Trench	pMPA

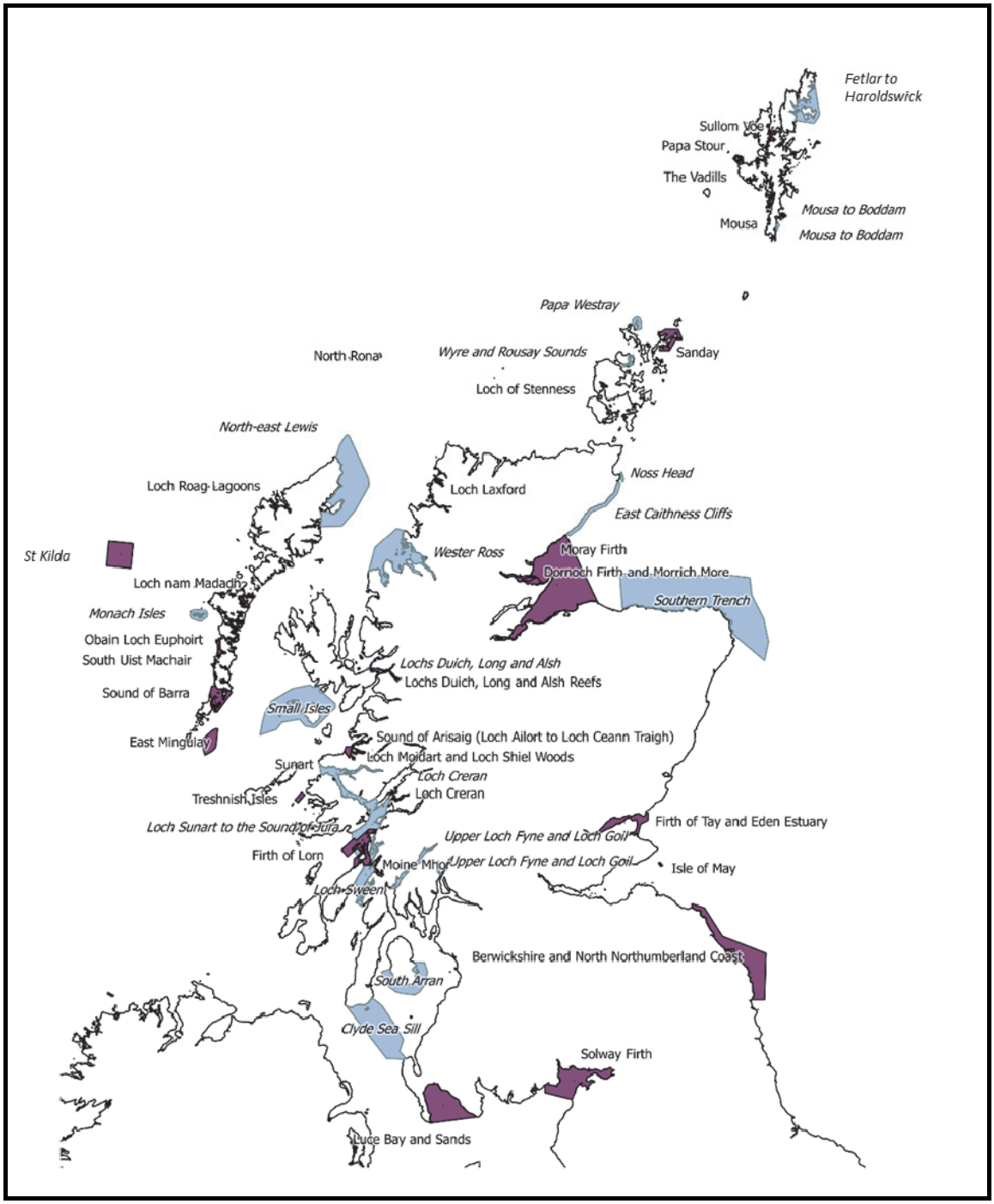

Figure 2.1 – Map showing the location of the 48 inshore MPA network locations investigated within this study. MPAs coloured blue, with names in italic labels; SACs coloured purple, non-italic labels (Contains OS data © Crown copyright and database right (2015))

Therefore each biotope was assigned to a specific 'blue carbon' category for which accurate and appropriate carbon values exist. More details on the selection of these blue carbon categories and their associated carbon values can be found in Sections 3 and 4, dealing with the biological and geological categories respectively. Table 2.2 summarises the blue carbon categories adopted for this study.

Table 2.2 – Summary of the blue carbon category classification scheme used for this study

Biological	**Geological**
Kelp forest	Rock
Intertidal macroalgae	Gravel
Subcanopy algae	Gravel/Mud
Maerl beds	Gravel/Sand
Seagrass beds	Sand
Saltmarshes	Sand/Mud
Horse mussel (*Modiolus modiolus*)	Sand/Mud/Gravel
Flame shell (*Limaria hians*)	Mud
Lophelia pertusa reef	Sea Loch Mud
Tubeworm (*Serpula vermicularis)* reef	
Brittlestar beds	
Blue mussel (*Mytilus edulis*)	
Sabellaria reefs	

Each data point was assigned a biological and geological blue carbon category. Biological categories were designated based on the biotope assigned, whilst geological categories were based on the substrate part of biotope codes, or additional metadata supplied with each data point (e.g. sediment descriptions etc.). Another stage of the geological classification of data was based on geographical location of the sample, differentiating between coastal marine sediments and those found in sea lochs. These two types of sediment typically have different ratios of terrigenous carbon versus that of marine origin. Terrigenous detritus is far less labile in the marine environment than marine detritus (Glud, 2008), which has important consequences on the annual net and gross carbon sequestration potential.

2.2 Assessment of spatial extents of habitats

After data had been classified under the blue carbon categories, the spatial extent of these habitats was estimated within the 48 inshore MPA network locations of interest. As already mentioned, an initial review revealed that whilst many of the protected areas had point data that had been extrapolated into habitat polygons with attendant spatial data, there were several sites consisting of point data only.

A tiered approach to habitat category allocation was required to deal with the variability in data quality between the inshore MPA network locations as well as internally within each protected area. The data supplied reflected that sampling effort had been concentrated in certain appropriate areas of each protected area, with other areas receiving much less attention. Additionally, as already indicated, only some of the protected areas had complete polygon data, whilst others had only point data.

Maps of the best estimates of the location and extent of geological and biological habitats were built using data in declining order of quality. Where mapped polygon data existed within an MPA or SAC, these were used as the primary data source. Such data allowed direct

measurements of the type and extent of both biological habitat and geological substrate, with area estimates possible for each from the pre-existing polygons.

Where no polygon data had been generated, there was the option of examining known databases for alternative data. In the case of geological substrate, sediment grain size could be inferred from sediment data held by the British Geological Survey. Existing publicly available BGS data (BGS 1:250 000 superficial sediments) were imported into ArcGIS, and those data that covered the inshore MPA network identified. These alternative substrate polygon data were used in preference to point data as a second tier option. Such alternative data maps were available at a much lower resolution than the SNH supplied polygon data, but the method was far preferable to interpolation from point data.

The third tier of analysis was the automatic interpolation of habitat areas from point surveys. All point survey data were interpolated directly into polygons using the QGIS Voronoi Diagram algorithm[1]. The chosen method assumed that the point data were representative of an area extending in all directions until a point describing a different habitat was encountered. The polygon edges were defined as representing the median line between two data points, giving a mosaic of polygons identified by the nearest point data. However, this led to some polygons which were clearly incorrect, where the interpolation took no note of known biological constraints. For example, in many places kelp habitat was assigned to areas that extended to over 50 m water depth, which is a depth never reached by kelp in Scottish coastal waters. In this case an additional cut-off was imposed by limiting all kelp habitats to 15 m water depth or less, helping to create a more realistic scenario for this habitat type.

These tiers were applied throughout Scottish waters, to all locations, to ensure that the approach was applied methodically and equally in all areas. Mapped data from SNH took precedence over sediment extent data from BGS, which in turn were used in preference to areas interpolated from the biotope of the nearest surveyed point (example given in Figure 2.2 Sound of Arisaig). The inshore MPAs network locations were isolated from the data sets, and the spatial data for each habitat and substrate blue carbon category were extracted. Rates of net and gross carbon sequestration were then calculated for each protected area in turn, and itemised in this report, using data gathered from peer-reviewed literature as identified in Section 3 and 4. Results of the calculations have been tabulated in Section 5, before ranking the inshore MPA network locations according to their blue carbon resources. The most valuable habitats and substrates from a blue carbon perspective have been identified following this analysis, and are discussed in Section 6, itemising any known, or anticipated, threats to the continued blue carbon status of each protected area.

[1] http://docs.qgis.org/2.6/pdf/en/QGIS-2.6-UserGuide-en.pdf

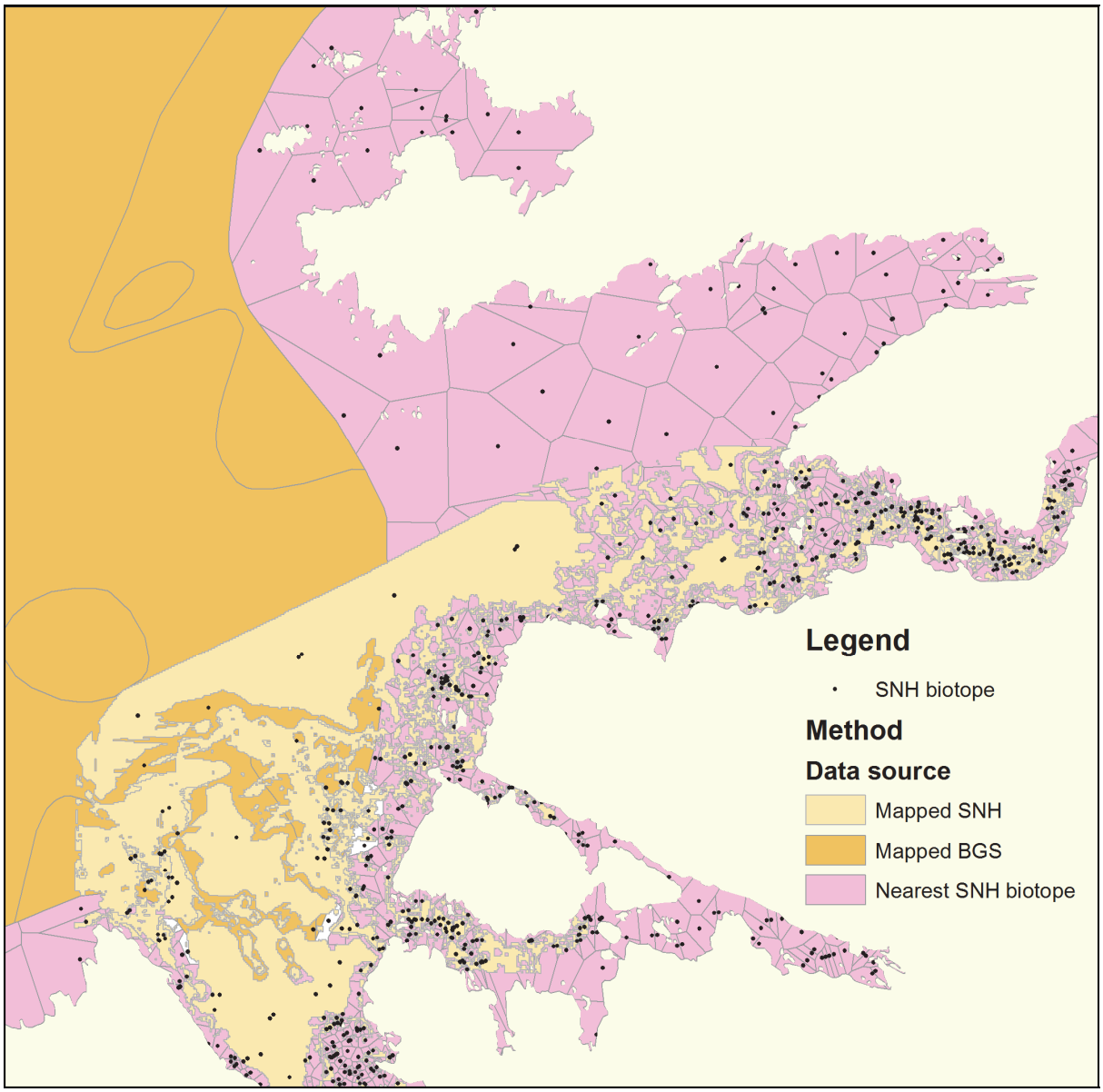

Figure 2.2 – Derivation of spatial extent of blue carbon features for Sound of Arisaig. In order of priority, areas were assigned to features on the basis of (1) mapped habitats provided by SNH, (2) mapped areas of sediment from BGS 1:625 000 shapefiles, and (3) the biotope of the nearest point survey location (shown as black circles). The source of data for the final map is indicated by the shading. (Contains OS data © Crown copyright and database right (2015))

3. HABITAT IDENTIFICATION: BIOLOGY

3.1 Introduction

Habitats identified as having distinct contributions to blue carbon stocks and distinct rates of production and storage follow those of Burrows *et al.* (2014), excluding the production from phytoplankton, with some additional classes added for habitats of particular local conservation importance. For each habitat, rates of production and sequestration of organic and inorganic carbon (units = g C m^{-2} yr^{-1}), along with values used for the biomass per unit area (g C m^{-2}), were taken directly from Burrows *et al.* (2014); see Annex 1 for more details. The 2014 report gives details of the literature and methods used to obtain values for each habitat.

3.2 Biological habitats

3.2.1 Kelp forest

Kelps are large brown seaweeds belonging to the Order Laminariales. Growing in "beds" or "forests" they form one of the most widespread and important coastal habitats of the temperate and subpolar oceans, extending from the lower intertidal zone to the shallow subtidal (Smale *et al*., 2013). Kelps are ubiquitous along rocky coastlines throughout Scotland, and occur in most of the 48 inshore MPA network locations considered here. The locally predominant kelp species vary according to habitat, with for example, *Laminaria hyperborea* and *Alaria esculenta* most abundant on wave-exposed open coasts, while *Saccarhina latissima* prefers sheltered conditions (Walker, 1954; Smale *et al*., 2013).

Kelp beds/forests are among the most dynamic coastal ecosystems, with high standing stock biomass, high rates of primary and secondary production, and an important role as providers of habitat for a wide range of marine plants and animals (Dayton, 1985). Kelp carbon production is not stored within kelp beds, and therefore these habitats alone offer no potential for carbon sequestration. Little carbon is directly grazed by herbivores, with most (>80%) entering the detrital food web as particulate detritus or dissolved organic matter. This detritus supports coastal food webs, particularly benthic suspension-feeding organisms such as mussels and barnacles (Duggins *et al*., 1989), and grazers such as limpets (Bustamante & Branch, 1996). Kelp detritus is also an important source of food for small deposit-feeders in coastal sediments (see Krumhansl & Scheibling (2012) for the most recent review). The incorporation of kelp detritus into sediments may ultimately be the fate of a significant fraction of the organic carbon produced by kelp around Scotland, and represent the major contribution of the habitat to the blue carbon inventory.

Standing stock densities of kelp were estimated as 187.7 g organic carbon (OC) m^{-2} with no inorganic carbon (IC), and the rate of fixation of carbon (through production of plant material) **685 g OC m^{-2} yr^{-1}** from literature value (Burrows *et al.,* 2014). No carbon is sequestered in kelp beds.

3.2.2 Intertidal macroalgae

Fucoid algae (commonly termed "wracks") are the characteristic brown seaweeds of the intertidal zone of bedrock and boulder shores, and may also occur on mixed sedimentary shores (e.g. muddy gravels) provided there are stones or other hard substrata for attachment. Fucoid species show distinct zonation with respect to position on the shore, with *Pelvetia canaliculata* occupying the upper shore, and species of *Fucus* (*F. spiralis, F. vesiculosus* and *F. serratus*) at successively lower levels. There is also local variation in species composition with respect to wave exposure. *Ascophyllum nodosum* prefers low-energy environments and is the dominant species of sheltered inlets and sea lochs along the Scottish west coast (Walker, 1947; Gibb, 1950).

Fucoid algae are ubiquitous around the Scottish coastline and are unlikely to be entirely absent from any location in the inshore MPA network. However, local abundance can vary from a sparse cover of small plants growing on isolated stones, to dense beds covering most of the intertidal zone. Productivity of fucoids may be comparable to that of kelps in some circumstances, and like kelp beds, dense stands of intertidal macroalgae are important contributors to the detrital food web (Mann, 1973; Charpy-Rouband & Sournia, 1990).

Intertidal macroalgae were not included in the 2014 evaluation of blue carbon storage in Scottish seas (Burrows *et al*., 2014), and data on standing stock and productivity in Scotland are very sparse. Gibb (1950) estimated tonnage of *Ascophyllum nodosum* and *Fucus vesiculosus* along 14 shorelines in Mull, Skye and Wester Ross. Converted from imperial units, values ranged from 57-213 tonnes (wet weight) per linear km, with a mean (±SD) of 99 ± 39 t km^{-1}. The width of the fucoid zone at each locality was not recorded, making it difficult to convert these values to standing stock per unit area of shore. Area-specific estimates for *A. nodosum* were provided by Walker (1947) for the Inner and Outer Hebrides, Orkney and mainland Scotland. *Ascophyllum* standing stock ranged from **5.11-8.76 kg (wet weight) m^{-2}**. Several authors have recorded intertidal fucoid biomass at sites on the North American Atlantic seaboard (e.g. Mann, 1973; Topinka *et al*., 1981; Cousens, 1984) and in continental Europe (e.g. Åberg, 1992; Viana *et al.,* 2015) but for local relevance it is probably prudent to use Walker's (1947) figures as indicative of macroalgal standing stock on Scottish shores. Ugarte *et al*. (2010) cite a figure for carbon content of *A. nodosum* as 37% of the dry weight. Assuming a dry weight/wet weight ratio of ~10%, Walker's (1947) figures would equate to a standing stock of ~189-324 g C m^{-2} for *A. nodosum* on Scottish shores, with a median value of ~250 g C m^{-2}. The standing stock per unit area adopted for this report was higher than these figures at **489 g C m^{-2}**, based on Walker's (1947) 180 000 t fresh weight of fucoids across 24.0 km^2 in Scotland, and Mann's (1973) 6.6% organic carbon estimated as a percentage of fresh mass.

Primary productivity of intertidal macroalgae is generally lower than recorded for subtidal kelps, as a consequence of the harsher environmental conditions of the intertidal zone (Mann, 1973). Nevertheless, values may still exceed 1000 g C m^{-2} yr^{-1} when rates of tissue loss (by grazing or abrasion) are high (Mann, 1973). For *Ascophyllum nodosum* on the Canadian Atlantic coast, Ugarte *et al.* (2010) cite values of 232-562 g C m^{-2} yr^{-1}, using a Production/Biomass (P/B) ratio of 0.54. Applying this P/B ratio to Walker's (1947) figures gives a productivity estimate of ~102-175 g C m^{-2} yr^{-1} (median **~135 g C m^{-2} yr^{-1}**) for Scottish shores.

3.2.3 Subcanopy algae

This category covers a range of foliose and filamentous algal species (mostly red algae, Rhodophyta) lacking a calcified skeleton, typically forming the understorey vegetation of kelp forests, and including species growing as epiphytes on the stipes of the kelp plants (Whittick, 1983). This ecological group has been rarely studied in comparison with the more conspicuous kelps and intertidal fucoids and there are few relevant data in the literature. In Norway, Pedersen *et al*. (2014) recorded red algal biomass in the range of 25-120 g (dry weight) m^{-2} in forests of *Laminaria hyperborea,* equivalent to an average of 22 g C m^{-2}. Poor light conditions under the kelp canopy resulted in low annual figures for net productivity, of 42-96 g (dry weight) m^{-2} yr^{-1}, depending on site, equivalent to 21 g C m^{-2} yr^{-1} (assuming a carbon content of 30% of dry matter). Pedersen *et al*. (2014) concluded that the net productivity of epiphytes was insignificant relative to that of the kelp itself, and that the observed epiphytic biomass took several years to accumulate. From a blue carbon perspective, subcanopy algae can therefore be considered to make a small additional contribution to the standing stock biomass of the associated kelp forest, assumed similar to the rate of annual production at **22 g OC m^{-2} yr^{-1}**, but can be disregarded as net primary

producers. The small amount of additional net production is likely to enter the detrital food web along with the much larger quantity generated by the kelp itself.

3.2.4 Maerl beds

"Maerl" is a collective term for several species of coralline red algae which secrete a calcareous skeleton and grow as unattached nodules (rhodoliths), often with a complex branching structure. In Scottish waters the principal maerl-forming species are *Phymatolithon calcareum* and *Lithothamnion glaciale* (Birkett *et al*., 1998). Maerl beds are typically found in channels, inlets and sounds sheltered from wave action but with strong tidal currents. In Scotland, maerl occurs in many localities along the west coast, and in the Western Isles, Orkney and Shetland, but is absent from the east coast (Hall-Spencer *et al*., 2008). This distribution range covers several locations within the inshore MPA network, including the Sound of Arisaig SAC, which was designated primarily because of its extensive maerl beds.

The calcium carbonate skeleton of maerl persists after the death of the living algal tissue and accumulates to form long-lasting deposits (Kamenos *et al*., 2004a, b). Living maerl beds on the west coast of Scotland can reach at least 60 cm depth with some relict deposits being significantly deeper (Kamenos, 2010). These deposits act as a long-term store for inorganic carbon and also lock-up associated calcifying biota in their matrix-like structure.

Maerl was assumed to have a density of 0.8667 t m^{-3}, with 12% of constituent calcite as inorganic carbon. Assuming a maerl bed thickness of 60 cm, this gives a stock per unit area of **62 402 g IC m^{-2}** (Burrows *et al.,* 2014). Production and sequestration of inorganic carbon was taken as **74 g IC m^{-2} yr^{-1}**, the average of rates reported for *Lithothamnion glaciale* and *Phymatolithon calcareum*. Stock and production rates of organic carbon were assumed to be negligible.

3.2.5 Seagrass beds

Seagrasses (usually termed "eelgrasses" in the UK) are marine flowering plants (~60 different species worldwide) that form extensive meadows in shallow waters of all continents except the Antarctic. In Scotland they typically occur from the lower saltmarsh limit (*Zostera noltii*) into the sublittoral zone (*Z. marina*) to ~10 m depth. Seagrass beds are especially well developed in Scotland compared to other parts of the UK, probably reflecting the presence of extensive suitable habitats and uncontaminated waters (Hiscock *et al*., 2004). Cromarty Firth alone supports probably the largest total area of dwarf eelgrass (*Z. noltii*) and narrow-leaved eelgrass (*Z. angustifolia*) in the UK (~1,200 ha).

It has recently been suggested that seagrass beds may be responsible for about 15% of the total carbon storage in the ocean, despite covering only ~1% of the global ocean floor (Laffoley & Grimsditch, 2009). This is due to the slow turnover time of seagrass biomass and the capacity of the plants' root networks to trap and bind organic detritus in the underlying sediments. Given the importance of Scottish beds in a UK and European context, it is valuable to assess the size of the eelgrass carbon sink contained within the inshore MPA network.

Organic carbon production by seagrasses was taken as **261 g OC m^{-2} yr^{-1}** and sequestration rate as **83 g OC m^{-2} yr^{-1}** (Laffoley & Grimsditch, 2009), with standing stocks of organic carbon and inorganic carbon rates and stocks assumed to be negligible.

3.2.6 Saltmarshes

Saltmarshes are intertidal ecosystems that are dominated by vascular plants (for example, the cord-grasses *Spartina* spp.). They occur on sheltered marine and estuarine coastlines

from the arctic to the tropics, but are most common in temperate regions. Approximately 3% of the Scottish coastline is covered by saltmarsh vegetation, with Scotland accounting for ~15% of the total extent of the habitat in the UK (Burd, 1995). The larger Scottish saltmarshes are mainly concentrated in the low lying firths of the eastern and south-west coasts, with a large number of much smaller examples located at the heads of sea lochs, in embayments and on beaches in the north-west of the country.

Saltmarshes may be one of the most efficient habitats on Earth for sequestering and storing carbon in their soils, with an average estimated production and sequestration rate of **210 g OC m^{-2} yr^{-1}** (Chmura *et al*., 2003). The high concentrations of sulphates and associated microbes in coastal and marine soils and sediments mitigate against the formation of methane, which is a considerably more potent greenhouse gas than carbon dioxide when emitted to the atmosphere. It is therefore important to quantify the contribution of saltmarshes to the carbon storage capacity of Scotland's inshore MPA network. Saltmarsh standing stock of organic carbon per unit area was taken as **127.5 g OC m^{-2}** (Burrows *et al.,* 2014)**.**

Despite the importance of saltmarshes, it was noted in Haynes (2016) that there are currently a number of pressures on Scottish saltmarshes that can cause damage, and degradation. The report recommends that further controls and management be put in place to protect Scottish saltmarshes from construction and increased grazing intensity.

3.2.7 Horse mussel (Modiolus modiolus)

The horse mussel *Modiolus modiolus* is widely distributed in shallow subtidal waters around Scotland, particularly on western and northern coasts, including Orkney and Shetland (Mair *et al*., 2000). Many records are of isolated individuals or of sparse, low-density populations, but beds dense enough to be regarded as biogenic reefs are formed in some localities. As for *Limaria hians* (see below), records of horse mussel beds have increased recently as MPA search feature surveys have applied modern habitat mapping methods to poorly-known regions of the Scottish seas (Hirst *et al*., 2012; Moore *et al*., 2012, 2013). Horse mussel beds occur in several of the 48 inshore MPA network locations considered in this report. The *Modiolus* bed off Noss Head, Caithness, is by far the largest currently known from Scottish waters. The Noss Head mussel bed lies at 37-47 m depth with an estimated extent of ~3.85 km^2 (Hirst *et al*., 2012). Density of living *M. modiolus* within the bed is patchy but the SACFOR category of Superabundant (10-90 individuals m^{-2}) was recorded at several stations (Hirst *et al*., 2012). *Modiolus modiolus* is a large bivalve with a robust shell, and where it occurs in dense beds the accumulated relict shells may be important repositories of biogenic carbonate. For a mean thickness of 75cm of *Modiolus* beds and based on 5-7cm deep grab samples of 2 219 g $CaCO_3$ m^{-2} and a 12% inorganic carbon percentage of $CaCO_3$, **4 000 g IC m^{-2}** was taken as the area-specific stock estimate (Burrows *et al.,* 2014). A sequestration rate of **40 g IC m^{-2} yr^{-1}** was assumed from growth rates of beds in the Firth of Lorn (Burrows *et al.,* 2014).

3.2.8 Blue mussel (Mytilus edulis)

The blue mussel (*Mytilus edulis*) is one of the most common and widespread shallow-water invertebrates of Scottish coastal waters. Its habitat range extends from the high intertidal to the shallow subtidal zone, and from exposed rocky shores to sheltered bays, estuaries and sea lochs. *Mytilus edulis* is one of the most intensively-studied marine animals, with a huge primary literature (reviewed by Bayne, 1976; Gosling, 1992), but literature relevant to its potential contribution to blue carbon storage is rather sparse. The spatial extent, density and temporal persistence of blue mussel beds is highly variable, depending on local environmental conditions, but in some areas beds can attain dimensions justifying their classification as biogenic reefs (Holt *et al*., 1998). *Mytilus* reefs are composed of layers of

living and dead mussels, with a matrix of accumulated sediment and shell debris bound together by networks of byssal threads. In the U K, reefs rarely exceed 30-50 cm in thickness, but subtidal examples up to 120 cm thick have been reported (Holt *et al*., 1998). Blue mussel beds (of varying extent) occur widely around the Scottish coast and exist in several sites within the inshore MPA network.

Mytilus edulis was not included in the Scotland-wide assessment of blue carbon by Burrows *et al*. (2014) and a comprehensive review of the extensive literature on mussel growth and productivity is beyond the scope of the present report. In optimal conditions *Mytilus edulis* can reach a shell length of 60-80 mm within two years, but in the high intertidal zone growth rate is significantly lower, and mussels may take 15-20 years to reach only 20-30mm in length (Seed & Suchanek, 1992). Standing stock biomass and carbonate production rate will therefore be heavily dependent on local conditions and no single set of values can accurately represent all cases. Without detailed site-specific information (on bed/reef thickness, mussel population size structure and shell growth rate) it is not possible to assign figures for individual MPAs, and blue mussel beds are therefore treated as a "data deficient" category in this study. Stocks and rates of production and sequestration of carbon were assumed to the same as for *Modiolus* beds in the absence of any appropriate alternative information.

3.2.9 Flame shell (Limaria hians)

The flame shell *Limaria hians* is an epifaunal bivalve that constructs a "nest" of byssal threads interwoven with shell and algal fragments and partially infilled with trapped sediment (Hall-Spencer & Moore, 2000a). In dense populations these nests can form continuous reef-like structures 10-20 cm thick and several hectares in extent. Densities may reach several hundred individuals m^{-2}, with >700 m^{-2} recorded from a bed at Creag Gobhainn, Loch Fyne (Hall-Spencer & Moore, 2000a). Historical records are widespread around the western and northern Scottish coasts, particularly on muddy gravels and sands in tidal channels and other areas with moderate-to-strong tidal streams. The species is also often associated with maerl beds (Hall-Spencer & Moore, 2000b). *Limaria hians* has suffered a severe decline in abundance in Scotland (and elsewhere in the UK) and until very recently few extensive beds were known to survive. However, surveys mounted by SNH have located (or re-located) several dense populations in west coast sea lochs, with the largest-known covering an estimated 75 ha near Kyle Akin, Loch Alsh (Moore *et al*., 2013). Burrows *et al*. (2014) list spatial extent and population density for seven Scottish flame shell beds, using data from Moore *et al*. (2013). Six of these seven beds are located within the inshore MPA network and their contribution to local blue carbon inventories will be assessed in this report. The thin, delicate shells of *Limaria hians* are likely to persist for timescales of only years to decades. For this reason, and owing to the lack of data on rates of shell production, carbon sequestration was assumed to be zero for this report, but shell densities suggest a standing stock of **63.8 g IC m^{-2}** (Burrows *et al.,* 2014).

3.2.10 Cold water coral (Lophelia pertusa)

Lophelia pertusa, the most important reef-building cold-water coral species, occurs around the north-east Atlantic margin in the approximate depth range 100-1 500 m (Roberts *et al*., 2006). In Scottish waters there are many historical records from the offshore banks, ridges and seamounts of the northern Rockall Trough (Roberts *et al*., 2003), and also from a few sites on the western Scottish continental shelf (Roberts *et al*., 2005). However, the Mingulay Reef Complex, first mapped in 2003, is currently the only cold-water coral habitat known to exist in Scottish inshore waters, and this has led to the designation of the area as the East Mingulay SAC (Roberts *et al*., 2009). The Mingulay Reef Complex includes both living coral framework and accumulations of relict calcareous material which collectively represent a carbon sink operating over a timescale of up to 7.7 thousand years ago, based on

radiocarbon dating of coral fragments (Douarin *et al*., 2013, 2014). Although its localised occurrence means that the contribution of *L. pertusa* to total carbon storage in Scotland's inshore MPA network is likely to be very small, the East Mingulay SAC provides an opportunity to assess its significance at a local scale. Simple calculations of coral mass per unit area based on the reported size of coral mounds (Burrows *et al.,* 2014) gave a stock estimate of **9 375 g IC m^{-2}.** Rates of accumulation of *Lophelia pertusa* mounds suggested a sequestration rate of **35 g IC m^{-2} yr^{-1}** (Burrows *et al*., 2014)**.**

3.2.11 Tubeworm (Serpula vermicularis)

The serpulid polychaete *Serpula vermicularis* is common and widespread throughout Scottish waters but the formation of reefs composed of masses of aggregated tubes is a very localised phenomenon. Serpulid reefs are currently known to exist only in Loch Creran, Argyll (Moore *et al*., 1998) and in Loch Teacuis, a small inlet of Loch Sunart on the Morvern Peninsula (Dodd *et al*., 2009). Serpulid reefs were also recorded in the Linne Mhuirich arm of Loch Sween (mid-Argyll) during the 1980s, but they have subsequently disappeared from this locality and the most recent scientific surveys have found no evidence of regeneration (Hughes *et al*., 2008; Hughes, 2011).

Serpulid reefs are known to occur in only two of the 48 locations considered within this report (Loch Creran SAC/MPA and Sunart SAC/MPA), and are therefore likely to make only a small contribution to total carbon storage in the inshore MPA network. However, on a local scale they can form an important biogenic habitat and their calcareous tubes (occupied or relict) are a potential blue carbon sink. This is particularly relevant in Loch Creran, which supports the most extensive serpulid reefs (Moore *et al*., 2009), and for which the loch originally received its SAC designation.

Production and sequestration of inorganic carbon by serpulid tubeworm reefs in Loch Creran has been estimated as around 3.5 kg $CaCO_3$ per m^2 (Burrows *et al.*, 2014) giving a rate of **420 g IC m^{-2} yr^{-1}**, the highest rate of any blue carbon habitat. Stock estimates are suggested as **781 g IC m^{-2}** based on area-specific masses per unit area.

3.2.12 Sabellaria *reefs*

Tubes constructed by the reef-building polychaetes *Sabellaria alveolata* and *S. spinulosa* consist of agglutinated sand grains and shell fragments (Naylor & Viles, 2000). In this respect they differ from the calcium carbonate tubes of *Serpula vermicularis* (Section 3.2.11), which are secreted *de novo* by the worms. *Sabellaria* reefs are therefore merely a temporary structural rearrangement of sand and shelly particles from the surrounding sediment. They have no additional blue carbon potential and are not considered further in this report.

3.2.13 Brittlestar beds

Dense beds of brittlestars are common in Scottish inshore waters, particularly around the west coast but with examples known also from Orkney, Shetland and the North Sea (Hughes, 1998). The two main bed-forming species, *Ophiothrix fragilis* and *Ophiocomina nigra*, may occur together or in monospecific aggregations (Aronson, 1989). In a few localities, particularly in Lochs Duich and Alsh, beds are formed by a third species, *Ophiopholis aculeata* (Emu Ltd, 2006). Brittlestar beds have been recorded from many recent surveys in Scottish waters, including several marine SACs and MPAs (e.g. Hirst *et al*., 2012; Moore & Atkinson, 2013; Moore *et al*., 2013). Off Keppel Pier, Great Cumbrae, Aronson (1989) recorded densities of *Ophiocomina nigra* in excess of 2 000 individuals m^{-2}. On this scale, brittlestar beds represent substantial concentrations of benthic biomass. Like all echinoderms, brittlestars have an endoskeleton of calcareous plates, and owing to their abundance in benthic environments throughout the oceans, carbonate-producing

echinoderms may play an important (and largely overlooked) role in the marine carbon cycle (Lebrato *et al*., 2010). The potential contribution of brittlestar beds to carbon storage in Scotland's inshore MPA network therefore warrants consideration. Based on carbonate production rates for *Ophiothrix fragilis* in the Dover Strait an inorganic carbon production rate of **82 g IC m^{-2} yr^{-1}** was used for brittlestar beds.

4. HABITAT IDENTIFICATION: GEOLOGY

4.1 Introduction

It is well known that marine sediments are a significant store of biologically derived carbon (Santschi *et al.*, 1990; Glud, 2008), with up to 50% of primary production in coastal waters reaching the sea floor as organic detritus (Glud, 2008) and a significant percentage of terrestrially derived organic carbon also being deposited in coastal sediments (Stahl, 2012a; 2012b). Biologically derived carbon may be sequestered in marine sediments in a number of forms, conventionally described as precipitated carbonates in the form of inorganic carbon or as particulate organic carbon, collectively known as total carbon. The accumulation of these materials in marine sediments tends to occur at faster rates (e.g. 0.01-0.03 g cm^{-2} yr^{-1}, Nørgaard-Pederson, 2006) close to the coastal areas, particularly in semi-enclosed fjords close to land, in Scotland referred to as sea lochs (Stumm & Morgan, 1996). The coastal sediments are the main long-term stores of both OC and IC in the coastal ocean; they are capable of storing a significant mass of carbon over interglacial time periods.

A complete understanding of accumulation rates and the mechanisms that maintain sediment basins in coastal waters has yet to be reached, but the rapid supply of phytoplankton and the rich ecosystem it supports is likely to be a key factor in maintaining a rapid deposition of carbon rich sediments and storage (Bauer *et al.*, 2013).

This study focuses on determining the annual carbon accumulation to the sea bed and the total carbon stock of the sediment in a given MPA or SAC. While discussing the stocks only the top 10 cm of the sediment will be considered, as sediment depth data are only available for a few sites. This follows the methodological format used by Burrows *et al*. (2014). It should be noted that there is significant variation in sediment depth in the coastal ocean ranging from centimetres to hundreds of metres. In this report a conservative approach has been taken, with only the top 10 cm of sediment included in the report calculations, therefore it is recognised that stocks reported here represent a small fraction of full-thickness sedimentary carbon stocks.

4.2 Substrate identification

The following section discusses, in some detail, the geological categories and associated sediment types that were chosen for the purposes of calculating the net accumulation and stocks of organic carbon and inorganic carbon in the sediment. In each case the sediment types were derived from examination of the substrate type identified in the list of biotopes, with one exception. The organic carbon content and rate of accumulation of sediments in sea lochs is known to be significantly higher than that of coastal mud (fine grained sediment) found in other coastal areas (Overnell *et al*., 2002; Smith *et al*., 2015). Therefore it was clear that this sediment type needed to be accounted for separately in order to more accurately calculate rates for the contribution of blue carbon resource provided by sea lochs in Scotland. The geographic location of the particular inshore MPA was used to define between “Mud” and “Sea Loch Mud”.

It should be noted that the substrate types derived from the biotope data do not reflect the complexity and heterogeneity of sediments that can be frequently observed in the scale of millimetres to metres and even on the sub-millimetre scale (Glud *et al*., 2009). However, given the spatial scale of the calculations required, the number of discrete sediment types for which reliable data could be obtained to a sufficient standard, the uncertainties inherent in sample collection methodology and the extrapolation procedures required for conversion of point data to the polygon and spatial scale, the potential error associated with microscale variation is relatively small (while often undeniably important on the local scale).

Additionally, it should be noted that the sediment classifications were made using the biotope categories for the simple reason that the sediment detail provided by the high resolution and geologically exacting British Geological Survey (BGS) seabed sediment map (DigSBS250) is often restricted in proximity to the coast, although it was applied on such occasions as merited by a lack of pre-existing polygon data and adequate spatial coverage of an MPA/SAC.

The range of the identified sediment types within the data set was large. These categories do not take into account the details of any geological analysis, instead focusing on grain size for a classification system concerned with the biota living on, and in, the sediment rather than the sediment *per se*. As a result, no account is taken in the classification system of the dominant materials. Whether the sediment is dominantly composed of carbonate from crushed shell material, or from weathering of nearby siliceous rock, for example, is not mentioned in the biotope classification system. Thus the possible range of carbon values for some sediment types will be high. For simplicity for this report the biotope classification is used which adheres to grain size as the principle sediment characteristic. Similarly, this report adheres to the information provided by the BGS inasmuch as it considers the top 10 cm of sediment burden in these calculations.

4.2.1 Rock

Coastal rock is a foundation on which many biological habitats are based. In the context of this report, the rock formations can be considered to be either coastal rock, dipping into the sea, or underwater exposures of rock kept clear of sediment either due to steepness or swept clear by strong underwater currents. While the rock often acts as a substrate on which many species can anchor, it provides little to no direct contribution to the blue carbon resource in Scotland's inshore MPA network. Due to its very nature, there is no carbon accumulation rate and therefore no net or gross contribution to blue carbon from the substrate in this case. Of course, there will be contribution from the biota living on the substrate, but this will be accounted for in the appropriate biological habitat.

4.2.2 Coarse grained sediments (gravel and sand, with or without a minor component of mud)

Gravel sediments in coastal areas of Scotland can often be described as being relict, with occasional reworking by modern processes (Howe *et al*., 2012). In effect, they represent the deposition from retreating glacial masses, and as such do not represent any current deposition features extant in Scotland in the present day. The exception is if they are proximal to riverine input from a large, vigorously flowing river or an area of rapid erosion of terrestrially derived material such as a coastal dune system. In essence gravels are considered relict re-worked glacial sediment or eroded bedrock (Howe *et al*., 2002, 2015). The variety of Scotland's terrestrial and coastal geology is remarkable, with a wide range of igneous, metamorphic and sedimentary rocks (Trewin, 2002), presumably covering a huge range of chemical constituents in a similarly large range of ratios.

However, there are many differences between the sands and gravels in coastal waters in Scotland. Some of these substrates are of biological origin, with a high component of biogenic carbonate. In particular these sediments are concentrated in the Inner Hebrides, the Hebridean Shelf, Orkney and Shetland, with a few notable examples on the east coast of Scotland such as the Ythan Estuary. These areas are notable for the carbonate-rich sands and gravels around rocky areas, with the sand consisting of fragments of biogenic shell material, such as bivalves, molluscs, echinoderms, worm tubes and foraminifer debris (Pantin, 1991). The precise ratios of shell fragments from these species are usually closely reflective of the species found in nearby communities.

4.2.3 Fine grained sediment (mud, with or without a minor component of sand or gravel)

Muddy sediments accumulate in sheltered coastal waters by the settlement of fine grained particles, such as organic detritus and clay minerals from the overlying water. Commonly areas of coastal mud within the photic zone play host to algal mats that help to stabilise the material. The algal mats also help to trap and retain fresh detritus, as well as acting as a source for organic carbon. The relative proportion of inorganic carbon and organic carbon in these sediments varies greatly, depending on the rate at which organic carbon is remineralised and recycled as carbon dioxide or buried within the sediment, and the rate at which carbonate containing phytoplankton are deposited as detritus. The relative importance of bioturbation by burrowing bivalves and other crustaceans in the sediment and a range of other factors also influence the inorganic carbon and organic carbon proportions within muddy sediments.

4.2.4 Sea loch mud

Sea loch mud is similar in its physical properties to fine grained sediment consisting mostly of fine grained particles of organic detritus and clay minerals. The submarine geomorphology of sea lochs means that they are excellent natural sediment traps. Large quantities of mud can be trapped within the sedimentary basins separated by sills within these sea lochs; it is not uncommon to find up to 30 m thickness of mud in these basins (Howe *et al.,* 2002; Baltzer *et al*., 2010; Cage & Austin 2010; Mokeddem *et al.,* 2010). The restrictive nature of sea lochs also results in a more depositional sedimentation regime, this combined with potentially high sedimentation rates (0.5-1 cm yr^{-1}) (Overnell & Young 1995; Howe *et al.*, 2010; Loh *et al*., 2010; Smith *et al*., 2015) makes these systems excellent at burying and storing carbon over long time periods on the scale of 10^3 years.

The proximity of sea lochs to the terrestrial environment results in mud that contains a greater amount of refractory organic material (OM) compared to more labile marine OM components (Loh *et al*., 2008). Since the terrestrial OM is more refractory it is believed that a greater amount will reach the sea bed resulting in the mud having significantly higher organic carbon values in comparison to coastal mud (Payne *et al.,* 1989; Loh *et al*., 2008; Smeaton *et al.,* 2016) derived from primary production.

4.3 Geological blue carbon values

The carbon values for all identified sediment types were collated after a careful examination of published literature based on sediments as proximal to the Scottish coast as possible, with only a small number of examples relating to information gained from Irish or English waters. Annex 2 catalogues the original literature sources. The data types listed below were extracted from the available literature.

- Total Organic Carbon, expressed as a percentage of sediment dry mass (%OC)
- Total Inorganic Carbon, expressed as a percentage of dry sediment mass (%IC)
- Organic Carbon Accumulation Rate (OC AR), expressed as g OC m^{-2} yr^{-1}
- Inorganic Carbon Accumulation Rate (IC AR), expressed as g IC m^{-2} yr^{-1}
- Sedimentation Accumulation Rate (SAR) expressed as cm yr^{-1}
- Dry Bulk Density of each sediment type, expressed as g cm^{-3}.

4.3.1 Data availability and quality

The availability of data was the most constraining factor for this study. Organic carbon data were sparse but there is a growing body of work in the literature. There is a reasonable selection of %OC data for sea loch muds (Payne *et al*., 1989; Loh *et al*., 2008; Russell *et al*., 2010; Smeaton *et al*., 2016). The number of organic carbon data sources for the remaining coastal ocean is far smaller with two studies focusing on high density sampling of small

areas of the coast (Thornton & McManus, 1994; Serpetti *et al.,* 2012) and a single study taking spot samples around Scotland (MEMG, 2004). This sparsity of OC data from the wider coastal ocean meant that our capacity to quantify and constrain estimates of carbon in the coastal sediment was reduced.

The availability of inorganic carbon data was poor for the coastal ocean with a single study having measured values (Smeaton *et al*., 2016) for a sea loch. To fill the gaps in these data the BGS Offshore Geoindex was used which has % carbonate data for all BGS samples listed. 1000 points from the Geoindex were selected from as close to the coast as possible and consisted of all listed geological substrates. The BGS data were reported as % $CaCO_3$. As only 12% of calcium carbonate ($CaCO_3$) is inorganic carbon, these values were adjusted appropriately. The BGS values do not account for the other forms of inorganic carbon, so it is expected that the total quantity of inorganic carbon in the sediment may have been underestimated. However, there were no other data for comparison besides the BGS %$CaCO_3$.

To calculate the net accumulation of carbon both sediment accumulation rates (SAR) and the carbon accumulation rate (CAR) were required. Though SARs were available for the different geological substrates in the literature there were only a few sites with associated CARs. Through assessing the combination of SAR and the sediments' physical properties, the organic carbon AR and inorganic AR for each geological substrate were calculated (see Annex 3). Though SAR were available; the methods (^{14}C, ^{210}Pb, and Sediment Traps) used to calculate them differ, each with advantages and disadvantages. The variance in SAR methodology combined with the large geographical variation in the data extracted from the literature resulted in high disparity between the rates for a particular geological substrate. As sedimentation is highly dependent on local environment conditions this is not unexpected, but caution must be applied as it is highly likely that using standard rates over the inshore MPA network will both under and overestimate (in different locations) net accumulation of carbon to the sea bed.

4.3.2 Carbon Values for Geological Substrate Type

Table 4.1 below summarises the geological blue carbon categories used within this study and the associated carbon values derived from the literature review.

Table 4.1 – Sediment types and relevant carbon values (SD refers to standard deviation)

Geological Substrate	**%OC**	**SD**	**%IC**	**SD**	**OC AR (g OC m^{-2} yr^{-1})**	**SD**	**IC AR (g IC m^{-2} yr^{-1})**	**SD**
Rock	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0
Gravel/Mud	1.13	0.82	3.09	1.84	18.65	3.40	23.07	12.39
Gravel/Sand	0.33	0.30	3.78	2.57	3.96	2.40	38.79	30.47
Sand	0.33	0.30	3.78	2.57	3.96	2.40	38.79	30.47
Sand/Mud	1.13	0.82	3.09	1.84	18.65	3.40	23.07	12.39
Sand/Mud/Gravel	1.13	0.82	3.09	1.84	18.65	3.40	23.07	12.39
Mud	2.35	1.53	2.03	1.47	42.26	20.50	16.35	15.66
Sea Loch Mud	2.47	1.43	0.92	0.46	87.60	56.40	29.84	14.92

4.4 Calculations

With the spatial extent of geological blue carbon categories mapped for each of the inshore MPA network locations, and carbon values defined from current literature sources (Table 4.1), the next step of the procedure involved quantifying the total carbon accumulation and total carbon stock of both organic carbon and inorganic carbon. Full protocols for the calculations can be found in Annex 4.

4.4.1 Annual carbon accumulation

To calculate the annual carbon accumulation (g yr^{-1}) at the sea bed, the area (m^2) of each geological blue carbon category was combined with the appropriate organic carbon AR and the inorganic carbon AR (g C m^{-2} yr^{-1}) values. All geological blue carbon categories within a given inshore MPA network location were combined to calculate the annual carbon accumulation.

4.4.2 Total carbon stocks

There were two options to calculate the total stock of carbon in the top 10 cm of the sediment. The first was to build upon the net annual accumulation calculations by computing the time period it would take to accumulate 10 cm of sediment, and then determining the mass of carbon in that 10 cm. However, this method fails to account for the significant variation in carbon accumulation rates for the same geological substrate type and the variability in the physical properties of the sediment. For example, differences in compaction, porosity and water content would result in an underestimation of the sedimentary stock of carbon.

The approach chosen to quantify the stock was based on volumetric and mass calculations. The geological spatial maps provided the area (m^2) of the different geological substrates within a given protected area. Multiplying the area by the depth of the sediment (0.1 m) gives the volume of sediment held within that geological substrate. To convert the sediment volume to a mass (kg), dry bulk density (kg m^{-3}) was integrated. Dry bulk density values (Flemming & Delafontaine, 2000; Smeaton *et al.*, 2016) were collated from the literature (see Annex 5), and using the %OC and %IC values for each geological blue carbon category, the total organic carbon and inorganic carbon held within the sediment was calculated. This volumetric and mass based approach avoided many of the problems associated with option one as by integrating bulk density into the calculation, the physical properties of the sediment were taken into consideration.

5. BLUE CARBON RESULTS OF SCOTLAND'S INSHORE MPA NETWORK

Once the entire area of each inshore MPA had been assigned to biological and geological blue carbon types as maps (see Annex 7), the total area of each habitat was calculated. These areal extent measurements were combined with the habitat-specific estimates of carbon stocks and rates per unit area (Tables 5.1 to 5.4) to give total stocks and rates of fixation of carbon (production of biological material for biological types) and sequestration (storage; for some biological and all sedimenting geological types) for organic and inorganic carbon (Annex 6). The values of these stocks and rates across the in shore MPAs are described in this section.

5.1 Carbon budget results

Totals for carbon present in living material, fixed and stored in each inshore MPA are presented in Annex 6. Here the values are also presented diagrammatically in Figures 5.1 to 5.8 and are briefly summarised before examination of detailed rankings (Section 5.2). Amounts of organic and inorganic carbon produced (fixed) and in stocks are also shown by the relative proportions in each habitat in each inshore MPA in Figures 5.5 to 5.8.

Patterns of biological stocks of total organic and inorganic carbon around the inshore MPAs were dominated by the patterns of inorganic carbon, (Figure 5.1) with a total of 5.79 Mt inorganic carbon stored across the network. SACs in the Sound of Arisaig (1.08 Mt IC), the Sound of Barra (0.98 Mt IC) and Luce Bay (0.40 Mt IC), and NC MPAs South Arran (1.16 Mt IC), Wester Ross (0.89 Mt IC) and Wyre and Rousay Sounds (0.44 Mt IC) were the top three in each type of conservation area. All these values were high because of the large extent of maerl beds in each conservation area (see also Figure 5.8). Extensive cold water coral reefs in the East Mingulay SAC, which contribute 0.18 Mt IC, were the next most important stores of inorganic carbon. *Modiolus* beds were a much less important contributor to inorganic carbon stocks.

In contrast to inorganic carbon (5.79 Mt), a much smaller value of 93 000 t organic carbon (0.09 Mt) were stored in living resources across the inshore MPA network, with most in kelp beds or intertidal algae (Figure 5.6). Of these stores, the five most important were the Sea of the Hebrides proposed NC MPA (28 000 t OC, but not included here), Sanday SAC (14 000 t OC), Sound of Barra (13 000 t OC), Luce Bay SAC (10 000 t OC), Wester Ross NC MPA (8 000 t OC) and Loch Sunart to the Sound of Jura NC MPA (7 500 t OC).

For geological blue carbon habitats, effectively the sediment stores, the totals for organic and inorganic carbon stored in the top 10cm of the sediment dwarf those held in living resources; 9.3 Mt of organic carbon and 42.0 Mt inorganic carbon were estimated as stored across the inshore MPA network. Patterns among the totals in NC MPAs and SACs were similar for organic and inorganic carbon and scaled directly to the area of the conservation areas (Figure 5.2), reflecting the similar proportions of carbon of each type and the similarity of rates of sequestration and stocks across the network. For NC MPAs, the largest stocks were in the proposed Southern Trench (2 487 km^2, 1.88 Mt OC, 11.5 Mt IC), Northeast Lewis (884 km^2, 0.71 Mt OC, 4.0 Mt IC) and Clyde Sea Sill (712 km^2, 0.46 Mt OC, 3.5 Mt IC). For SACs, the most important stocks in sediment stores were in the Moray Firth (1 513 km^2, 1.31 Mt OC, 6.0 Mt IC), Luce Bay (478 km^2, 0.29 Mt OC, 2.3 Mt IC) and in the Solway Firth (373 km^2, 0.24 Mt OC, 2.0 Mt IC).

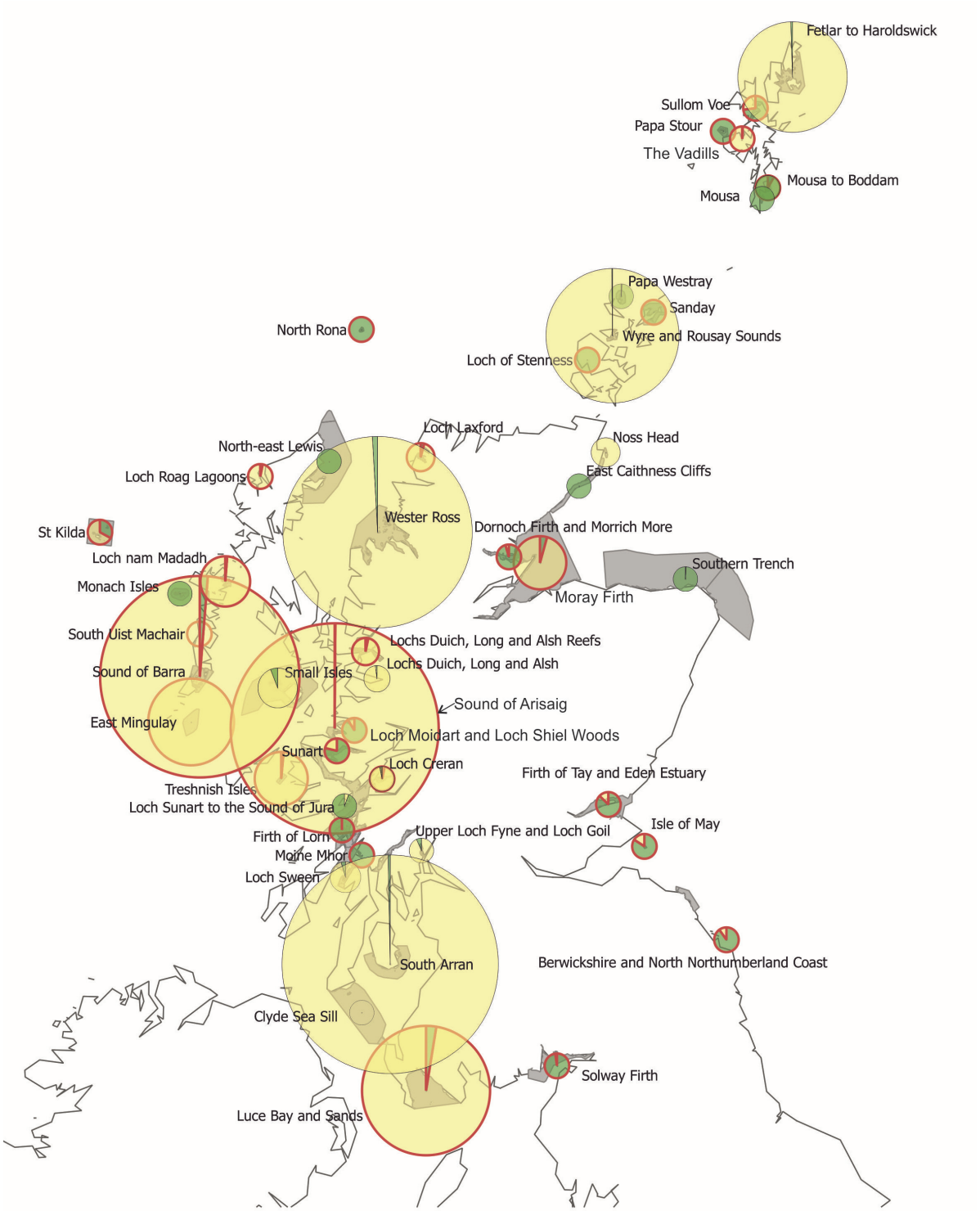

Figure 5.1 – Summary of biological blue carbon stocks in relevant habitats. Pie charts show the relative proportions of biological organic (green) and inorganic (yellow) blue carbon stocks, with their size scaled to the total carbon stored by each inshore MPA to a maximum 1 172 000 t (South Arran). Charts for SACs are outlined in red here and in Figs. 5.2 to 5.8. (Coastline derived from GEBCO Digital Atlas)

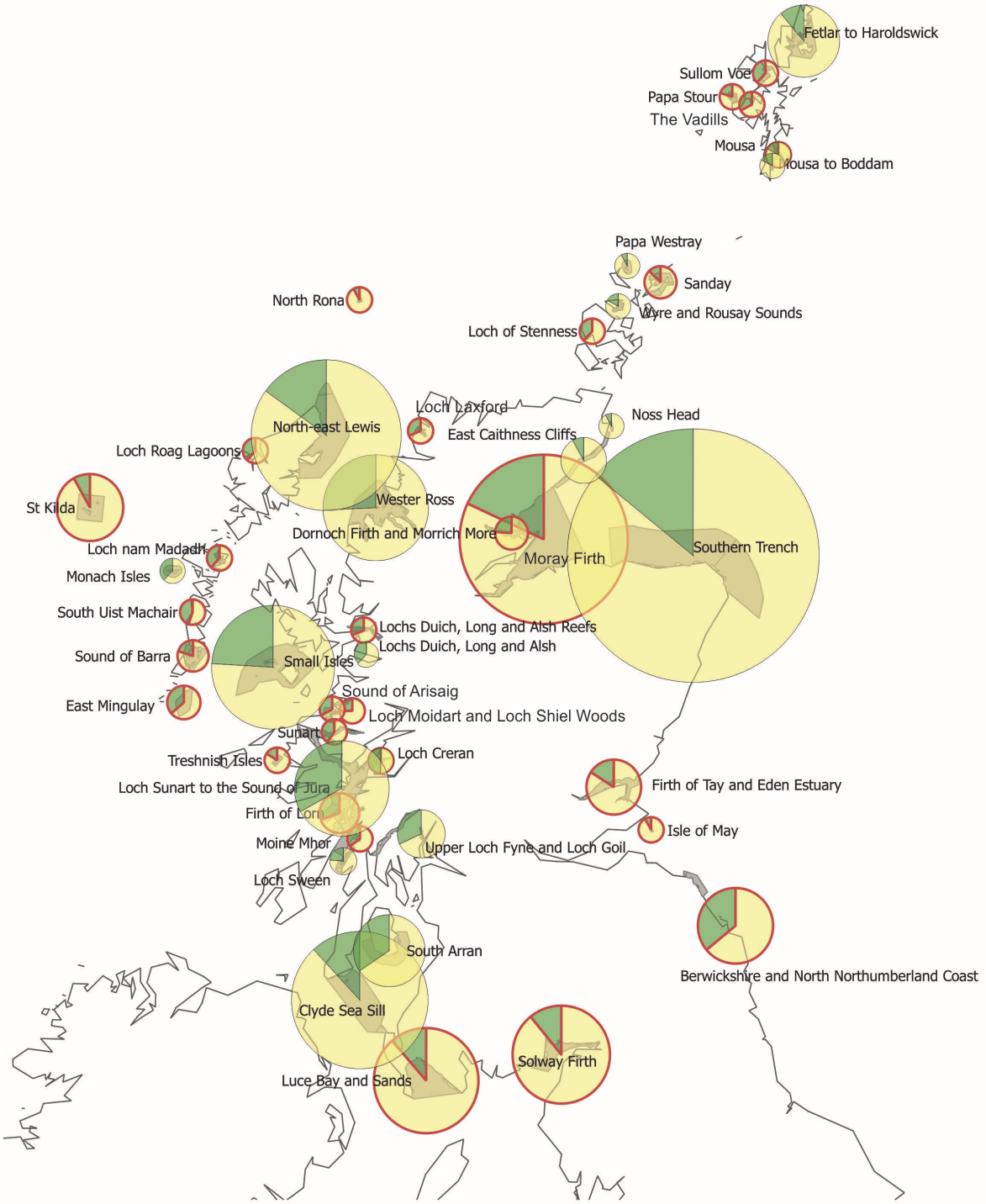

Figure 5.2 – Summary of geological blue carbon stocks in relevant sediment types. Pie charts show the relative proportions of geological organic (green) and inorganic (yellow) stocks in sediment types, with the area of circles scaled to the total carbon stored by each inshore MPA to a maximum of 13.5 Mt (Southern Trench). (Coastline derived from GEBCO Digital Atlas)

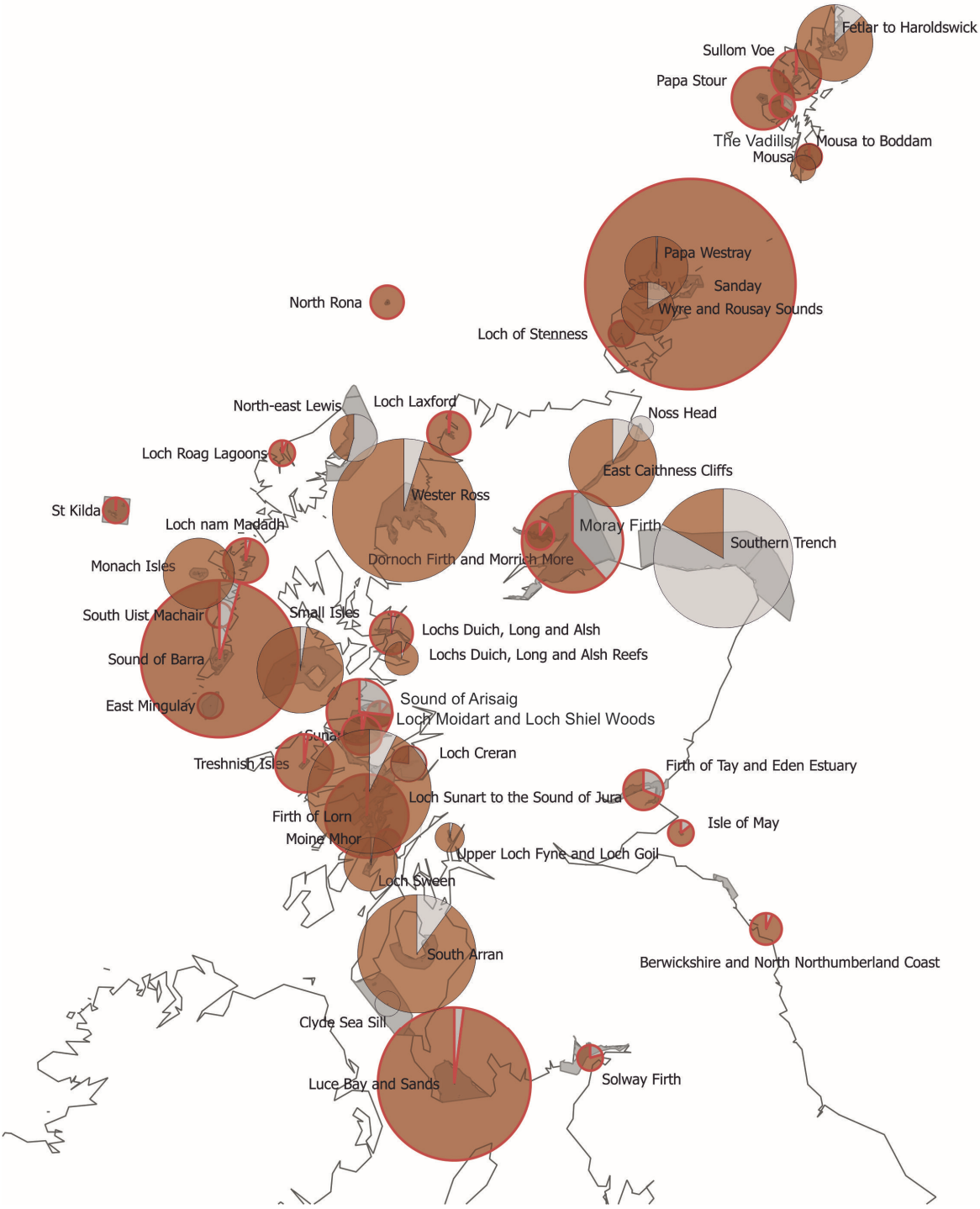

Figure 5.3 – Summary of biological blue carbon production in relevant habitats. Pie charts show the relative proportions of the production of biological organic (brown) and inorganic (grey) blue carbon, with the area of circles scaled to the total carbon produced by each inshore MPA, to a maximum of 50 000t (Sanday). (Coastline derived from GEBCO Digital Atlas)

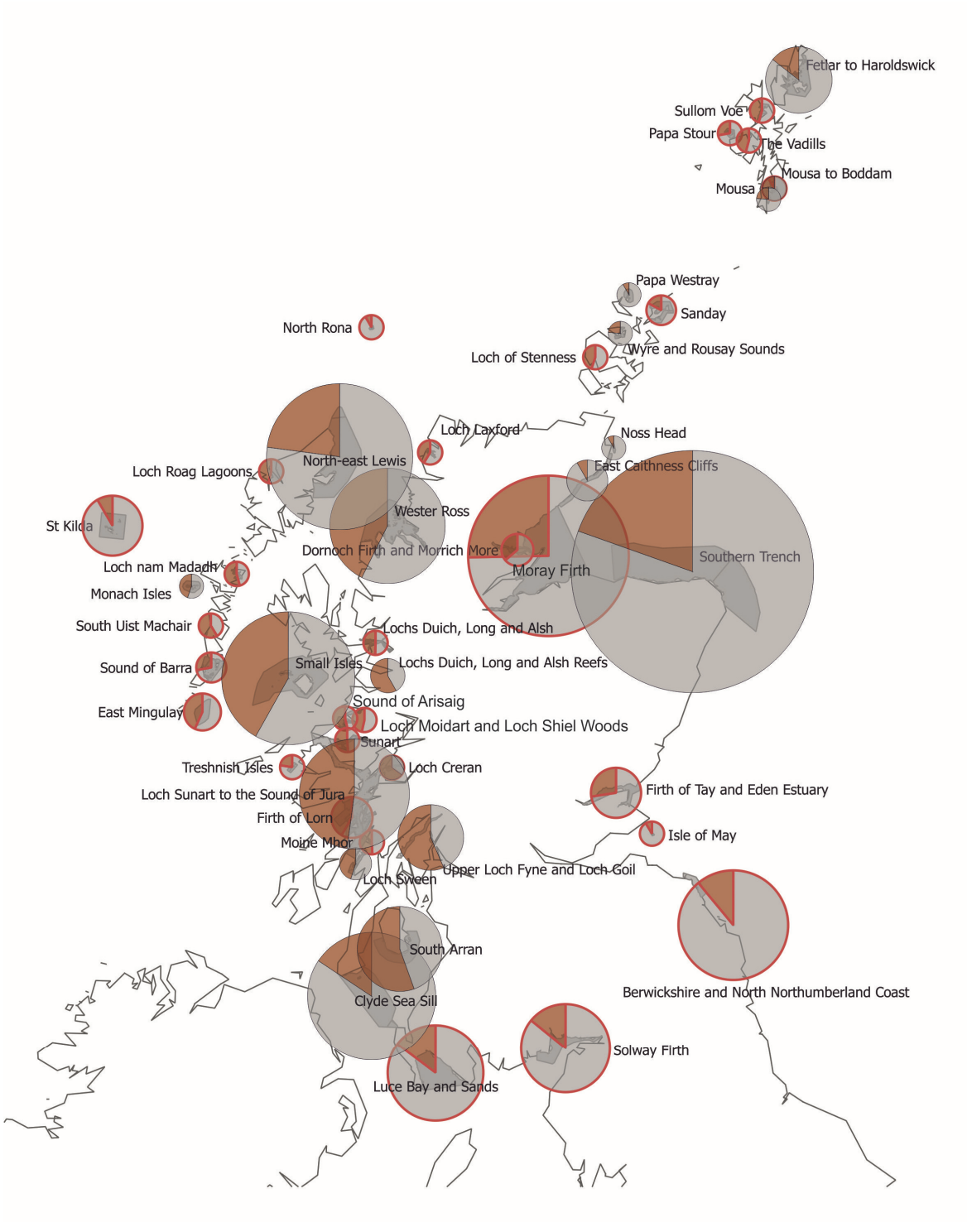

Figure 5.4 – Summary of geological carbon sequestration in relevant sediment types. Pie charts show the relative proportions of the production of geological organic (brown) and inorganic (grey) carbon, with the area of circles scaled to the total carbon sequestered by each inshore MPA to a maximum of 111 000t (Southern Trench). (Coastline derived from GEBCO Digital Atlas)

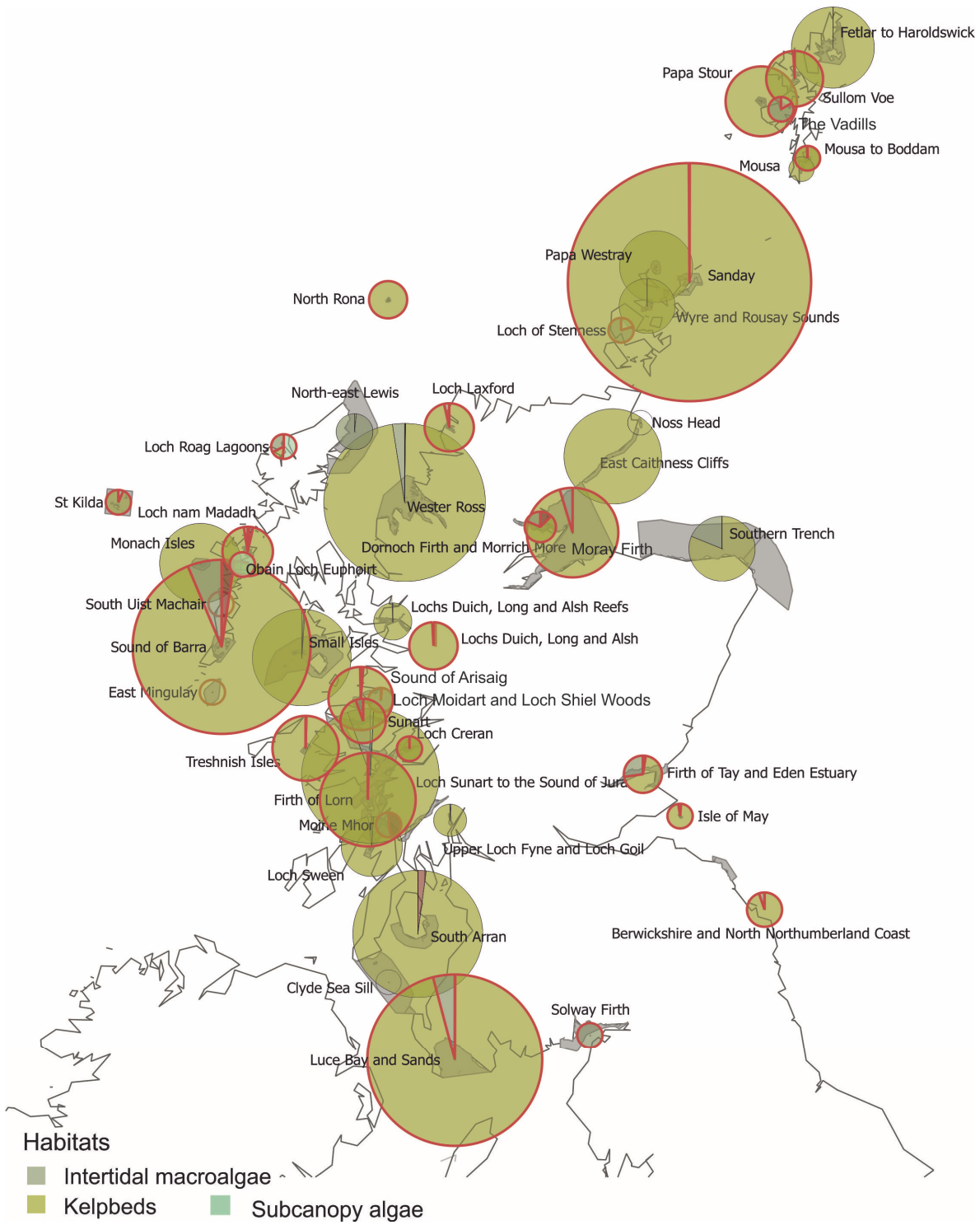

Figure 5.5 – Summary of biological organic carbon production in relevant habitats. Pie charts show the relative contribution of each habitat type to biological organic carbon production within each MPA and SAC, with the area of circles scaled to the total organic carbon produced in each inshore MPA to a maximum 50 000t yr^{-1}, (Sanday). (Coastline derived from GEBCO Digital Atlas)

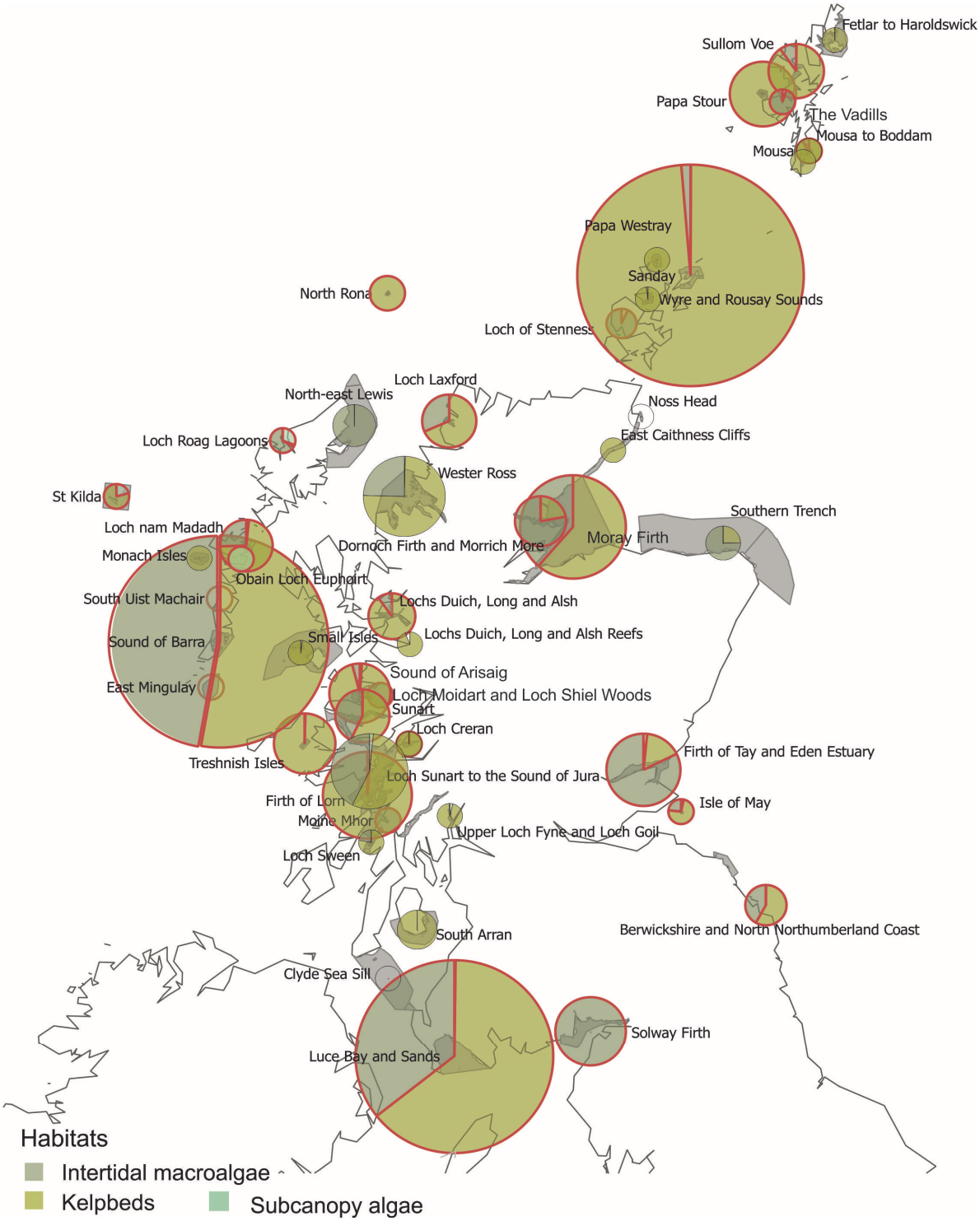

Figure 5.6 – Summary of biological organic carbon stocks in relevant habitats. Pie charts show the relative contribution of each habitat type to biological organic carbon stocks within each MPA and SAC, with areas of circles scaled to the total organic carbon stock in each inshore MPA, from a minimum of zero (shown as empty circles) to a maximum value of 13 800t (Sanday). (Coastline derived from GEBCO Digital Atlas)

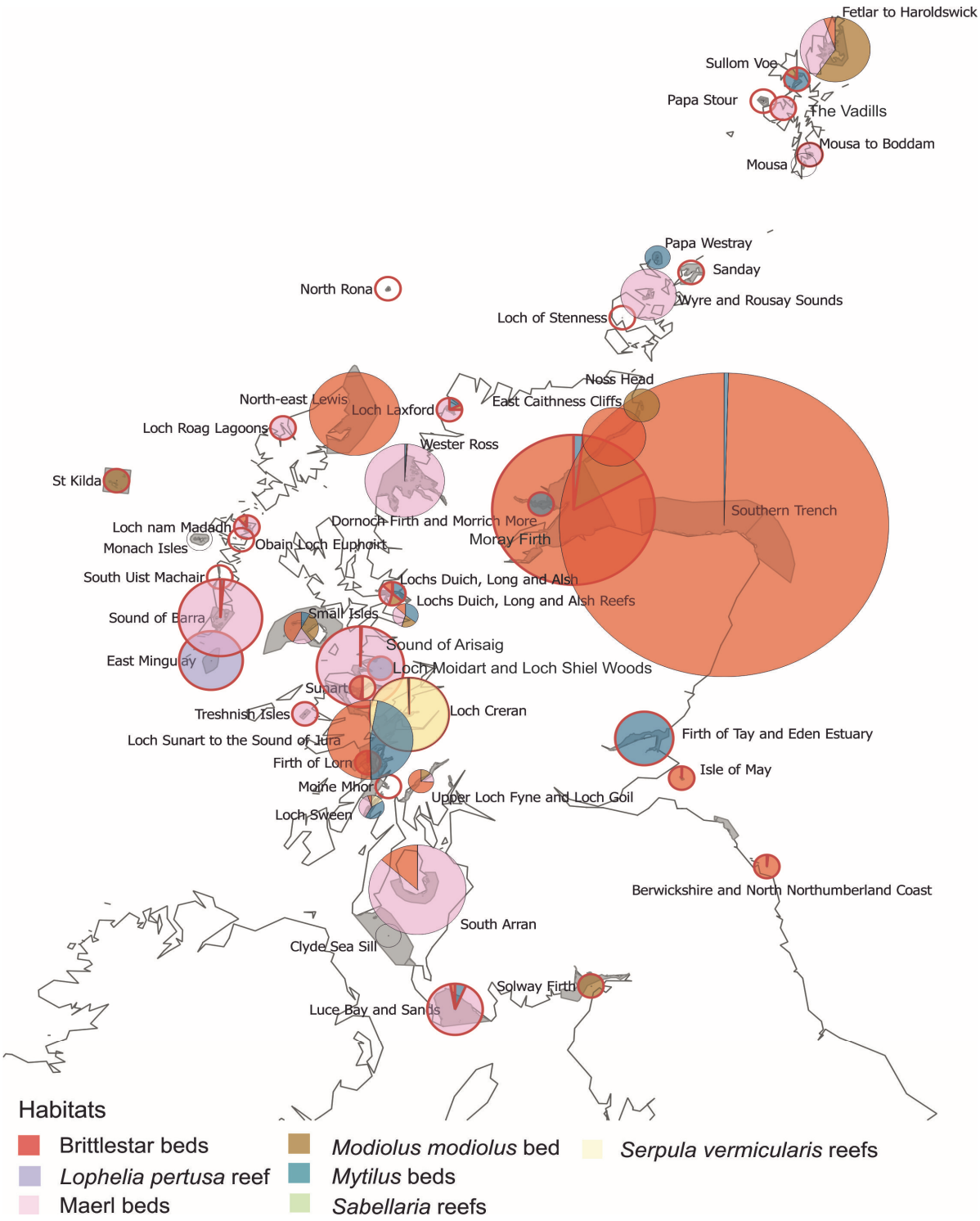

Figure 5.7 – Summary of biological inorganic carbon production in relevant habitats. Pie charts show the relative contribution of each habitat type to biological inorganic carbon production within each MPA and SAC, with the area of circles scaled to the total inorganic carbon produced in each inshore MPA to a maximum 18 250 t yr^{-1}, (Southern Trench). (Coastline derived from GEBCO Digital Atlas)

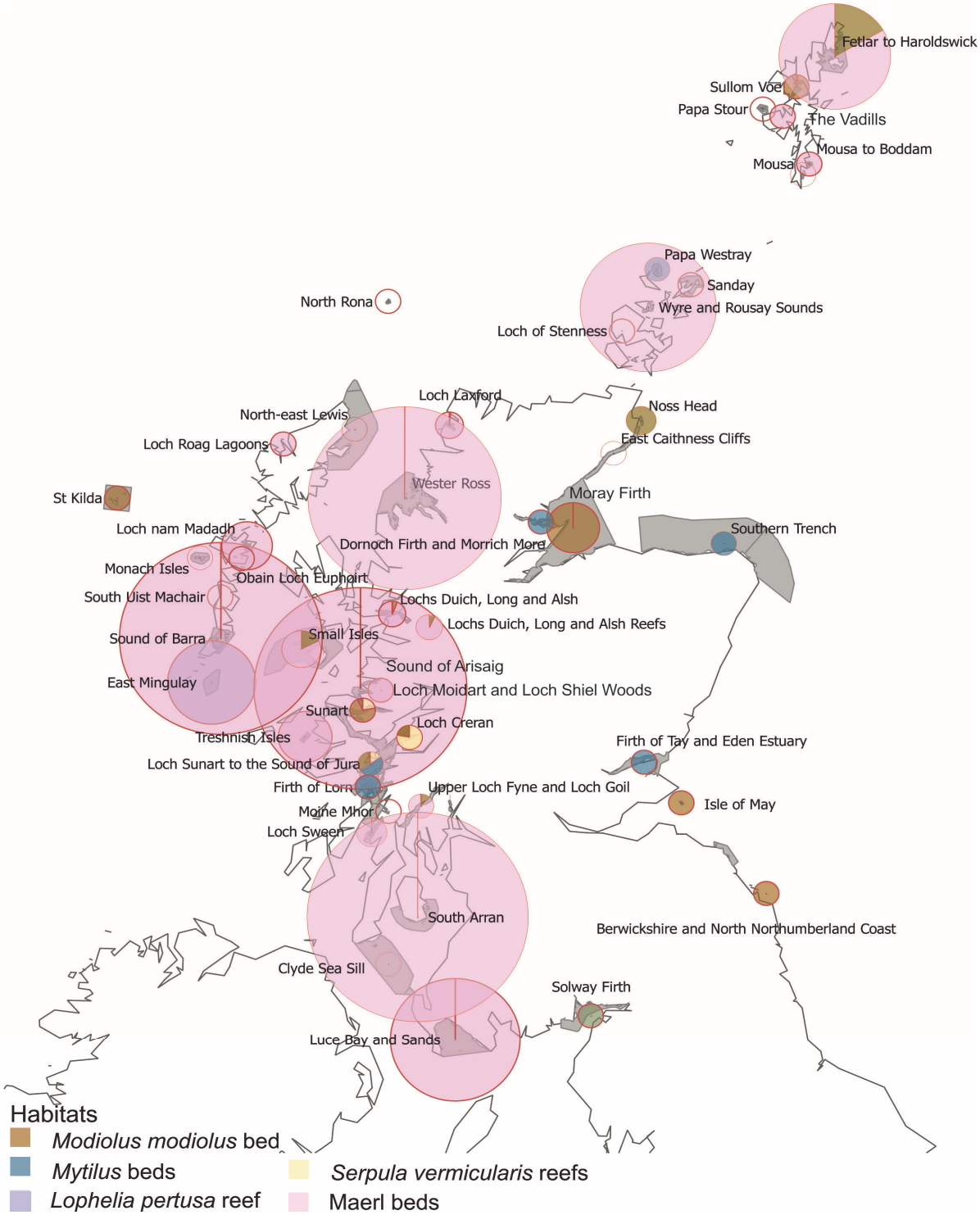

Figure 5.8 – Summary of biological inorganic carbon stocks in relevant habitats. Pie charts show the relative contribution of each habitat type to biological inorganic carbon stocks within each MPA and SAC, with the area of circles scaled to the total inorganic carbon stock in each inshore MPA to a maximum 1 168 000 t (South Arran). (Coastline derived from GEBCO Digital Atlas)

Total production in blue carbon biological habitats, in contrast to stocks, was dominated by organic carbon, with 249,000 t OC produced compared to 36 000 t IC per year (Figure 5.3). Inshore MPAs with extensive kelp beds were the most productive (Figures 5.5, 5.6), with Sanday (73 km^2 kelp, 50 000 t OC yr^{-1}), Luce Bay (36 km^2 kelp, 26 000 t OC yr^{-1}) and Sound of Barra (36 km^2 kelp, 27 000 t OC yr^{-1}). For inorganic production (Figure 5.7), maerl beds were near the top of the rankings in the Sound of Arisaig (17.3 km^2, 1 290 t IC yr^{-1}) and Sound of Barra (15.7 km^2, 1 178 t IC yr^{-1}), but the largest quantity of inorganic carbon sequestered per year was in the Southern Trench SAC with 18 250 t IC yr^{-1} over 2487 km^2.

The total estimated sequestration of carbon in inshore MPAs was 126,000 t OC and 348,000 t IC per year. The pattern was very similar to that of stocks and was again directly related to the extent of each area. Most carbon was sequestered in the largest inshore MPAs: the Southern Trench, Moray Firth, Solway Firth, Northeast Lewis and Berwickshire and North Northumberland areas (Figure 5.4).

Table 5.1 – Summary of the biological organic carbon (OC) and inorganic carbon (IC) values measured in the NC MPAs investigated (The values represent the sum of all the different biotopes outlined in Figure 2.2 found at each site).

NC MPA Name	Standing stock OC (t)	Production OC (t yr^{-1})	Sequestration OC (t yr^{-1})	Standing stock IC (t)	Production IC (t yr^{-1})
Clyde Sea Sill	0	0	0	0	0
East Caithness Cliffs	2 201	8 034	0	0	685
Fetlar to Haroldswick	1 600	5 832	0	297 937	835
Loch Sunart to the Sound of Jura	7 391	16 049	7	437	1 244
Loch Sween	1 091	3 189	10	22 545	73
Lochs Duich, Long and Alsh	357	1 228	0	16 892	58
Monach Isles	1 553	5 667	0	0	0
Mousa to Boddam	106	387	0	0	0
North-east Lewis	4 110	1 150	0	0	1 374
Noss Head	0	0	0	21 514	215
Papa Westray	1 234	4 504	0	13	33
Small Isles	2 282	8 246	15	36 487	200
South Arran	3 827	14 242	92	1 167 774	1 598
Southern Trench	3 361	3 721	0	30	18 250
Upper Loch Fyne and Loch Goil	265	933	0	3 672	30
Wester Ross	7 862	22 114	6	891 678	1 069
Wyre and Rousay Sounds	747	2 669	0	442 291	524

Table 5.2 – Summary of the biological organic carbon (OC) and inorganic carbon (IC) values measured in the SACs investigated (The values represent the sum of all the different biotopes outlined in Figure 2.2 found at each site).

SAC Name	Standing stock OC (t)	Production OC (t yr^{-1})	Sequestration OC (t yr^{-1})	Standing stock IC (t)	Production IC (t yr^{-1})
Berwickshire and North Northumberland Coast	467	1 044	0	51	74
Dornoch Firth and Morrich More	709	824	32	35	91
East Mingulay	0	0	0	184 589	689
Firth of Lorn	2 148	7 777	0	1	65
Firth of Tay and Eden Estuary	1 482	1 237	2	219	568
Isle of May	46	126	0	9	21
Loch Creran	86	313	0	2 506	1 055
Loch Laxford	798	2 063	0	18 592	29
Loch Moidart and Loch Shiel Woods	30	8	0	3	1
Loch nam Madadh	761	2 155	20	61 307	83
Loch Roag Lagoons	6	4	0	198	0
Loch of Stenness	249	80	0	0	0
Lochs Duich, Long and Alsh Reefs	600	1 987	0	17 813	60
Luce Bay and Sands	10 555	25 791	0	400 715	523
Moine Mhor	149	77	11	0	0
Monach Islands	1 080	3 942	0	0	0
Moray Firth	3 031	7 110	0	66 877	4 448
Mousa	154	513	0	1 742	2
North Rona	340	1 241	0	0	0
Obain Loch Euphoirt	65	205	0	0	0
Papa Stour	1 183	4 318	0	0	0
Sanday	13 843	49 894	0	0	0
Solway Firth	1 350	373	0	32	97
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	1 004	3 533	11	1 082 865	1 290
Sound of Barra	12 680	26 648	191	980 519	1 178
South Uist Machair	0	0	0	0	0
St Kilda	115	357	0	236	2
Sullom Voe	830	2 754	0	307	18
Sunart/Loch Sunart MPA	796	1 754	0	217	52
The Vadills	12	4	0	1 626	2
Treshnish Isles	1 018	3 716	3	69 444	82

Table 5.3 – Summary of the geological organic carbon (OC) and inorganic carbon (IC) values measured in the NC MPAs investigated

NC MPA Name	Stock OC (t)	Sequestration OC (t yr^{-1})	Stock IC (t)	Production IC (t yr^{-1})
Clyde Sea Sill	465 909	4 868	3 474 130	26 278
East Caithness Cliffs	35 662	267	408 752	2 947
Fetlar to Haroldswick	120 467	1 216	964 230	7 222
Loch Sunart to the Sound of Jura	630 915	10 961	1 273 676	11 945
Loch Sween	36 084	881	116 488	1 073
Lochs Duich, Long and Alsh	49 257	1 326	80 111	955
Monach Isles	4 245	63	6 920	77
Mousa to Boddam	7 745	96	37 202	302
North-east Lewis	711 131	9 271	4 023 325	31 160
Noss Head	3 906	29	44 768	323
Papa Westray	9 578	72	109 659	791
Small Isles	769 965	14 034	2 428 121	19 479
South Arran	373 208	7 599	709 238	6 092
Southern Trench	1 883 175	21 729	11 474 976	89 293
Upper Loch Fyne and Loch Goil	156 096	4 653	332 011	3 586
Wester Ross	605 823	10 786	1 749 297	14 489
Wyre and Rousay Sounds	12 499	154	61 370	496

Table 5.4 – Summary of the geological organic carbon (OC) and inorganic carbon (IC) values measured in the SACs investigated

SAC Name	Stock OC (t)	Sequestration OC (t yr^{-1})	Stock IC (t)	Production IC (t yr^{-1})
Berwickshire and North Northumberland Coast	671 903	2 807	1 194 982	22 729
Dornoch Firth and Morrich More	72 522	1 124	231 527	1 977
East Mingulay	135 071	1 997	236 943	2 620
Firth of Lorn	147 284	2 282	336 549	3 202
Firth of Tay and Eden Estuary	119 352	1 816	631 261	4 798
Isle of May	424	3	4,742	34
Loch Creran	19 132	552	19 464	297
Loch Laxford	8 068	126	17 717	178
Loch Moidart and Loch Shiel Woods	3 160	77	9 442	89
Loch nam Madadh	17 285	382	27 708	324
Loch Roag Lagoons	284	4	450	5
Loch of Stenness	9 452	140	15 357	172
Lochs Duich, Long and Alsh Reefs	21 788	485	47 643	493
Luce Bay and Sands	294 403	2 997	2 303 211	17 312
Moine Mhor	3 134	57	5 835	55
Monach Islands	5 299	78	8 637	97
Moray Firth	1312 043	16 579	5 952 871	48 876
Mousa	1 225	9	13 822	100
North Rona	19	0	213	2
Obain Loch Euphoirt	2 338	36	3 624	40
Papa Stour	2 168	28	8 642	73
Sanday	31 253	339	216 462	1 654
Solway Firth	244 659	2 461	2 003 090	14 947
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	47 656	1 194	95 467	1 034
Sound of Barra	51 929	676	206 190	1 743
South Uist Machair	1 985	37	2 444	26
St Kilda	82 597	624	940 919	6 788
Sullom Voe	29 581	444	47 525	530
Sunart/Loch Sunart MPA	47 673	877	70 352	837
The Vadills	311	6	634	7
Treshnish Isles	7 592	92	39 545	316

5.2 Inshore MPA rankings

Using the results as detailed in section 5.1 above, the inshore MPAs have been ranked in various ways to highlight the extent to which different protected areas contribute to the blue carbon resource of the inshore MPA network. Full tables of the inshore MPAs rankings can be found in Annex 6, and include rankings of carbon budget per area, and rankings standardised by the geographical area (km^2) of each location.

Table 5.5 summarises the top ten inshore MPAs in terms of total carbon (TC) stock standardised by area (km^2). The total carbon is a sum of the inorganic carbon and organic carbon for both the biological and geological blue carbon categories. Wyre and Rousay Sounds NC MPA contained the highest amount of total carbon stock per unit area (~31 000 t km^{-2}), dominated by the inorganic carbon content found in the maerl beds that cover a significant proportion of theNC MPA.

Table 5.5 – Ranking for total carbon (TC) stocks (a sum of the inorganic carbon (IC) and organic carbon (OC) for both the biological and geological categories) standardised by area km^2

Inshore MPA name	Stock TC ($t\ km^{-2}$)	Ranking TC ($t\ km^{-2}$)
Wyre and Rousay Sounds MPA	31 232	1
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC	27 211	2
Sound of Barra SAC	10 116	3
Noss Head MPA	9 316	4
South Arran MPA	8 046	5
Fetlar to Haroldswick MPA	6 648	6
Treshnish Isles SAC	6 363	7
Loch nam Madadh SAC	6 312	8
Luce Bay and Sands SAC	6 301	9
Solway Firth SAC	6 030	10

Within the top ranked inshore MPAs for total carbon stock standardised by area, four out of the top five all contain maerl beds. This highlights that maerl beds play an important role in contributing to a high inorganic carbon stock. In general, the highest ranked inshore MPAs were those with smaller geographical areas, but with focused, discrete protected features. The data available typically covered the entirety, or at least a significant proportion, of these areas, providing high confidence in the carbon predictions (Biological assumptions used in this study can be found in Annex 1 and Section 3.2).

Despite the dominance of the smaller NC MPAs/SACs in the top ranking levels, a number of them are also in the top ten ranking without standardisation by area (Table 5.6), perhaps suggesting a bias to smaller designations as the data are easier to collect, so is more detailed, providing robust carbon estimates. However, Southern Trench is the largest inshore MPA, so not surprisingly it contains the most carbon (see Table 5.6).

Table 5.6 – Ranking for total carbon (TC) stock (a sum of the inorganic carbon (IC) and organic carbon (OC) for both the biological and geological categories)

Inshore MPA name	Stock TC (t)	Ranking TC (t)
Southern Trench pMPA	13 361 542	**1**
Moray Firth SAC	7 334 821	**2**
North-east Lewis pMPA	4 738 566	**3**
Clyde Sea Sill MPA	3 940 039	**4**
Wester Ross MPA	3 254 660	**5**
Small Isles MPA	3 236 855	**6**
Luce Bay and Sands SAC	3 008 884	**7**
South Arran MPA	2 254 047	**8**
Solway Firth SAC	2 249 131	**9**
Loch Sunart to the Sound of Jura MPA	1 912 419	**10**

Rankings have also been split into organic carbon and inorganic carbon for both biology (Tables 5.7 and 5.8) and geology (Tables 5.9 and 5.10) within each designation, standardised by area.

Table 5.7 – Ranking for organic carbon (OC) standing stocks: Biology

Inshore MPA name	Standing stock OC (t)	Standing stock OC (t km^{-2})	Ranking OC (t km^{-2})
Sanday SAC	13 843	127	**1**
Sound of Barra SAC	12 680	102	**2**
North Rona SAC	340	68	**3**
Loch Laxford SAC	798	67	**4**
Moine Mhor SAC	149	59	**5**
Papa Stour SAC	1 183	57	**6**
Treshnish Isles SAC	1 018	55	**7**
Wyre and Rousay Sounds MPA	747	45	**8**
Loch nam Madadh SAC	761	44	**9**
Papa Westray MPA	1 234	37	**10**

The organic carbon biology rankings are dominated by the smaller inshore MPAs that contain kelp beds and seagrass (Table 5.7), whilst the inorganic carbon rankings are dominated by maerl (Table 5.8), particularly in the top four, and this is reflected in the overall rankings (see Table 5.5 and 5.6).

Table 5.8 – Ranking for inorganic carbon (IC) standing stocks: Biology

Inshore MPA name	**Standing stock IC (t)**	**Standing stock IC (t km^{-2})**	**Ranking IC (t km^{-2})**
Wyre and Rousay Sounds MPA	442 291	26 643	**1**
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC	1 082 865	24 032	**2**
Sound of Barra SAC	980 519	7 911	**3**
South Arran MPA	1 167 774	4 163	**4**
Treshnish Isles SAC	69 444	3 767	**5**
Loch nam Madadh SAC	61 307	3 448	**6**
The Vadilis SAC	1 626	3 077	**7**
Noss Head MPA	21 514	2 856	**8**
East Mingulay SAC	184 589	1 604	**9**
Loch Laxford SAC	18 592	1 578	**10**

The organic carbon rankings for geological habitats are dominated by relatively small inshore MPAs, and are covered by extensive areas of mud, sand, gravel, or a mixture of the two (Table 5.9). Upper Loch Fyne and Loch Goil, is one of the largest inshore MPAs in this ranking, and ranked second, is dominated by an extensive muddy sediment area covering >60% of the total area, where much of the organic carbon is sequestered. In contrast, the inorganic carbon rankings (Table 5.10) are dominated by much larger inshore MPAs, with the exception of Noss Head NC MPA (8 km^2) ranked top, and Loch Moidart and Loch Shiel Woods SAC (3 km^2), ranked tenth. Most of these designations contain widespread expanses of sandy sediment and gravel.

Table 5.9 – Ranking for organic carbon (OC) stocks: Geology

Inshore MPA name	Stock OC (t)	Stock OC (t km^{-2})	Ranking OC (t km^{-2})
Loch Creran SAC	19 132	1 580	**1**
Upper Loch Fyne and Loch Goil MPA	156 096	1 504	**2**
Lochs Duich, Long and Alsh MPA	49 257	1 357	**3**
South Arran MPA	373 208	1 334	**4**
Moine Mhor SAC	3 134	1 224	**5**
Loch Moidart and Loch Shiel Woods SAC	3 160	1 206	**6**
Loch of Stenness SAC	9 452	1 193	**7**
Sullom Voe SAC	29 581	1 181	**8**
Dornoch Firth and Morrich More SAC	135 071	1 173	**9**
Loch Roag Lagoons SAC	284	1 065	**10**

Table 5.10 – Ranking for inorganic carbon (IC) stocks: Geology

Inshore MPA name	Stock IC (t)	Stock OC (t km^{-2})	Ranking IC (t km^{-2})
Noss Head MPA	44 768	5 942	**1**
Solway Firth SAC	2 003 090	5 370	**2**
Clyde Sea Sill MPA	3 474 130	4 880	**3**
Luce Bay and Sands SAC	2 303 211	4 823	**4**
Fetlar to Haroldswick MPA	964 230	4 666	**5**
Southern Trench pMPA	11 474 976	4 615	**6**
North-east Lewis pMPA	4,023,325	4 553	**7**
Firth of Tay and Eden Estuary SAC	631 261	4 197	**8**
Moray Firth SAC	5 952 871	3 936	**9**
St Kilda SAC	940 919	3 824	**10**

Overall, maerl beds are the blue carbon biological habitat, which contain the most significant inorganic carbon stores, whilst the geology is dominated by mud for organic carbon and sand/gravel/mixture of sediments for inorganic carbon stores.

5.3 Confidence and uncertainty

5.3.1 Confidence and uncertainty

The terms confidence and uncertainty are used here as per the recent Fifth Assessment of the IPCC (IPCC, 2013)[2]. The level of confidence in the estimates of the blue carbon stocks, rates of carbon production and sequestration delivered by each inshore MPA depends on uncertainty in the estimation of the spatial extent of blue carbon features, and uncertainty in the values for habitat-specific blue carbon stocks and rates of carbon production and sequestrationper unit area. Uncertainty in estimation of spatial extent was derived from the sources of data and the method used to produce GIS polygon files that represent the areas.

5.3.2 Confidence maps

Two types of confidence maps are presented here. The first type takes the level of confidence from the sources of data and the method used to assign areas to blue carbon categories, and reflects the priority of data used in map making (Section 2.1). Using this approach (Figure 5.9), the highest confidence (level 1) was given to data derived from maps produced with the expressed intention of defining habitat extent (i.e. data provided by SNH for this project in shapefile gemshabitatpolygons.shp). Medium confidence (level 2) was assigned to mapped data produced at a coarser scale than that needed for assignment of habitats at the scale of inshore MPAs, mostly represented by the BGS 1:250,000 superficial sediments data and that derived from other sources such as the HI1354 sediment map of the Firth of Lorn. The lowest level of confidence (level 3) was given to maps derived by assigning areas to the nearest point data source from marine surveys, recorded within Marine Recorder.

In some places, particularly the well-surveyed areas of some inshore MPAs, the level of confidence in level 3 areas may be such that confidence effectively exceeds that in levels 1 and 2. The effects of high density point sampling can be seen in the second type of confidence map, presented as a subset of the low-confidence (level 3) type data as defined above. In this map (Figure 5.10), confidence was inversely related to the size of the Voronoi polygons associated with each blue carbon category. Small polygons were produced by closely spaced survey sampling points and, where many surveys existed within a given protected area, the overall size of these Voronoi polygons was smaller and therefore confidence that the point surveys represented the prevailing habitat within the polygons was higher.

Spatial patterns of confidence in the data were evident from Figure 5.9 and Figure 5.10. High confidence in the source of data was generally in those places already mapped for habitats; namely inside those protected areas where survey efforts have been focused and across the shelf where a decision has been made to adopt BGS data as the mapping standard. Medium confidence mapped data sources were present usually up to 30-50 km offshore, but not immediately adjacent to the coast, reflecting the extent of the BGS sediment data layer. Low confidence areas were generally close inshore, and offshore beyond the range of the BGS data. Within this latter low-confidence source data, confidence increased as the density of survey sampling points increased in an area, as shown in Figure 5.10.

[2] "All three IPCC Working Groups in the AR5 have agreed to use two metrics for communicating the degree of certainty in key findings • Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g. data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement. Confidence is expressed qualitatively. • Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgement)."

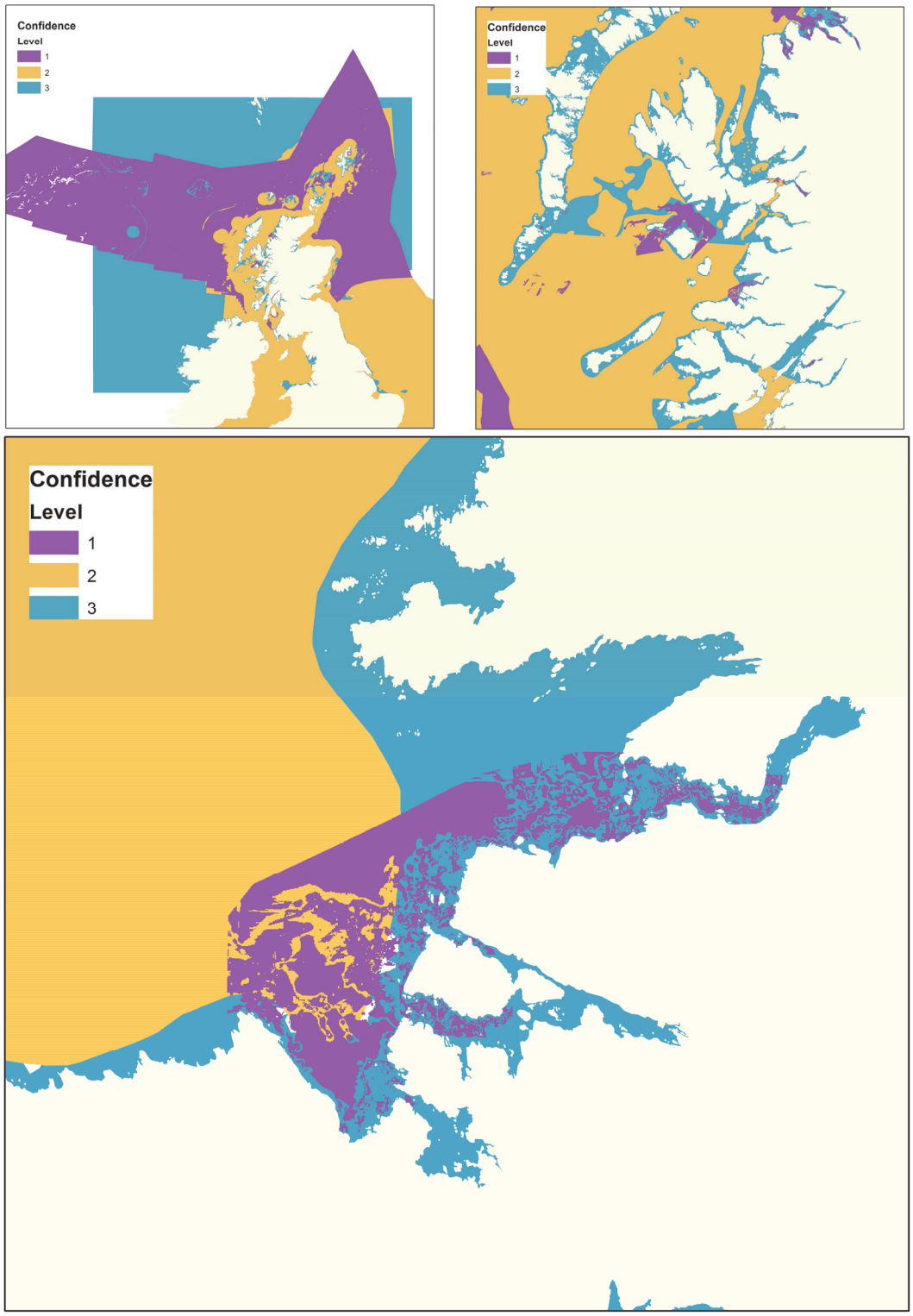

Figure 5.9 – Confidence maps of the habitat extent estimates for blue carbon biology and geology categories based on data sources and methods. High confidence (level 1, purple) was assigned to those areas derived from direct mapping of the seabed by SNH. Medium confidence (level 2, orange) was ascribed to mapped areas where data were collected by third parties at scales larger than the intended purpose, primarily BGS 1:250 000 superficial sediments. Low confidence (level 3, blue) was ascribed to those areas estimated from the nearest survey point. (Coastline derived from GEBCO Digital Atlas)

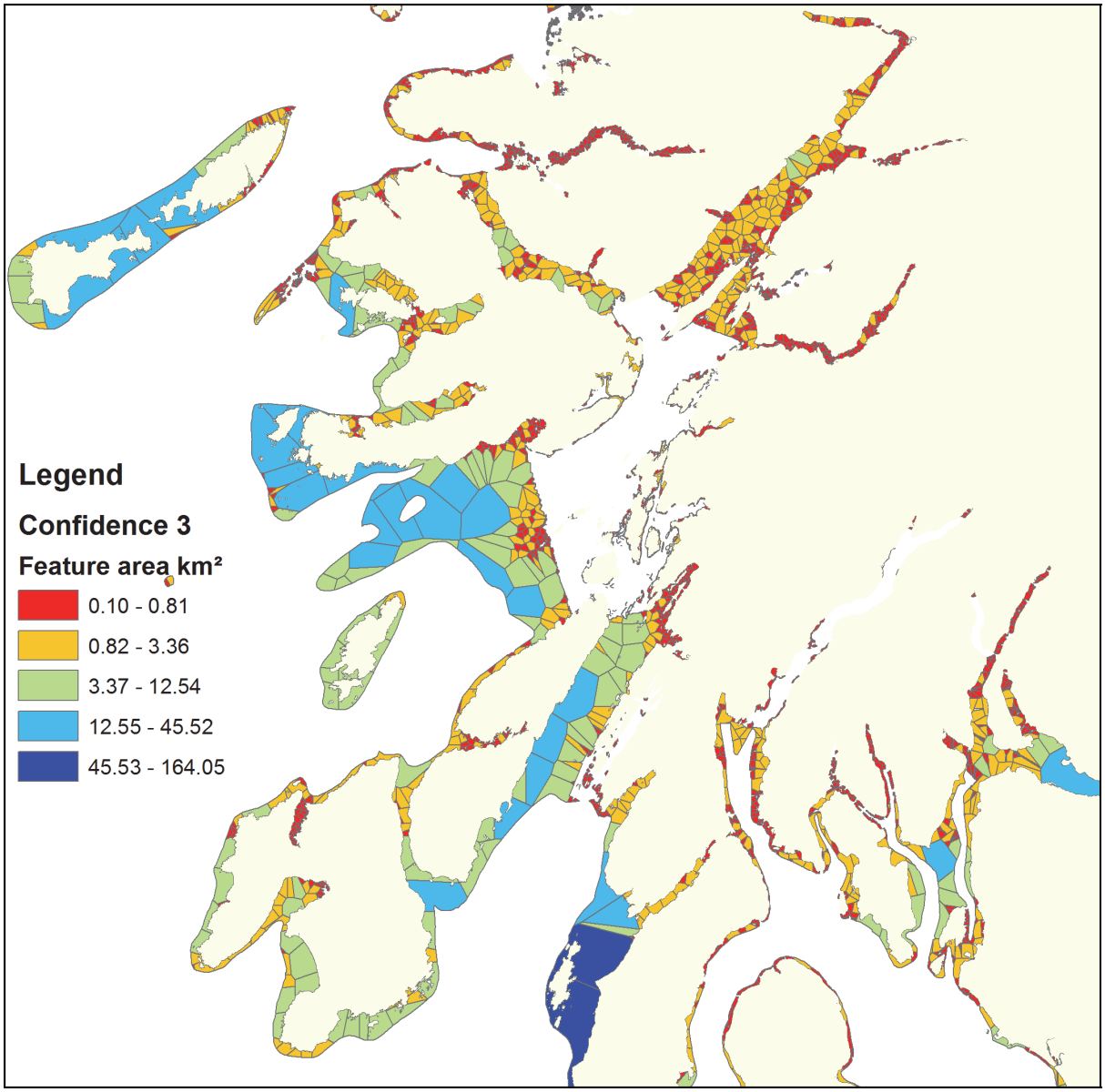

Figure 5.10 – Low-confidence areas for habitat extent further classified according to the area of Voronoi polygons interpolated from point source biotopes from sampling surveys in Marine Recorder. (Coastline derived from GEBCO Digital Atlas)

A good illustration of the problems of nearest-survey assignment of habitats, and why the method can produce low confidence data, can be seen in Figure 5.11. Where survey efforts are focused in areas of conservation interest, and surveys in adjoining areas are sparse, as in the Sound of Barra and East Mingulay SACs, the poorly sampled areas may be assigned habitat types from the neighbouring intensively sampled areas. This will tend to inflate the areas of those features of conservation interest. The effect will be carried through to the final estimates of blue carbon content across the inshore MPA network. The impact of this issue will be lessened, however, inside smaller NC MPAs and SACs since these places tend to be relatively well surveyed with a high proportion of small nearest-survey polygons (Figure 5.10).

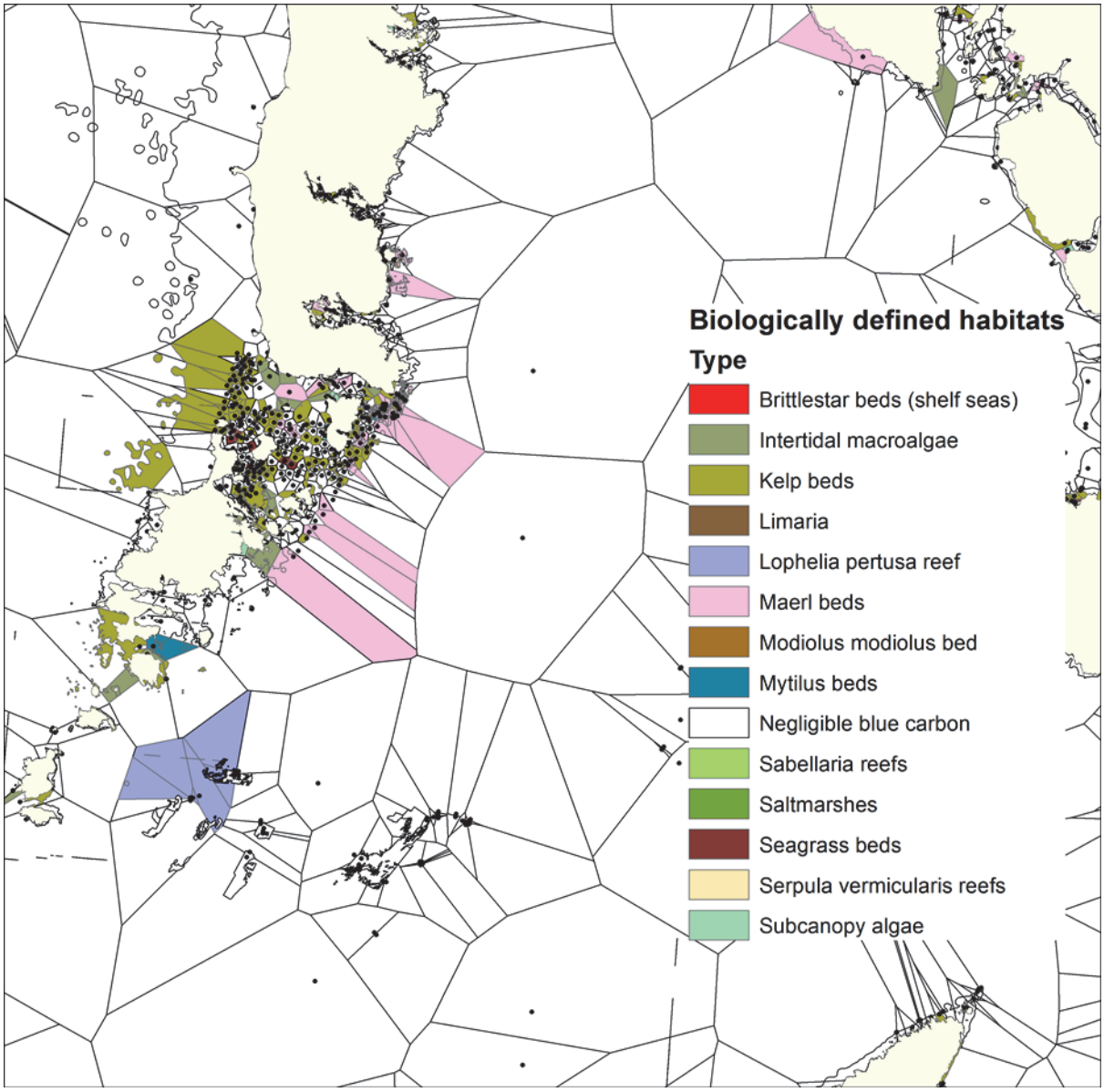

Figure 5.11 – Problems of assessment of extent in Low-confidence areas. Filled symbols show survey locations and filled polygons show habitats assigned on the basis of the nearest point survey. Large areas are assigned to maerl beds to the east of the Sound of Barra and to cold water coral reefs to the east of Mingulay because of the concentration of sampling effort in inshore areas and in the areas of conservation interest. (Coastline derived from GEBCO Digital Atlas)

6. DISCUSSION OF BLUE CARBON BUDGETS

6.1 Blue carbon assessment across the MPA network

6.1.1 Carbon standing stocks

From the data compiled in this report, the total mass of carbon contained in Scotland's inshore MPA network was estimated to be **57.1 Mt,** of which **9.4 Mt** (16.4% of the total) is organic carbon and **47.8 Mt** (83.6%) inorganic. Non-living organic material in the top 10 cm of seabed sediments (the "geology" component in Tables 5.3 and 5.4) accounts for 99.0% of the organic carbon standing stock, with the remaining 1.0% representing material contained within the living component ("biology" in Tables 5.1 and 5.2). Non-living organic carbon sequestered in sediments therefore vastly exceeds the standing stock in living tissues of the benthic organisms considered here (principally kelps, fucoids, seagrasses and other coastal macrophytes)).

For inorganic carbon, the estimates suggested that seabed sediments account for 87.9% (the majority derived from living material) of the total standing stock, with the remaining 12.1% contained within the skeletal structures of living organisms (maerl, bivalve beds, brittlestars, cold-water corals and other benthic calcifiers). The "geological" component – (dead shells, shell fragments and other biogenic carbonate buried in sediments) was much greater than the total contained within living organisms, but the contrast is not as extreme as for organic carbon. Beds or reefs of calcifying organisms therefore represent a minority, but non-negligible, fraction of the inorganic carbon standing stock within the inshore MPA network. For habitats consisting of beds or reefs the depths of deposited or dead material are greater than the 10cm considered for sediments (i.e. maerl beds – 60cm; *Modiolus* beds – 75cm).

6.1.2 Sequestration rates

Total carbon sequestration rate in the inshore MPA network was estimated as **511 000** t y^{-1}, of which **127 000** t y^{-1} (24.8%) was organic, and **384 000** t y^{-1} (75.2%) inorganic carbon. Approximately three-quarters of the total carbon sequestered annually was therefore contained within shells and other biogenic carbonates, with organic material comprising the remaining quarter. Respiration as a process was disregarded in these calculations, as it was considered of a much smaller order of magnitude than the significant accumulation of carbon in shells and other biogenic carbonates. More importantly, rates of production and fixation of organic carbon used here are net, **not** gross rates, with rates of respiration, and thereby release of CO_2 from fixed material through metabolism, already deducted from the production or fixation rate.

Organic carbon sequestration was overwhelmingly dominated by burial in seabed sediments. The estimated rate for this process (**126 000** t y^{-1}) was 99.7% of the total, with only an additional **401** t y^{-1} (0.3%) sequestered in the tissues of living organisms. This wide discrepancy reflects the rapid turnover of organic carbon in living tissue, particularly in the case of fast-growing kelps and other macroalgae. Dead macroalgal tissue entering the coastal food web will also be rapidly consumed and largely remineralised by bacteria, fungi and detritus-feeding metazoans, with only a residual fraction having the potential for long-term burial in sediments. Instead, the bulk of organic carbon sequestered in coastal sediments each year is likely to be of terrestrial rather than marine origin, comprising woody detritus and other refractory material. Terrigenous organic input will be particularly significant in coastal protected areas containing enclosed, accumulating basins (sea lochs) or river estuaries.

For inorganic carbon sequestration, the "geological" component (burial in sediments) also exceeded the amount incorporated annually into living organisms (i.e. biogenic carbonate

production), but the "biological" component was larger than for organic carbon. Burial in sediments accounted for an estimated 90.5% of inorganic carbon sequestration, with the remaining 9.5% representing accretion to the carbonate skeletons of living organisms. The greater importance of biological sequestration for inorganic carbon (relative to organic) reflects the long lifespan of many calcifying organisms (e.g. maerl, *Lophelia pertusa, Modiolus modiolus*), whose skeletal structures are maintained for much longer than the ephemeral tissue of kelps and other non-calcified seaweeds.

6.1.3 Carbon budgets: production versus sequestration

Total organic carbon production by the biological groups considered here was estimated as **248 000** t y^{-1}. This exceeded the estimated total organic carbon sequestration (**127 000** t y^{-1}) by a factor of 1.96. In other words, the inshore MPA network was estimated to sequester each year a mass of organic carbon equal to roughly half the annual total production. However, as noted in Section 6.1.2, most of the sequestered organic carbon is likely to be of terrestrial rather than marine origin.

Biological production of inorganic carbon (in skeletal carbonate) in theinshore MPA network was estimated as 37 000 t y^{-1}. The estimated burial rate of inorganic carbon in seabed sediments (348 000 t y^{-1}) exceeded the production rate by a factor of 9.5. In other words, the inshore MPA network was estimated to collectively sequester 9.5x the mass of inorganic carbon produced within the inshore MPAs each year. This wide discrepancy between production and sequestration has several possible explanations (note: these are not mutually exclusive, and more than one may be valid).

1) The inshore MPA network (or individual locations within it) acts as a sink for inorganic carbon produced outside its boundaries.
2) Inorganic carbon production within the MPA network (or individual MPAs) has been underestimated.
3) Inorganic carbon burial within the MPA network (or individual MPAs) has been overestimated.

At present it is not possible to firmly exclude any of these potential explanations. It is implausible that the inshore MPA network in its entirety could constitute a sink for inorganic carbon produced elsewhere, but it is possible that individual sites could do so. As discussed earlier (Section 5) the estimated network-wide values for total stock, production and sequestration of inorganic carbon were heavily influenced by the contributions of a small number of inshore MPAs. If some combination of geographic location, seabed topography or hydrography causes one or more of these key sites to function as local carbon sinks, they could exert a disproportionate influence on the values for the inshore MPA network as a whole.

Regarding point (2) above, it is likely that inorganic carbon production within the inshore MPA network has been underestimated. This study has focused on a small number of habitats characterised by calcifying benthic organisms (maerl, bivalve or brittlestar beds, tubeworm and cold-water coral reefs). These biogenic habitats are well-defined, mostly geographically discrete, and are created by one or two (rarely more) principal species. Published information on most of these principal species allows at least tentative estimates of inorganic carbon production rates. However, in addition to the conspicuous bed- and reef-forming taxa, all inshore MPAs will also support a range of calcifying benthic organisms whose contributions to inorganic carbon production are not included in the calculations. This "cryptic" component includes benthic foraminiferans, crustose red algae, barnacles and other crustaceans, bivalves (other than *Mytilus edulis, Modiolus modiolus* and *Limaria hians*), gastropods, bryozoans, echinoderms (other than bed-forming brittlestars) and several other groups. The taxonomic diversity and (in many cases) diffuse occurrence of these "cryptic"

calcifiers makes it extremely difficult to estimate their role in the carbon budget, and at present it is not possible to assess how far this additional input might narrow the gap between estimated inorganic carbon production and burial across the MPA network.

With respect to point (3), carbonate content (and hence inorganic carbon values) for different sediment types have been derived from the published literature, and sediment distribution maps have been compiled using the GIS data provided for each protected area. Inorganic carbon stocks and burial rates have therefore been estimated using the best available information, but we cannot exclude the possibility of inaccuracy in some cases. Again, data for specific protected areas that appear to make a disproportionate contribution to the network total are particularly crucial and in the event of any over-estimation are likely to skew the overall result. The only meaningful way of reducing these inaccuracies would be to complete focused surveys of key sites, e.g. the Southern Trench, thereby giving accurate assessments of sediment type, carbon content and other parameters.

6.1.4 Relative importance of biogenic habitats

Section 6.1.1 notes that the calcified skeletal structures of living organisms were estimated to account for approximately 12% of the total stock of inorganic carbon in the inshore MPA network. Although this was a much lower contribution than the approximately 88% represented by relict carbonate buried in sediments, it was still instructive to identify the communities most responsible for the biological component. Table 6.1 below lists the five sites with the largest biological standing stocks of inorganic carbon, plus three others whose protected area designations were made on the basis of biogenic reef occurrence. Sites are ranked by estimated standing stock of inorganic carbon in skeletal carbonate. The percentage contribution of each site to the total "biological" inorganic carbon inventory for the inshore MPA network is listed. The principal calcifying organisms (among the groups considered here) are also listed for each site.

Table 6.1. - Summary of inshore MPAs in which the biogenic habitats represent the largest inorganic carbon (IC) standing stocks. The table lists the five sites with the largest biological standing stocks of inorganic carbon, plus three others whose protected area designations were made on the basis of biogenic reef occurrence.

Site rank	Site	"Biological" IC standing stock (t)	% total inventory for MPA network	Principal calcifying organisms
1	South Arran MPA	1 167 774	20.2	Maerl, brittlestars
2	Sound of Arisaig SAC	1 082 865	18.7	Maerl
3	Sound of Barra SAC	980 519	16.9	Maerl
4	Wester Ross MPA	891 678	15.4	Maerl
5	Wyre & Rousay Sounds MPA	442 291	7.6	Maerl
8	East Mingulay SAC	184 589	3.2	*Lophelia pertusa*
14	Noss Head MPA	21 514	0.4	*Modiolus modiolus*
19	Loch Creran MPA/SAC	2 506	0.04	*Serpula vermicularis*, *M. modiolus, Limaria hians*

Table 6.1 shows that the "biological" component of the inorganic carbon standing stock was heavily weighted towards a small number of sites. The top three sites (South Arran, Sound

of Arisaig, Sound of Barra) together account for over half (55.8%) of the inventory for the entire inshore MPA network, with South Arran NC MPAalone contributing approximately 20%. The data also suggested that maerl was the most important biogenic habitat in terms of inorganic carbon storage, with extensive beds being found in all five highest-ranked sites. In contrast, the unique to inshore sites (on current knowledge) cold-water coral reefs of the East Mingulay SAC accounted for a modest 3.2% of the "biological" inorganic carbon inventory, while two other notable biogenic habitats – the Noss Head NC MPAhorse mussel bed and Loch Creran SAC serpulid reefs – were insignificant in comparison with the maerl component.

6.2 Threats to blue carbon resources

Many of the threats identified are anthropogenic, either through direct activity (such as fishing or recreation) or indirectly (climate change through carbon emissions). Many of these identified stressors will occur simultaneously, so it is very likely marine habitats will experience multiple stressors, and the interactions of these stressors with each other and the environment will influence the properties of marine habitats and organisms. Each stressor has been discussed independently.

6.2.1 Threats to carbon stored in sediment

Geologists often portray geological carbon storage as long-term, part of the slow carbon cycle that locks carbon resources into sediments for many millions of years. Whilst this is certainly the case, there are several crucial steps in this process that must be successful for long-term burial to remove carbon from biological availability. Sedimentary stores of carbon that have accumulated over the very recent geological past (i.e. within the postglacial and last ~10,000 years, all coastal marine sediments have accumulated in this timeframe) do not truly enter the slow carbon cycle until diagenesis is complete. The very early stages of diagenesis can be thought of as a biogeochemical, rather than a purely geological, process (Revsbech *et al*., 1983; Santschi *et al*., 1990; Glud, 2008). Organic carbon in particular is itself a source of energy for many benthic organisms, from bacteria to macrofauna. If the carbon is labile and available as a source of nutrients in the most useful ratios, it may be quickly consumed by organisms and re-enter the fast carbon cycle and be recycled into organic matter. However, the competition for these resources is fierce. In many cases within coastal marine sediments the limiting factor is not the availability of organic carbon on which to feed, but the availability of oxygen to fuel the conversion of carbon to carbon dioxide, releasing energy (Canfield *et al*., 1993; Glud, 2008). In other words, the shortage of energetically suitable electron acceptors is the crucial factor governing remineralisation of OC in sediments. Therefore in most coastal marine sediment, particularly cohesive sediments, the pore waters are anoxic within only a few millimetres of the sediment/water interface, as the chemical diffusion of oxygen is exceeded by the demand for that oxygen within the sediment (Glud *et al*., 2003; Glud, 2008). Thus, any carbon that has been buried to the depth of 5 mm to 1 cm has a much higher chance of being buried and entering the slow, geological carbon cycle than carbon sitting on the sediment surface, or in well oxygenated sediments.

The principal threat to long term carbon burial in sediments is any process that stirs up the sediment, particularly the top few millimetres of sediment. Resuspension of sediment disturbing the natural gradient of oxygen and re-oxygenating the sediment pore waters allows rapid consumption of buried carbon by organisms and its subsequent release as carbon dioxide. This effectively reduces the carbon burial rate significantly and reduces the blue carbon inventory. The threat of sediment resuspension is most obviously linked to mobile fishing gears, but also can be linked to boat moorings and any other items on the sea bed that are not fully fixed in place. Such activities include, but are not limited to, dredging and trawling, which cause surface and subsurface abrasion and/or penetration. In addition,

trawling or dredging activities will affect the species diversity within the sediment, thus affecting the carbon burial rate due to reduced oxygen within the porewaters by reducing faunal bioturbation.

Ocean acidification is another threat to the carbon stored in sediments, and is one of the impacts of climate change. Ocean acidification is 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. An increase of H^+ causes a decrease in the pH, making the sea water more 'acidic'. Currently, the pH of sea water has declined globally by around 0.1 pH units since the 1800s, coinciding with the start of the industrial revolution. However, this equates to ~30% increase in acidity. The rising carbon dioxide affects the carbonate system of the oceans, not only increasing bicarbonate and H^+ in sea water, but decreasing the availability of carbonate, which is important for calcifying organisms. Carbonate is used to construct shells or skeletons (e.g. molluscs, crustaceans, coral reefs), and increasing ocean acidification reduces availability of carbonate, in addition to increasing the rate at which calcium carbonate dissolves. Calcium carbonate comprises 12% by weight of carbon, and this figure has been used to calculate carbon budgets in sediments in this report. However, the effects of ocean acidification on sediments will likely be higher in protected areas that contain carbonate sediments, found predominantly in Orkney and Shetland. Carbonate sediments, by definition, constitute at least 30% carbonate, made up of shell particles from many organisms. It is still unclear how the observed changes from ocean acidification will impact the sequestration of calcium carbonate shell material in sediments, although it is highly likely that this process will hinder, rather than enhance, carbon sequestration potential.

Coastal marine sediments are particularly vulnerable, as the meeting point between terrestrial and marine ecosystems, and will be sensitive to changes in land use (e.g. increased eutrophication) and direct anthropogenic activity (e.g. tourism, recreation).

Climate change effects such as rising temperature and increasing deoxygenation (hypoxia) may also have implications for sediments and their ability to store carbon; however, these effects have not been studied in any detail.

6.2.2 Threats to carbon stored in organisms

Carbon stored in organisms can be broadly defined as either 'transient' stores, such as the carbon stored in seagrass beds, kelp and macroalgae; and 'long term' biological stores, such as biogenic structures (coral reefs, serpulid reefs, mussel beds). Biological habitats, like sediments, are also subject to physical changes due to anthropogenic activity such as dredging and trawling, which can damage or remove species. Removal of seagrass beds affects the rhizomes that are important for regeneration and growth, reducing or limiting the ability to store carbon. It is very likely a large proportion of the carbon produced by seagrass beds and kelp eventually ends up in the marine sediments as detritus.

Long-term biological stores of carbon, such as those that calcify (coral and serpulid reefs, maerl and molluscs), will be sensitive to changes in ocean pH, salinity, temperature and deoxygenation (hypoxia). Much research has focused on identifying the response of maerl and cold-water corals (*Lophelia* spp.) to changes in temperature and ocean acidification. The maerl species *Lithothamnion glacialis* and the cold water coral *Lophelia pertusa* are both sensitive to increasing temperature, and demonstrate short-term reduced calcification rates in sea water with lower pH conditions (albeit not sustained over longer periods, Form & Riebesell, 2012). The associated lesser availability of carbonate reduces the calcification in

live reefs / maerl beds. In addition, changes in pH may cause dissolution of dead reef structures, which act as foundations upon which many cold water coral reefs are built. Such effects would have a direct impact on the amount of carbon stored within these structures.

6.2.3 Threats caused by land use changes

Nearly 66% of Scotland is covered by peat and organic soils, representing over 50% of the UK's soil carbon stocks. Peatland erosion, while partly a natural process, is also accelerated by human activities, such as land management and potentially by the impacts of climate change. The loss of soil carbon represents a potentially important contribution (i.e. net gain) in refractory carbon within the marine environment. Currently arable soils on the east coast suffer a soil erosion loss of 2 t ha^{-1} yr^{-1}, which is greater than the European tolerable soil loss of 0.3–1.4 t ha^{-1} yr^{-1} (Scotland's Soils, 2011).

In recent years land managers have recognised the problem with soil erosion and soil carbon loss. The introduction of buffer strips, new ploughing techniques and cover crops has resulted in a reduction of soil erosion and carbon loss from agricultural land. The commercial forestry industry has also attempted to tackle this problem with abolition of clear felling and new planting techniques. Although both industries have tried to tackle the problem there is also pressure for these industries to expand, which will again increase the pressure on the soil and in turn increase the quantity of carbon reaching the coastal environment. Whilst these problems are well documented, land managers rarely take the coastal marine environment into consideration when making land management decisions.

Potentially, climate change is the greatest pressure on soil carbon stores as it could have a range of impacts on soil processes due to changes in soil moisture, temperature and rainfall patterns. Climate change is predicted to lead to:

- loss of soil organic matter;
- changes in soil biodiversity;
- increased rates of soil erosion.

With greater levels of erosion, more frequent landslides and increased peat erosion it is expected that a greater quantity of terrestrial carbon will reach the coastal marine environment.

The proximity of the inshore MPA network to the terrestrial environment means land use and management practices potentially have significant influence on carbon supply to the biological habitats and the geological substrates of the coastal ocean.

Increases in terrestrial carbon input may change the turbidity of the water column resulting in reduced light penetration, which in turn will impact the biological ecosystems ability to cycle and store carbon. An increased quantity of terrestrial carbon to the coastal ocean will result in higher sedimentation rates, and as terrestrial carbon is more refractory in nature to marine carbon components, so a greater amount will reach the sea bed.

6.3 Knowledge gaps and priority research areas/considerations

Blue carbon is often loosely defined as the carbon captured and sequestered by the oceans and the organisms within them (Nellemann *et al.*, 2009b). However, many reports that discuss 'blue carbon' only focus on charismatic, well studied habitats (such as seagrass, kelp, saltmarsh and mangroves), with less attention given to marine sub-littoral habitats and sediment habitats, which sequester carbon on a long-term scale. For the purpose of differentiating between these different types of storage, this report has used 'transient' stores to refer to habitats and organisms that store carbon for a relatively short time scale

(weeks/seasonal) (such as non-calcareous photosynthetic organisms). The transient carbon is moved elsewhere (usually ending in the sediments) through natural degradation or seasonal cycling within the oceans. However, it is yet unknown how much carbon moves from the transient stores to a long-term storage, what the timescale of this process is, and how variable this may be. Reports that have discussed the potential of blue carbon have highlighted the important 'missing sinks of carbon' (Pidgeon, 2009) in the oceans. They have focused on specific habitats (mangroves, kelp forests and seagrass, saltmarshes and coral reefs) (Laffoley & Grimsditch, 2009), or have given an overview of oceans as a complete system within the global carbon cycle (Nellemann *et al.*, 2009a). This report demonstrates that a significant proportion of carbon is sequestered in marine sediments. However, an understanding of blue carbon in marine sediments is lacking particularly compared to knowledge of terrestrial ecosystems.

On the basis of this study, there are some key knowledge gaps that should be considered as priority research areas. Addressing these areas is vital in assessing the natural variability and carbon storage capacity of marine habitats, and will provide information important in determining appropriate management strategies.

Recommendations:

- **Availability of accurate data:** The estimates in this study were based on a very small amount of robust data, particularly for the broader sediment habitats. Despite this, the largest carbon sinks were the sediments, and many assumptions have been made to calculate an overall budget. Although there is a paucity of data this report provides a good 1st-order starting point to show the importance of carbon in the Scottish inshore MPA network, providing a methodology on which to build further research. The initial estimates reported in this document could be improved with additional data. Targeted research would provide information on sediment accumulation rates for different types of sediment (sand vs mud, sea loch mud vs carbonate coastal sediments) within the inshore MPA network, and would reduce variability and uncertainty in carbon budget calculations. To date, very few relevant studies have been carried out on UK sediments, and so much of the knowledge has been drawn from other geographical locations (e.g. Baltic Sea, Skagerrak), resulting in low confidence in the precise values discussed here. Section 6.4 highlights how inaccuracies in geological calculations can be improved.

- **Fate of macrophyte-derived detritus:** Very little is known of the fate of dead plant material in the near coastal ocean, and nothing about the proportion of this detritus that is ultimately stored in sediments. Much of this material may be converted back into CO_2 through decay and respiration by organisms that consume it, a process known as remineralisation. Without this knowledge it is difficult to put a value on the ecosystem service for climate regulation provided by plants in the coastal zone and, therefore, coastal blue carbon resources.

- **Depth of carbon burial and sediment accumulation rates:** This report has standardised sediment burial and accumulation by only taking into account the top 10cm of sediment. However, this depth is likely to vary in age and accumulation between different sites. For example, 10cm of sediment at one site may contain carbon buried over 10 years, whilst another site may contain older or newer sediment. The differences between sediment sites will also be influenced by sediment type, the physical properties of the habitat and those that surround it. Therefore focused studies would help tighten estimations and predictions. In habitats such as maerl beds, collection of geological cores may provide further detail on carbon sequestration, by ascertaining the depth of maerl beds at each site.

- **Differentiation between sediment types:** Little is known about carbonate sediments, which are key habitats in Orkney and Shetland NC MPAs, but for the purpose of this report, this sediment has not been treated any differently to non-carbonate sediments when calculating budgets. By their definition, 'carbonate' sediments contain at least 30% carbonate, which means they are likely to have higher inorganic carbon content. This report has differentiated between sand, mud and sea loch mud, but these categories are extremely broad and do not capture natural variability, particularly in coastal marine sediments where the supply of carbon from catchment areas (terrestrial or marine) will have an influence on the carbon content. For carbonate sediments in this study, it is highly likely the inorganic carbon has been underestimated.

- **Negligible blue carbon:** Within many of the inshore MPAs, much of the biology and geology of each site was allocated to 'negligible blue carbon' on the assumption that the biotopes reported were unlikely to be significant stores or producers of carbon. Further data on each habitat type assigned to this category to validate these assumptions will increase certainty on carbon sequestration potential for each habitat and across the network of inshore MPAs.

- **Priority Marine Features:** There appears to be a disconnect between habitats listed as Priority Marine Features and those habitats containing the greatest amounts of blue carbon, as existing protected areas have been designated on the presence / abundance of key parameters, often related to the organisms (e.g. *Lophelia pertusa*; maerl beds; kelp forests). These sites, although containing considerable carbon stores, are not necessarily the most important in terms of carbon sequestration. However, in many cases, such as in sea loch protected areas, these designations encompass areas of high carbon sequestration (e.g. sea loch mud). It is important to note that not all high carbon content habitats will fall inside inshore MPAs, and they do not necessarily contain good blue carbon habitats, but the existence of this network provides the potential for additional protection to these habitats that might not otherwise be considered priority marine features in their own right.

- **Future environmental change:** This report has touched on some of the effects of climate change (rising temperature, ocean acidification), with cautious predictions of likely effects. Some habitats (such as cold-water corals and maerl beds) are better understood with respect to changing environmental variables. However, in order to predict and mitigate future environmentally driven changes within these habitats, it is essential that baseline data are collected to encompass natural variability, and to ascertain changes that are separate to background variability and can be attributed to other causes. This would be best approached through a combination of *in-situ* measurements and observations and experimental conditions that simulate predicted changes, whilst monitoring the response of a habitat (e.g. ability of sediments to store carbon; how much carbon is stored in seagrass beds under different future scenarios). A cautionary note: impacts of stressors on marine habitats will occur in tandem with additional existing stressors (e.g. eutrophication, rising temperature, ocean acidification, trawling, dredging). It is vital that any study examining effects of environmental change examines multiple stressors and the interaction between them, as single stressor studies may provide misleading results.

- **Lack of understanding in carbon processes between habitats:** There remains a huge amount of uncertainty of how much carbon is captured, how it is captured, and how much remains within a specific habitat or where it moves to; e.g. carbon is captured by kelp on a relatively short timescale (transient store: weeks / season) – as the kelp dies, the carbon moves out of this store to somewhere else. It is assumed it reaches the sediment, but it is unclear how it does this (does it travel far?); how much of it reaches the sediment; and how long this process takes.

The overall recommendation is to prioritise research that reduces uncertainty in carbon sequestration habitats (e.g. extent, depth etc.), captures natural variability (temporal and spatial), and contributes to appropriate mitigation of future environmental change through suitable management of these ecosystems, based on robust knowledge.

6.4 Availability of geological accurate data: Future outlook

As discussed this report only considers the top 10 cm of the sediment in the calculation of sedimentary carbon stocks. However, it is known that the depth of deposits of seabed sediments varies signficantly from shallow depths in the some areas of the shelf sea to significant depths in sea lochs (Figure 6.1). Until now intergrating depth of sediment into these calculations has been impossible due to the lack of methodology.

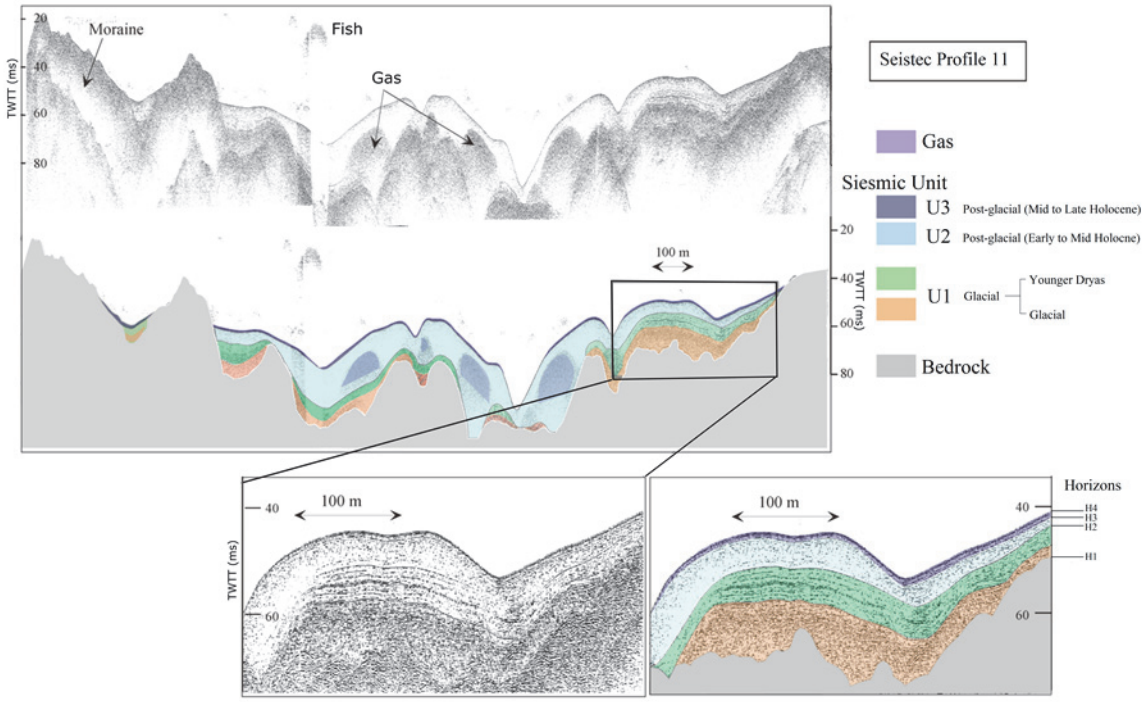

Figure 6.1 – Seismic stratigraphy adapted from illustrating sediment depth in Loch Sunart (from Smeaton et al.*, 2016).*

A newly developed joint geophysical and geochemical methodology by Smeaton *et al*. (2016) provides a robust technique for the quantification of sedimentary carbon in the inshore waters. The method utilises seismic geophysics to map and calculate the total volume of sediment held within a surveyed area, this combined with the measurement of dry bulk density and carbon held within the sediment allows the total quantity of sedimentary carbon to be determined.

Smeaton *et al*. (2016) applied this methodology to Loch Sunart and calculated that the loch's sediment holds a total of 26.88 ± 0.52 Mt of carbon comprising 11.05 ± 0.23 Mt of organic carbon and 15.02 ± 0.35 Mt of inorganic carbon. When these quantities are compared to the estimates made in this report of 0.048 Mt of organic carbon and 0.070 Mt of inorganic carbon being stored in the top 10 cm of sediment in Loch Sunart it clearly illustrates the importance of sediment depth in these calculations. Smeaton *et al*. (2016) stated that the average depth of sediment held within Loch Sunart is around 25 m. If the estimates from this report are scaled up accordingly, then the resulting calculation results in a total of 23.6 Mt of carbon is stored in the sediment. Though this process yields similar results to that of Smeaton *et al*. (2016), it cannot be advised to ultise the simple application of this methodology over the

whole inshore MPA network, as the mean depth of sediment in the majority of theinshore MPAs is unknown. In addition, there is such localised variability in sediment depth that this process would result in significant inaccuracies in the estimation of sedimentary carbon stocks. Nevertheless it is very likely that the current estimates for total carbon stored in inshore MPA sediments are underestimated by some orders of magnitude in some places. The future development and application of the Smeaton *et al*. (2016) methodology in both the coastal and shelf seas will provide robust estimation of sedimentary carbon stores in the MPA network and in the wider context of Scotland's territorial waters.

7. CONCLUSION

By combining existing knowledge on the biology, ecology and geology of the means of carbon production and storage in Scotland's marine environment, it has been possible to estimate minimum quantities of blue carbon resources that lie within the **11 350 km^2** of the inshore MPA network as Nature Conservation Marine Protected Areas and Special Areas of Conservation. Stocks of carbon in living material and in sediment stores within the inshore MPAs are estimated at **9.4 Mt OC** and **47.8 Mt IC.** These values represents **1.6%** of the total of 592Mt organic C (revised Burrows *et al.* (2014) value) and **2.7%** of the total 1739 Mt inorganic C within Scottish waters.

Every year, living components of habitats in the inshore MPA network are thought to produce **248 000 t OC yr^{-1}** and **36 000 t IC yr^{-1},** while sediment stores accumulate **126 000 t OC yr^{-1}** and **348 000 t IC yr^{-1}.** As percentages of the totals across all of Scottish seas, living components of habitats in the MPA network produce 0.6% of the organic carbon assimilated when including phytoplankton production, or 14% of the total produced by attached plants (macroalgae including kelp beds, seagrasses and saltmarshes). The inshore MPAs sequester **1.8%** of the total organic carbon, while **79%** of the previously estimated inorganic sequestration rate across all of Scotland's seas occurs in the inshore MPAs. This latter figure is certainly a significant overestimate, based on the generous method of estimating habitat extent in this report and built on data from areas of very low confidence in the estimates of extent, but does reflect the targeting of conservation efforts in Scotland towards sensitive biogenic reefs of organisms building shells and calcareous skeletons, such as maerl beds, cold water corals and horse mussel beds (*Modiolus*).

Most of the threats to organic carbon stored in sediments derive from surface disturbance, such as by mobile fishing gears and moorings or increases in other human activities such as coastal developments and renewable energy installations. This is because resuspension of previously buried material may increase the rate of remineralisation of organic carbon to CO_2. Ocean acidification may pose a threat to carbon in sediments stored as carbonate but the mechanisms whereby that threat may be realised are as yet unclear. However this plays out, it is unlikely that ocean acidification will increase the sequestration capacity of inshore waters.

In the biological components of coastal marine habitats, stores can be seen as either transient, being made up of the living or newly dead organisms that make up most of the biomass in these areas, or long-term, made up of accumulated calcareous reef material or buried dead vegetation. Similar disturbance-related threats affect these stores, while ocean acidification may have a direct negative effect on the capacity of calcareous reef builders to build carbonate skeletons. On the other hand, macroalgae such as kelp may benefit from ocean acidification with greater production and growth rates (Kroeker *et al.*, 2013; Brodie *et al.*, 2014). Carbon assimilation may also be negatively impacted by greater soil erosion, increasing suspended material and light attenuation.

Much of the information used in this assessment of blue carbon stocks is based on legacy data, some from older, published sources. Spatial extents of blue carbon habitats at the scales required for this report are poorly constrained. This information is, however, the best available, and is likely to remain so without further work on estimating stocks and rates of carbon uptake and storage. The methods used to get areas of blue carbon habitats at the scales required for this report have considerable drawbacks too, especially where accurate maps do not exist. Finally, the science of understanding the effects of climate change on these systems is very much in its infancy and new developments will allow a much better informed outlook for the fate of these stocks and flows in a changing world. By establishing a methodology that integrates existing knowledge and understanding of blue carbon it should be possible to easily update reports such as this as new information emerges.

This report aims to provide a starting point and a methodology for the examination of blue carbon storage in an MPA network. It is clear throughout the report that there is paucity within the data set. Despite these difficulties, and the uncertainty around accurate values of estimates, the general conclusions are unlikely to change with more detailed information, Therefore, the authors believe that enough information exists to begin to draw conclusions about the importance of blue carbon stocks in the marine environment, both within Scotland and globally. Variable and limited data will be a common feature of MPA networks throughout the world. The methodology proposed allows conclusions to be made on incomplete data, providing the start of a management tool to aid protection of blue carbon in the marine environment.

7.1 Recommendations for future work

In the sampling and observation of inshore MPAs, it has been noted in this report that marine sediments are generally under-represented compared with biologically diverse substrates. In particular, soft muddy sediments in deeper water are sparsely sampled, yet are known to contain by far the largest stock of marine OC in Scottish coastal waters (Smeaton *et al*., in review). The extensive offshore MPAs, however, which have not been part of this assessment, contain very large areas of deepwater seabed sediments. The relationship between sediment type and OC content within a region is often strongly correlated. In addition, remote sensing techniques of the sea bed, such as multi-beam bathymetric survey, provide a good first-order estimate of sediment type and hence could be used to estimate OC content. It is therefore recommended that targeted spatial mapping of these sediments should be a priority for further research in order to improve estimates of sediment OC content.

While this report has largely focused on a first-order estimate of sediment OC in surficial layers (i.e. the top 10 cm), there is clearly a need to obtain a better understanding of the long-term OC stocks accumulating in these inshore MPAs. In particular, the stability of these stocks and their role as a net sink for terrestrial OC transfer into the inshore marine environment are poorly understood. As recently shown by Smeaton *et al*. (in review), these long-term (i.e. post-glacial stocks) can contain very significant stores of OC, often acting more efficiently per unit area than equivalent terrestrial peatland stocks. Therefore, a greater research focus on obtaining sediment volume estimations and long sediment coring in these long-term sedimentary archives is recommended.

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9. GLOSSARY

^{14}C	Method for determining the age of an organic substance by measuring the amount of the carbon isotope, carbon-14, remaining in the substance; useful for determining ages in the range of 500 to 40,000 years. Also known as radiocarbon dating.
^{210}Pb	^{210}Pb is a radioactive isotope in the ^{238}U decay chain which can be used to date sediment up to 100 years old.
Basin	A large depression in which sediments are accumulated, or a tectonic circular, syncline-like depression of strata.
Carbon Accumulation Rate	The rate at which carbon is reaches the seabed sediment, expressed in g C m^{-2} yr^{-1}.
Blue Carbon	Carbon stored and sequestered in coastal and marine ecosystems, including tidal and estuarine salt marshes, seagrass meadows, and mangrove forests'. For the purposes of this study, this definition has been extended to include the geological substrate on which the marine ecosystem has developed.
Dry Bulk Density	Bulk density is defined as the dry weight of sediment per unit volume of soil. Bulk density considers both the solids and the pore space; expressed as g cm^{-3}.
Calcite	A mineral consisting of calcium carbonate ($CaCO_3$) whose crystals have a double image refraction property.
Carbonate	A mineral composed mainly of carbonate (CO_3^{--}) ions with calcium (Ca) and may also include magnesium (Mg), iron (Fe) and other elements. Carbonate also refers to rock or sediments derived from debris of organic materials composed mainly of calcium carbonate such as shells or corals.
Continental Shelf	A region of submerged rock of the same type, at depths (of up to a few hundred metres) that are shallow compared with those in the ocean; around Scotland is a wide area of shelf reaching about 120 metres at its outer edge (deeper in a few glacier dredged troughs); the shelf seas, including the North and Malin Seas, are the waters over this shelf.
Diagenesis	The physical and chemical changes during the conversion of sediment to sedimentary rock.
Estuary	An area where fresh water comes into contact with seawater, usually in a partly enclosed coastal body of water; a mix of fresh and salt water where the current of a stream meets the tides.
Fixation (or capture)	The conversion of carbon dioxide to solid carbon by animals and plants.

Foraminifera	A class of oceanic protozoa most of which have shells composed of calcite.
Geochronology	The science of absolute dating and relative dating of geologic formations and events, primarily through the measurement of daughter elements produced by radioactive decay in minerals.
Geomorphology	The science of surface landforms and their interpretation on the basis of geology and climate.
Gravel	Coarse-grained sediment, containing mostly particles larger than 2 mm in size and including cobbles and boulders.
Inorganic carbon (IC)	Carbon dioxide (CO_2) gas, dissolved CO_2 and the ions bicarbonate (HCO_3^-) and carbonate (CO_3^{--}); particulate compounds of carbonate, e.g. calcium carbonate (Chalk,$CaCO_3$).
Labile carbon	Consists of sugars, proteins and other compounds easily used by marine bacteria.
Lithification	The processes that convert a sediment into a sedimentary rock.
Mud	A sediment having predominance of grains with diameters less than 0·06 mm. The term is a general term referring to mixtures of sediments in water and applies to both clays and silts.
Organic Carbon (OC)	Compounds of carbon, nitrogen and hydrogen and, in some cases, oxygen and sulphur, used by living organisms in the structure of their cells and as a reservoir of energy.
Refractory carbon	Consists of high molecular weight and structurally complex compiunds that are difficult for marine organisms to use (e.g. lignin, humic acid, etc.).
Rock	An extensive geological term, but limited in hydrography to hard, solid masses of the Earth's surface rising from the bottom of the sea, either completely submerged or projecting permanently, or at times, above water.
Sand	Medium-grained sediment with a size range of 0.063 – 2 mm . This is the most common sediment on the continental shelf.
Sea Loch (Fjord)	A former glacial valley with steep walls and a U-shaped profile now occupied by the sea.
Sill	Oceanographically, the saddle or any submarine morphological feature which separates basins from one another.
Shelf Slope	The edge of the continental shelf, beyond which is the continental slope.
Sediment	Any solid material that has settled out of a state of suspension in liquid.

Sediment Accumulation	The rate that sediment builds up on the seabed rate (SAR). expressed in cm yr^{-1}
Sedimentation	The process of deposition of mineral grains or precipitates in beds or other accumulations.
Sediment Trap	Sediment traps are containers that placed in the water column to collect particles falling toward the sea floor.
Sequestration	The process of addition of solid carbon to the standing stock.
Standing stocks	Stores of solid carbon in sediments.
Total Carbon (TC)	The total quantity of carbon (organic + inorganic).

ANNEX 1: CARBON VALUES COLLATED FROM REVIEW OF LITERATURE FOR EACH BIOLOGICAL HABITAT

Blue carbon values assigned to each biological blue carbon habitat types, taken largely from Burrows *et al.* (2014).

Habitat		Production rate (g C m^{-2} yr^{-1})		Sequestration rate (g C m^{-2} yr^{-1})		Stock g C m^{-2}		Stock total across Scotland's Marine Atlas Regions (1000 t C)	
		OC	IC	OC	IC	OC	IC	OC	IC
Biogenic habitats	Kelp beds[1]	685	0.0	0.0	0.0	187.7	0.0	404.4	0.0
	Intertidal macroalgae	135	0.0	0.0	0.0	489.0	0.0	11.8	0.0
	Maerl beds[2]	0	74.0	0.0	74.0	0.0	62 402.4	0.0	440.6
	Seagrass beds	261	0.0	83.0	0.0	0.0	0.0	0.0	0.0
	Saltmarshes	210	0.0	210.0	0.0	127.5	0.0	8.6	0.0
Biogenic reefs	*Modiolus modiolus* beds[3]	0	40.0	0.0	40.0	0.0	4 000.0	0.0	15.4
	Limaria	0	0.0	0.0	0.0	0.0	63.8	0.0	0.1
	Lophelia pertusa reef	0	35.0	0.0	35.0	0.0	9 375.0	0.0	112.0
	Serpula vermicularis reefs	0	420.0	0.0	420.0	0.0	781.3	0.0	1.0
	Brittlestar beds (shelf seas)	0	82.0	0.0	82.0	0.0	0.0	0.0	0.0
	Mytilus beds[4]	0	40.0	0.0	40.0	0.0	15.4	0.0	15.4
	Sabellaria reefs	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Subcanopy algae	21	0.0	0.0	0.0	22.0	0.0	22.0	0.0
Novel classes	Negligible blue carbon	0	0	0.0	0.0	0	0.0	0	0

NB: 1. Kelp beds only store carbon in living material. 2. Assuming 60cm-deep maerl beds. 3. *Modiolus* beds are assumed to be 75cm deep. *Mytilus* beds given same values as *Modiolus* beds. Sources of values and other assumptions are given in Section 3.2.

ANNEX 2: CARBON VALUES COLLATED FROM REVIEW OF LITERATURE FOR EACH GEOLOGICAL SUBSTRATE

Reference	Location	Geological Substrate	% TC			% OC			% IC		
			Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Loh et al., 2008	Loch Creren	Sea Loch Mud	3.53 ± 1.18	1.9	5.1	2.85 ± 1.39	1.1	4.8	0.68 ± 0.26*	0.3*	1*
	Loch Etive	Sea Loch Mud	5.3 ± 1.24	2.1	6.3	4.48 ± 1.67	2.1	6	0.83 ± 0.46*	0.3*	1.4*
Payne et al., 1989	Loch Sunart	Sea Loch Mud	4.89 ± 3.92	0.45	11.73						
Russell et al., 2010	Multiple Lochs	Sea Loch Mud				2.31 ± 1.21	0.49	5.04			
Smeaton et al. (In Prep)	Loch Sunart	Sea Loch Mud				1.80 ± 1.47	0.37	4.93	1.24 ± 0.60	0.30	1.82
Thornton & McManus, 1994	Tay Estuary	Mud				2.4 ± 1.34	0.54	5.37			
Serpetti et al., 2012	Stonehaven	Sand				0.37 ± 0.27	0.15	0.9			
		Sand/Mud				0.68 ± 0.28	0.23	1.33			
		Sand/Mud/Gravel				0.39 ± 0.20	0.13	0.73			
MEMG, 2004	Scottish Coastal Waters	Sand/Mud/Gravel				0.42 ± 0.25	0.13	1.03			
		West Coast Sand/Mud				0.68 ± 0.28	0.23	1.33			
		West Coast Mud				2.98 ± 1.11	1.8	4.2			
		East Coast Mud				2.3 ± 1.7	1.1	3.5			
		East Coast Sand/Mud				1.08 ± 0.64	0.43	2			
		Sand				0.25 ± 0.12	0.1	0.41			
BGS Offshore Geoindex	Scottish Coastal Water	Gravel/Mud							3.09 ± 1.84+		
		Gravel/Sand							3.78 ± 2.57+		
		Sand							3.78 ± 2.57+		
		Sand/Mud							3.09 ± 1.84+		
		Sand/Mud/Gravel							3.09 ± 1.84+		
		Mud							2.03 ± 1.47+		

*Values calculated from TC and OC data from literature source.

+ Reported as $CaCO_3$ adjusted to IC (12% of $CaCO_3$)

ANNEX 3: SEDIMENTATION RATES COLLECTED FROM REVIEW OF CURRENT LITERATURE

Reference	Substrate	Location	Method	SR (cm yr^{-1})	SD	Burial Rate (g OC m^{-2} yr^{-1})
Cage et al., 2010	Sea Loch Mud	Loch Sunart	^{210}Pb	1.08	0.63	
Norgaard-Pedersen et al., 2006	Sea Loch Mud	Loch Etive	^{14}C	0.03	0	
Loh et al., 2010	Sea Loch Mud	Loch Creran	Sed Trap	0.35	0.21	
Overnell & Young, 1995	Sea Loch Mud	Loch Linnhe	Sed Trap	1.6	1.56	
Ansell, 1974	Sea Loch Mud	Loch Creran				50-200
Zuo et al., 1989	Mud	North Sea (Oyster Ground)	^{210}Pb	0.49	0.64	
de Hass et al., 1997	Muddy sand	Norwegian Channel	^{210}Pb	0.16	0.17	
Jorgensen et al., 1990	Muddy sand	Norwegian Channel	^{210}Pb	0.25	0.21	
Kershaw et al., 1988	Mud	Eastern Irish Sea	^{14}C	0.16	0.20	
Austin & Scourse, 1997	Mud	Irish Sea	^{14}C	0.041	0.00	
Marret *et al., 2004*	Sandy Mud	Celtic Sea	^{14}C	0.017		
Scott *et al., 2003*	Sandy Mud	Celtic Sea	^{14}C	0.037		
Austin *et al., 2004*	Muddy sand	St Kilda Basin	^{14}C	0.022	0.01	
Stahl *et al., 2004*	Sandy mud/mud	Skagerrak/Kattegat		0.375	0.36	
Van Weering *et al., 1987*	Coarse Sediment	Skagerrak		0.26	0.20	
Anton *et al., 1993*	Mud	Skagerrak		0.655	0.39	
de Haas & van Weering, 1997	Sandy mud	Skagerrak/Northern Kattegat				35
Meyenburg & Liebezeit, 1993	Sandy mud	Skagerrak				45

ANNEX 4: GEOLOGICAL CALCULATIONS

1. Carbon Accumulation Rate (CAR) for a given Geological Substrate

CAR = %C x SAR x (Porosity - 1) x bulk density

Where:

%C	Percentage Carbon/Organic Carbon/Inorganic Carbon
SAR	Sediment Accumulation Rate (cm yr^{-1})
Porosity	Porosity (PU) =0.7 - Loh *et al*., 2010
Bulk Density	Wet bulk density (g cm^{-3}) – Flemming & Delafontaine, 2000
CAR	Carbon Accumulation Rate (g C m^{-2} yr^{-1})

Based on Loh *et al*., 2010 & Smith *et al*., 2015

2. Annual C Accumulation for a given Geological Substrate

Annual CAR (g C yr^{-1}) = Area (m^2) x CAR (g C m^{-2} yr^{-1})

Where:

Area	Area of geological substrate
CAR	Carbon Accumulation Rate

3. Calculating the Total C Stock of a Geological Substrate (Top 10 cm)

3.1 Volume of Sediment in Geological Substrate

Volume of Sediment (m^3) = Area (m^2) x 0.1

Where:

Area	Area of geological substrate
0.1	0.1 = top 10 cm of sediment, expressed in meters

3.2 Mass of Sediment in Geological Substrate

Mass of sediment (kg) = Volume of Sediment (m^3) x Bulk Density (kg m^{-3})

Where:

Bulk Density	Dry bulk density - Flemming & Delafontaine 2000

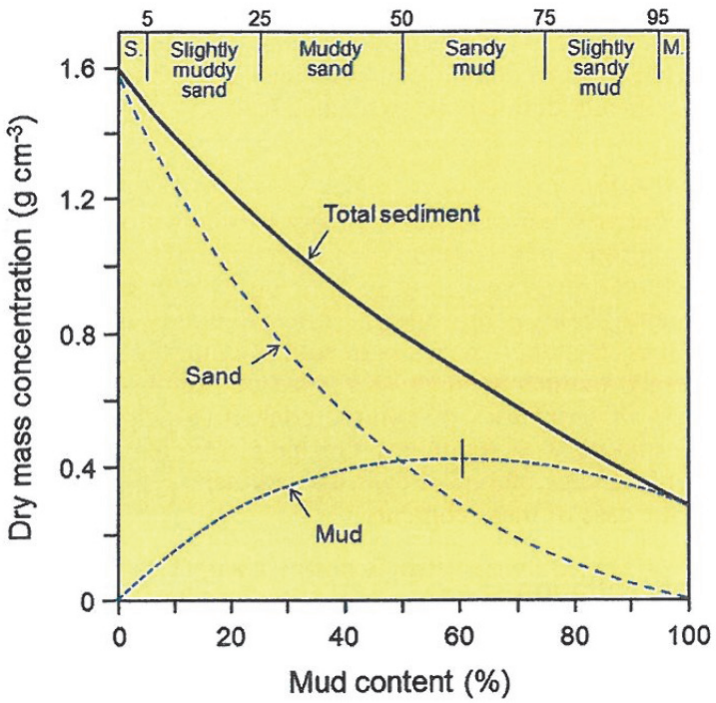
3.3 C stock of given geological substrate

Mass of Carbon (kg) = %C x Mass of Sediment (kg)

Where:

%C	Percentage Carbon/Organic Carbon/Inorganic

ANNEX 5: DRY BULK DENSITY VALUES



Reference	Location	Geological Substrate	Dry Bulk Density ($g\ cm^{-3}$)
Flemming & Delafontaine (2000)	Coastal Sediments	Gravel/Mud	1.60
		Gravel/Sand	1.60
		Mud	0.80
		Sand	1.60
		Sand/Mud	1.12
		Sand/Mud/Gravel	1.12
Smeaton *et al*., (In Prep)	Loch Sunart	Sea Loch Mud	1.02

ANNEX 6: MPA/SAC RANKING TABLES

Table showing the rankings for various elements of the Biology data, including organic carbon, inorganic carbon and total carbon. *(An average ranking value is given when values are zero).*

BIOLOGY		Organic Carbon			Inorganic Carbon			Total Carbon (IC + OC)			
NC MPA / SAC	Sum of Area km^2	Standing Stock OC t	Standing Stock t OC km^{-2}	**Ranking Stock t OC km^{-2}**	Standing Stock IC t	Standing Stock t IC km^{-2}	**Ranking Stock t IC km^{-2}**	Standing Stock TC (t)	**Ranking Stock TC (t)**	Standing Stock t TC km^{-2}	**Ranking Stock t TC km^{-2}**
MPA Clyde Sea Sill	712	0	0	**46.5**	0	0	**42**	0	**47**	0	**47**
MPA East Caithness Cliffs	114	2 201	19	**23**	0	0	**42**	2 201	**24**	19	**33**
MPA Fetlar to Haroldswick	214	1 600	7	**35**	297 937	1 392	**12**	299 537	**7**	1 399	**12**
MPA Loch Sunart to the Sound of Jura	717	7 391	10	**31**	437	1	**30**	7 828	**19**	11	**39**
MPA Loch Sween	39	1 091	28	**16**	22 545	576	**16**	23 636	**13**	604	**16**
MPA Lochs Duich, Long and Alsh	37	357	10	**33**	16 892	458	**17**	17 249	**17**	468	**17**
MPA Monach Isles	62	1 553	25	**19**	0	0	**42**	1 553	**29**	25	**32**
MPA Mousa to Boddam	13	106	8	**34**	0	0	**42**	106	**43**	8	**41**
MPA North-east Lewis	884	4 110	5	**37**	0	0	**42**	4 110	**20**	5	**42**
MPA Noss Head	8	0	0	**46.5**	21 514	2 856	**8**	21 514	**14**	2 856	**8**
MPA Papa Westray	33	1 234	37	**10**	13	0	**31**	1 247	**31**	38	**28**
MPA Small Isles	803	2 282	3	**40**	36 487	45	**21**	38 769	**12**	48	**24**
MPA South Arran	280	3 827	14	**27**	1 167 774	4 163	**4**	1 171 601	**1**	4 177	**4**
MPA Southern Trench	2 487	3 361	1	**42**	30	0	**34**	3391	**22**	1	**45**
MPA Upper Loch Fyne and Loch Goil	88	265	3	**39**	3 672	42	**22**	3 937	**21**	45	**26**

MPA Wester Ross	601	7 862	13	**28**	891 678	1 484	**11**	899 540	**4**	1 497	**11**
MPA Wyre and Rousay Sounds	17	747	45	**8**	442 291	26 643	**1**	443 038	**5**	26 688	**1**
SAC Berwickshire and North Northumberland Coast	615	467	1	**43**	51	0	**33**	518	**37**	1	**46**
SAC Dornoch Firth and Morrich More	46	709	15	**25**	35	1	**29**	744	**36**	16	**36**
SAC East Mingulay	115	0	0	**47**	184 589	1 604	**9**	184 589	**8**	1 604	**10**
SAC Firth of Lorn	208	2 148	10	**30**	1	0	**35**	2 149	**25**	10	**40**
SAC Firth of Tay and Eden Estuary	147	1 482	10	**32**	219	1	**26**	1 701	**27**	12	**38**
SAC Isle of May	3	46	14	**26**	9	3	**25**	54	**45**	17	**35**
MPA/SAC Loch Creran	12	86	7	**36**	2 506	209	**19**	2 592	**23**	216	**19**
SAC Loch Laxford	12	798	68	**4**	18 592	1 578	**10**	19 390	**15**	1 646	**9**
SAC Loch Moidart and Loch Shiel Woods	3	30	12	**29**	3	1	**27**	33	**46**	13	**37**
SAC Loch nam Madadh	17	761	44	**9**	61 307	3 548	**6**	62 068	**11**	3 592	**6**
SAC Loch Roag Lagoons	0	6	32	**12**	198	988	**13**	205	**41**	1 021	**13**
SAC Lochs Duich, Long and Alsh Reefs	23	600	26	**18**	17 813	766	**15**	18 413	**16**	792	**15**
SAC Luce Bay and Sands	477	10 555	22	**22**	400 715	839	**14**	411 270	**6**	861	**14**
SAC Moine Mhor	3	149	59	**5**	0	0	**42**	149	**42**	59	**22**
SAC Moray Firth	1 459	3 031	2	**41**	66 877	46	**20**	69 907	**10**	48	**25**
SAC Mousa	5	154	30	**15**	1 742	337	**18**	1 896	**26**	366	**18**
SAC North Rona	5	340	69	**3**	0	0	**42**	340	**39**	69	**21**
SAC Papa Stour	20	1 183	58	**6**	0	0	**42**	1 183	**32**	58	**23**
SAC Sanday	109	13 843	127	**1**	0	0	**42**	1 3843	**18**	127	**20**
SAC Solway Firth	374	1 350	4	**38**	32	0	**32**	1 382	**30**	4	**43**
SAC Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	45	1 004	22	**21**	1 082 865	24 032	**2**	1 083 869	**2**	24 054	**2**
SAC Sound of Barra	124	12 680	102	**2**	980 519	7 911	**3**	993 199	**3**	8 013	**3**
SAC South Uist Machair	3	0	0	**46.5**	0	0	**42**	0	**47**	0	**47**
SAC St Kilda	245	115	0	**44**	236	1	**28**	351	**38**	1	**44**
SAC Sullom Voe	27	830	31	**14**	307	12	**23**	11 37	**33**	43	**27**
SAC Sunart/MPA Loch Sunart	29	796	28	**17**	217	8	**24**	1 013	**35**	35	**29**
SAC The Vadills	1	12	23	**20**	1 626	3 077	**7**	1 638	**28**	3 100	**7**

SAC Treshnish Isles	18	1 018	55.2	**7**	69 444	3 767	**5**	70 462	**9**	3 822	**5**
SAC Obain Loch Euphoirt	3	65	18.7	**24**	0	0	**42**	65	**44**	19	**34**
SAC Loch of Stenness	8	249	31.4	**13**	0	0	**42**	249	**40**	31	**31**
SAC Monarch Isles SAC	33	1 080	33.2	**11**	0	0	**42**	1080	**34**	33	**30**

Table showing the rankings for various elements of the Geology data, including organic carbon, inorganic carbon and total carbon.

GEOLOGY		Organic Carbon			Inorganic Carbon			Total Carbon			
NC MPA / SAC	Sum of Area km^2	Stock OC (t)	Stock OC ($t\ km^{-2}$)	**Ranking OC ($t\ km^{-2}$)**	Stock IC (t)	Stock IC ($t\ km^{-2}$)	**Ranking IC ($t\ km^{-2}$)**	Stock TC (t)	**Ranking TC (t)**	Stock TC ($t\ km^{-2}$)	**Ranking TC ($t\ km^{-2}$)**
MPA Clyde Sea Sill	712	465 909	654	**32**	3 474 130	4 880	**3**	3 940 039	**4**	5 534	**3**
MPA East Caithness Cliffs	114	35 662	313	**40**	408 752	3 590	**13**	444 414	**17**	3 903	**18**
MPA Fetlar to Haroldswick	207	120 467	583	**35**	964 230	4 666	**5**	1 084 697	**11**	5 249	**7**
MPA Loch Sunart to the Sound of Jura	733	630 915	861	**23**	1 273 676	1 739	**34**	1 904 591	**9**	2 600	**35**
MPA Loch Sween	37	36 084	977	**16**	116 488	3 155	**17**	152 572	**22**	4 132	**15**
MPA Lochs Duich, Long and Alsh	36	49 257	1357	**3**	80 111	2 207	**24**	129 368	**24**	3 564	**21**
MPA Monach Isles	62	4 245	69	**47**	6 920	112	**47**	11 165	**40**	181	**47**
MPA Mousa to Boddam	13	7 745	601	**34**	37 202	2 888	**20**	44 947	**33**	3 489	**23**
MPA North-east Lewis	884	711 131	805	**24**	4 023 325	4 553	**7**	4 734 456	**3**	5 358	**6**
MPA Noss Head	8	3 906	518	**36**	44 768	5 942	**1**	48 674	**30**	6 460	**1**
MPA Papa Westray	33	9 578	291	**41**	109 659	3 334	**15**	119 237	**25**	3 625	**20**
MPA Small Isles	812	769 965	949	**18**	2 428 121	2 992	**18**	3 198 086	**5**	3 941	**16**
MPA South Arran	280	373 208	1334	**4**	709 238	2 535	**22**	1 082 446	**12**	3 869	**19**
MPA Southern Trench	2 487	1 883 175	757	**27**	11 474 976	4 615	**6**	13 358 151	**1**	5 372	**5**
MPA Upper Loch Fyne and Loch Goil	104	156 096	1504	**2**	33 2011	3 200	**16**	488 107	**15**	4 704	**11**

MPA Wester Ross	598	605 823	1014	**15**	1 749 297	2 927	**19**	2 355 120	**7**	3 941	**16**
MPA Wyre and Rousay Sounds	16	12 499	769	**26**	61 370	3 775	**11**	73 869	**28**	4 544	**12**
SAC Berwickshire and North Northumberland Coast	644	671 903	1043	**14**	1 194 982	1 854	**32**	1 866 885	**10**	2 897	**31**
SAC Dornoch Firth and Morrich More	69	72 522	1054	**11**	231 527	3 364	**14**	304 049	**19**	4 418	**13**
SAC East Mingulay	115	135 071	1173	**9**	236 943	2 058	**28**	372 014	**18**	3 231	**24**
SAC Firth of Lorn	206	147 284	716	**29**	336 549	1 636	**39**	483 833	**16**	2 352	**38**
SAC Firth of Tay and Eden Estuary	150	119 352	794	**25**	631 261	4 197	**8**	750 613	**14**	4 991	**8**
SAC Isle of May	3	424	129	**45**	4 742	1 443	**41**	5 166	**44**	1 572	**44**
SAC Loch Creran	12	19 132	1580	**1**	19 464	1 608	**40**	38 596	**34**	3 188	**25**
SAC Loch Laxford	11	8 068	752	**28**	17 717	1 651	**38**	25 785	**35**	2 403	**37**
SAC Loch Moidart and Loch Shiel Woods	3	3 160	1206	**6**	9 442	3 604	**12**	12 602	**39**	4 810	**9**
SAC Loch nam Madadh	17	17 569	1045	**13**	28 158	1 675	**37**	45 727	**32**	2 720	**33**
SAC Loch Roag Lagoons	0	284	1065	**10**	450	1 685	**35**	734	**47**	2 750	**32**
SAC Lochs Duich, Long and Alsh Reefs	23	21 788	968	**17**	47 643	2 116	**26**	69 431	**29**	3 084	**28**
SAC Luce Bay and Sands	478	294 403	617	**33**	2 303 211	4 823	**4**	2 597 614	**6**	5 440	**4**
SAC Moine Mhor	3	3134	1224	**5**	5 835	2 280	**23**	8 969	**42**	3 504	**22**
SAC Moray Firth	1 513	1 312 043	867	**22**	5 952 871	3 936	**9**	7 264 914	**2**	4 803	**10**
SAC Mousa	5	1 225	246	**43**	13 822	2 778	**21**	15 047	**37**	3 024	**30**
SAC North Rona	5	19	4	**48**	213	42	**48**	232	**48**	46	**48**
SAC Papa Stour	20	2 168	111	**46**	8 642	441	**45**	10 810	**41**	552	**45**
SAC Sanday	108	31 253	289	**42**	216 462	2 003	**29**	247 715	**21**	2 292	**39**
SAC Solway Firth	373	244 659	656	**31**	2 003 090	5 370	**2**	2 247 749	**8**	6 026	**2**
SAC Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	45	47 656	1051	**12**	95 467	2 106	**27**	143 123	**23**	3 157	**26**
SAC Sound of Barra	123	51 929	423	**37**	206 190	1 680	**36**	258 119	**20**	2 103	**41**
SAC South Uist Machair	2	1 985	874	**21**	2 444	1 076	**43**	4 429	**45**	1 950	**42**
SAC St Kilda	246	82 597	336	**39**	940 919	3 824	**10**	1 023 516	**13**	4 160	**14**
SAC Sullom Voe	25	29 581	1181	**8**	47 525	1 898	**31**	77 106	**27**	3 079	**29**
SAC Sunart/MPA Loch Sunart	54	47 673	887	**19**	70 352	1 308	**42**	118 025	**26**	2 195	**40**
SAC The Vadills	0	311	877	**20**	634	1 787	**33**	945	**46**	2 664	**34**

SAC Treshnish Isles	19	7 592	409	**38**	39 545	2 132	**25**	47 137	**31**	2 541	**36**
SAC Obain Loch Euphoirt 1	3	2 338	671	**30**	3 624	1 041	**44**	5 962	**43**	1 712	**43**
SAC Loch of Stenness	8	9 452	1193	**7**	15 357	1 938	**30**	24 809	**36**	3 131	**27**
SAC Monarch Isles SAC	33	5 299	162	**44**	8 637	263	**46**	13 936	**38**	425	**46**

Table showing the rankings for total carbon.

BIOLOGY AND GEOLOGY	Total Carbon			
NC MPA / SAC	Stock TC(t)	Ranking TC (t)	Stock TC (t km^{-2})	Ranking TC (t km^{-2})
MPA Clyde Sea Sill	3 940 039	**4**	5 534	**12**
MPA East Caithness Cliffs	446 615	**21**	3 922	**27**
MPA Fetlar to Haroldswick	1 384 234	**12**	6 648	**6**
MPA Loch Sunart to the Sound of Jura	1 912 419	**10**	2 611	**38**
MPA Loch Sween	176 208	**24**	4 736	**21**
MPA Lochs Duich, Long and Alsh	146 617	**25**	4 032	**25**
MPA Monach Isles	12 718	**39**	206	**47**
MPA Mousa to Boddam	45 053	**34**	3 497	**32**
MPA North-east Lewis	4 738 566	**3**	5 363	**15**
MPA Noss Head	70 188	**32**	9 316	**4**
MPA Papa Westray	120 484	**26**	3 663	**30**
MPA Small Isles	3 236 855	**6**	3 989	**26**
MPA South Arran	2 254 047	**8**	8 046	**5**
MPA Southern Trench	13 361 542	**1**	5 373	**14**
MPA Upper Loch Fyne and Loch Goil	492 044	**19**	4 749	**20**
MPA Wester Ross	3 254 660	**5**	5 438	**13**
MPA Wyre and Rousay Sounds	516 907	**18**	31 232	**1**
SAC Berwickshire and North Northumberland Coast	1 867 403	**11**	2 898	**37**
SAC Dornoch Firth and Morrich More	304 793	**22**	4 434	**22**
SAC East Mingulay	556 603	**17**	4 835	**18**
SAC Firth of Lorn	485 982	**20**	2 362	**40**
SAC Firth of Tay and Eden Estuary	752 314	**16**	5 003	**16**
SAC Isle of May	5 220	**44**	1 589	**44**
SAC Loch Creran	41 188	**35**	3 404	**33**
SAC Loch Laxford	45 175	**33**	4 049	**24**
SAC Loch Moidart and Loch Shiel Woods	12 635	**40**	4 823	**19**
SAC Loch nam Madadh	107 795	**29**	6 312	**8**
SAC Loch Roag Lagoons	939	**47**	3 771	**29**
SAC Lochs Duich, Long and Alsh Reefs	87 844	**30**	3 876	**28**
SAC Luce Bay and Sands	3 008 884	**7**	6 301	**9**
SAC Moine Mhor	9 118	**42**	3 563	**31**
SAC Moray Firth	7 334 821	**2**	4 851	**17**
SAC Mousa	16 943	**37**	3 390	**34**
SAC North Rona	572	**48**	115	**48**
SAC Papa Stour	11 993	**41**	610	**45**
SAC Sanday	261 558	**23**	2 419	**39**

SAC Solway Firth	2 249 131	**9**	6 030	**10**
SAC Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	1 226 992	**14**	27 211	**2**
SAC Sound of Barra	1 251 318	**13**	10 116	**3**
SAC South Uist Machair	4 429	**45**	1 950	**42**
SAC St Kilda	1 023 867	**15**	4 161	**23**
SAC Sullom Voe	78 243	**31**	3 122	**36**
SAC Sunart/MPA Loch Sunart	119 038	**27**	2 230	**41**
SAC The Vadills	2 583	**46**	5 764	**11**
SAC Treshnish Isles	117 599	**28**	6 363	**7**
SAC Obain Loch Euphoirt 1	6 027	**43**	1 731	**43**
SAC Loch of Stenness	25 058	**36**	3 162	**35**
SAC Monarch Isles SAC	15 016	**38**	458	**46**

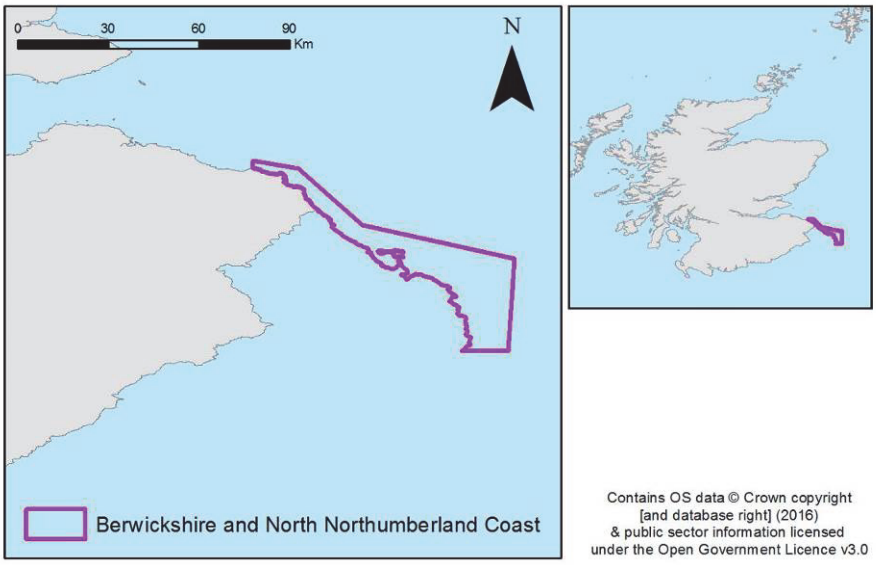
ANNEX 7: DESCRIPTIONS AND MAPS FOR EACH SAC AND MPA (IN ALPHABETICAL ORDER)

Area covered by blue carbon categories (biological) for each MPA/SAC is provided within the supplementary document.

1. Berwickshire and North Northumberland Coast SAC

Location: 55°39'14.000'N; 001°40'20.000'W – The protected area stretches along 115 km of the coastline from Alnmouth in Northumberland up to Fast Castle Head in Berwickshire. At its widest point it stretches four nautical miles offshore, including the Farne Islands and Holy Island.

Area: 650 km^2



Map of the location of Berwickshire and North Northumberland Coast SAC

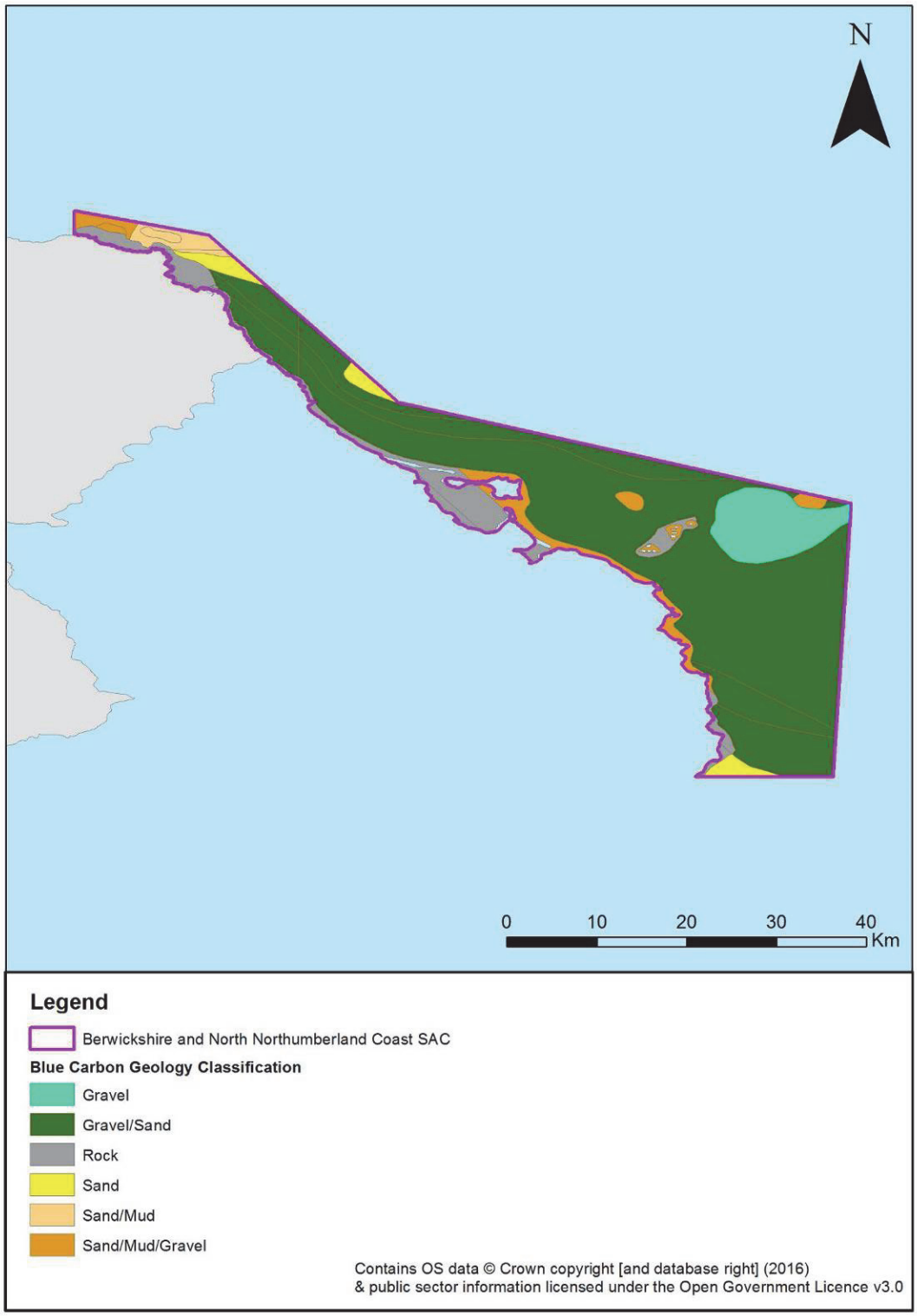
Designation: SAC for a range of marine features including grey seals, intertidal mudflats and sandflats, reefs, sea caves and shallow inlets and bays.

Along with the Lindisfarne SPA, the Berwickshire and North Northumberland Coast SAC make up the Berwickshire and North Northumberland Coast European Marine Site.

Blue carbon designation: Gravel, gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Modiolus modiolus* bed, *Mytilus edulis* beds, subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Berwickshire and North Northumberland Coast	671 903	2 807	1 194 982	22 729

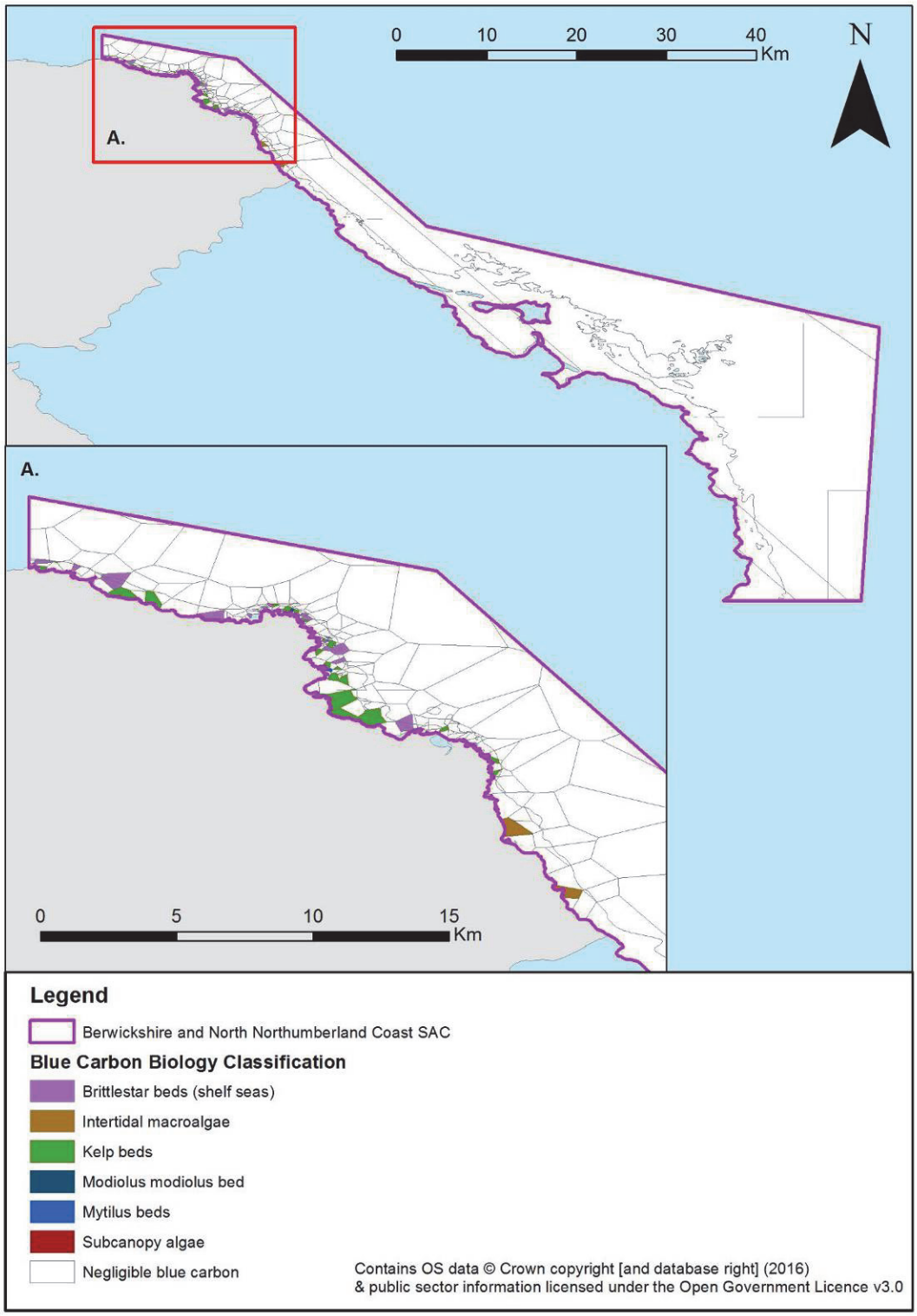
(SS: standing stock, seq: sequestration, prod: production)



Map of Berwickshire and North Northumberland Coast SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Berwickshire and North Northumberland Coast	467	1 044	0	51	74

(SS: standing stock, seq: sequestration, prod: production)



Map of Berwickshire and North Northumberland Coast SAC showing the different biological habitats. The table above reports the calculated IC and OC

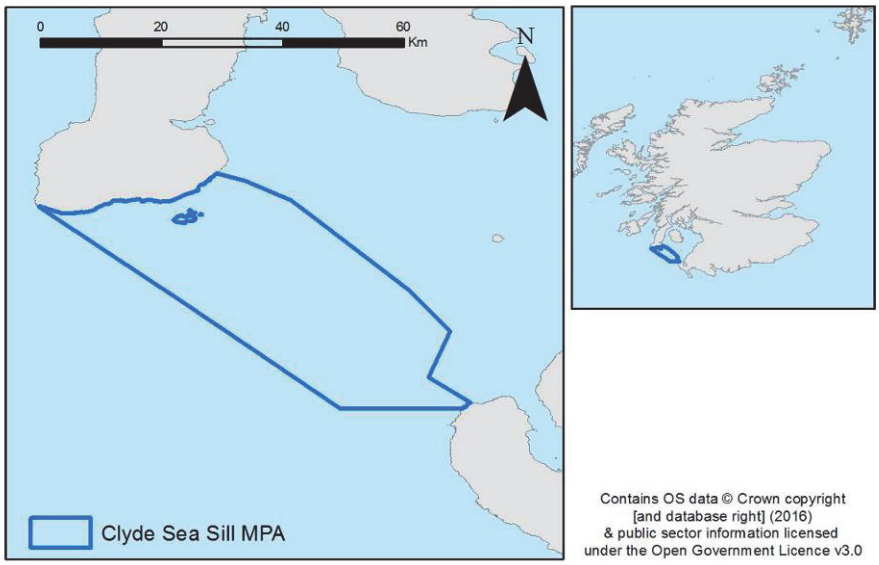
Table showing the calculated IC and OC values for each biological habitat: Berwickshire and North Northumberland Coast

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.89	0.14	0.00	0.00	73.04	98.37	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.40	0.06	53.93	5.16	0.00	0.00	195.34	41.85	0.00	0.00	0.00	-
Kelp beds	1.45	0.24	989.94	94.81	0.00	0.00	271.23	58.10	0.00	0.00	0.00	-
Modiolus modiolus bed	0.01	0.00	0.00	0.00	0.51	0.69	0.00	0.00	51.22	99.48	0.00	-
Mytilus beds	0.02	0.00	0.00	0.00	0.70	0.94	0.00	0.00	0.27	0.52	0.00	-
Negligible blue carbon	611.94	99.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.01	0.00	0.23	0.02	0.00	0.00	0.24	0.05	0.00	0.00	0.00	-
Total	**614.72**	**100.00**	**1044.09**	**100.00**	**74.25**	**100.00**	**466.81**	**100.00**	**51.49**	**100.00**	**0.00**	**-**

2. Clyde Sea Sill NC MPA

Location: 55°10.484'N; 005°26.203'W – Clyde Sea Sill NC MPA is on the west coast of Scotland, and stretches from the Mull of Kintyre to Corsewall Point on Rhins of Galloway near Stranraer.

Area: 712 km^2



Map of the location of Clyde Sea Sill NC MPA

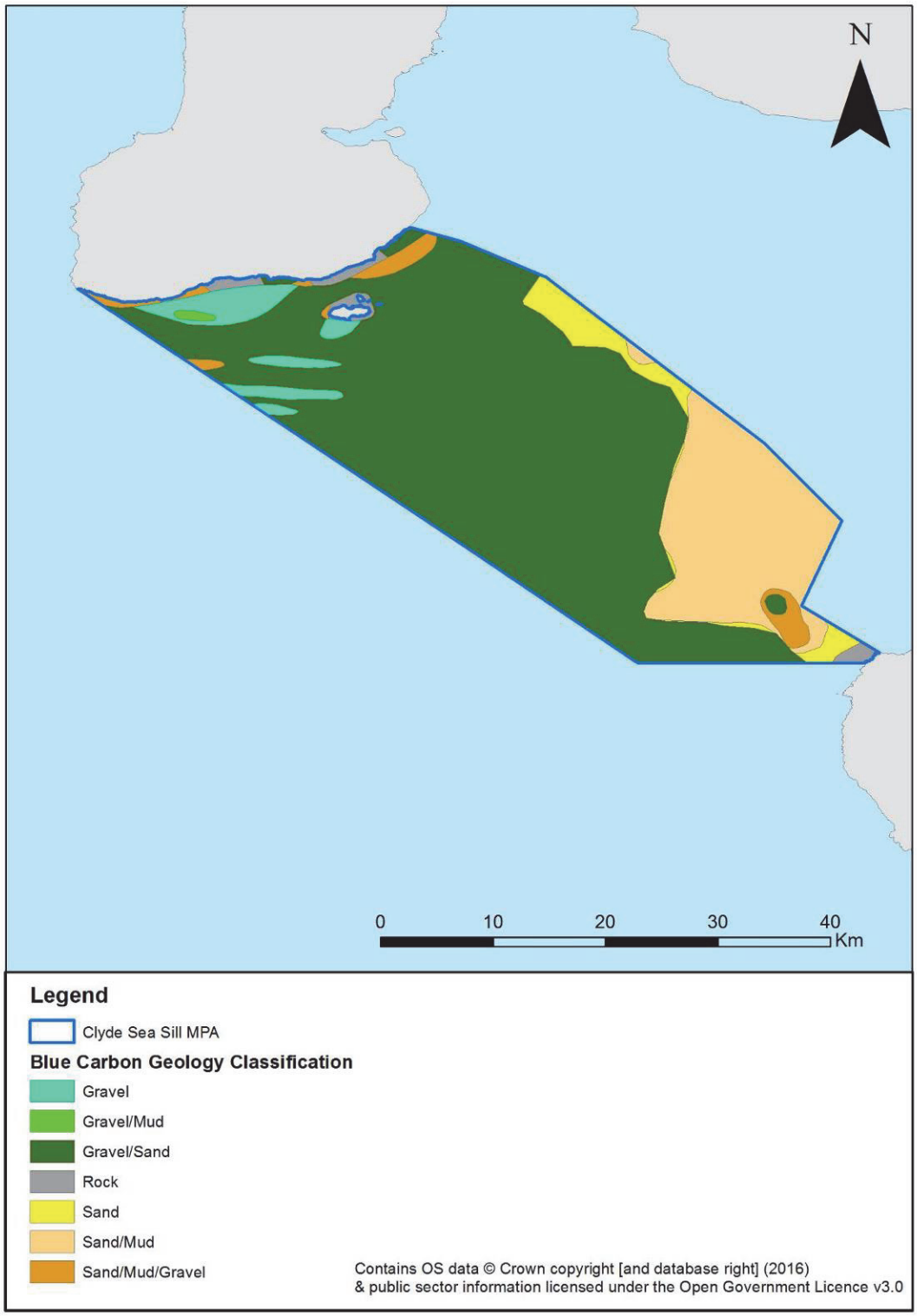
Designation: NC MPA for black guillemot (mobile species), circalittoral sand and coarse sediment communities (habitat), and fronts, sand banks, sand ribbon and sand wave fields (geomorphology). This is the most southerly NC MPA in Scottish seas, where the Irish Sea meets the Clyde Sea.

An existing SSSI on the cliffs of Sanda Island for breeding birds, predominantly black guillemots, which rely on the feeding grounds of the Clyde Sea Sill. The seabed contains patchy coarse sandy sediment, which harbours clam shells, polychaetes, starfish, brittle stars and hermit crabs.

Blue carbon designation: Gravel, gravel/mud, gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); negligible blue carbon (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Clyde Sea Sill	465 909	4 868	3 474 130	26 278

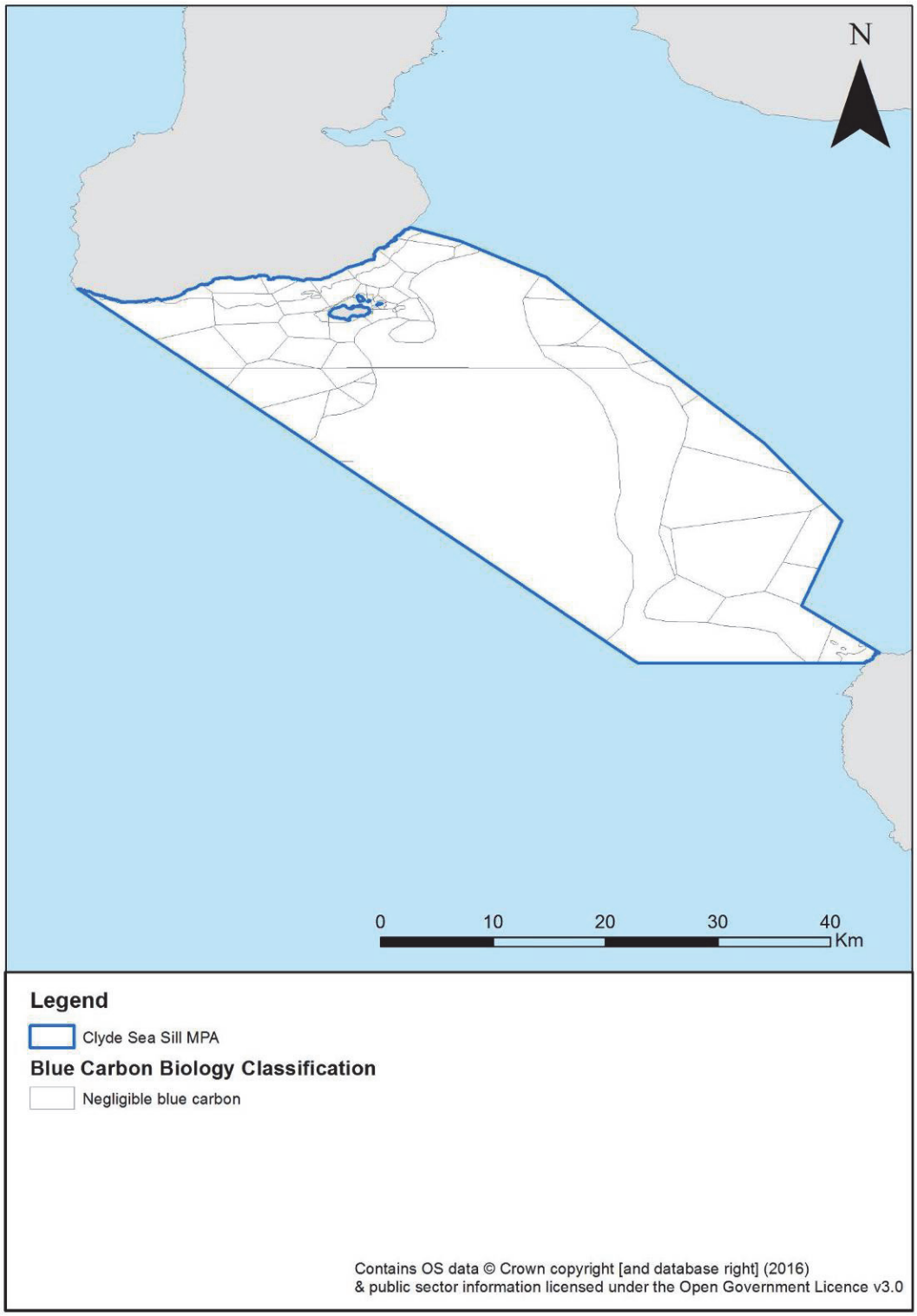
(SS: standing stock, seq: sequestration, prod: production)



Map of Clyde Sea Sill NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Clyde Sea Sill	0	0	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Clyde Sea Sill NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

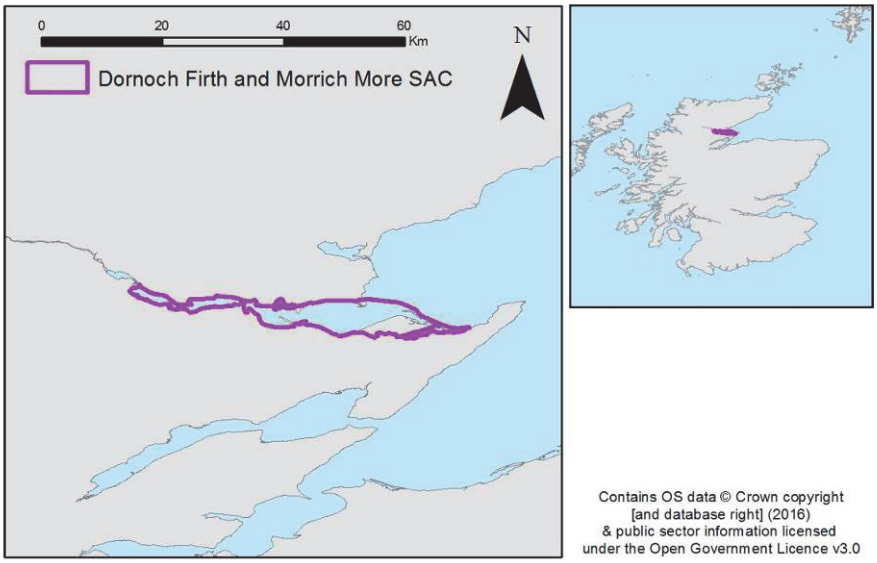
Table showing the calculated IC and OC values for each biological habitat:
Clyde Sea Sill

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Negligible blue carbon	711.77	100.00	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
Total	**711.77**	**100.00**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**

3. Dornoch Firth and Morrich More SAC

Location: 57°51'0.00'N; 004°2'30.00'W – Situated on the east coast of the Highlands of Scotland, Dornoch Firth (a large estuary) and Morrich More (a large area of sand dunes) form part of the boundary between Ross and Cromarty, to the south, and Sutherland, to the north.

Area: 87 km^2



Map of the location of Dornoch Firth and Morrich More SAC

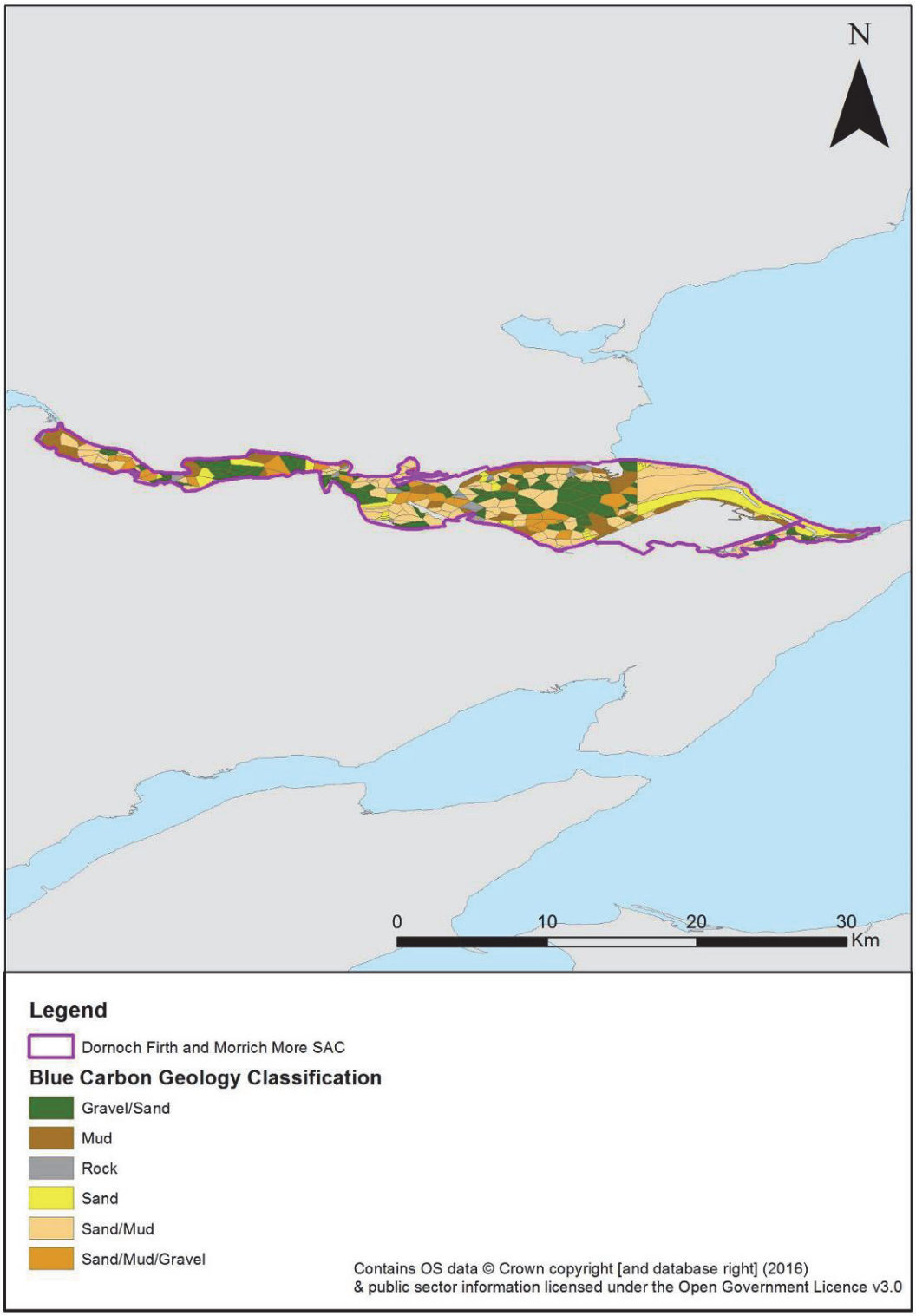
Designation: The SAC is designated for its coastal features, marine features and both marine and non-marine mammals (otters). Marine features include estuaries, harbour seal, intertidal mudflats and sandflats, reefs and subtidal sandbanks. Coastal features include Atlantic salt meadows, coastal dune heathland, dune grassland, dunes with juniper thickets, glasswort, humid dune slacks, lime-deficient dune heathland with crowberry, shifting dunes and shifting dunes with marram.

The area around the Dornoch firth also includes Dornoch Firth SSSI and National Scenic Area and Dornoch Firth and Loch Fleet Ramsar Site and SPA.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, *Mytilus edulis* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Dornoch Firth and Morrich More	72 522	1 124	231 527	1 977

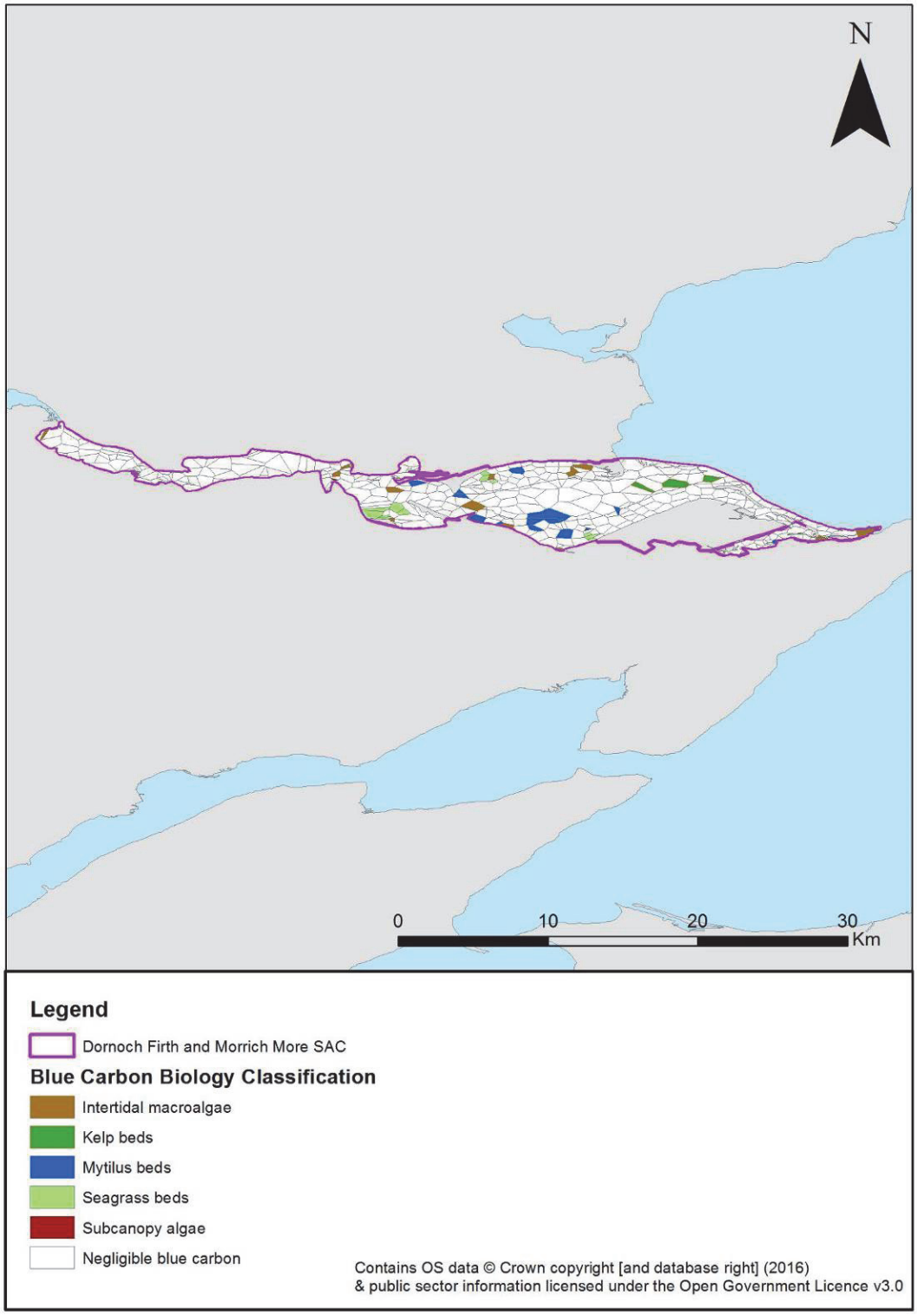
(SS: standing stock, seq: sequestration, prod: production)



Map of Dornoch Firth and Morrich More SAC showing the different geological habitats.The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Dornoch Firth and Morrich More	709	824	32	35	91

(SS: standing stock, seq: sequestration, prod: production)



Map of Dornoch Firth and Morrich More SAC showing the different biological habitats. The table above reports the calculated IC and OC

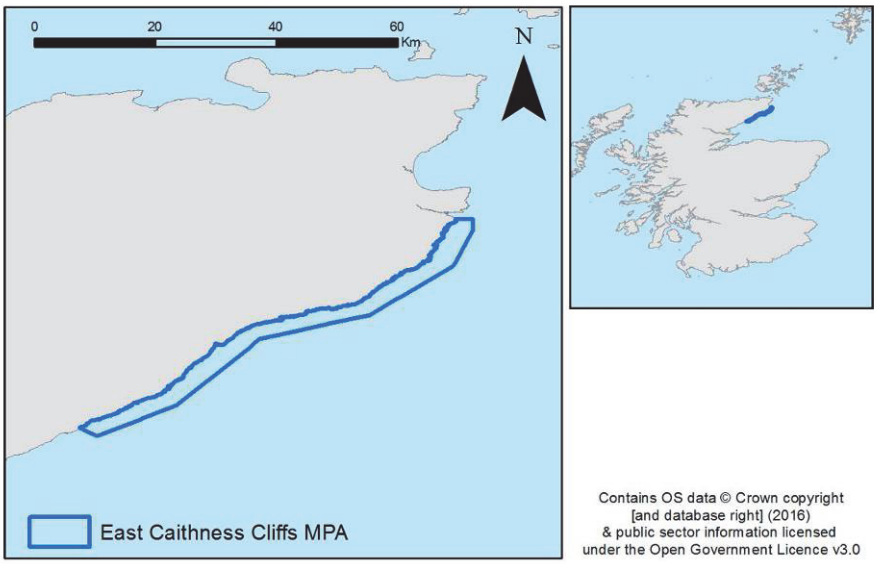
Table showing the calculated IC and OC values for each biological habitat: Dornoch Firth and Morrich More

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	1.13	2.46	152.67	18.53	0.00	0.00	553.00	77.97	0.00	0.00	0.00	0.00
Kelp beds	0.83	1.81	569.44	69.13	0.00	0.00	156.00	22.00	0.00	0.00	0.00	0.00
Mytilus beds	2.28	4.96	0.00	0.00	91.16	100.00	0.00	0.00	35.10	100.00	0.00	0.00
Negligible blue carbon	41.32	89.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.39	0.85	101.39	12.31	0.00	0.00	0.00	0.00	0.00	0.00	32.24	100.00
Subcanopy algae	0.01	0.03	0.25	0.03	0.00	0.00	0.31	0.04	0.00	0.00	0.00	0.00
Total	**45.97**	**100.00**	**823.75**	**100.00**	**91.16**	**100.00**	**709.31**	**100.00**	**35.10**	**100.00**	**32.24**	**100.00**

4. East Caithness Cliffs NCMPA

Location: 58°15.987'N; 003°18.869'W – East Caithness Cliffs NC MPA is located in the north of Scotland on the eastern coast of Caithness and Sutherland, and encompasses the nearshore coastal waters between Wick and Helmsdale.

Area: 114 km^2



Map of the location of East Caithness Cliffs NC MPA

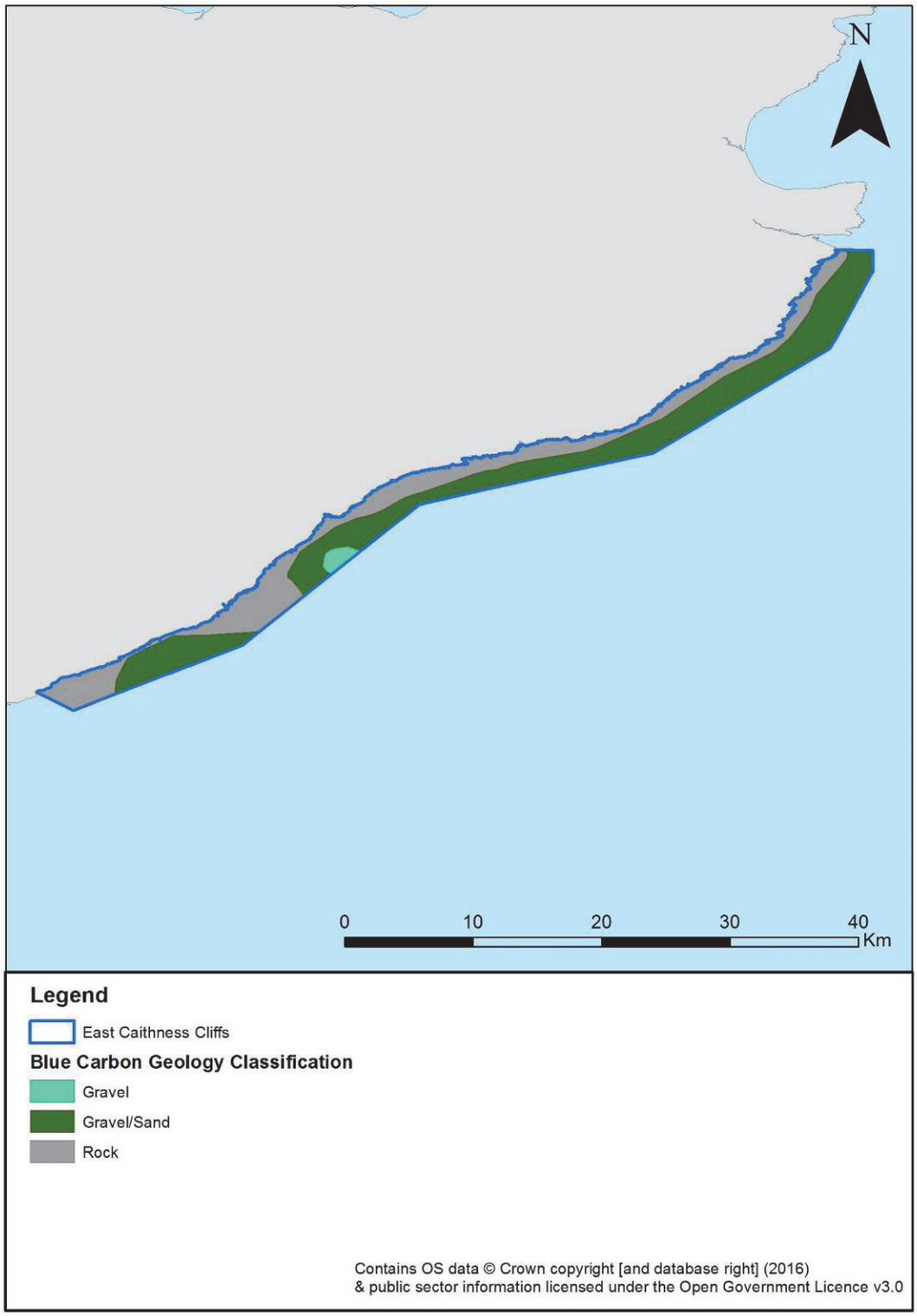
Designation: MPA for the protection of black guillemots (mobile species) and their feeding grounds, which are typically found close inshore.

The breeding cliffs are on the edge of the NC MPA, and the NC MPA itself consists of a rocky seabed with kelp beds.

Blue carbon designation: Gravel, gravel/sand and rock (geology); brittlestar beds and kelp beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
East Caithness Cliffs	35 662	267	408 752	2 947

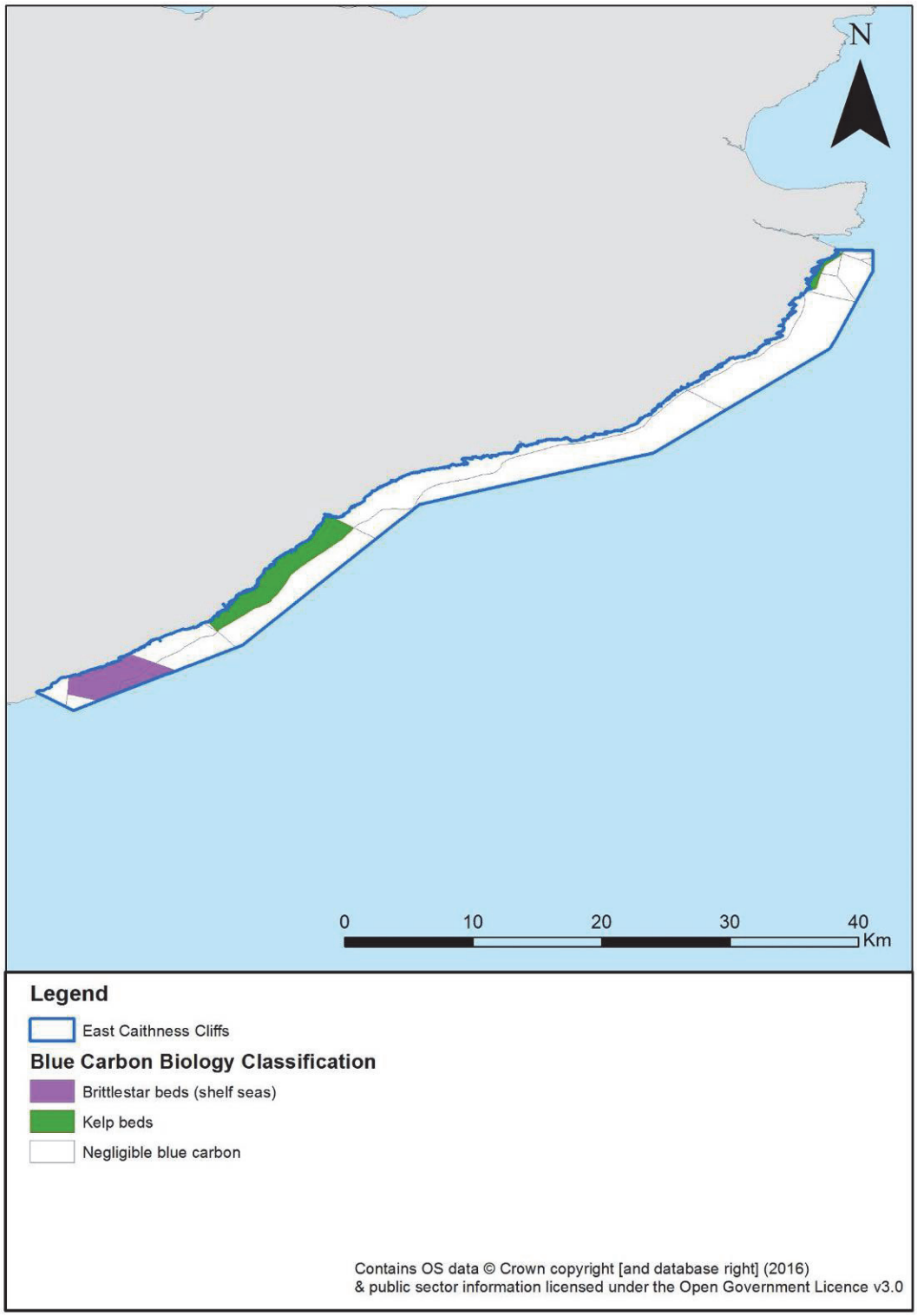
(SS: standing stock, seq: sequestration, prod: production)



Map of East Caithness Cliffs NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
East Caithness Cliffs	2 201	8 034	0	0	685

(SS: standing stock, seq: sequestration, prod: production)



Map of East Caithness Cliffs NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

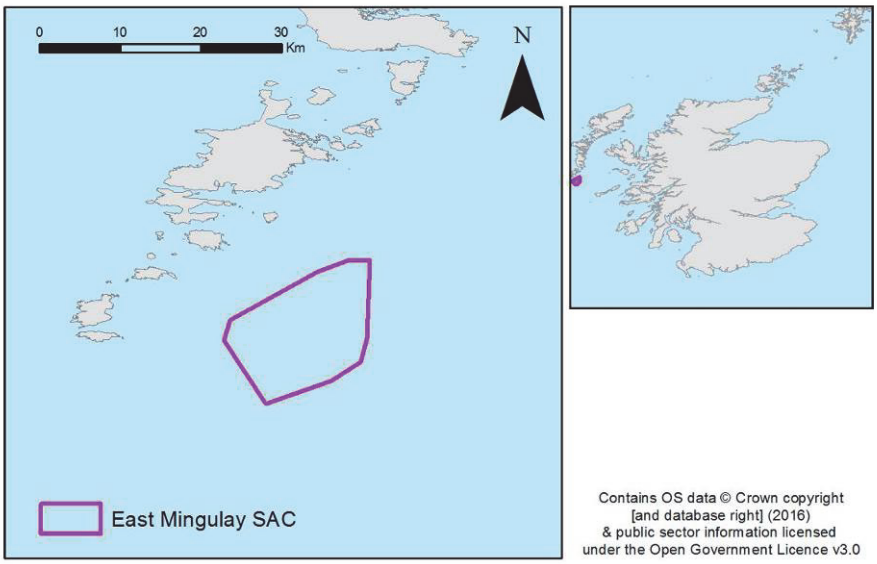
Table showing the calculated IC and OC values for each biological habitat: East Caithness Cliffs

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	8.36	7.36	0.00	0.00	685.26	100.00	0.00	0.00	0.00	-	0.00	-
Kelp beds	11.73	10.33	8033.78	100.00	0.00	0.00	2201.16	100.00	0.00	-	0.00	-
Negligible blue carbon	93.42	82.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	-
Total	**113.50**	**100.00**	**8033.78**	**100.00**	**685.26**	**100.00**	**2201.16**	**100.00**	**0.00**	**-**	**0.00**	**-**

5. East Mingulay SAC

Location: 56°47'20.00'N; 007°24'21.00'W – The SAC is situated to the east of the Island of Mingulay, south of Barra, in the Outer Hebrides.

Area: 115 km^2



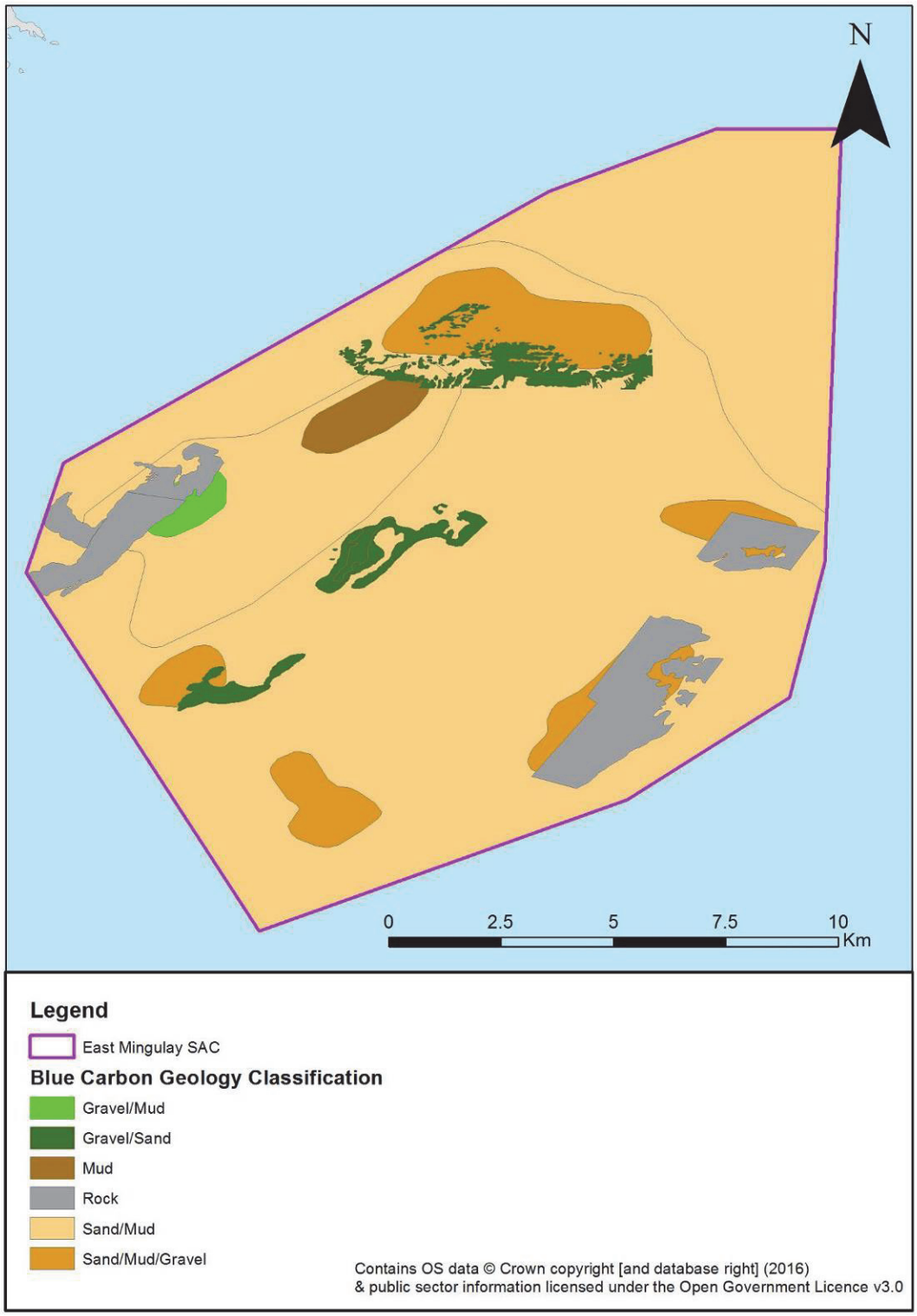
Map of the location of East Mingulay SAC

Designation: SAC for reefs, biogenic and geogenic. The East Mingulay reefs are of special importance due to the coldwater coral *Lophelia pertusa* found there. This is the only known example of coldwater coral reef in territorial waters (i.e. within the 12 nautical mile limit). The SAC consists of nine areas of reef, encompassed by a single boundary covering an overall area of 11,958ha.

Blue carbon designation: Gravel/mud, gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); *Lophelia pertusa* reef (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
East Mingulay	135 071	1 997	236 943	2 620

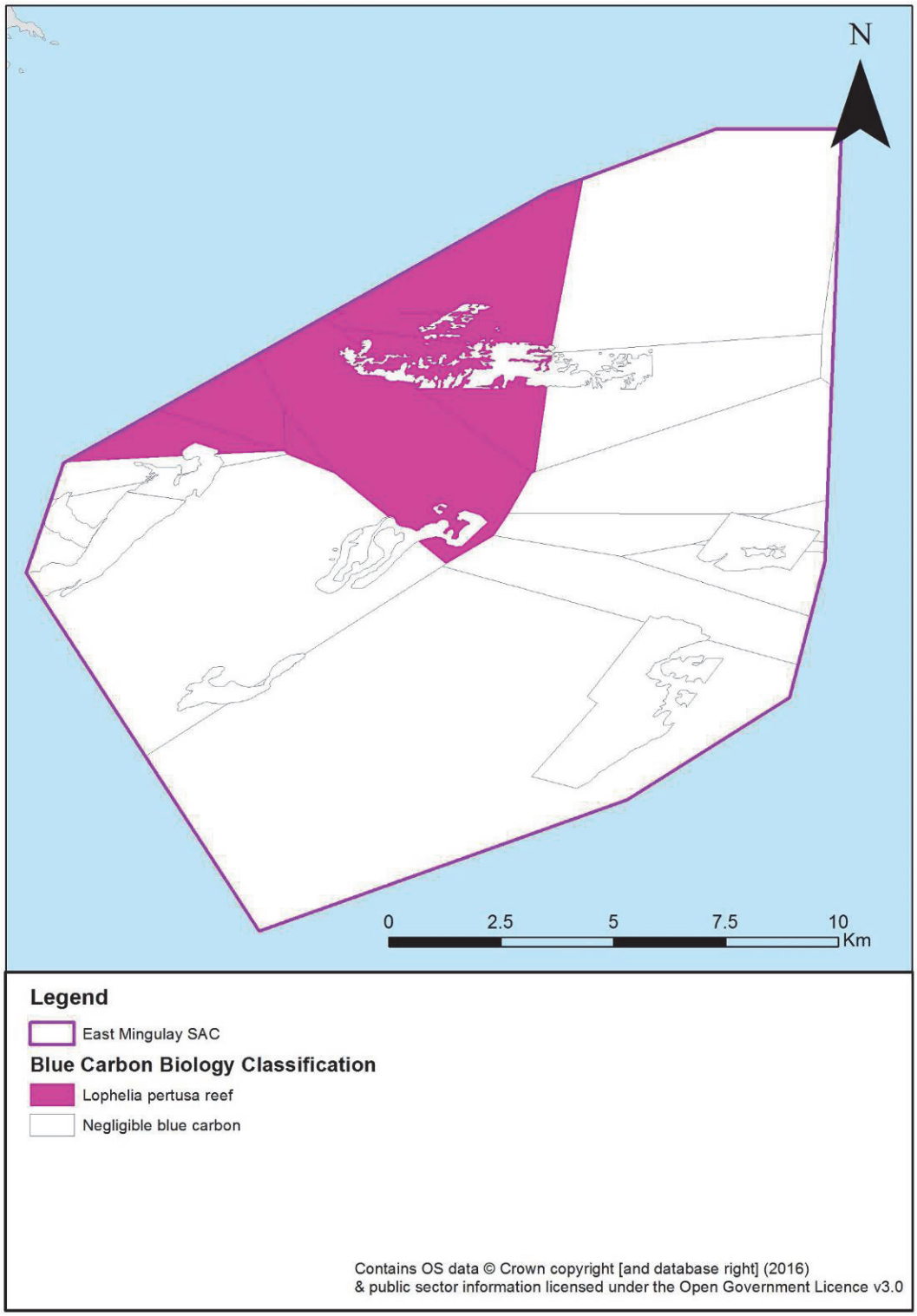
(SS: standing stock, seq: sequestration, prod: production)



Map of East Mingulay SAC showing the different geological habitats The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
East Mingulay	0	0	0	184 589	689

(SS: standing stock, seq: sequestration, prod: production)



Map of East Mingulay SAC showing the different biological habitats. The table above reports the calculated IC and OC

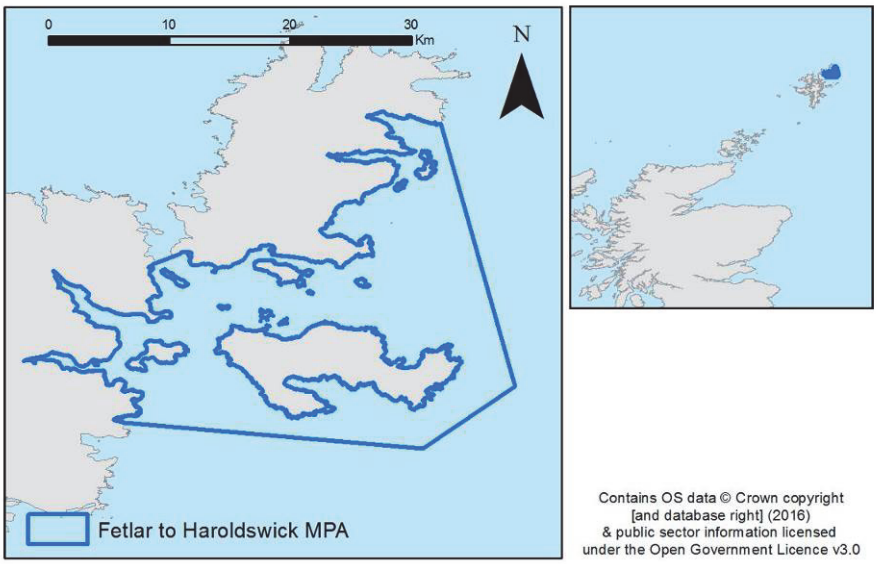
Table showing the calculated IC and OC values for each biological habitat: East Mingulay

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Lophelia pertusa reef	19.69	17.11	0.00	-	689.13	100.00	0.00	-	184588.62	100.00	0.00	-
Negligible blue carbon	95.42	82.89	0.00	-	0.00	0.00	0.00	-	0.00	0.00	0.00	-
Total	**115.11**	**100.00**	**0.00**	**-**	**689.13**	**100.00**	**0.00**	**-**	**184588.62**	**100.00**	**0.00**	**-**

6. Fetlar to Haroldswick NC MPA

Location: 60°38.219'N; 000°51.929'W – Fetlar to Haroldswick NC MPA is a mosaic of islands and waters in the north of Shetland, where the waters of the North Sea and the Atlantic Ocean meet. The NC MPA overlaps the seaward area of the existing Fetlar SPA

Area: 615 km^2



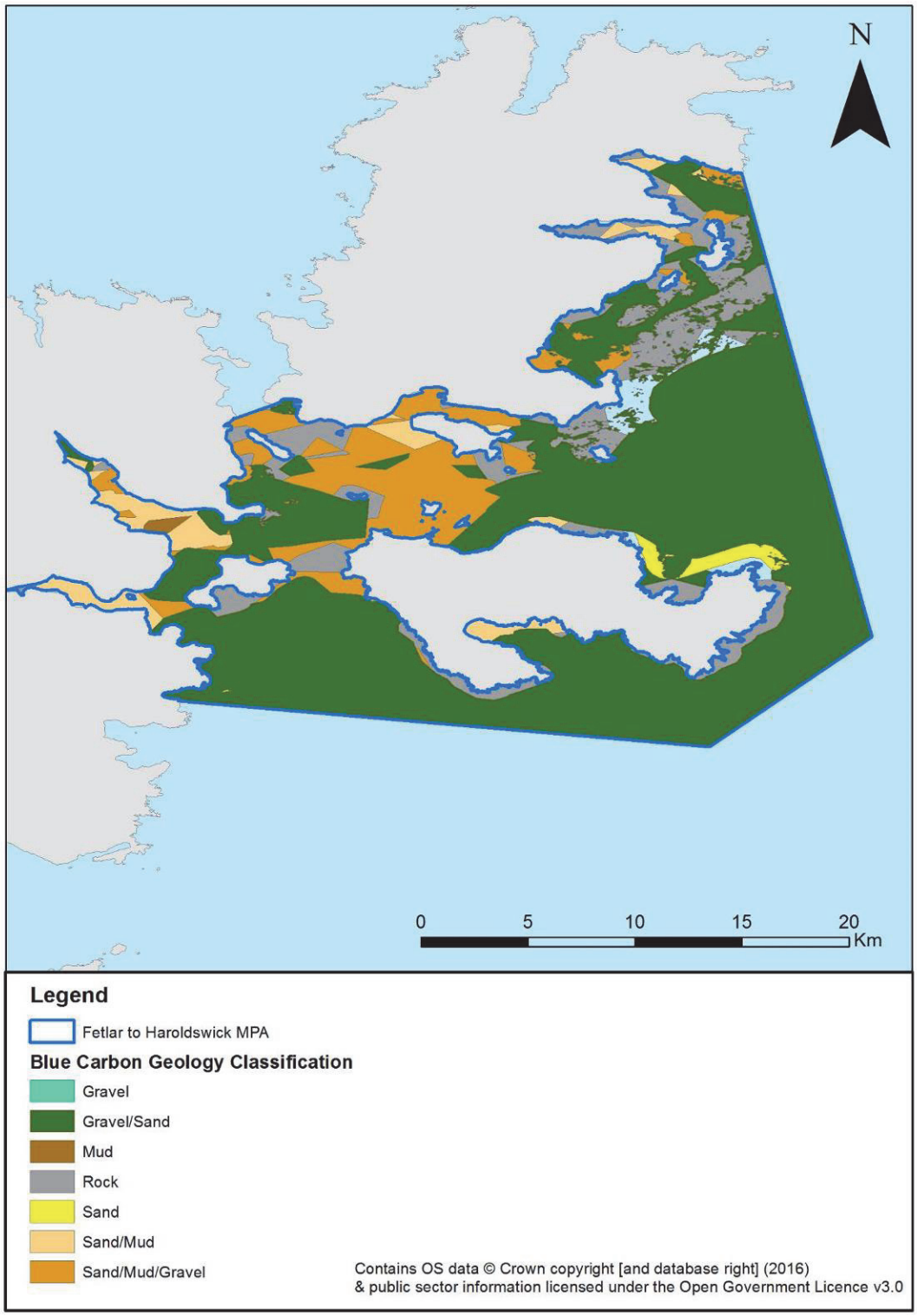
Map of the location of Fetlar to Haroldswick NC MPA

Designation: NC MPA for maerl beds, kelp and seaweed communities, shallow tide-swept sands with burrowing bivalves, and horse mussel bids. In addition, more than 2000 breeding black guillemots (mobile species), forage in the habitats.

Blue carbon designation: Gravel, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, kelp beds, maerl beds, *Modiolus modiolus* bed and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Fetlar to Haroldswick	120 467	1 216	964 230	7 222

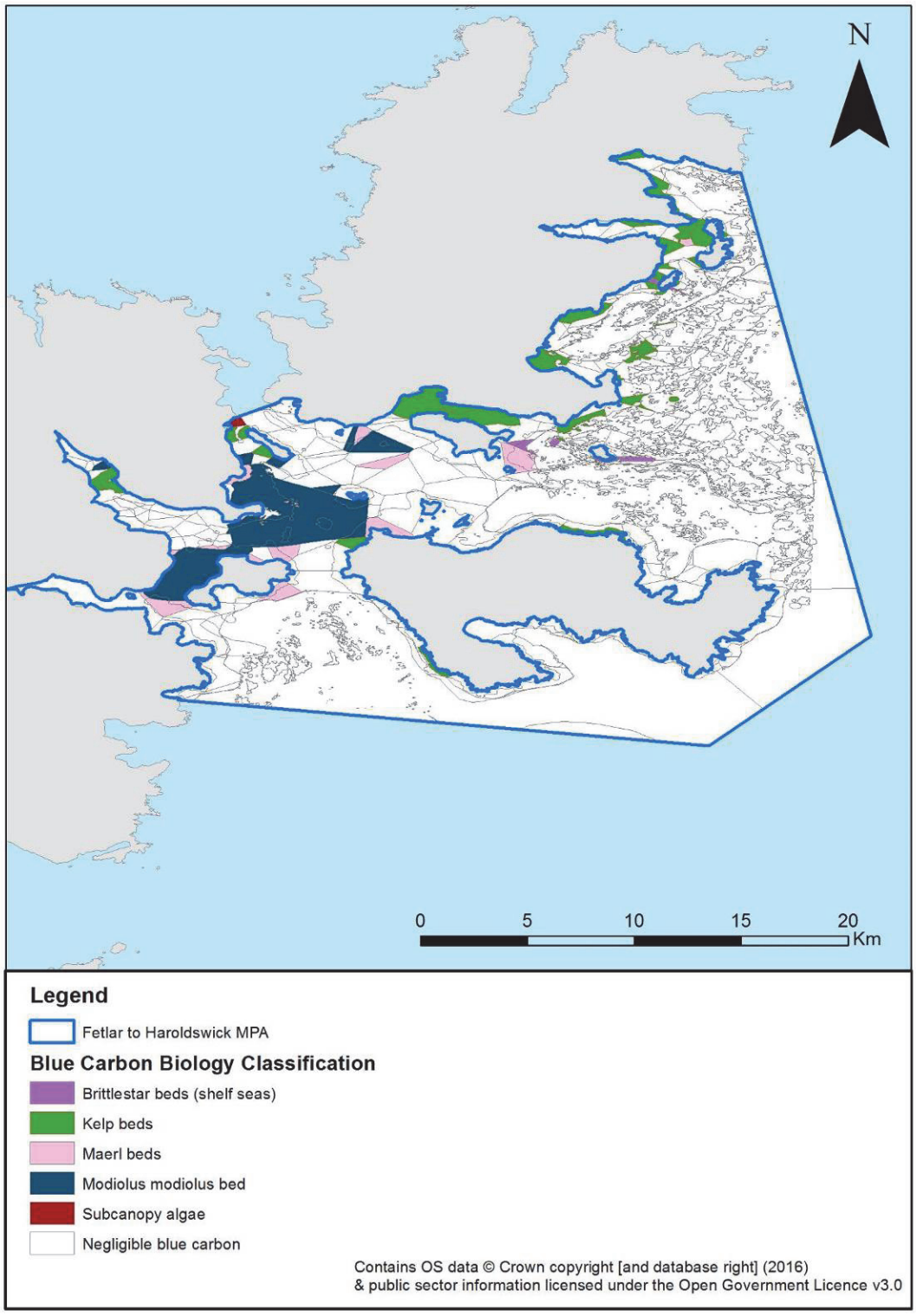
(SS: standing stock, seq: sequestration, prod: production)



Map of Fetlar to Haroldswick NC MPA showing the different geological habitats. The table above reports the calculated IC and OC in the SAC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Fetlar to Haroldswick	1 600	5 832	0	297 937	835

(SS: standing stock, seq: sequestration, prod: production)



Map of Fetlar to Haroldswick NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

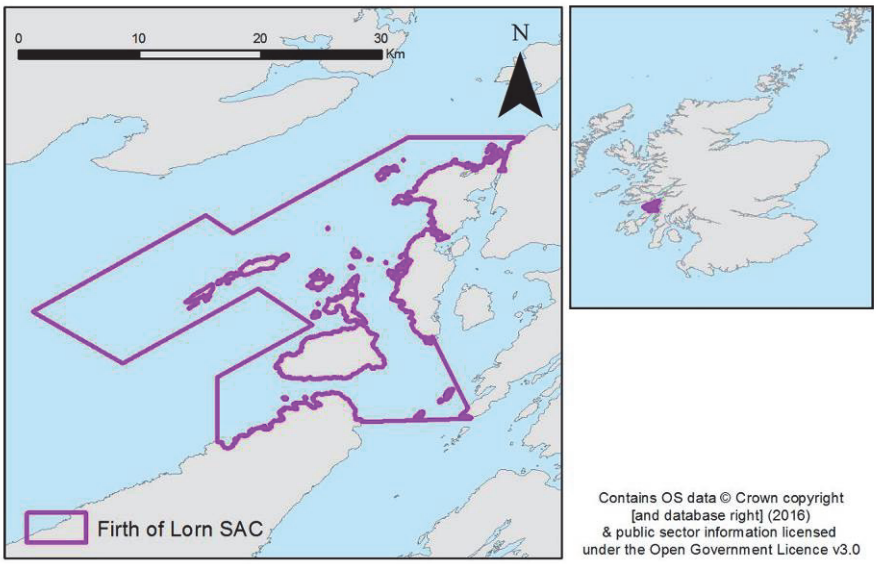
Table showing the calculated IC and OC values for each biological habitat: Fetlar to Haroldswick

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.89	0.14	0.00	0.00	44.53	5.33	0.00	0.00	0.00	0.00	0.00	-
Kelp beds	0.40	0.06	5828.88	99.95	0.0	0.00	1597.05	99.81	0.00	0.00	0.00	-
Maerl beds	1.45	0.24	0.00	0.00	294.48	35.26	0.00	0.00	248331.44	83.35	0.00	-
Modiolus modiolus bed	0.03	0.00	0.00	0.00	496.06	59.40	0.00	0.00	49605.67	14.95	0.00	-
Negligible blue carbon	0.02	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0	0.00	0.00	-
Subcanopy algae	611.94	99.55	2.97	0.05	0.0	0.00	3.11	0.19	0	0.00	0.00	-
Total	**614.73**	**100.00**	**5831.88**	**100.00**	**835.07**	**100.00**	**1600.16**	**100.00**	**297937.11**	**100.00**	**0.00**	**-**

7. Firth of Lorn SAC

Location: 56°13'0.00' N; 005°43'0.00'W – The area enclosed by the Firth of Lorn SAC boundary contains a complex group of islands, sounds and inlets: Encompassing the water adjacent to the Islands of the Garvellachs, Scarba, Luing and Seil.

Area: 210 km^2



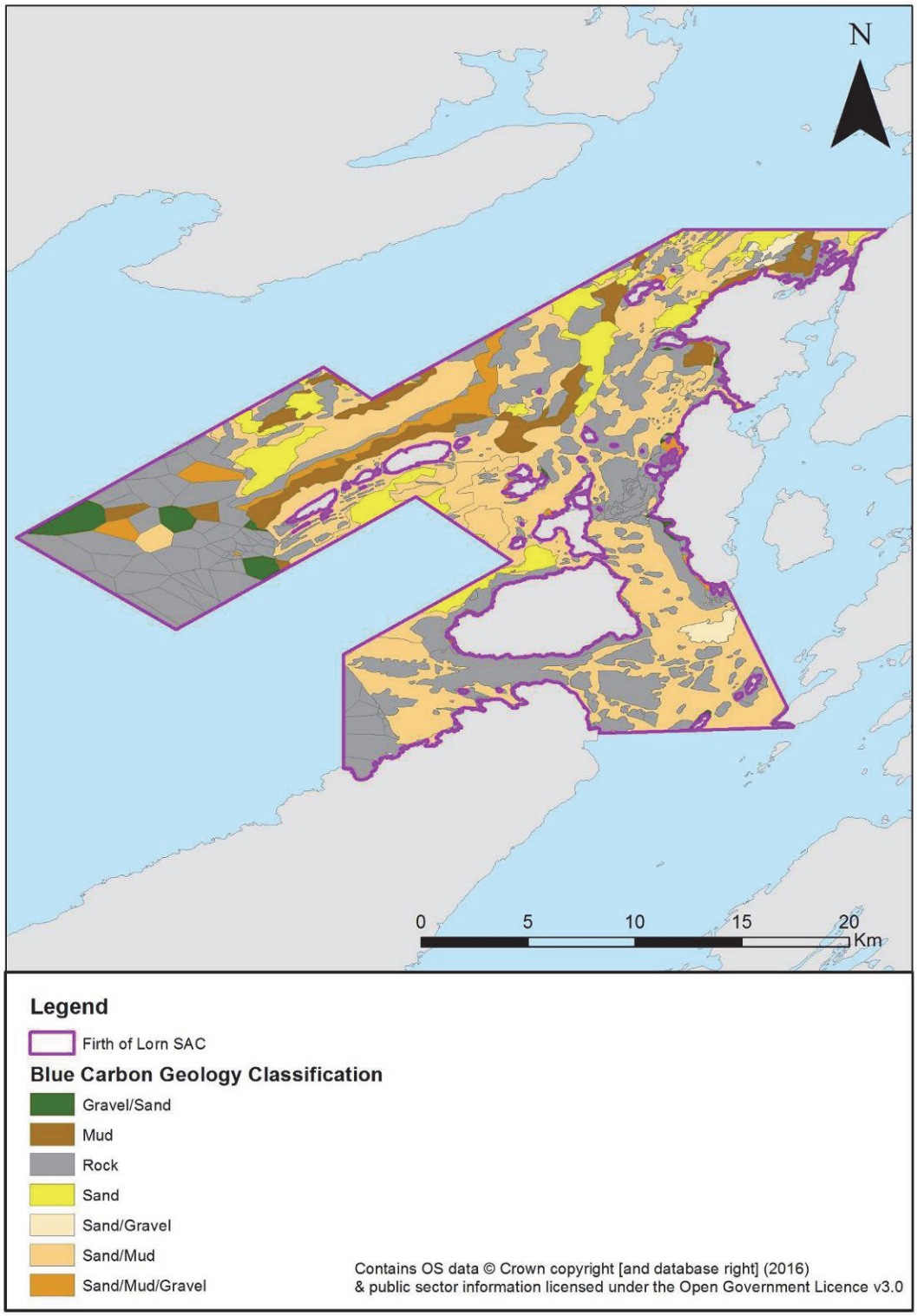
Map of the location of Firth of Lorn SAC

Designation: SAC for reefs. Designated for its rocky reef habitats, which extend from the shallow depths between the islands and mainland into depths of over 200 m, in many places close inshore. The varied physical environment (tide related) is reflected in the variety of reef types and associated communities and species, which are amongst the most diverse in both the UK and Europe.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/gravel, sand/mud and sand/mud/gravel (geology); brittlestar beds, kelp beds, *Mytilus edulis* beds, subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Firth of Lorn	147 284	2 282	336 549	3 202

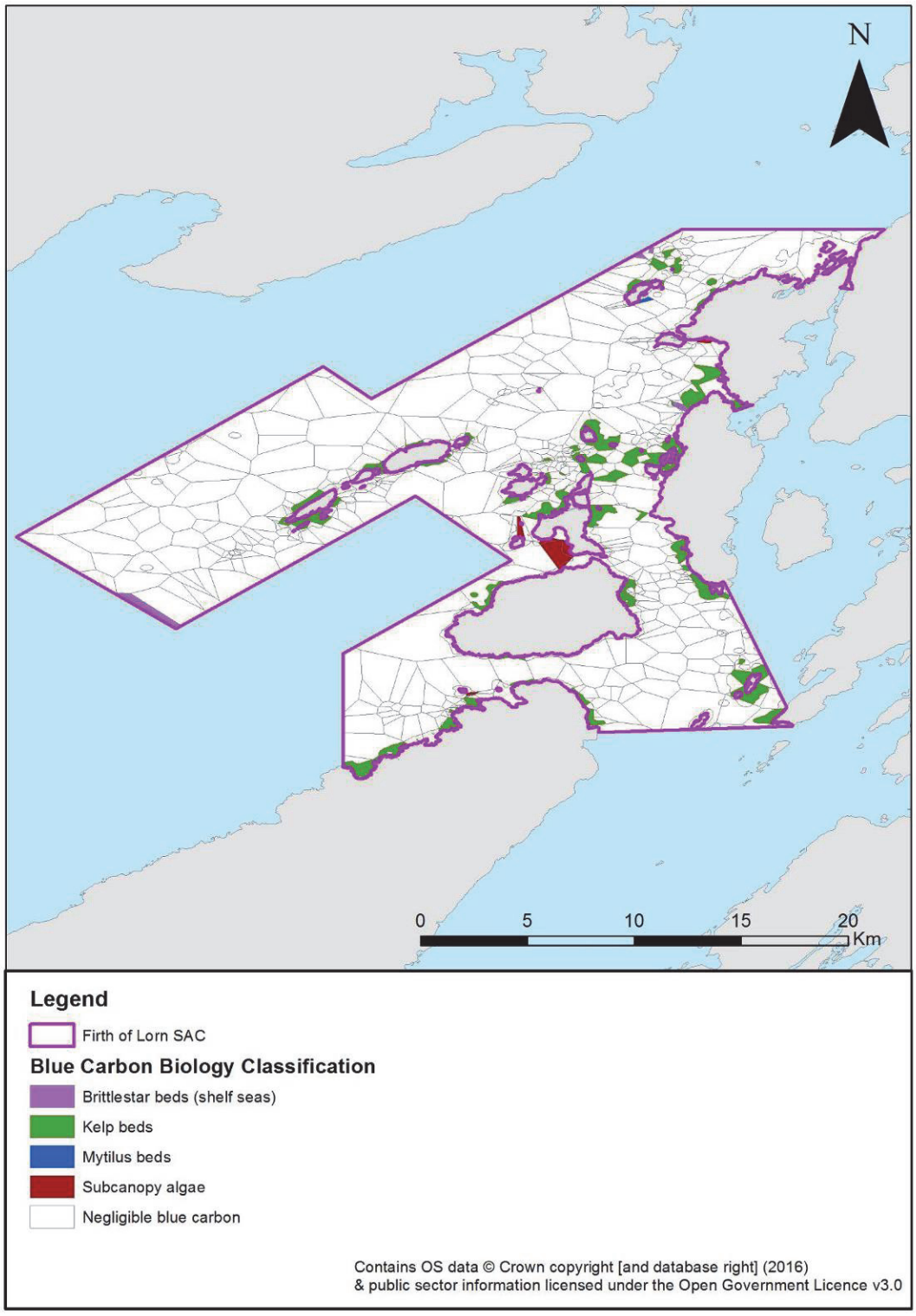
(SS: standing stock, seq: sequestration, prod: production)



Map of Firth of Lorn SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Firth of Lorn	2 148	7 777	0	1	65

(SS: standing stock, seq: sequestration, prod: production)



Map of Firth of Lorn SAC showing the different biological habitats. The table above reports the calculated IC and OC

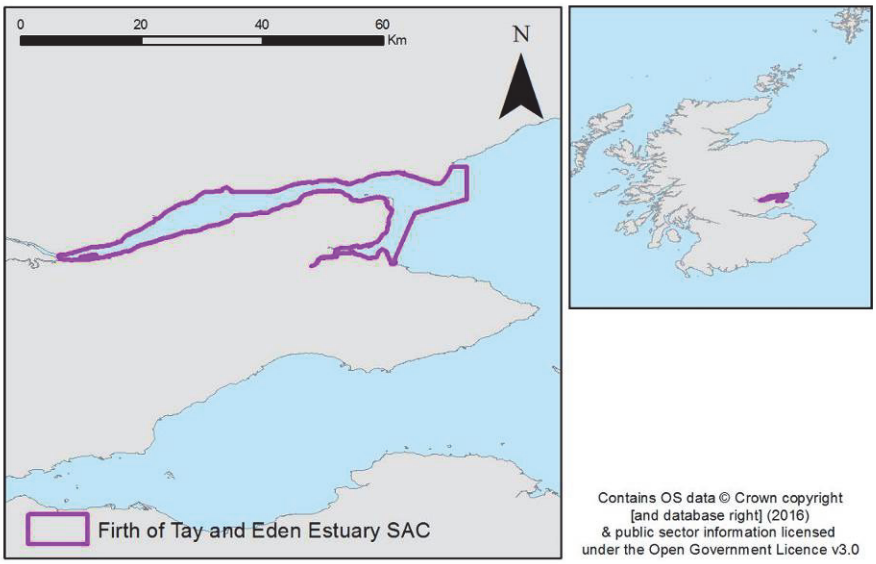
Table showing the calculated IC and OC values for each biological habitat: Firth of Lorn

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.76	0.37	0.00	0.00	62.30	95.89	0.0	**0.00**	0.00	**0.00**	0.00	**-**
Kelp beds	11.32	5.44	7754.91	99.71	0.00	0.00	2124.75	**98.90**	0.00	**0.00**	0.00	**-**
Mytilus beds	0.07	0.03	0.00	0.00	2.67	4.11	0.00	**0.00**	1.03	**100.00**	0.00	**-**
Negligible blue carbon	194.87	93.65	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.00**	0.00	**-**
Subcanopy algae	1.07	0.51	22.50	0.29	0.00	0.00	23.57	**1.10**	0.00	**0.00**	0.00	**-**
Total	**208.09**	**100.00**	**7777.41**	**100.00**	**64.97**	**100.00**	**2148.32**	**100.00**	**1.03**	**100.00**	**0.00**	**-**

8. Firth of Tay and Eden Estuary SAC

Location: 56°22'0.00'N; 002°57'0.00'W – The Firth of Tay and Eden Estuary SAC is situated on the east coast of Scotland north of the Firth of Forth between the coastal towns of St Andrews and Carnoustie.

Area: 154 km^2



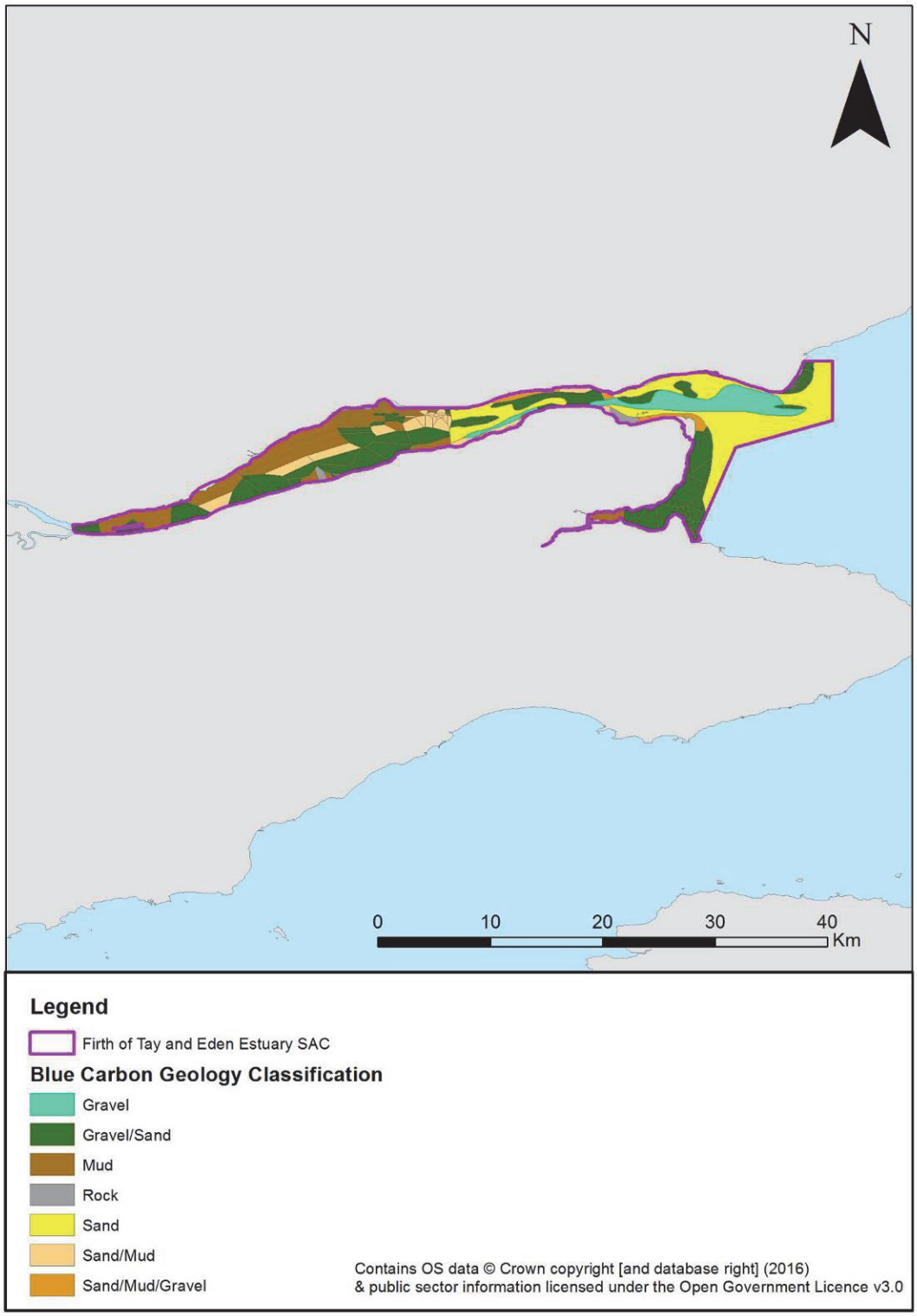
Map of the location of Firth of Tay and Eden Estuary SAC

Designation: The SAC, made up of two estuarine areas, is designated for its marine features, including, estuaries, harbour seal, intertidal mudflats and sandflats and subtidal sandbanks. The area is also an SPA and Ramsar site due to the large array of breeding and non-breeding birds for example, little tern, marsh harrier and oystercatcher.

Blue carbon designation: Gravel, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, *Mytilus edulis* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Firth of Tay and Eden Estuary	119 352	1 816	631 261	4 798

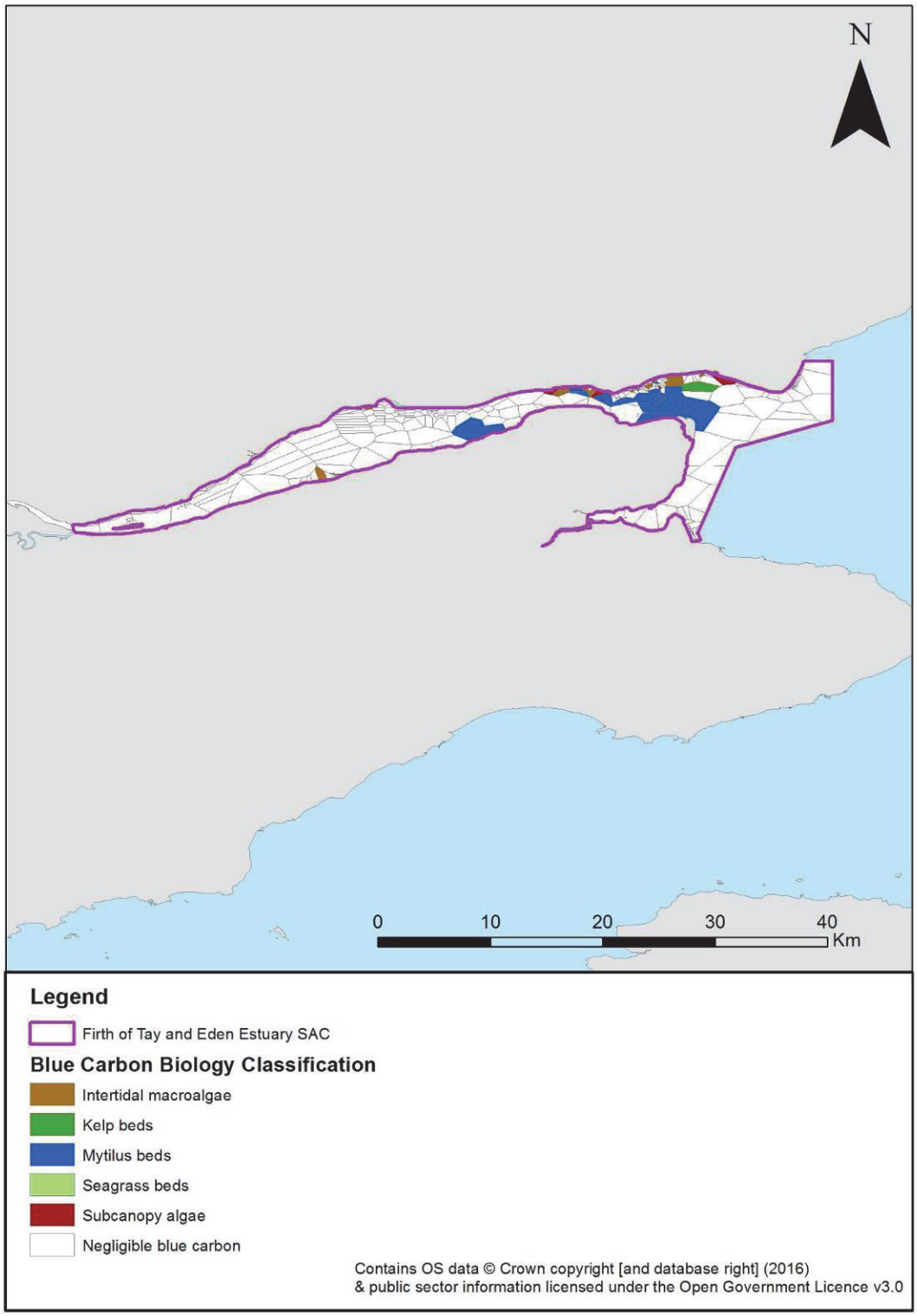
(SS: standing stock, seq: sequestration, prod: production)



Map of Firth of Tay and Eden Estuary SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Firth of Tay and Eden Estuary	1 482	1 237	2	219	568

(SS: standing stock, seq: sequestration, prod: production)



Map of Firth of Tay and Eden Estuary SAC showing the different biological habitats. The table above reports the calculated IC and OC

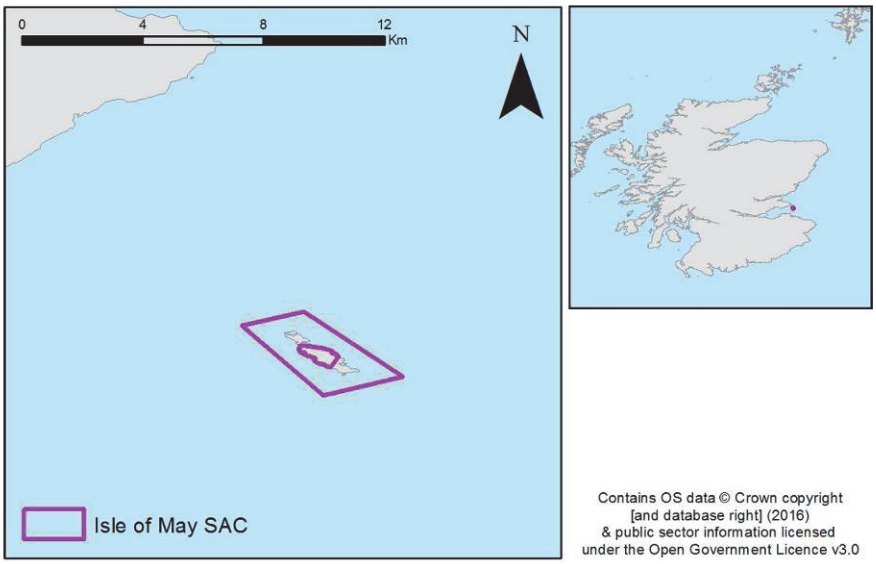
Table showing the calculated IC and OC values for each biological habitat: Firth of Tay and Eden Estuary

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	2.49	1.69	336.77	27.22	0.00	0.00	1219.91	82.29	0.00	0.00	0.00	0.00
Kelp beds	1.27	0.86	870.89	70.40	0.00	0.00	238.61	16.10	0.00	0.00	0.00	0.00
Mytilus beds	14.19	9.63	0.00	0.00	567.64	100.00	0.00	0.00	218.54	100.00	0.00	0.00
Negligible blue carbon	128.32	87.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.03	0.02	6.56	0.53	0.00	0.00	0.00	0.00	0.00	0.00	2.09	100.00
Subcanopy algae	1.09	0.74	22.81	1.84	0.00	0.00	23.89	1.61	0.00	0.00	0.00	0.00
Total	**147.39**	**100.00**	**1237.02**	**100.00**	**567.64**	**100.00**	**1482.41**	**100.00**	**218.54**	**100.00**	**2.09**	**100.00**

9. Isle of May SAC

Location: 56°11'25.00'N; 002°34'25.00'W – The Isle of May lies at the entrance to the Firth of Forth on the east coast of Scotland.

Area: 3.57 km^2



Map of the location of Isle of May SAC

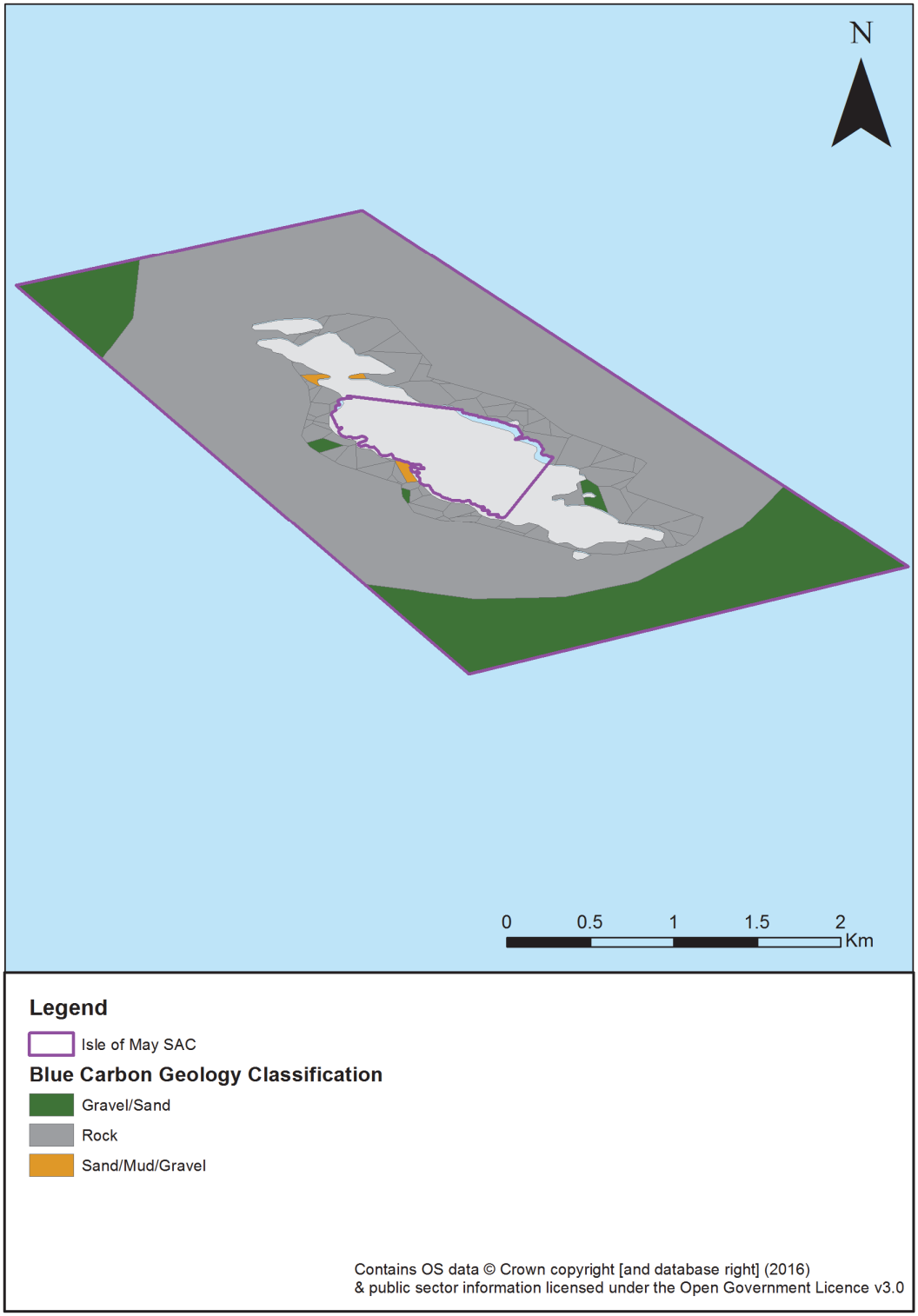
Designation: The SAC is designated for two marine features, grey seal and reefs. The Isle of May is noted for the high quality of bedrock reefs that fringe 90% of its coastline and is the largest east coast breeding colony of grey seals in Scotland.

The Isle of May is also a SSSI and a National Nature Reserve.

Blue carbon designation: Gravel/sand, rock and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Modiolus modiolus* and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Isle of May	424	3	4 742	34

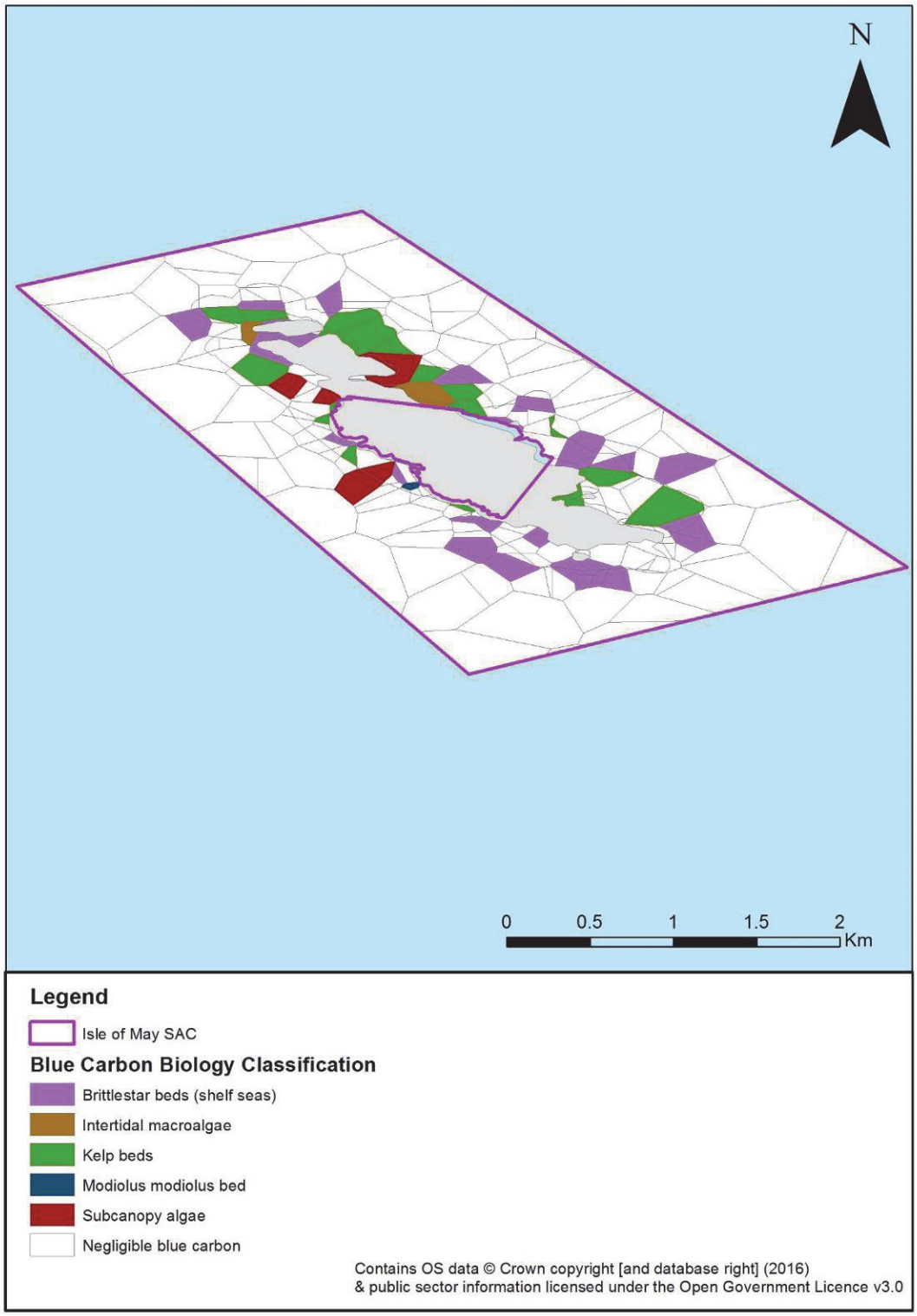
(SS: standing stock, seq: sequestration, prod: production)



Map of Isle of May SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Isle of May	46	126	0	9	21

(SS: standing stock, seq: sequestration, prod: production)



Map of Isle of May SAC showing the different biological habitats. The table above reports the calculated IC and OC

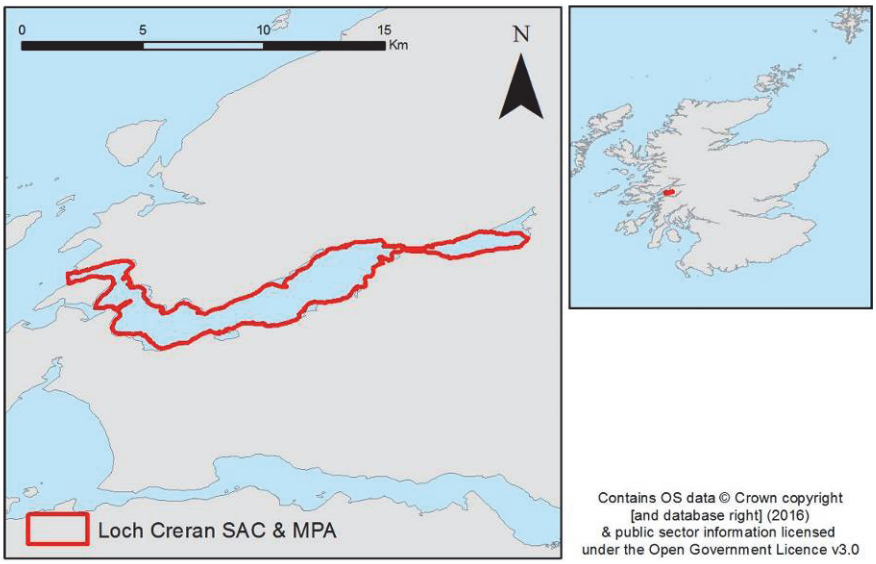
Table showing the calculated IC and OC values for each biological habitat: Isle of May

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.25	7.71	0.00	0.00	20.71	99.58	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.02	0.66	2.94	2.33	0.00	0.00	10.65	23.37	0.00	0.00	0.00	-
Kelp beds	0.18	5.44	122.02	96.56	0.00	0.00	33.43	73.39	0.00	0.00	0.00	-
Modiolus modiolus bed	0.00	0.07	0.00	0.00	0.09	0.42	0.00	0.00	8.64	100.00	0.00	-
Negligible blue carbon	2.76	84.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.07	2.05	1.41	1.12	0.00	0.00	1.48	3.24	0.00	0.00	0.00	-
Total	**3.28**	**100.00**	**126.37**	**100.00**	**20.80**	**100.00**	**45.56**	**100.00**	**8.64**	**100.00**	**0.00**	**-**

10. Loch Creran SAC/ NC MPA

Location: 56°31.940'N; 005°20.583'W – Loch Creran NC MPA is a small sea loch on the west of Scotland, just north of Oban, with four deep basins separated by rocky sills. The NC MPA boundary overlaps the Loch Creran Special Area of Conservation (SAC).

Area: 12 km^2



Map of the location of Loch Creran SAC/ NC MPA

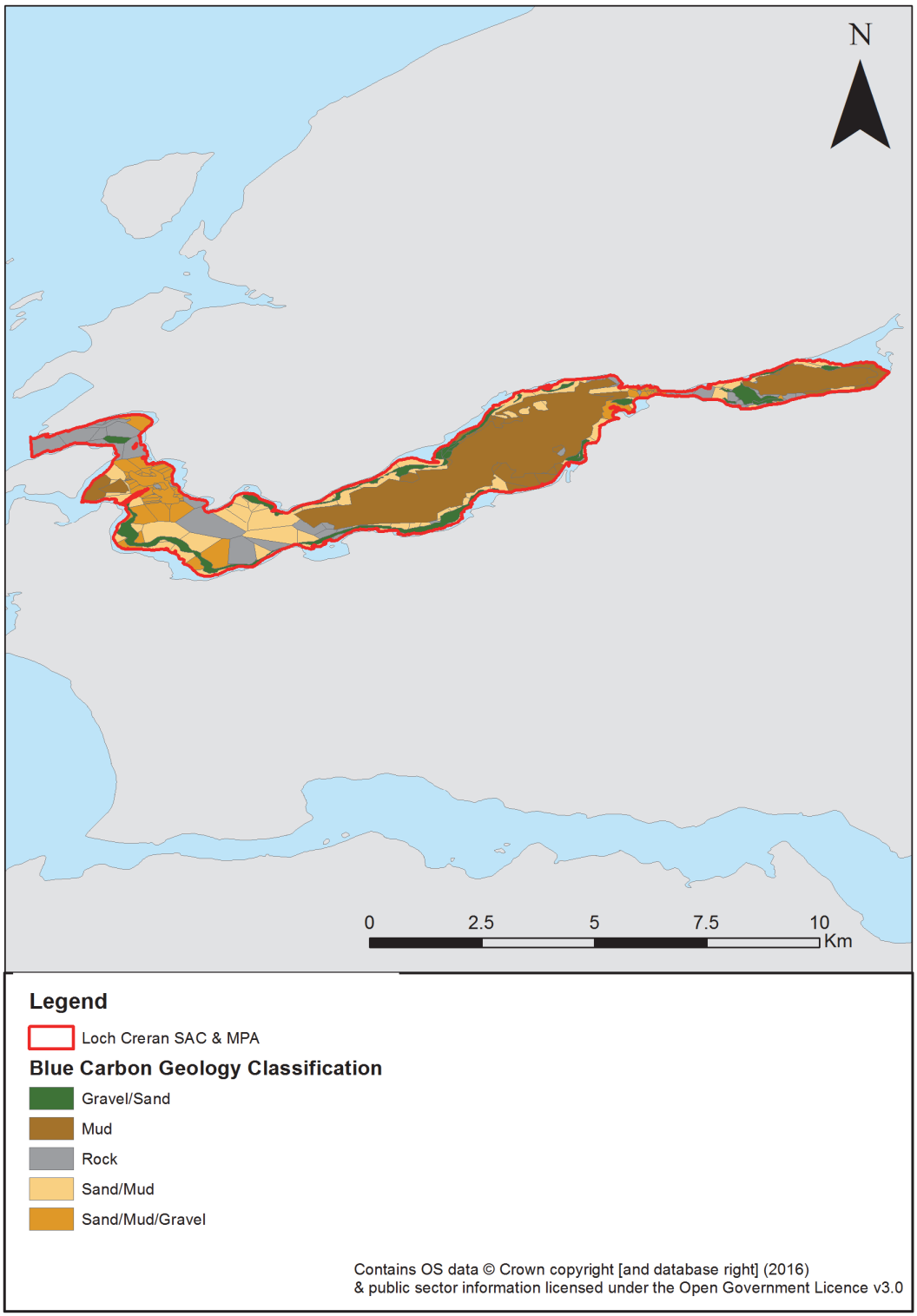
Designation: NC MPA for the flame shell beds (bivalve molluscs), and habitats within the loch range from mud, providing habitat to Norway lobsters and seapens in the deep basins, to sponges and anemones in shallower waters. Flame shell beds, horse mussel beds and serpulid reefs contribute to the unique and high biodiversity of the loch, as well as different seaweeds, whelks, starfish, brittlestars, crabs and sea squirts.

Loch Creran is a designated SAC due to the biogenic reefs of the calcareous tube-worm *Serpula vermicularis* present. This species has a world-wide distribution but the development of reefs is extremely rare.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); (geology); brittlestar beds, kelp beds, *Limaria hians* beds, *Modiolus modiolus* bed, *Serpula vermicularis* reef, subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Creran	19 132	552	19 464	297

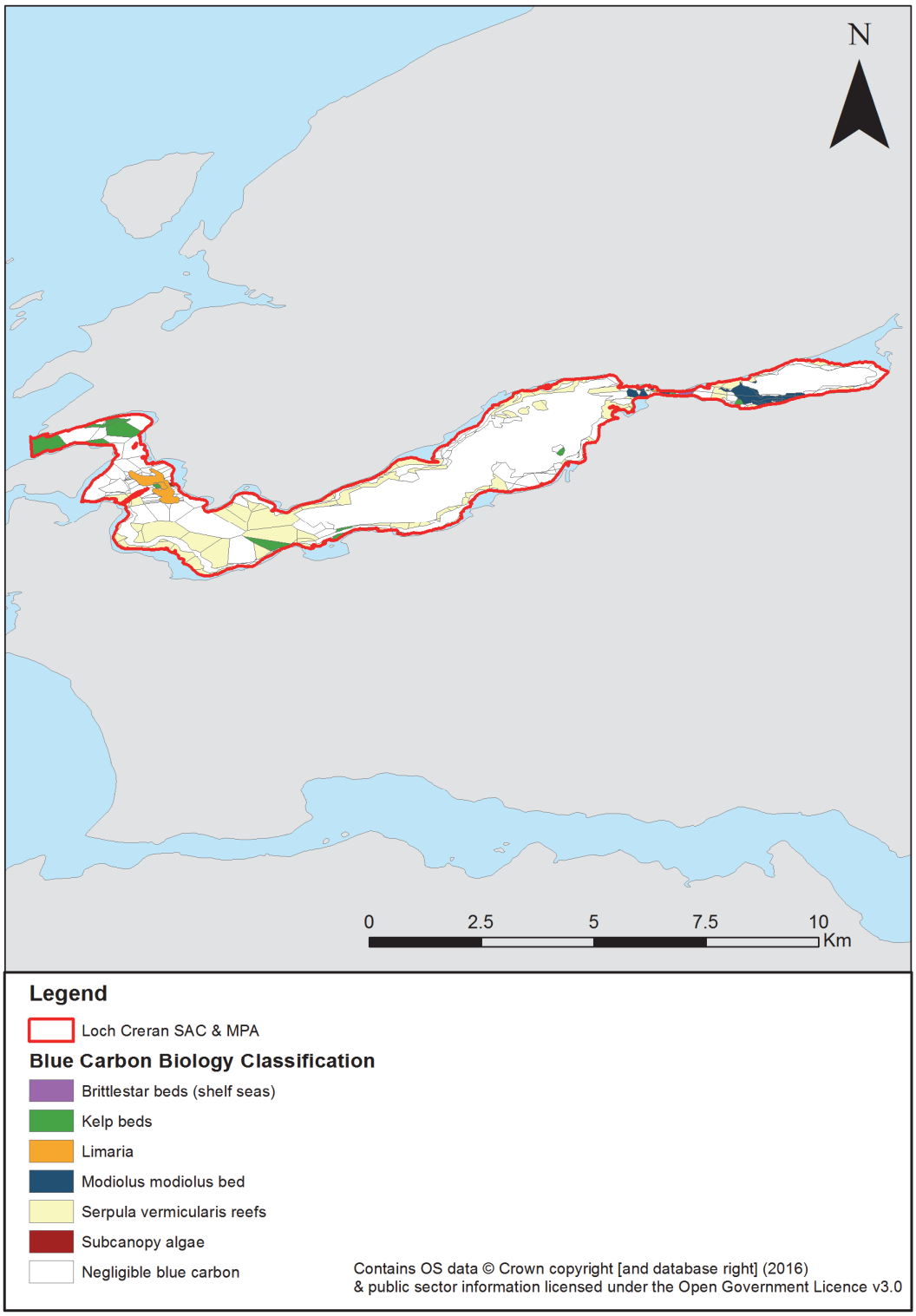
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Creran SAC/ NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Creran	86	313	0	2 506	1 055

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Creran SAC/ NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

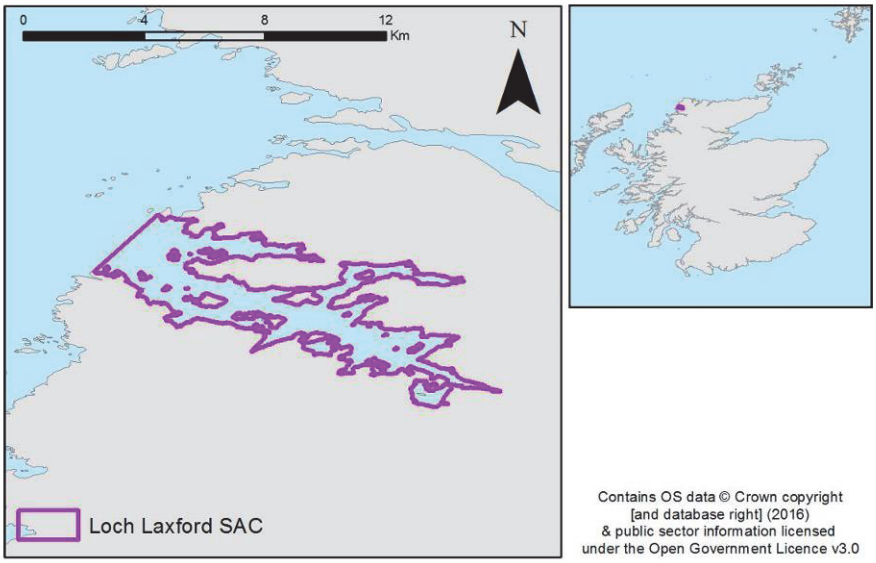
Table showing the calculated IC and OC values for each biological habitat: Loch Creran

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.00	0.02	0.00	0.00	0.22	0.02	0.00	0.00	0.00	0.00	0.00	-
Kelp beds	0.46	3.94	312.80	99.96	0.00	0.00	85.70	99.86	0.00	0.00	0.00	-
Limaria hians	0.19	1.64	0.00	0.00	0.00	0.00	0.00	0.00	12.10	0.48	0.00	-
Modiolus modiolus bed	0.14	1.17	0.00	0.00	5.43	0.51	0.00	0.00	543.13	21.67	0.00	-
Negligible blue carbon	8.29	71.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Serpula vermicularis reefs	2.50	21.57	0.00	0.00	1048.99	99.46	0.00	0.00	1951.25	77.85	0.00	-
Subcanopy algae	0.01	0.05	0.12	0.04	0.00	0.00	0.12	0.14	0.00	0.00	0.00	-
Total	**11.58**	**100.00**	**312.91**	**100.00**	**1054.64**	**100.00**	**85.82**	**100.00**	**2506.48**	**100.00**	**0.00**	**-**

11. Loch Laxford SAC

Location: 58°24'8.00'N; 005°5'5.00'W – The Loch Laxford SAC located to the south of Cape Wrath in a remote area in Northwest Sutherland. The SAC consists of the main loch, Loch Laxford, and two large subsidiary lochs; Loch Dùghaill and Loch a'Chadh-Fi. There are numerous small islands within the SAC boundary.

Area: 12.15 km^2



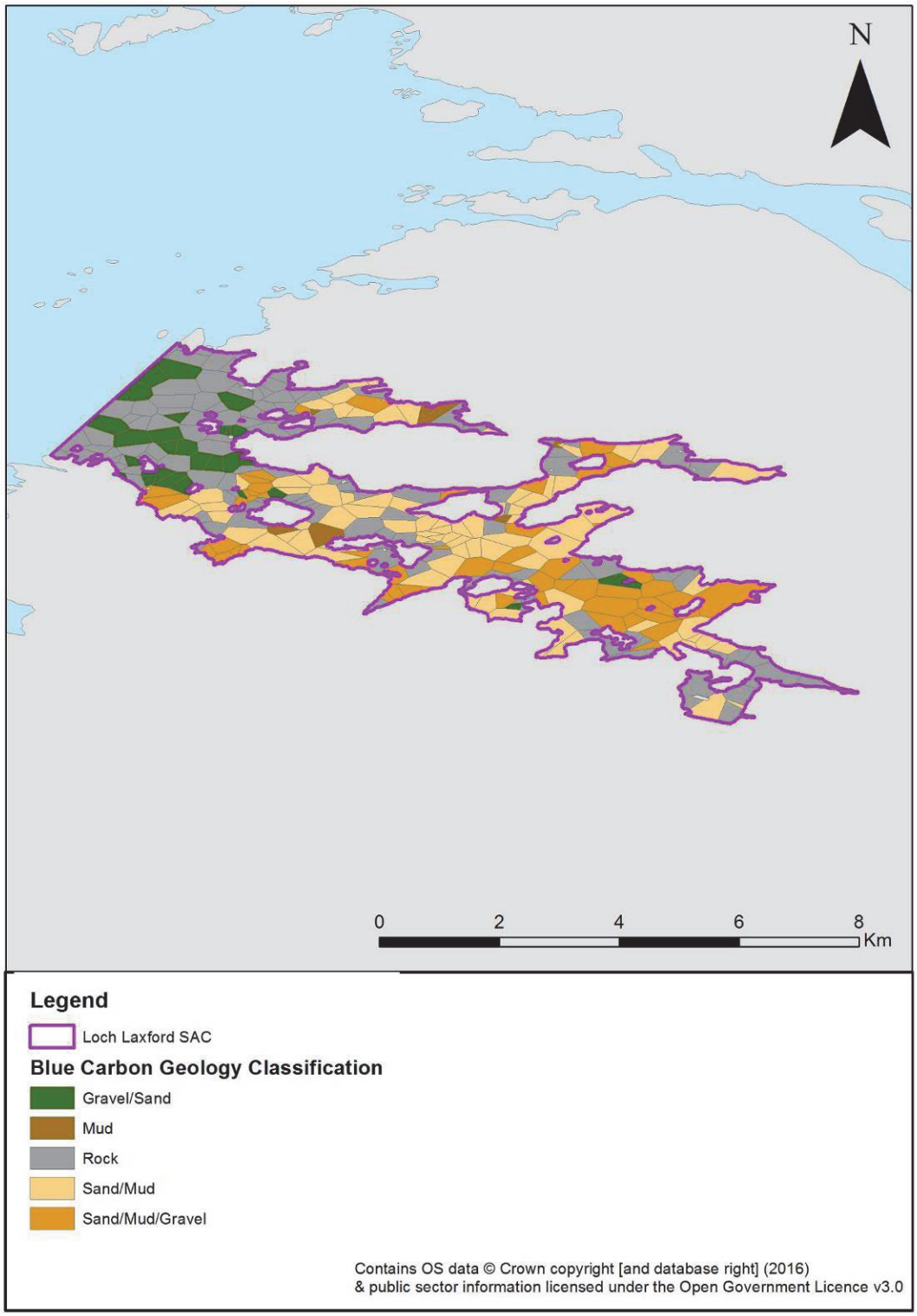
Map of the location of Loch Laxford SAC

Designation: The SAC is designated for two marine features namely; reefs and shallow inlets and bays. The primary reason for selection is the complex fjard with numerous small islands and side branches that include the two subsidiary lochs. A range of exposed and sheltered sites result in a range of habitats and associated communities.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, maerl beds, *Modiolus modiolus* bed and *Mytilus edulis* beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Laxford	8 068	126	17 717	178

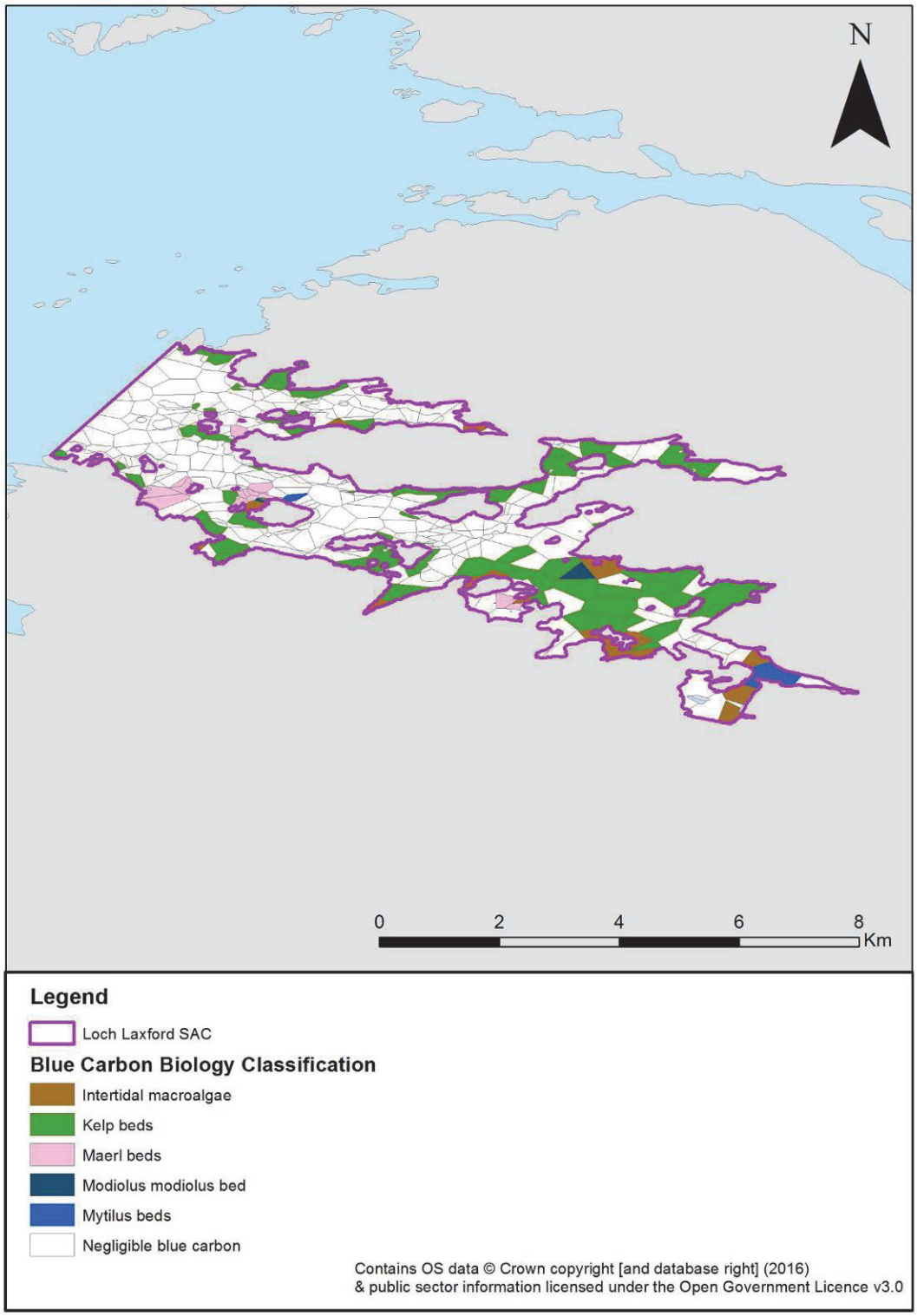
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Laxford SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Laxford	798	2 063	0	18 592	29

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Laxford SAC showing the different biological habitats. The table above reports the calculated IC and OC

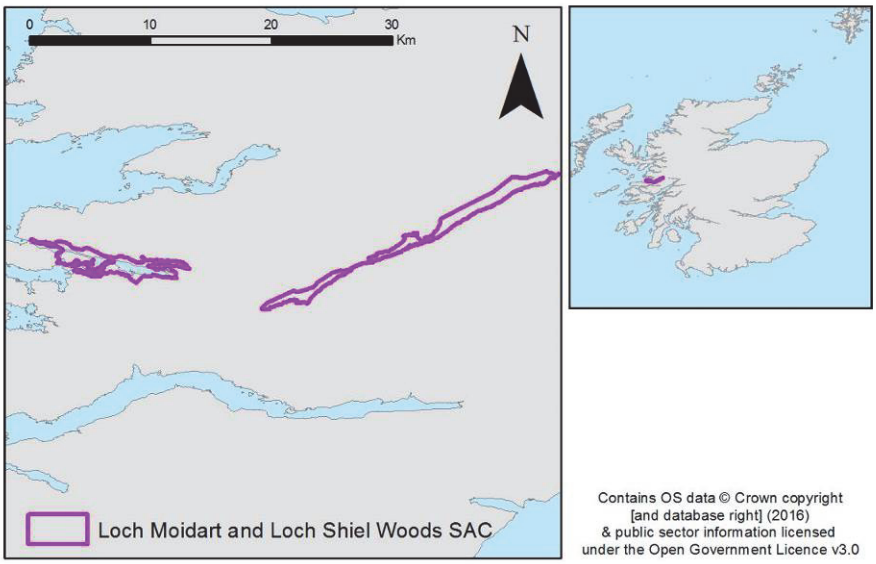
Table showing the calculated IC and OC values for each biological habitat: Loch Laxford

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.52	4.37	69.53	3.37	0.00	0.00	251.85	31.56	0.00	0.00	0.00	-
Kelp beds	2.91	24.70	1993.78	96.63	0.00	0.00	546.27	68.44	0.00	0.00	0.00	-
Maerl beds	0.29	2.50	0.00	0.00	21.79	74.69	0.00	0.00	18376.20	98.84	0.00	-
Modiolus modiolus bed	0.05	0.45	0.00	0.00	2.14	7.34	0.00	0.00	214.16	1.15	0.00	-
Mytilus beds	0.13	1.11	0.00	0.00	5.24	17.97	0.00	0.00	2.02	0.01	0.00	-
Negligible blue carbon	7.88	66.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**11.78**	**100.00**	**2063.31**	**100.00**	**29.18**	**100.00**	**798.12**	**100.00**	**18592.37**	**100.00**	**0.00**	**-**

12. Loch Moidart and Loch Shiel Woods SAC

Location: 56°48'35.00'N; 005°34'0.00'W – The Loch Moidart and Loch Shiel Woods SAC lies on the west coast of Scotland, to the west of Fort William n Lochaber.

Area: 17.53 km^2



Map of the location of Loch Moidart and Loch Shiel Woods SAC

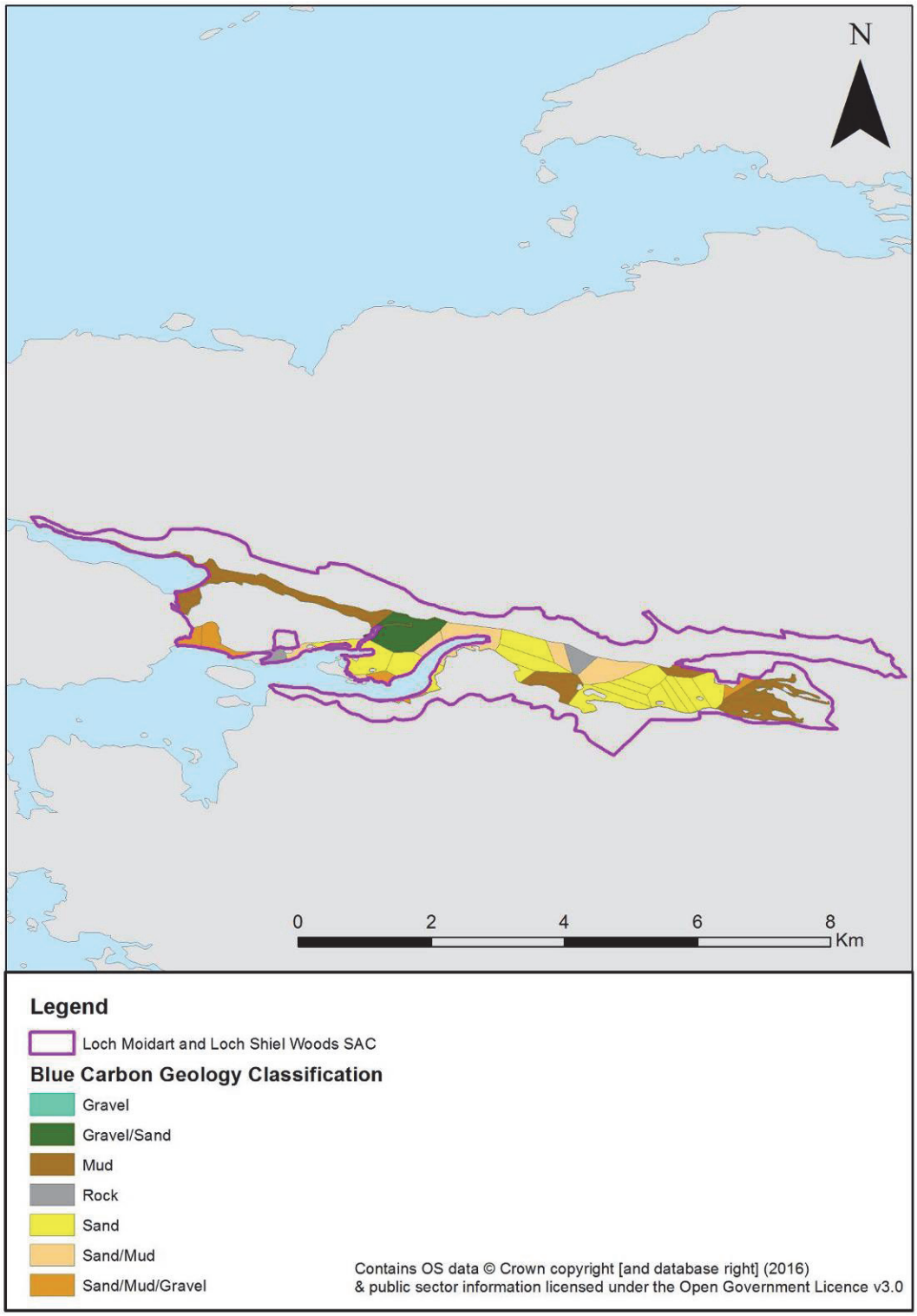
Designation: The SAC is designated for both terrestrial features and a marine feature. The marine feature is intertidal mudflats and sandflats. The terrestrial features are otters and a range of woodlands namely; alder woodland on floodplains, mixed woodland on base-rich soils associated with rocky slopes, western acidic oak woodland.

Loch Moidart is also a SSSI, designated for a range of features including, moine, mudflats, saltmarsh, upland oak woodland and beetle (*Schizotus pectinicornis*).

Blue carbon designation: Gravel, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, maerl beds, and *Mytilus edulis* beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Moidart and Loch Shiel Woods	3 160	77	9 442	89

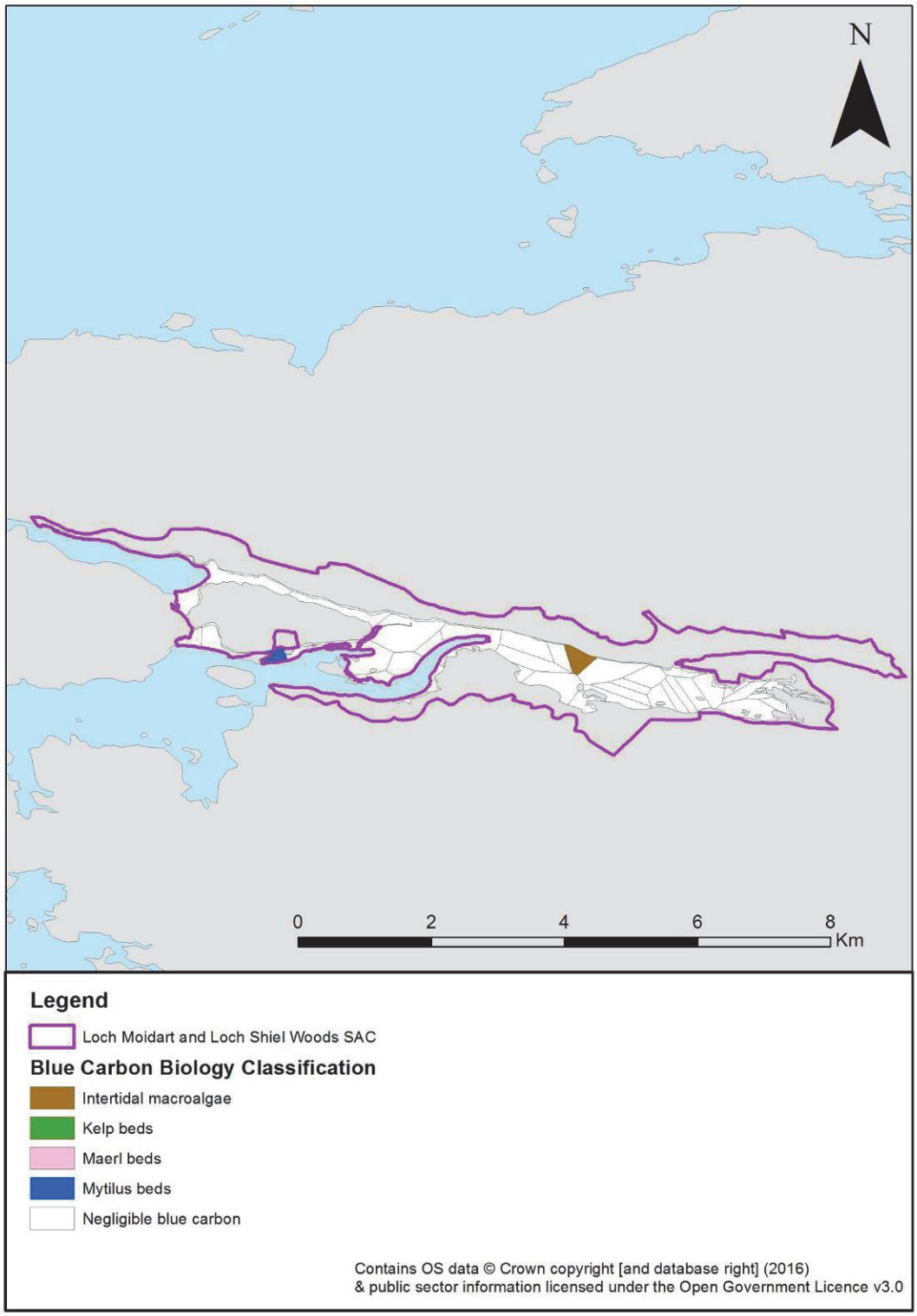
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Moidart and Loch Shiel Woods SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Moidart and Loch Shiel Woods	30	8	0	3	1

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Moidart and Loch Shiel Woods SAC showing the different biological habitats. The table above reports the calculated IC and OC

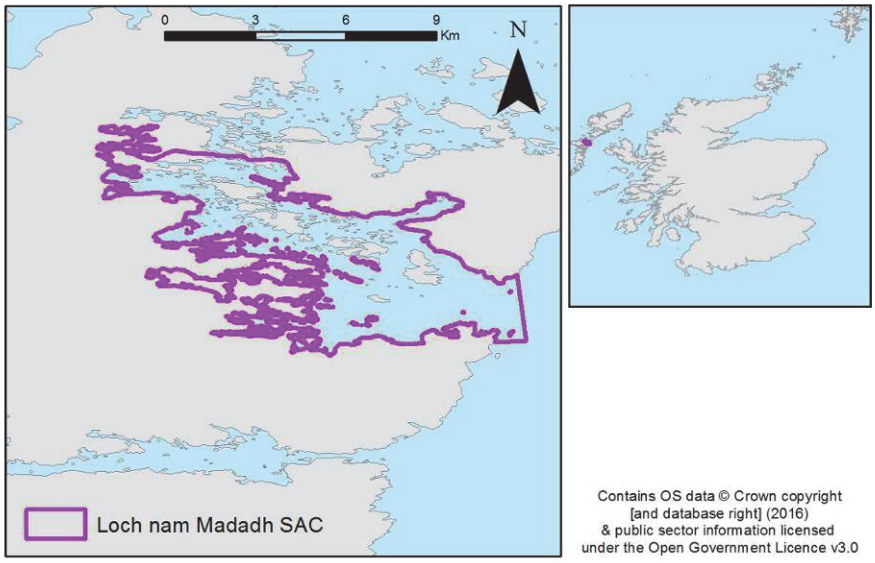
Table showing the calculated IC and OC values for each biological habitat: Loch Moidart and Loch Shiel Woods

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.06	2.41	8.25	99.25	0.00	0.00	29.90	99.94	0.00	0.00	0.00	-
Kelp beds	0.00	0.00	0.06	0.75	0.00	0.00	0.02	0.06	0.00	0.00	0.00	-
Maerl beds	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	2.56	86.18	0.00	-
Mytilus beds	0.03	1.05	0.00	0.00	1.07	99.72	0.00	0.00	0.41	13.82	0.00	-
Negligible blue carbon	2.44	96.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**2.53**	**100.00**	**8.32**	**100.00**	**1.07**	**100.00**	**29.92**	**100.00**	**2.97**	**100.00**	**0.00**	**-**

13. Loch nam Madadh SAC

Location: 57°37'20.00'N; 007°9'20.00'W – Loch nam Madadh is a large and complex fjord system located in the northeast of North Uist in the Outer Hebrides..It has a highly irregular coastline and contains a large number of inlets, islands and channels including two major tidal rapids at Leireabhagh and Sponais.

Area: 23.21 km^2



Map of the location of Loch nam Madadh SAC

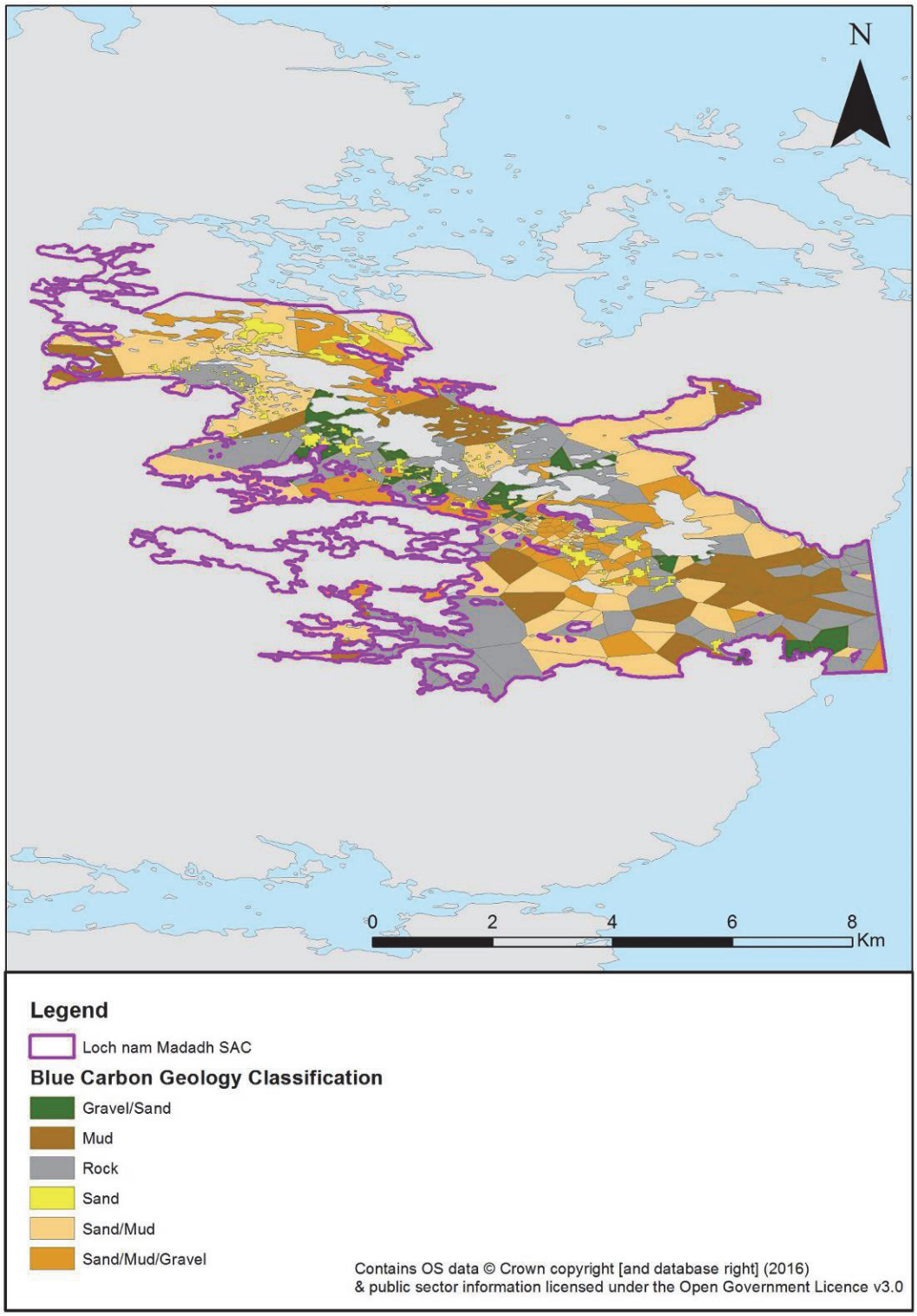
Designation: The SAC is designated for a range of marine features, namely; intertidal mudflats and sandflats, lagoons, otter, reefs, shallow inlets and bays, and subtidal sandbanks. The Loch has a number of different marine habitats owing to the range of degree of exposure, from the expose outer reefs to the inner sheltered bays and inlets, which connect to freshwater lochans inland via the most extensive and diverse system of saline lagoons in the UK.

Loch nam Madadh is also a designated SSSI, for the unique coastal geomorphology in the area, along with the presence of foxtail stonewort. Marine features under the SSSI designation include mudflats, rocky shore, saline lagoon and tidal rapids.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds intertidal macroalgae, kelp beds, maerl beds, seagrass beds, and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch nam Madadh	17 285	382	27 708	324

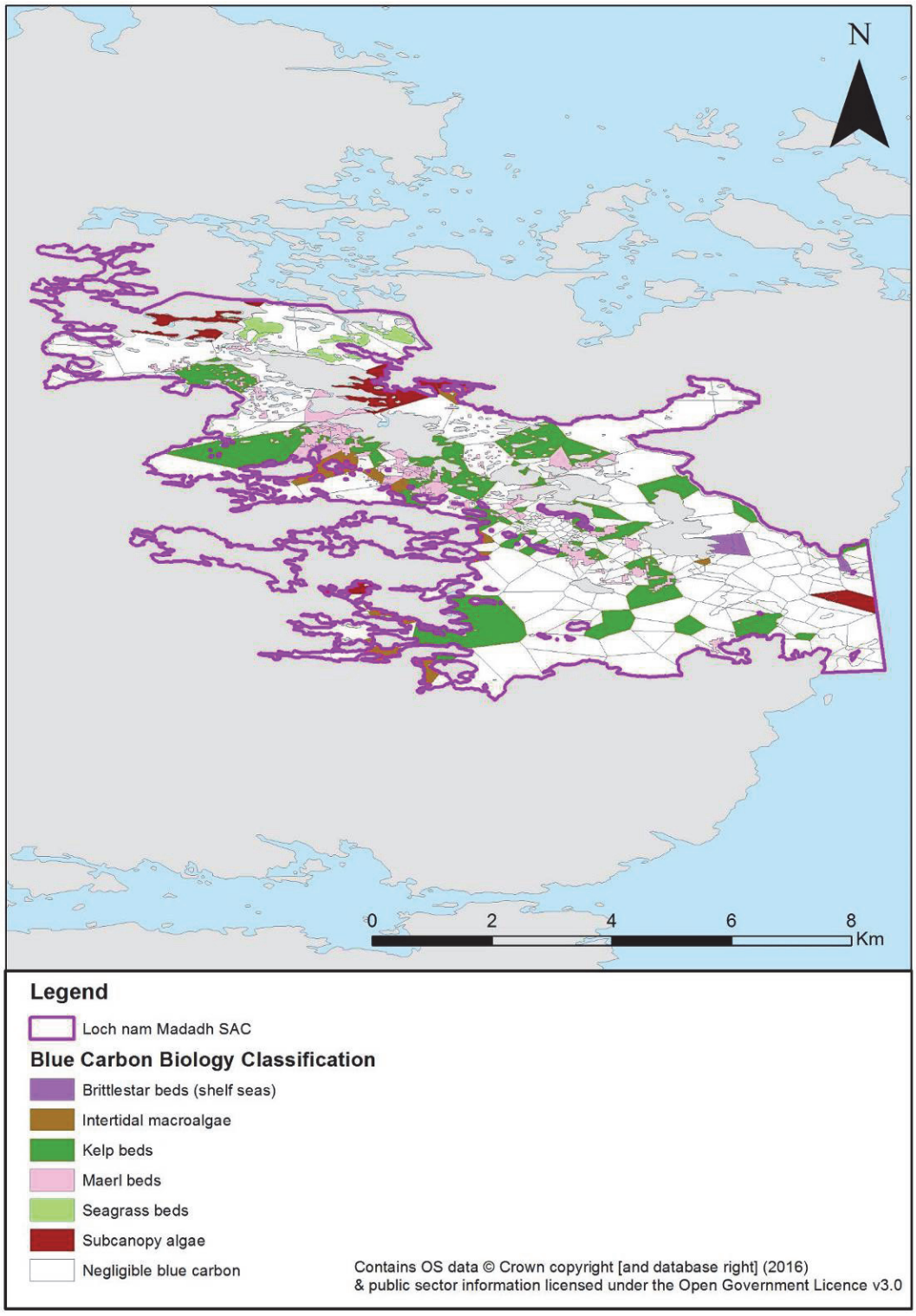
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch nam Madadh SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch nam Madadh	761	2 155	20	61 307	83

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch nam Madadh SAC showing the different biological habitats. The table above reports the calculated IC and OC

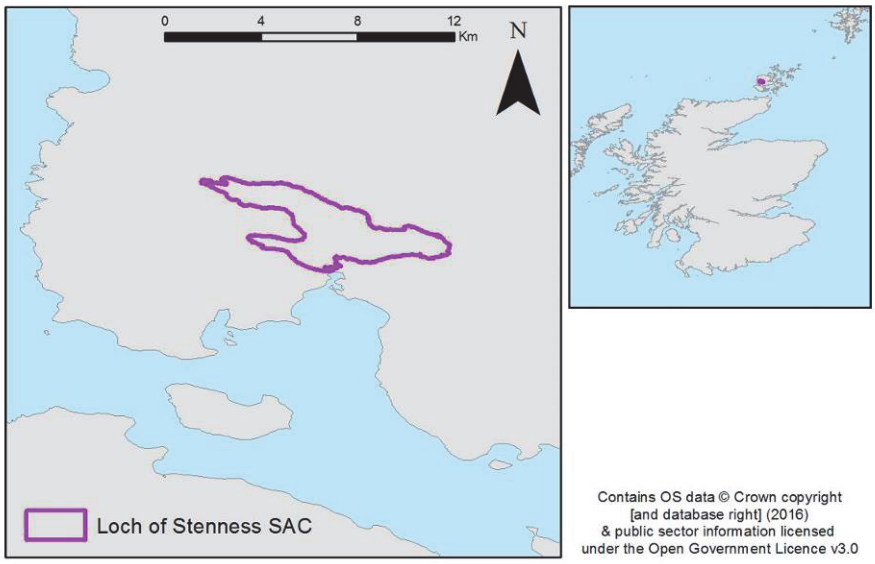
Table showing the calculated IC and OC values for each biological habitat: Loch nam Madadh

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.12	0.70	0.00	0.00	9.89	11.98	0.00	0.00	0.00	0.00	0.00	0.00
Intertidal macroalgae	0.40	2.29	53.51	2.48	0.00	0.00	193.82	25.46	0.00	0.00	0.00	0.00
Kelp beds	2.96	17.13	2026.89	94.06	0.00	0.00	555.34	72.94	0.00	0.00	0.00	0.00
Maerl beds	0.98	5.69	0.00	0.00	72.70	88.02	0.00	0.00	61306.58	100.00	0.00	0.00
Negligible blue carbon	12.02	69.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.24	1.39	62.76	2.91	0.00	0.00	0.00	0.00	0.00	0.00	19.96	100.00
Subcanopy algae	0.56	3.22	11.70	0.54	0.00	0.00	12.26	1.61	0.00	0.00	0.00	0.00
Total	**17.28**	**100.00**	**2154.86**	**100.00**	**82.59**	**100.00**	**761.42**	**100.00**	**61306.58**	**100.00**	**19.96**	**100.00**

14. Loch of Stenness SAC

Location: 58°59'45.00'N; 003°15'0.00'W – The Loch of Stenness is located on the mainland of Orkney, situated 2 miles northeast of the town of Stromness. The Loch is not totally landlocked, but is connected with the sea, creating a saline lagoon inlet.

Area: 7.93 km^2



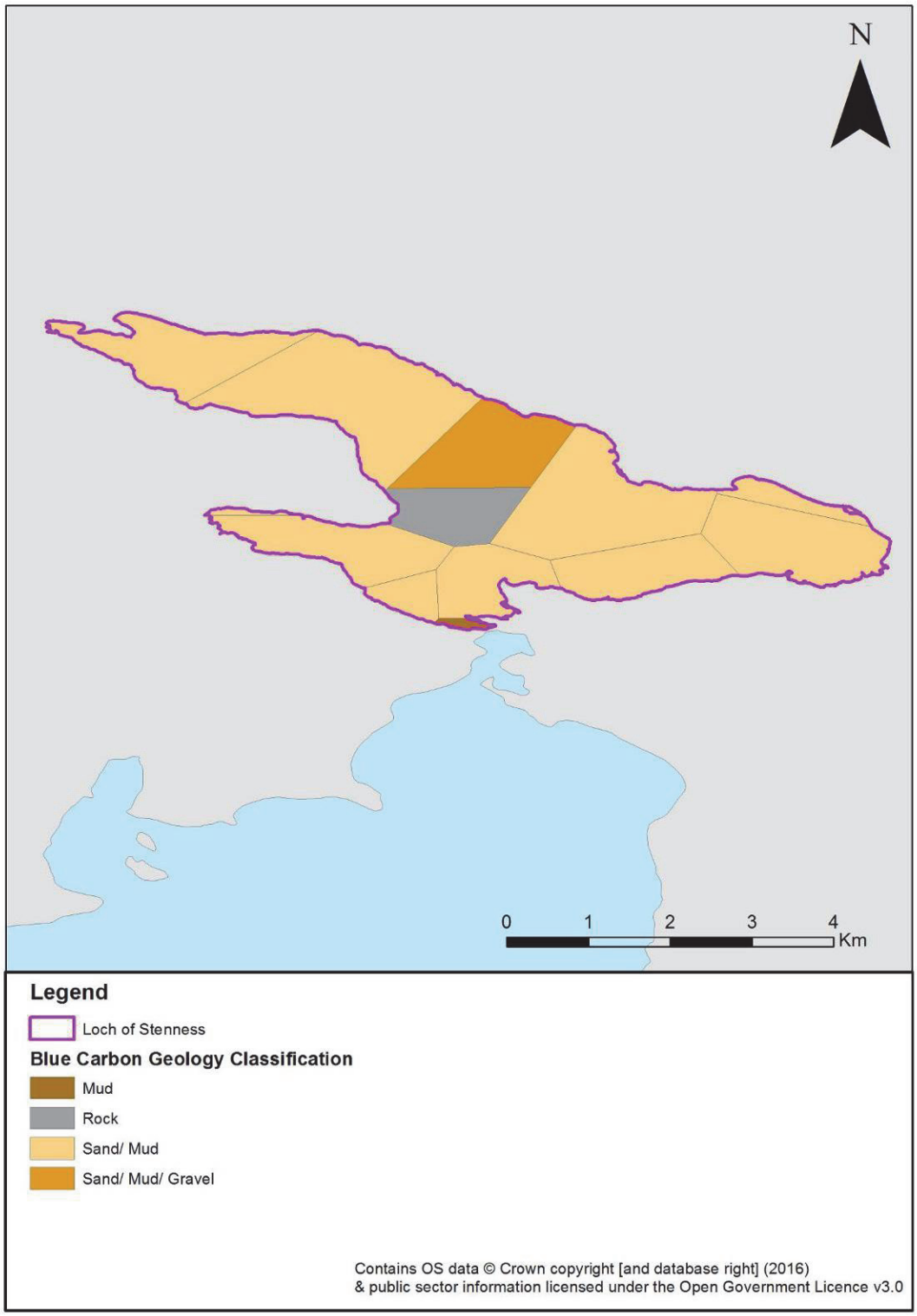
Map of the location of Loch of Stenness SAC

Designation: The SAC is designated for its marine feature; lagoon. The Loch of Stenness is the largest brackish lagoon in the UK, considered particularly important due to the large salinity gradient in the lagoon, leading to a rich variety of rare and highly specialised lagoon communities.

Blue carbon designation: Mud, rock, sand/mud and sand/mud/gravel (geology); intertidal macroalgae and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch of Stenness	9 452	140	15 357	172

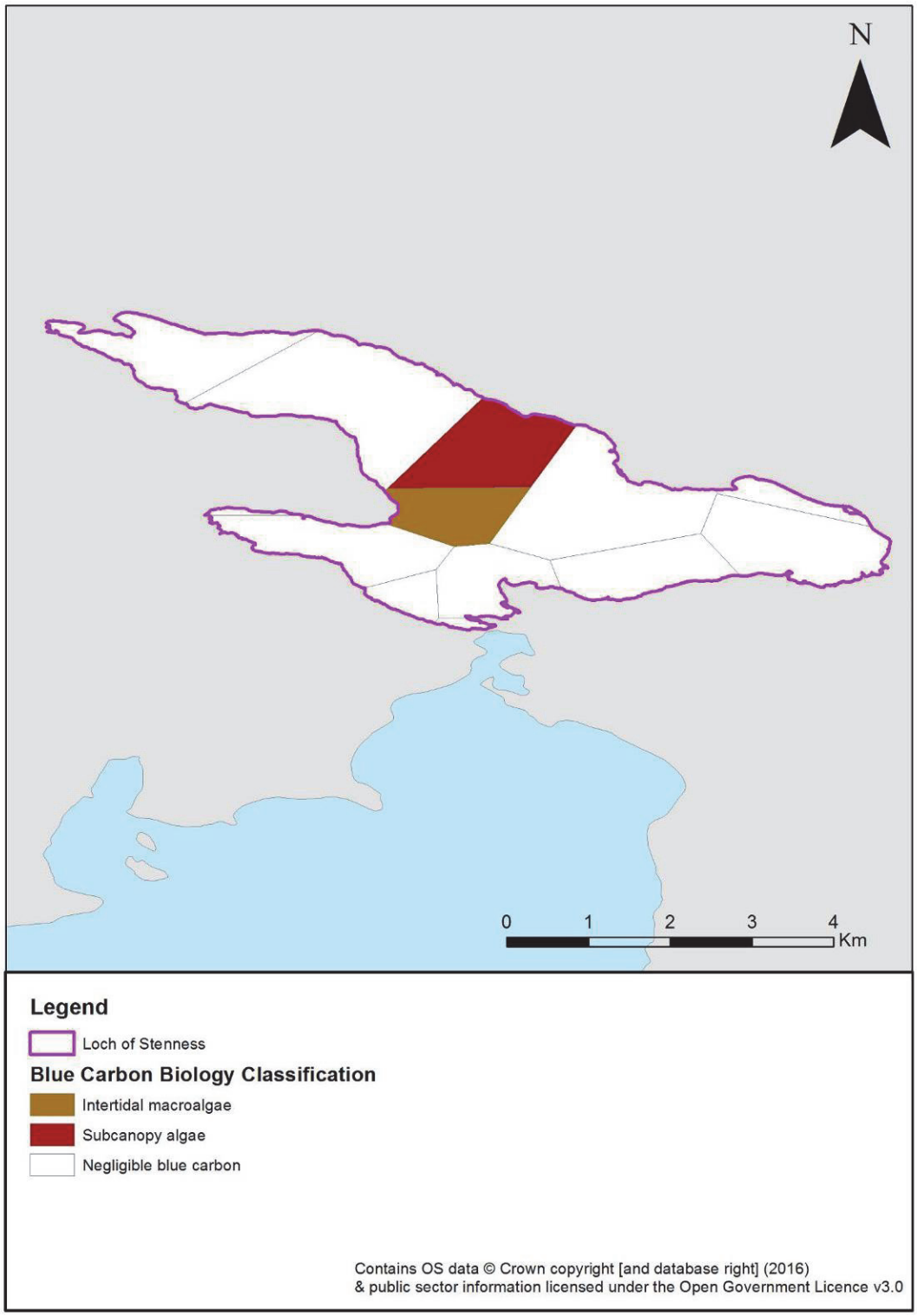
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch of Stenness SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch of Stenness	249	80	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch of Stenness SAC showing the different biological habitats. The table above reports the calculated IC and OC

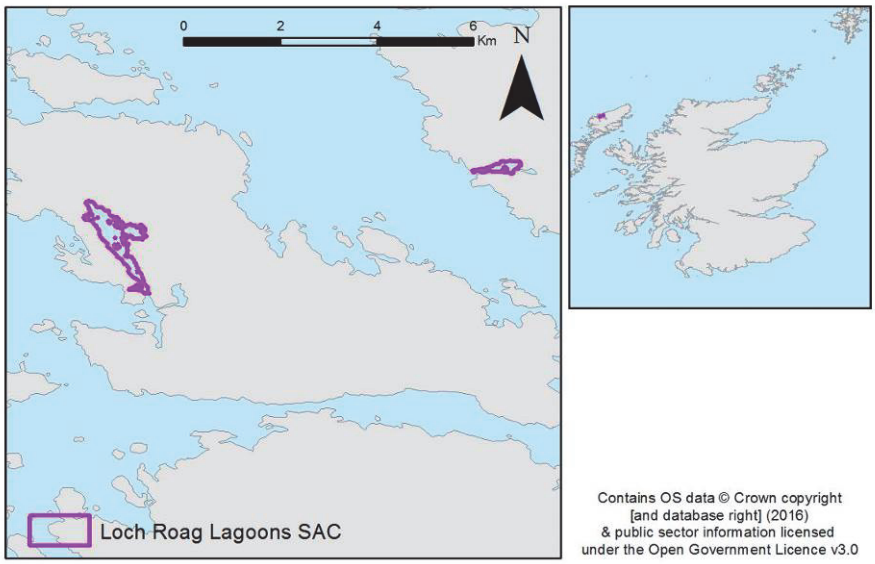
Table showing the calculated IC and OC values for each biological habitat: Loch of Stenness

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Subcanopy algae	0.77	9.68	16.12	20.11	0.00	0.00	16.89	6.79	0.00	-	0.00	-
Negligible blue carbon	6.68	84.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	-
Intertidal macroalgae	0.47	5.99	64.04	79.89	0.00	0.00	231.99	93.21	0.00	-	0.00	-
Total	**7.93**	**100.00**	**80.16**	**100.00**	**0.00**	**0.00**	**248.88**	**100.00**	**0.00**	**-**	**0.00**	**-**

15. Loch Roag Lagoons SAC

Location: 58°13'60.00'N; 006°52'30.00'W– Loch Roag Lagoons are situated on the west coast of the Isle of Lewis, in the Outer Hebrides.

Area: 0.43 km^2



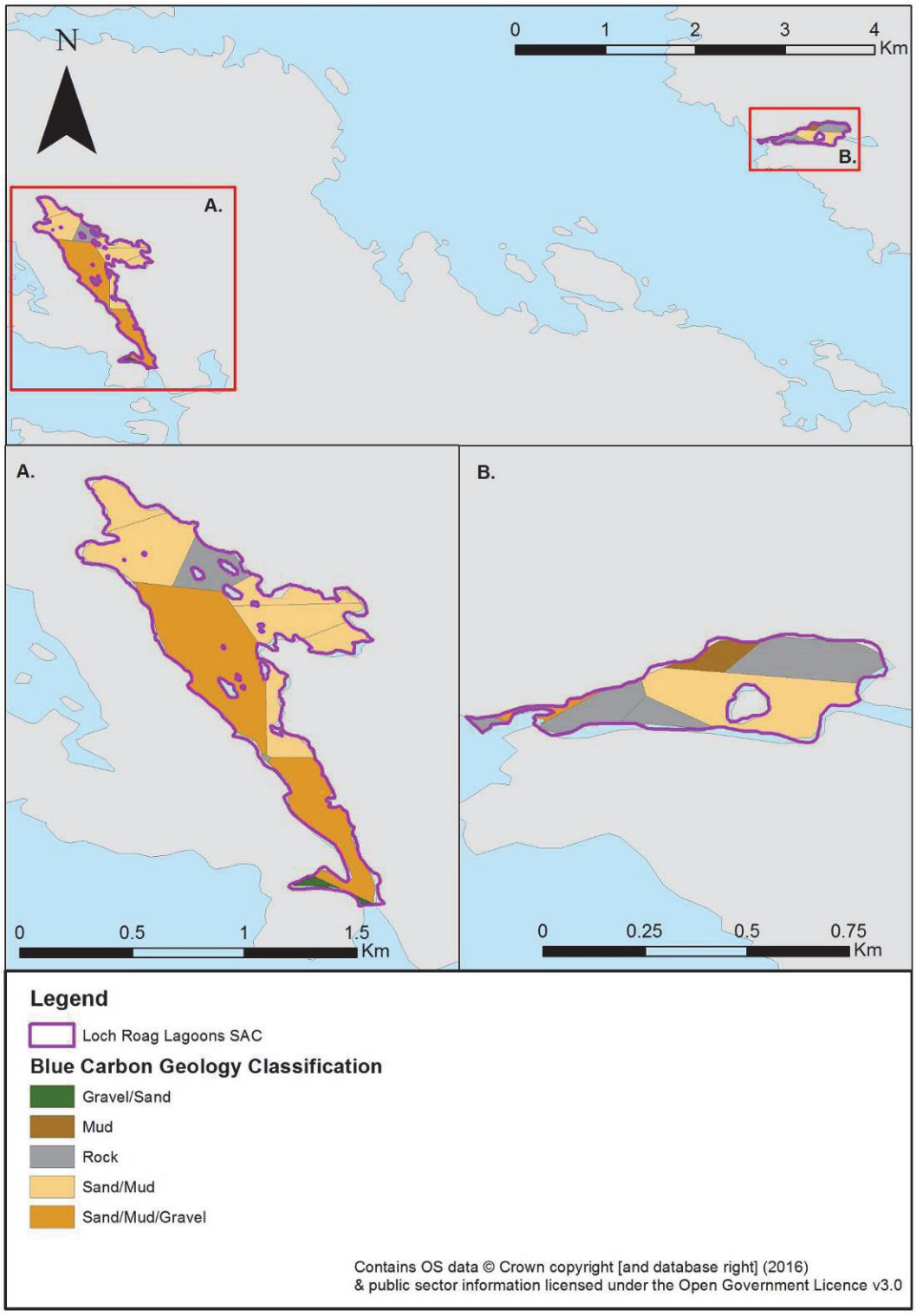
Map of the location of Loch Roag Lagoons SAC

Designation: The SAC is designated for under the marine feature; lagoons. The Loch Roag Lagoons is a complex of silled lagoons with a range of salinities and the diverse range of habitats associated, including **r**ocky outcrops, boulders and muddy sand, with softer mud in the inner basins, cobbles and shell gravel in the narrows. Biologically beds of eelgrasses *Zostera* spp. and tasselweeds *Ruppia* spp. are present along with turfs of marine algae and stands of large brown algae.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, maerl beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Roag Lagoons	284	4	450	5

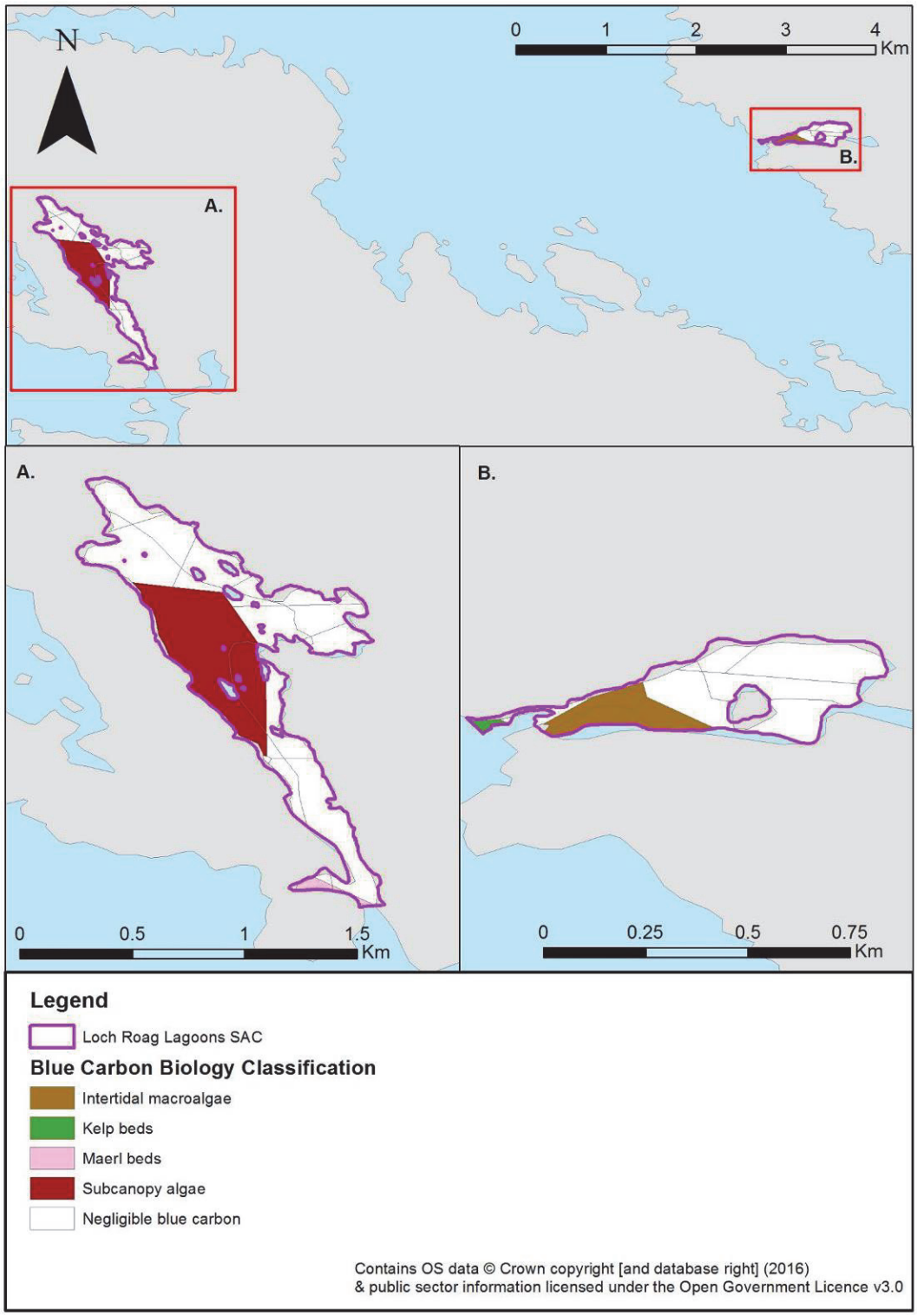
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Roag Lagoons SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Roag Lagoons	6	4	0	198	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Roag Lagoons SAC showing the different biological habitats. The table above reports the calculated IC and OC

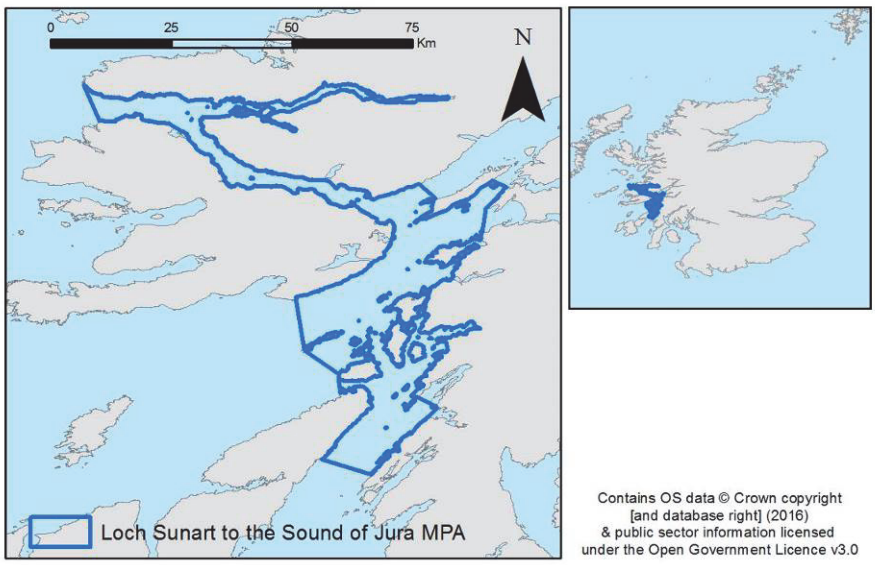
Table showing the calculated IC and OC values for each biological habitat: Loch Roag Lagoons

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.01	4.39	1.19	32.32	0.00	0.00	4.31	66.45	0.00	0.00	0.00	-
Kelp beds	0.00	0.41	0.56	15.25	0.00	0.00	0.15	2.37	0.00	0.00	0.00	-
Maerl beds	0.00	1.58	0.00	0.00	0.24	100.00	0.00	0.00	198.26	100.00	0.00	-
Negligible blue carbon	0.10	47.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.09	45.80	1.93	52.44	0.00	0.00	2.02	31.18	0.00	0.00	0.00	-
Total	**0.20**	**100.00**	**3.68**	**100.00**	**0.24**	**100.00**	**6.48**	**100.00**	**198.26**	**100.00**	**0.00**	**-**

16. Loch Sunart to the Sound of Jura NC MPA

Location: 56°21.880'N; 005°43.689'W – Loch Sunart to the Sound of Jura NC MPA is on the west coast of Scotland, and encompasses the coastal waters around the Isle of Mull and Ardnamurchan towards Oban, including Loch Sunart and the Corryvreckan whirlpools. This NC MPA overlaps with Loch Sunart SAC to the north and Firth of Lorn SAC the centre.

Area: 741 km^2



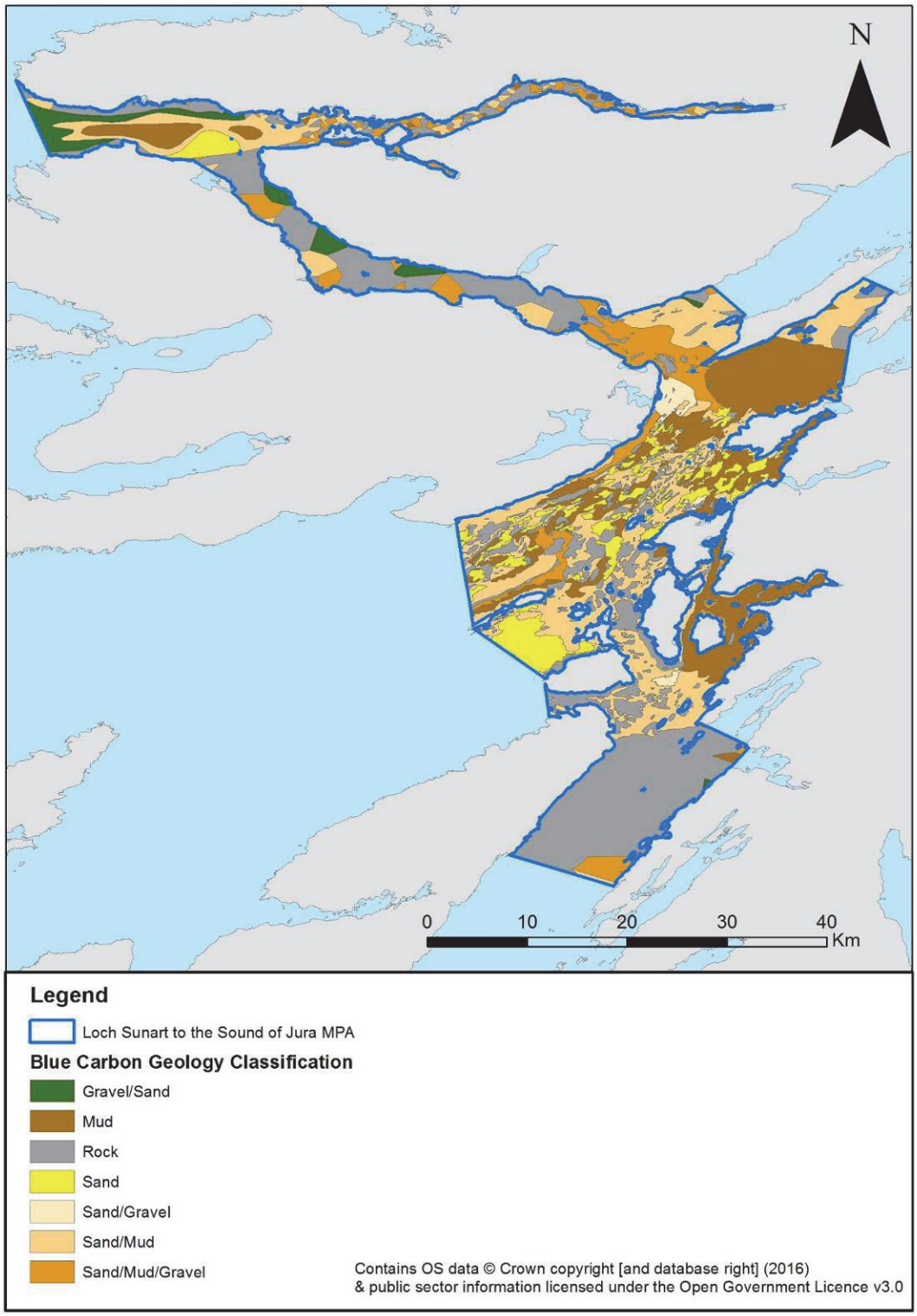
Map of the location of Loch Sunart to the Sound of Jura NC MPA

Designation: NC MPA set up to protect a resident population of common skate, the largest skate species in the world. The NC MPA covers a diverse range of bathymetry, including the Gulf of Corryvreckan in the Firth of Lorn.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/gravel, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Limaria hians* beds, *Modiolus modiolus* beds, *Mytilus edulis* beds, seagrass beds, *Serpula vermicularis* reefs and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Sunart to the Sound of Jura	630 915	10 961	1 273 676	11 945

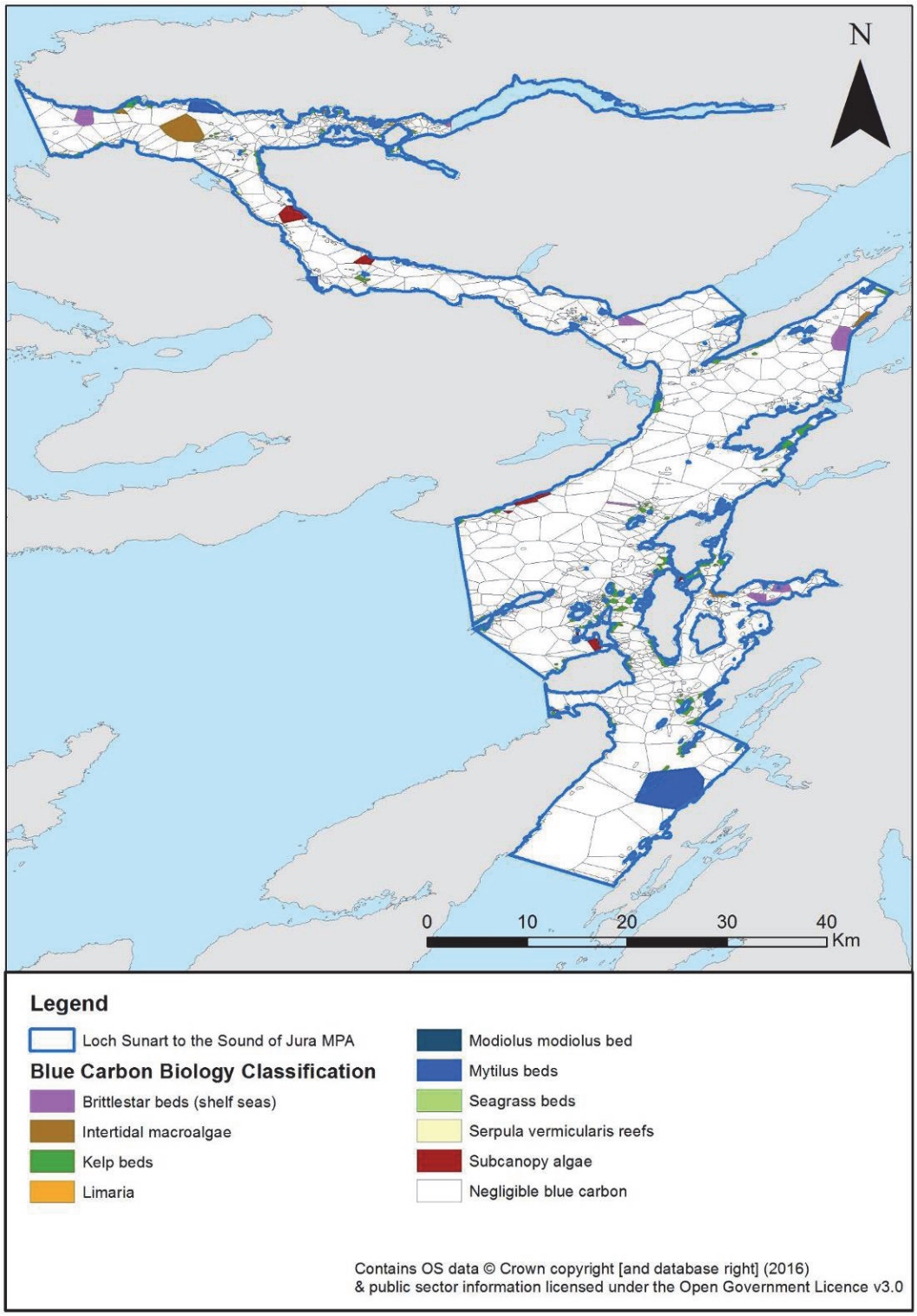
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Sunart to the Sound of Jura NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Sunart to the Sound of Jura	7 391	16 049	7	437	1 244

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Sunart to the Sound of Jura NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

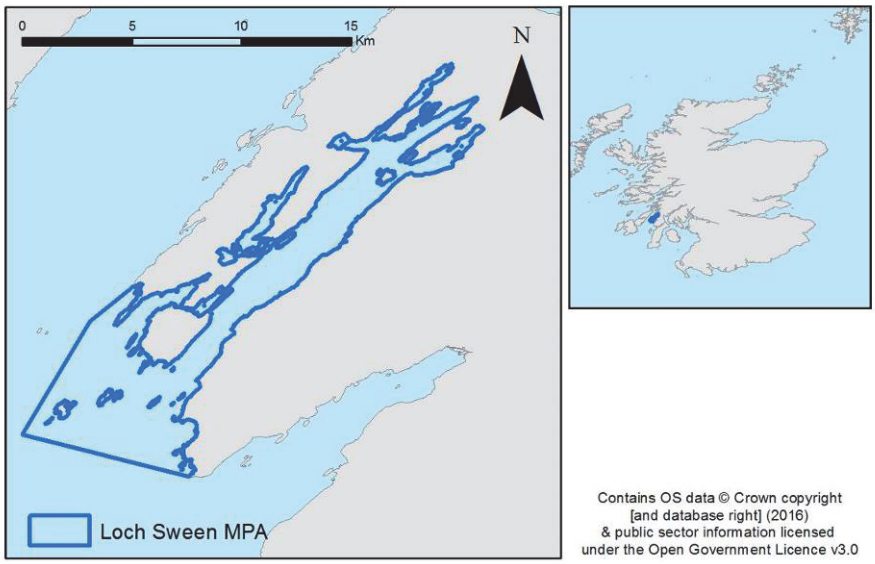
Table showing the calculated IC and OC values for each biological habitat: Loch Sunart to the Sound of Jura

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Brittlestar beds (shelf seas)	7.64	1.07	0.00	0.00	626.76	50.39	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Intertidal macroalgae	6.45	0.90	870.50	5.42	0.00	0.00	3153.30	**42.66**	0.00	**0.00**	0.00	**0.00**
Kelp beds	21.97	3.06	15046.30	93.75	0.00	0.00	4122.50	**55.77**	0.00	**0.00**	0.00	**0.00**
Limaria hians	0.24	0.03	0.00	0.00	0.00	0.00	0.00	**0.00**	15.16	**3.47**	0.00	**0.00**
Modiolus modiolus bed	0.03	0.00	0.00	0.00	1.33	0.11	0.00	**0.00**	133.15	**30.50**	0.00	**0.00**
Mytilus beds	14.53	2.02	0.00	0.00	581.03	46.71	0.00	**0.00**	223.70	**51.24**	0.00	**0.00**
Negligible blue carbon	661.16	92.16	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Seagrass beds	0.08	0.01	21.94	0.14	0.00	0.00	0.00	**0.00**	0.00	**0.00**	6.98	**100.00**
Serpula vermicularis reefs	0.08	0.01	0.00	0.00	34.70	2.79	0.00	**0.00**	64.55	**14.79**	0.00	**0.00**
Total	**717.43**	**100.00**	**16049.01**	**100.00**	**1243.81**	**100.00**	**7391.32**	**100.00**	**436.55**	**100.00**	**6.98**	**100.00**

17. Loch Sween NC MPA

Location: 55°57.259'N; 005°40.375'W – Loch Sween NC MPA is located on the west coast of Scotland, near Lochgilphead and North of Campbeltown.

Area: 41 km^2



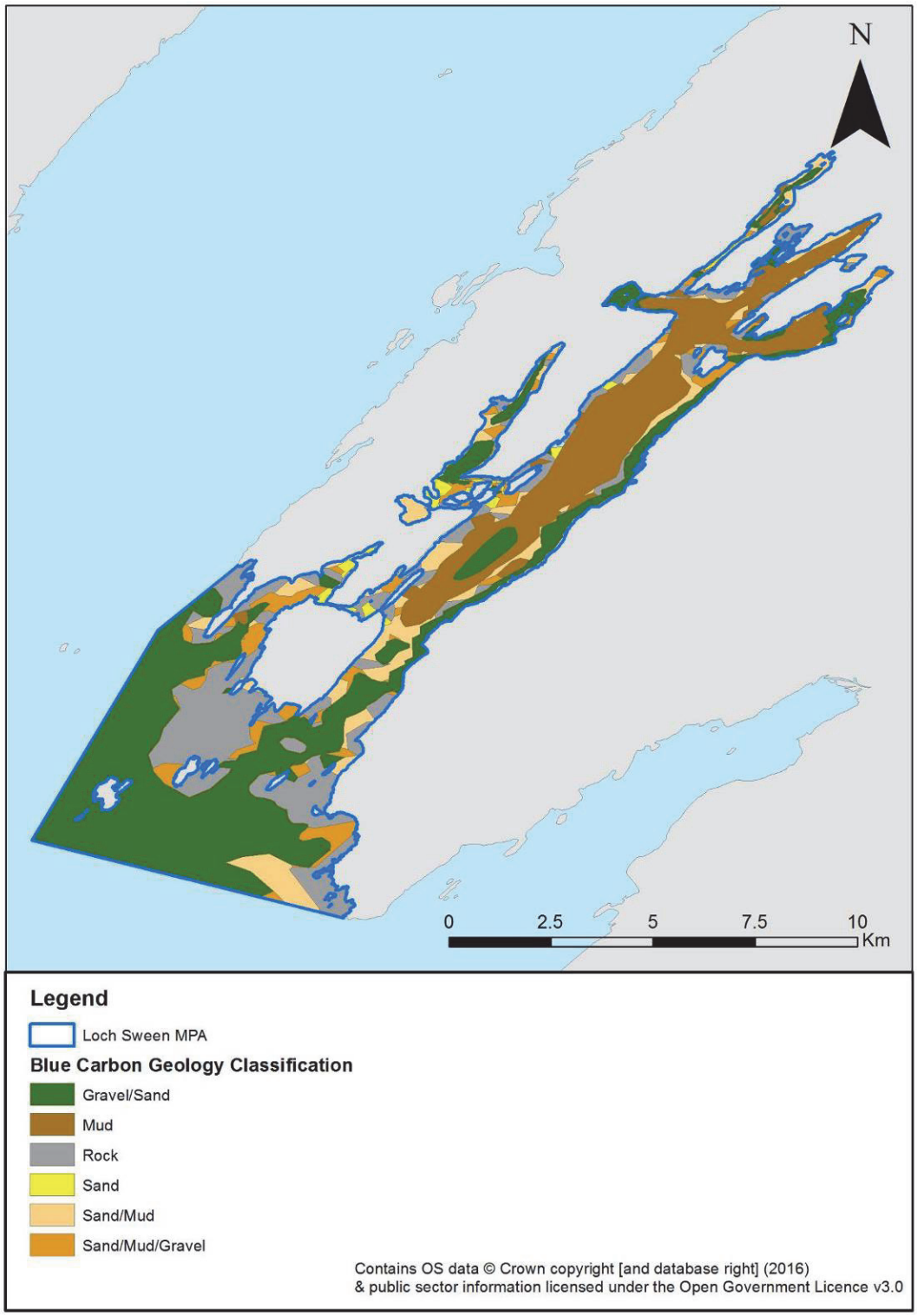
Map of the location of Loch Sween NC MPA

Designation: NC MPA is home to dense beds of pink maerl, and the branched type of maerl provides a habitat for feather stars, scallops, sponges, crabs and many fish species. Scattered seaweeds are home to sea slugs and sea firs. Evidence of shells suggests a bed of native oysters within the loch. The seabed consists of sublittoral mud (home to the large green volcano worms, Norway lobsters, shrimps and gobies) to coarse sediment at the mouth of the loch in the Sound of Jura.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud, sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, maerl beds, *Mytilus edulis* beds, saltmarshes, seagrass beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Sween	36 084	881	116 488	1 073

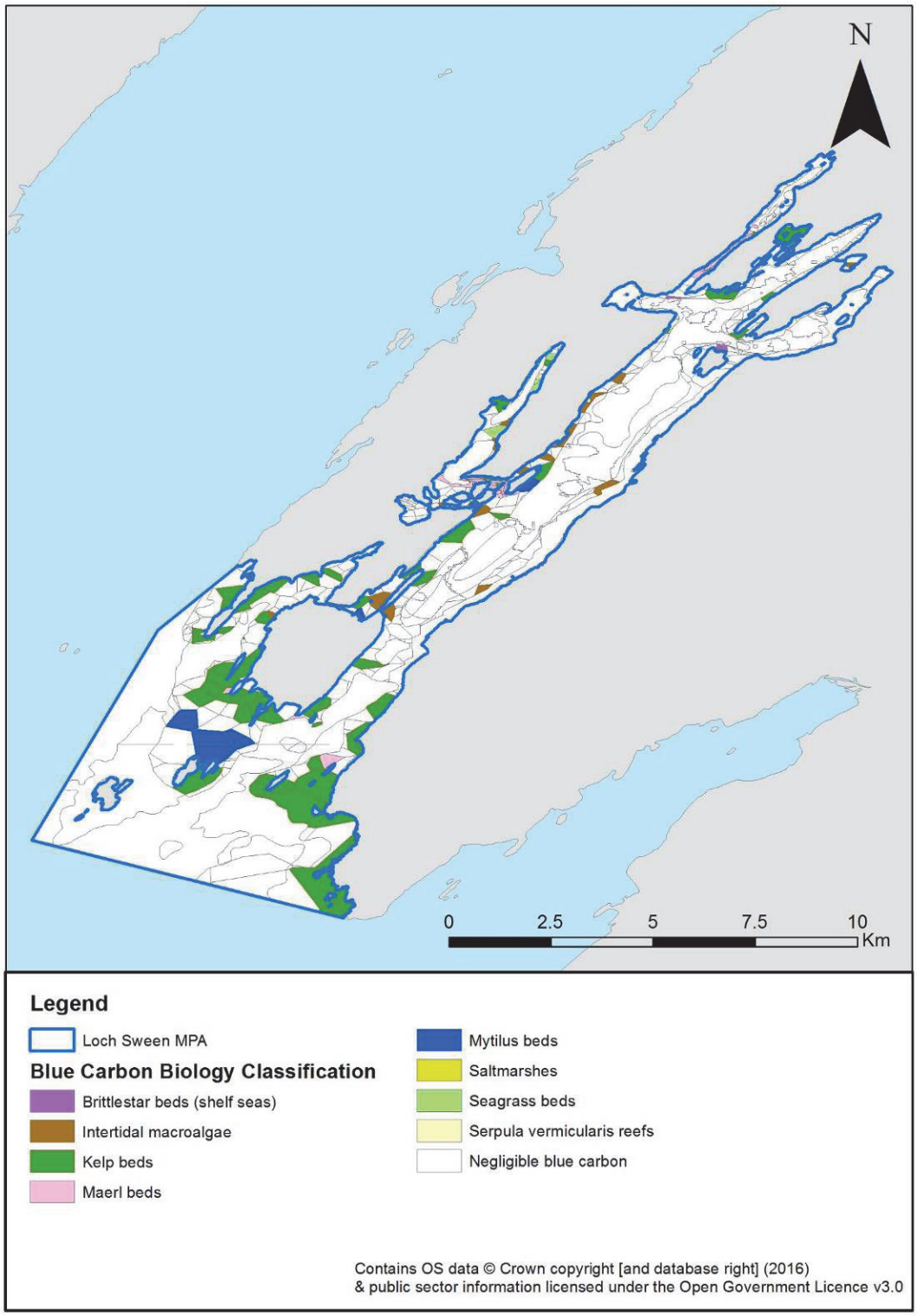
(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Sween NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Loch Sween	1 091	3 189	10	22 545	73

(SS: standing stock, seq: sequestration, prod: production)



Map of Loch Sween NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

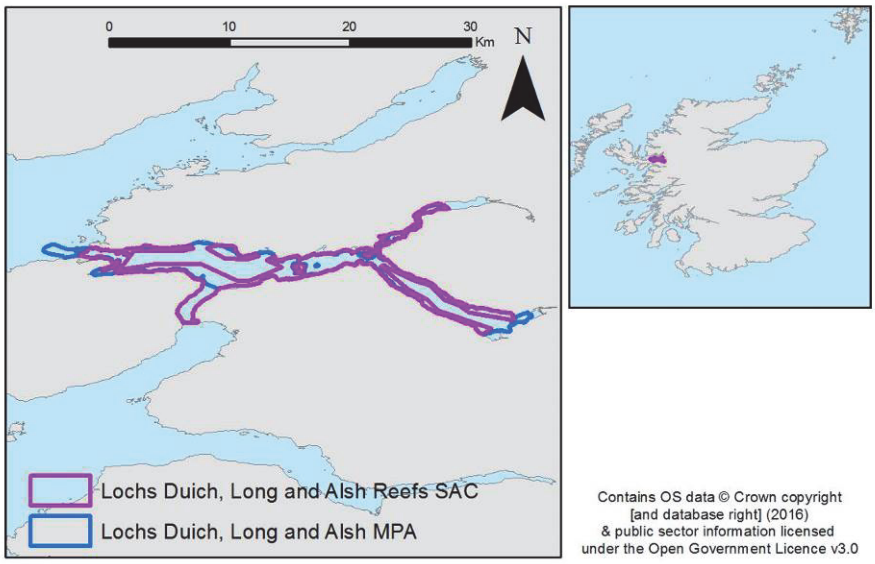
Table showing the calculated IC and OC values for each biological habitat: Loch Sween

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.04	0.11	0.00	0.00	3.57	4.92	0.00	0.00	0.00	0.00	0.00	0.00
Intertidal macroalgae	0.50	1.27	67.01	2.10	0.00	0.00	242.75	22.24	0.00	0.00	0.00	0.00
Kelp beds	4.52	11.55	3094.26	97.02	0.00	0.00	847.79	77.69	0.00	0.00	0.00	0.00
Maerl beds	0.36	0.92	0.00	0.00	26.70	36.82	0.00	0.00	22511.43	99.85	0.00	0.00
Mytilus beds	0.76	1.94	0.00	0.00	30.42	41.96	0.00	0.00	11.71	0.05	0.00	0.00
Negligible blue carbon	32.80	83.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saltmarshes	0.01	0.02	1.27	0.04	0.00	0.00	0.77	0.07	0.00	0.00	1.27	12.94
Seagrass beds	0.10	0.26	26.86	0.84	0.00	0.00	0.00	0.00	0.00	0.00	8.54	87.06
Serpula vermicularis reefs	0.03	0.07	0.00	0.00	11.82	16.30	0.00	0.00	21.99	0.10	0.00	0.00
Total	**39.12**	**100.00**	**3189.41**	**100.00**	**72.50**	**100.00**	**1091.31**	**100.00**	**22545.13**	**100.00**	**9.81**	**100.00**

18. Lochs Duich, Long and Alsh NC MPA

Location: 57°15.755'N; 005°35.049'W – Lochs Duich, Long and Alsh NC MPA consist of three lochs on the West coast, between the mainland and the Isle of Skye. The NC MPA overlaps the Lochs Duich, Long and Alsh Special Area of Conservation (SAC).

Area: 37 km^2



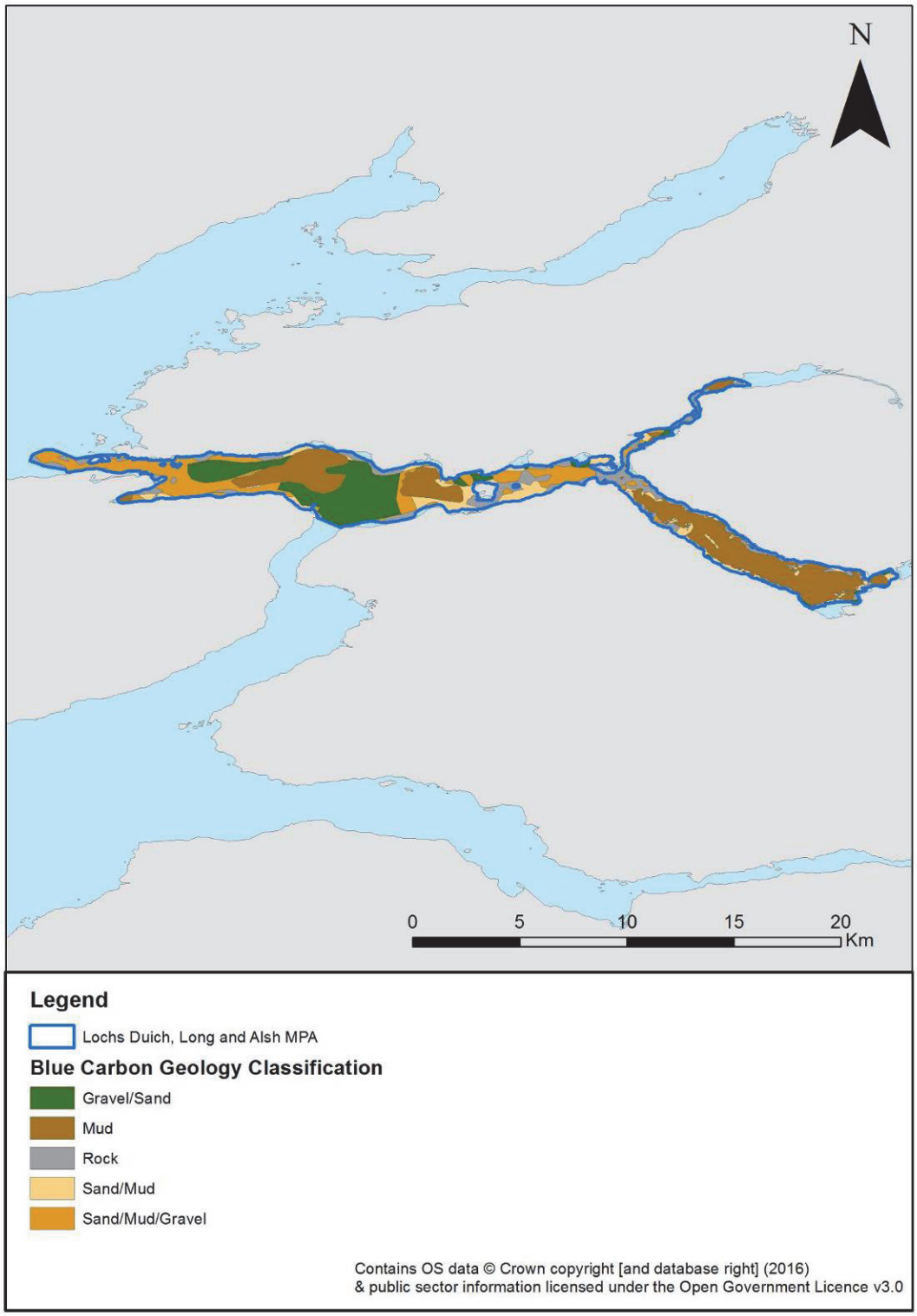
Map of the location of Lochs Duich, Long and Alsh NC MPA and Lochs Duich, Long and Alsh Reefs SAC

Designation: NC MPA created to protect the deep burrowed mud and an estimated 100 million flame shells, the largest known bed in the world, and this creates a habitat for peacock worms, anemones and sponges. The SAC was designated for the extensive reefs and horse mussel beds. The soft mud in the deep basins provides a habitat to Norway lobsters, forests of seapens and fireworks anemones.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Limaria hians* beds, maerl beds, *Modiolus modiolus* beds, *Mytilus edulis* beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Lochs Duich, Long and Alsh	49 257	1 326	80 111	955

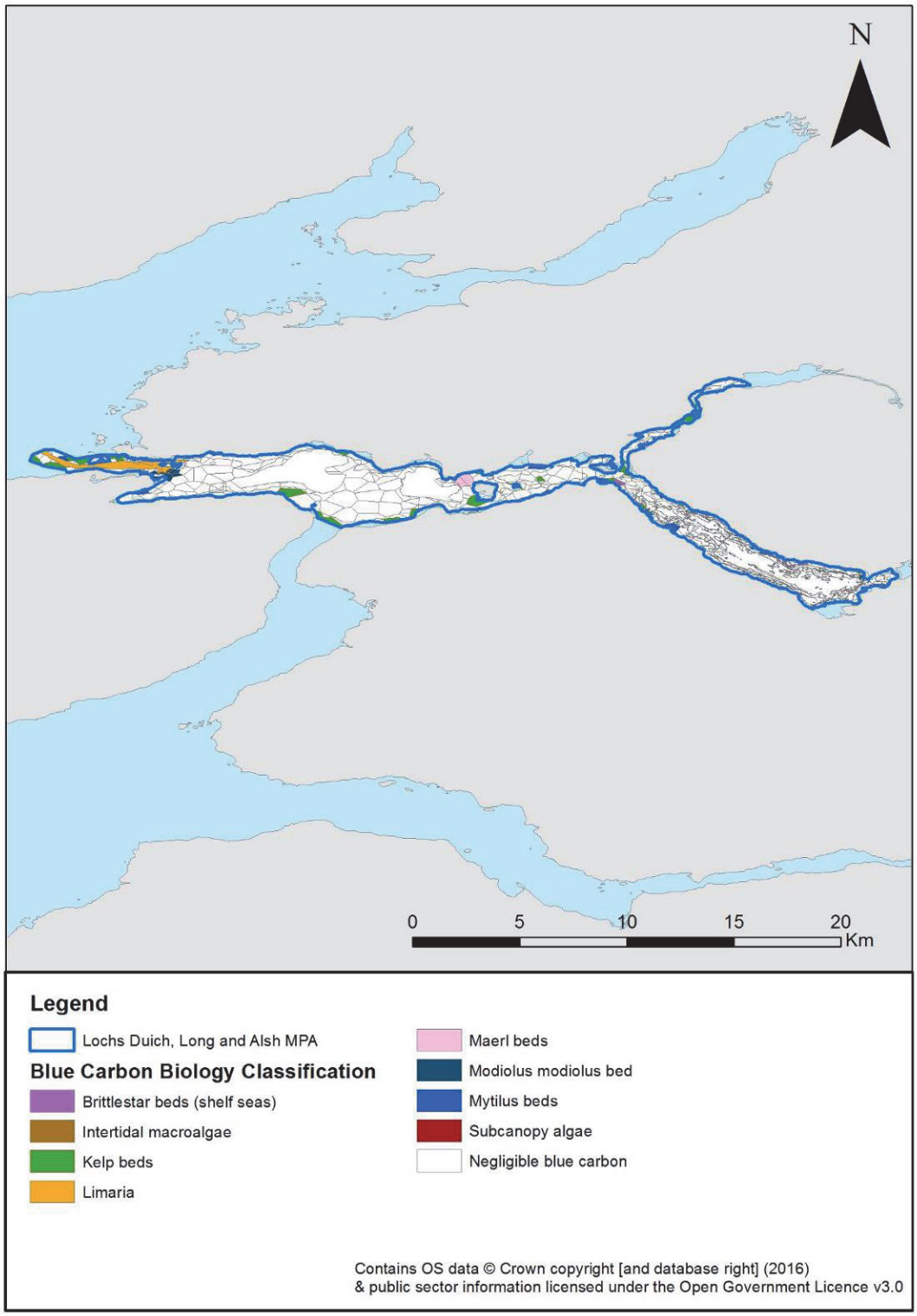
(SS: standing stock, seq: sequestration, prod: production)



Map of Lochs Duich, Long and Alsh NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Lochs Duich, Long and Alsh	357	1 228	0	16 892	58

(SS: standing stock, seq: sequestration, prod: production)



Map of Lochs Duich, Long and Alsh NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

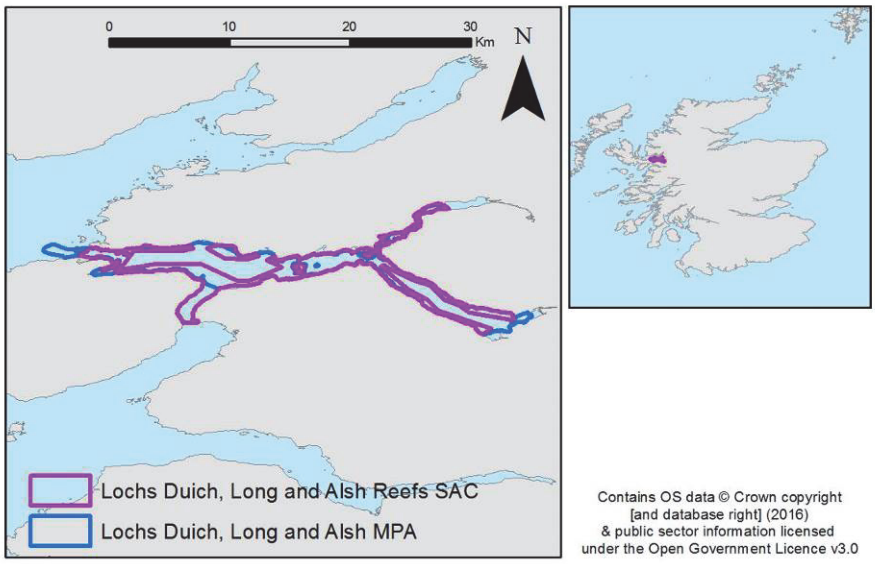
Table showing the calculated IC and OC values for each biological habitat: Lochs Duich, Long and Alsh

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.09	0.25	0.00	0.00	7.66	13.20	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.05	0.12	6.15	0.50	0.00	0.00	22.29	6.25	0.00	0.00	0.00	-
Kelp beds	1.78	4.83	1221.41	99.49	0.00	0.00	334.65	93.74	0.00	0.00	0.00	-
Limaria hians	0.94	2.54	0.00	0.00	0.00	0.00	0.00	0.00	59.87	0.35	0.00	-
Maerl beds	0.25	0.68	0.00	0.00	18.62	32.08	0.00	0.00	15697.80	92.93	0.00	-
Modiolus modiolus bed	0.28	0.76	0.00	0.00	11.27	19.42	0.00	0.00	1126.69	6.67	0.00	-
Mytilus beds	0.51	1.39	0.00	0.00	20.48	35.29	0.00	0.00	7.88	0.05	0.00	-
Negligible blue carbon	32.98	89.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.0002	0.01	0.05	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00	
Total	**36.89**	**100.00**	**1227.61**	**100.00**	**58.02**	**100.00**	**356.99**	**100.00**	**16892.24**	**100.00**	**0.00**	**-**

19. Lochs Duich, Long and Alsh Reefs SAC

Location: 57°16'30.00' N; 005°34'30.00'W – Loch Duich, Long and Alsh are all sea lochs situated on the west coast of Scotland. The SAC includes extensive representative examples of reef communities.

Area: 23.73 km^2



Map of the location of Lochs Duich, Long and Alsh NC MPA and Lochs Duich, Long and Alsh Reefs SAC

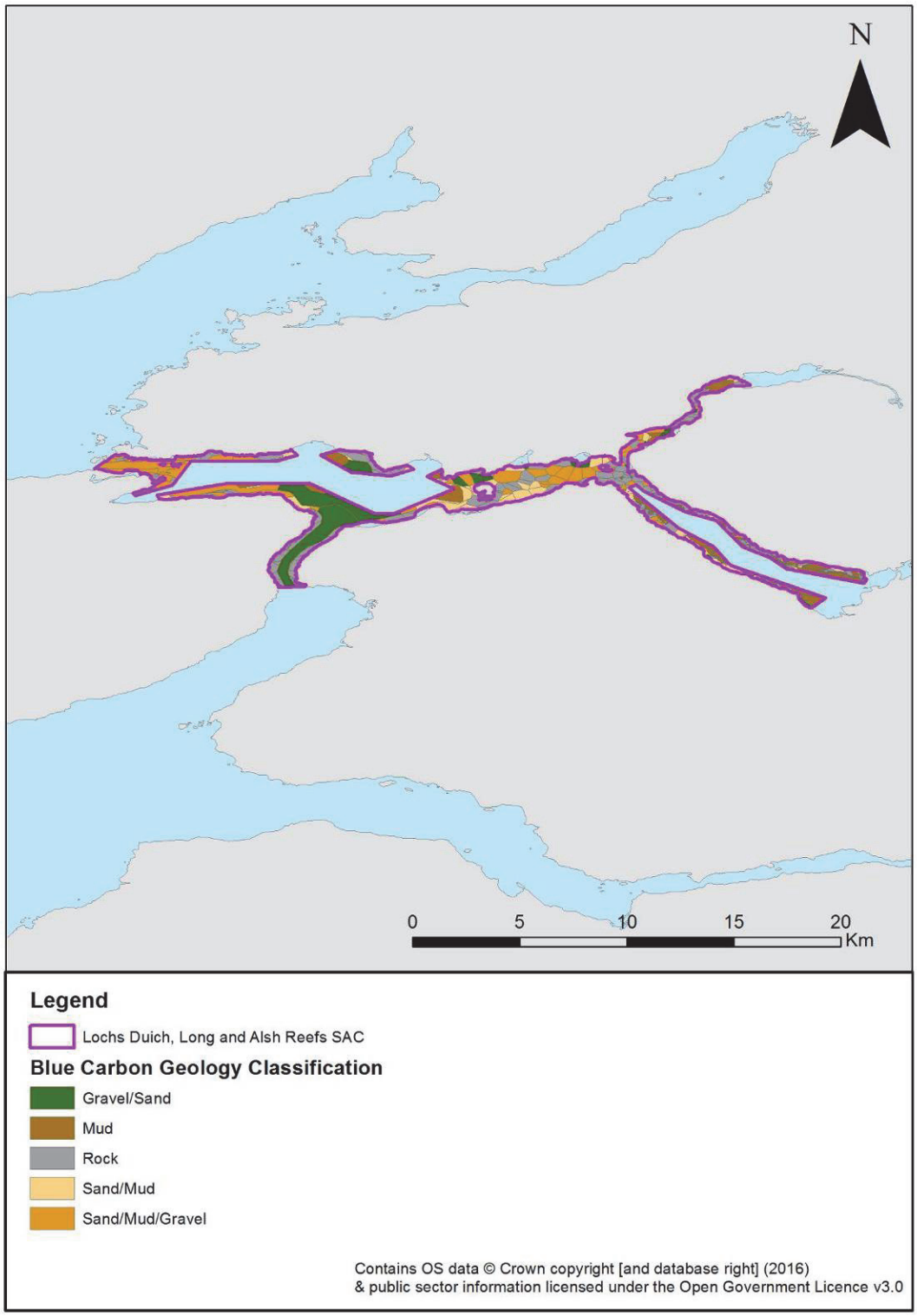
Designation: The SAC is designated under the marine feature; reefs. This site is an extensive area of extremely sheltered reefs within a system of fjordic sea lochs in north-west Scotland. There is considerable biological diversity within the site, including unusual assemblages of encrusting sponges and solitary ascidians, and tide-swept kelp forests influenced by brackish water.

The site Lochs Duich, Long and Alsh is also a designated NC MPA, for inshore sublittoral sediment, namely burrowed mud and flame shell bed.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Limaria hians* beds, maerl beds, *Modiolus modiolus* beds, *Mytilus edulis* beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Lochs Duich, Long and Alsh Reefs	21 788	485	47 643	493

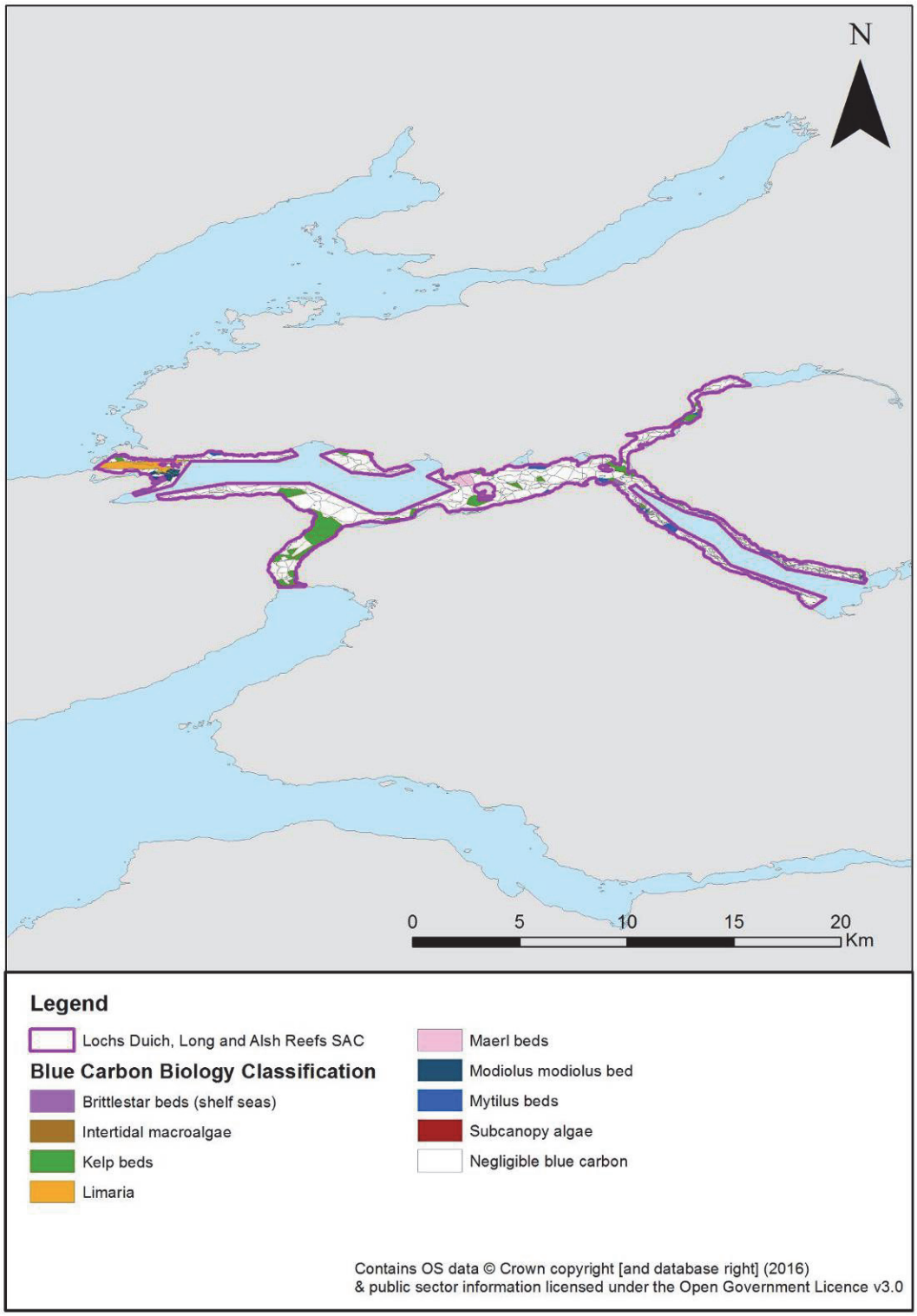
(SS: standing stock, seq: sequestration, prod: production)



Map of Lochs Duich, Long and Alsh Reefs SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Lochs Duich, Long and Alsh Reefs	600	1 987	0	17 813	60

(SS: standing stock, seq: sequestration, prod: production)



Map of Lochs Duich, Long and Alsh Reefs SAC showing the different biological habitats. The table above reports the calculated IC and OC

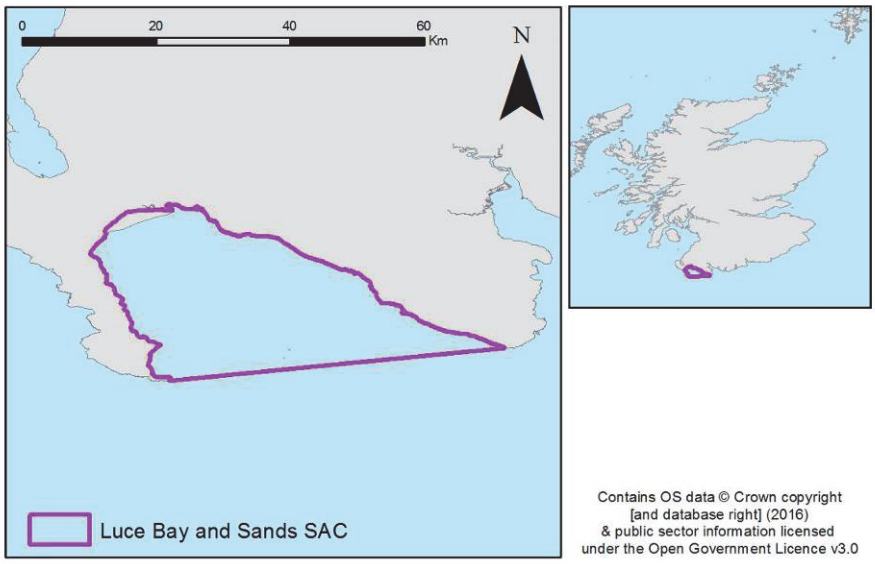
Table showing the calculated IC and OC values for each biological habitat: Lochs Duich, Long and Alsh Reefs

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.09	0.40	0.00	0.00	7.67	12.83	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.12	0.52	16.45	0.83	0.00	0.00	59.57	9.94	0.00	0.00	0.00	-
Kelp beds	2.88	12.37	1970.77	99.17	0.00	0.00	539.97	90.06	0.00	0.00	0.00	-
Limaria hians	0.66	2.84	0.00	0.00	0.00	0.00	0.00	0.00	42.10	0.24	0.00	-
Maerl beds	0.27	1.15	0.00	0.00	19.80	33.14	0.00	0.00	16693.46	93.71	0.00	-
Modiolus modiolus bed	0.27	1.15	0.00	0.00	10.69	17.90	0.00	0.00	1069.20	6.00	0.00	-
Mytilus beds	0.54	2.32	0.00	0.00	21.59	36.14	0.00	0.00	8.31	0.05	0.00	-
Negligible blue carbon	18.43	79.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**23.25**	**100.00**	**1987.21**	**100.00**	**59.74**	**100.00**	**599.54**	**100.00**	**17813.07**	**100.00**	**0.00**	**-**

20. Luce Bay and Sands SAC

Location: 54°45'0.00'N; 004°45'0.00'W – Luce Bay is a large bay in the county of Wigtown in southern Scotland. The mouth of the bay is 3.2 km wide, with the body of water bounded by the Rhins of Galloway to the west and the Machars to the east.

Area: 488 km^2



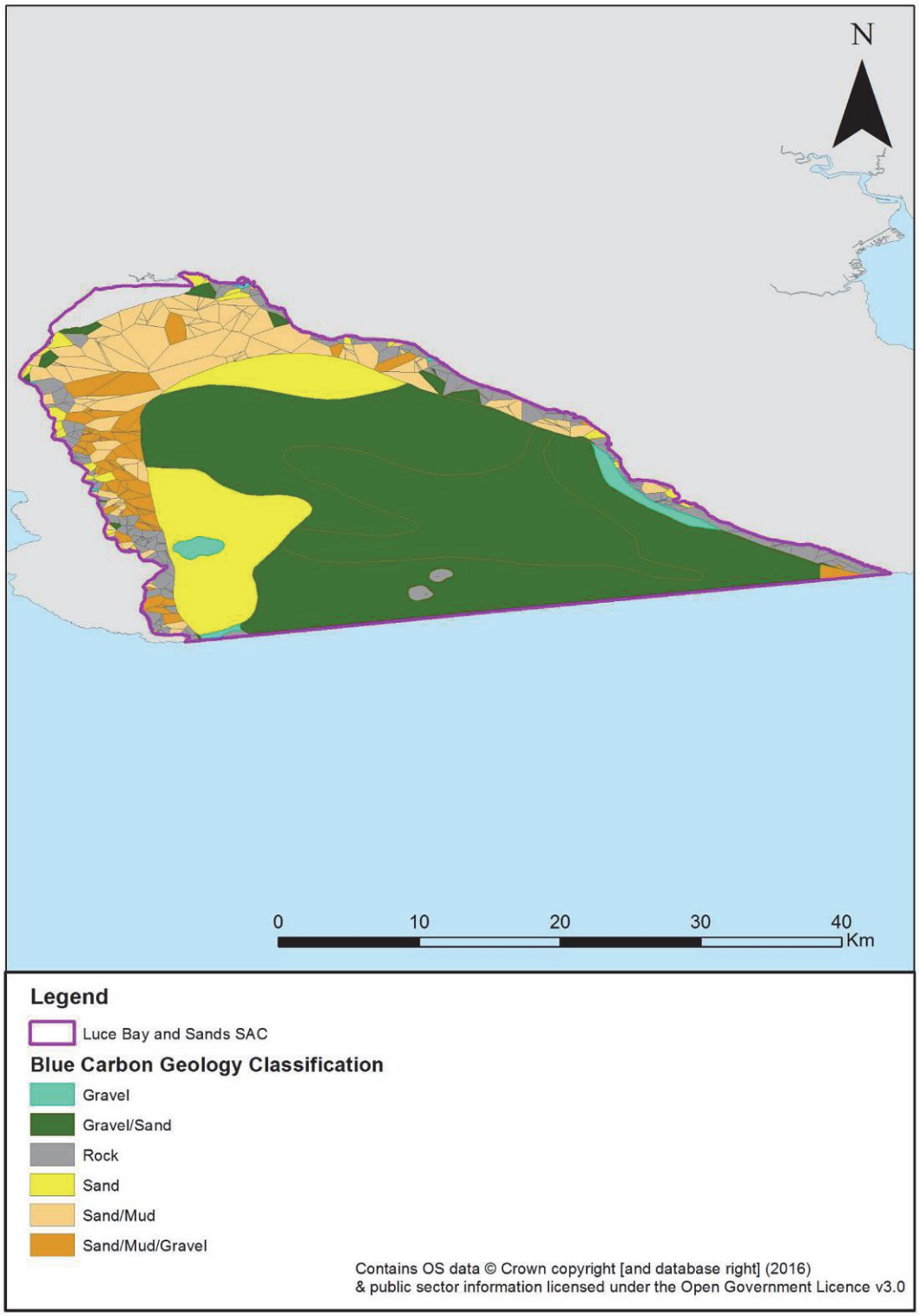
Map of the location of Luce Bay and Sands SAC

Designation: The area has been designated an SAC due to its marine and coastal features and the presence of great crested newts. The marine features include; intertidal mudflats and sandflats, reefs, shallow inlets and bays and subtidal sandbanks. The coastal features include; coastal dune heathland, dune grassland, shifting dunes and shifting dunes with marram. In addition to being an SAC, the northern part of the Luce Bay SAC is also designated a SPA, a Ramsar and a SSSI, namely Loch of Inch and Torrs Warren SPA, Loch of Inch and Torrs Warren Ramsar and Torrs Warren – Luce Sands SSSI.

Blue carbon designation: Gravel, gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, maerl beds, *Mytilus edulis* beds, *Sabellaria* reefs and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Luce Bay and Sands	294 403	2 997	2 303 211	17 312

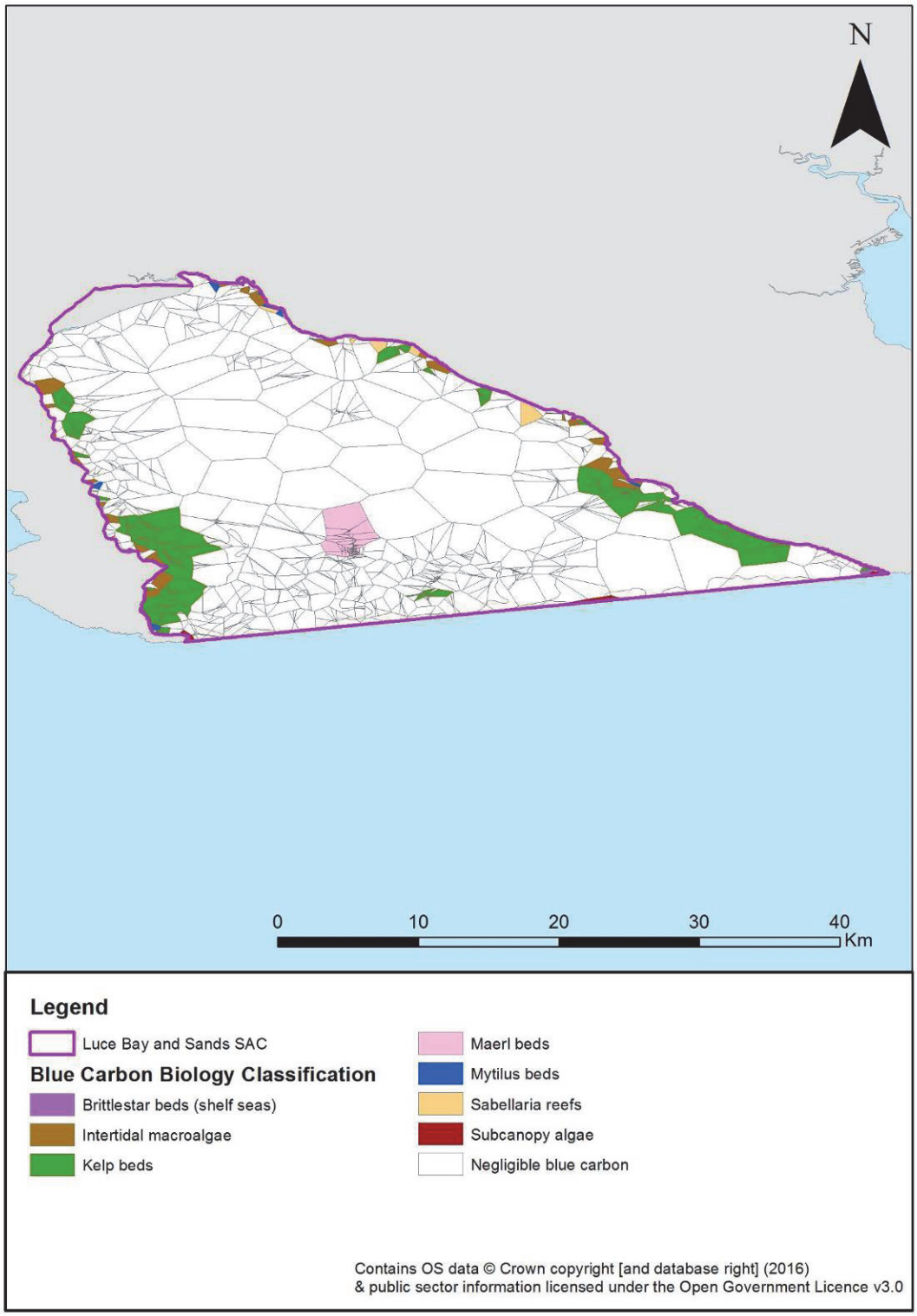
(SS: standing stock, seq: sequestration, prod: production)



Map of Luce Bay and Sands SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Luce Bay and Sands	10 555	25 791	0	400 715	523

(SS: standing stock, seq: sequestration, prod: production)



Map of Luce Bay and Sands SAC showing the different biological habitats. The table above reports the calculated IC and OC

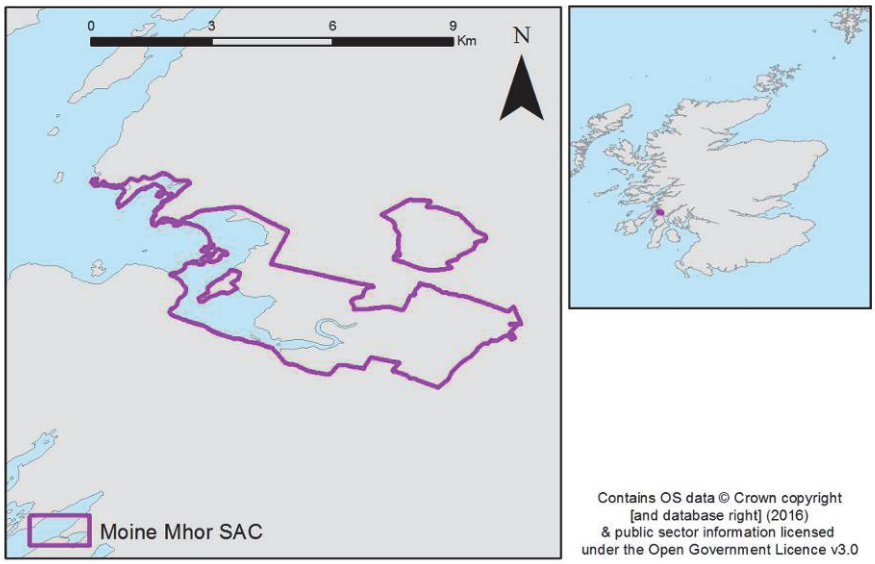
Table showing the calculated IC and OC values for each biological habitat: Luce Bay and Sands

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.18	0.04	0.00	0.00	14.49	2.77	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	7.69	1.61	1037.67	4.02	0.00	0.00	3758.83	35.61	0.00	0.00	0.00	-
Kelp beds	36.11	7.56	24735.04	95.91	0.00	0.00	6777.09	64.21	0.00	0.00	0.00	-
Maerl beds	6.42	1.34	0.00	0.00	475.17	90.79	0.00	0.00	400702.48	100.00	0.00	-
Mytilus beds	0.84	0.18	0.00	0.00	33.74	6.45	0.00	0.00	12.99	0.00	0.00	-
Negligible blue carbon	423.47	88.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Sabellaria reefs	1.91	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.85	0.18	17.80	0.07	0.00	0.00	18.65	0.18	0.00	0.00	0.00	-
Total	**477.47**	**100.00**	**25790.51**	**100.00**	**523.40**	**100.00**	**10554.58**	**100.00**	**400715.47**	**100.00**	**0.00**	**-**

21. Mòine Mhór SAC

Location: 56°4'50.00'N; 005°31'5.00'W – Mòine Mhór is located on the west coast of Scotland in Argyll and Bute, 10 kilometres north of Lochgilphead.

Area: 11.49 km^2



Map of the location of Mòine Mhór SAC

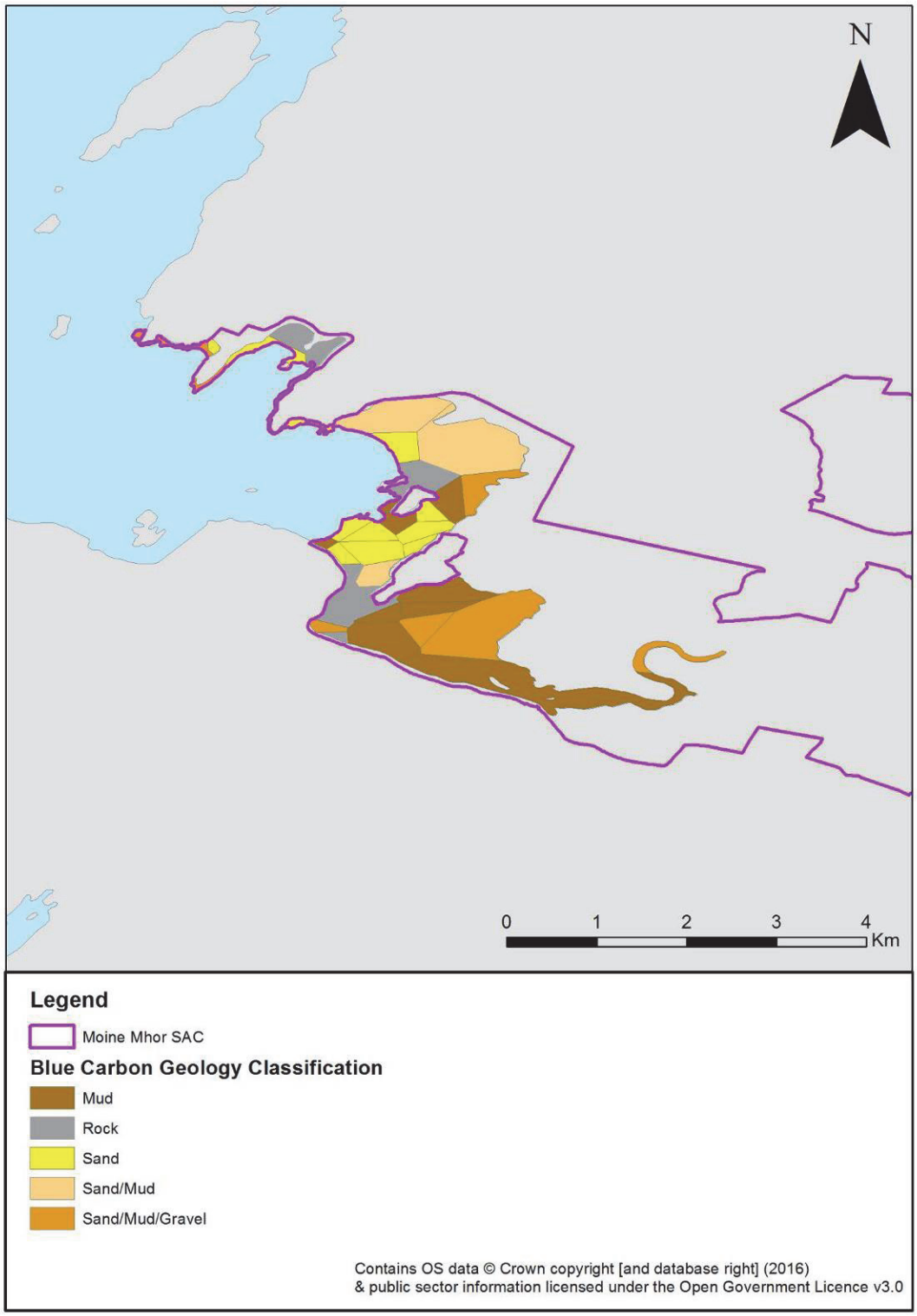
Designation: The area has been designated an SAC for a range of features both terrestrial and marine. The marine feature included in the designation is intertidal mudflats and sandflats. Other terrestrial features include; active raised bog, Atlantic salt meadows, degraded raised bog, western acidic oak woodland, along with otters and marsh fritillary butterfly. The primary reason for the selection of this site as an SAC is due to the active raised bogs and degraded raised bogs present.

Mòine Mhór is also a National Nature Reserve and a SSSI. The SSSI is designated for its breeding bird assemblage, estuarine raised bog, marsh fritillary, salt marsh and upland oak woodland.

Blue carbon designation: Mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae and seagrass beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mòine Mhór	3 134	57	5 835	55

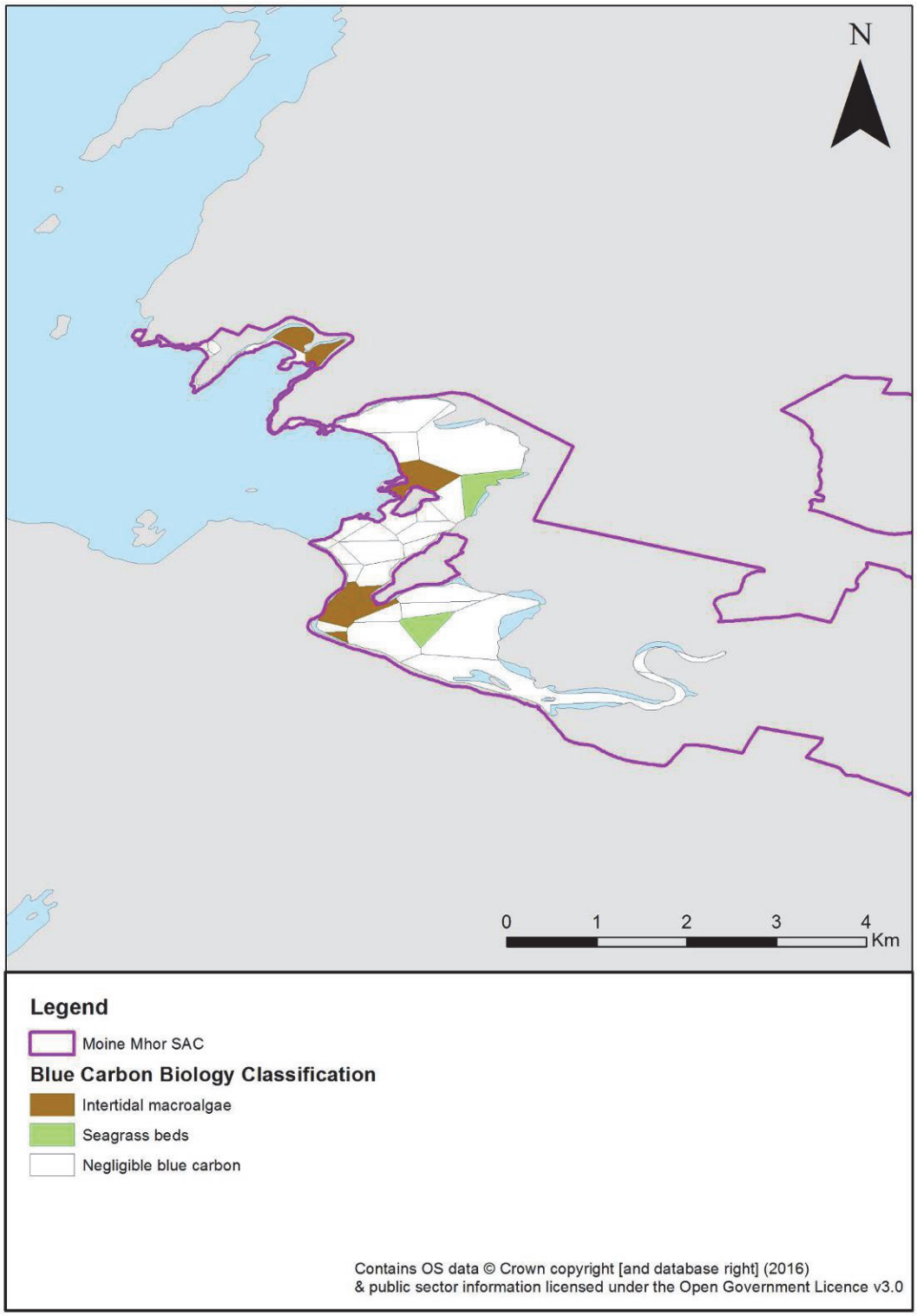
(SS: standing stock, seq: sequestration, prod: production)



Map of Mòine Mhór SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mòine Mhór	149	77	11	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Mòine Mhór SAC showing the different biological habitats. The table above reports the calculated IC and OC

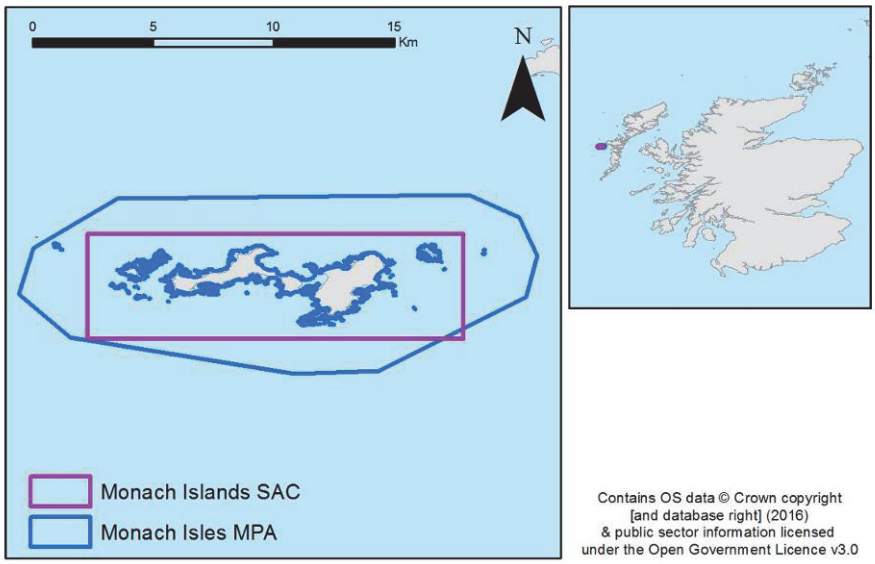
Table showing the calculated IC and OC values for each biological habitat: Moine Mhor

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.30	12.10	41.10	53.27	0.00	-	148.89	100.00	0.00	-	0.00	0.00
Negligible blue carbon	2.07	82.40	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	0.00
Seagrass beds	0.14	5.49	36.05	46.73	0.00	-	0.00	0.00	0.00	-	11.47	100.00
Total	**2.52**	**100.00**	**77.16**	**100.00**	**0.00**	**-**	**148.89**	**100.00**	**0.00**	**-**	**11.47**	**100.00**

22. Monach Islands SAC

Location: 57°31'30.00'N; 007°36'30.00'W - Also known as Heisker, the Monach Islands SAC is an island group in the Outer Hebrides, West of North Uist.

Area: 36.47 km^2



Map of the location of Monach Islands SAC and Monach Isles MPA

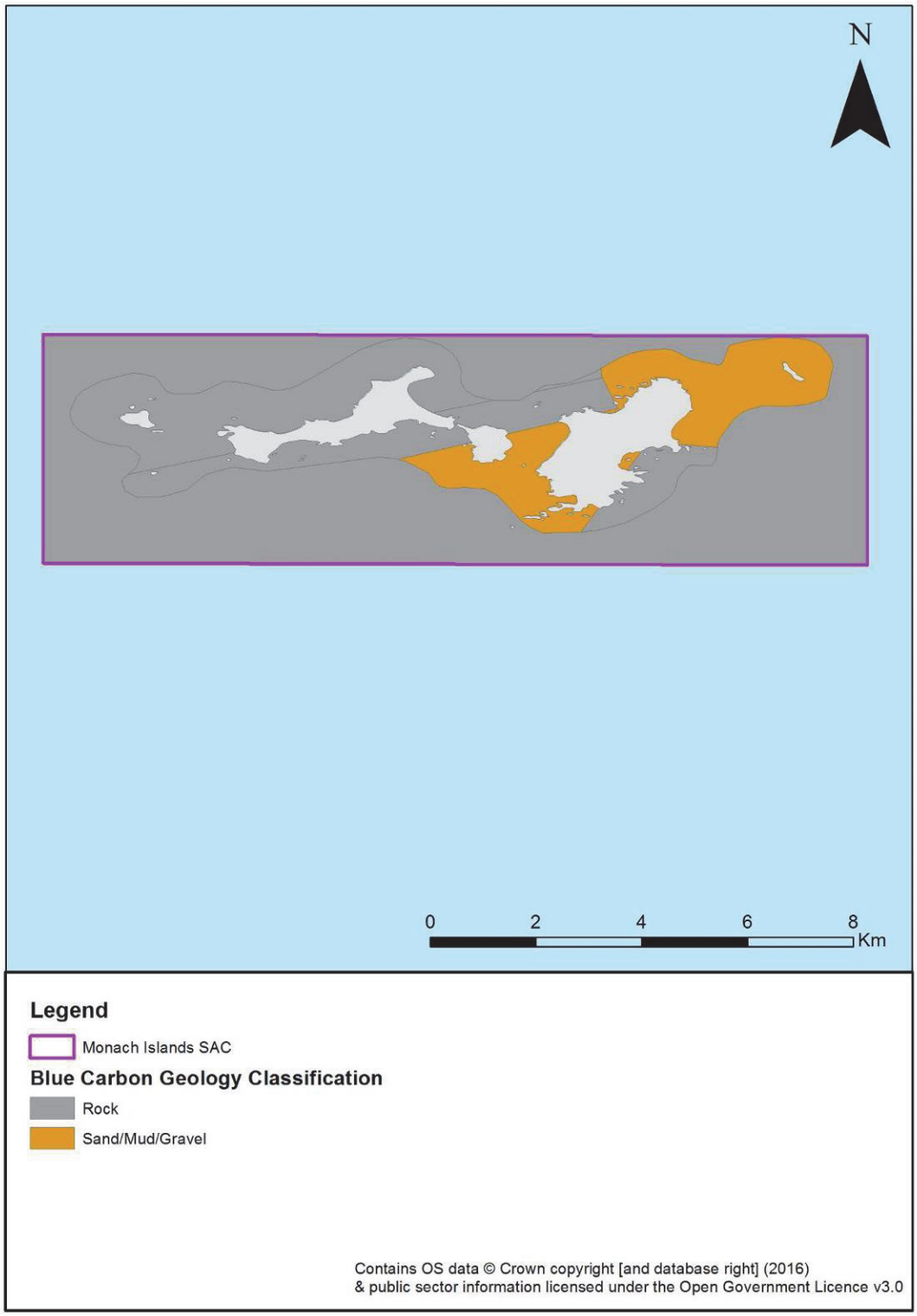
Designation: The SAC is designated for its coastal and marine feature namely: Dune grassland, grey seals, machair and shifting dunes with marram. The primary reasons for designation include machairs and grey seal. The Monach Islands consist almost entirely of machair and support some of the best examples of grazed uncultivated machair in the Outer Hebrides.

The Monach Islands are also a designated SPA (for common tern, Greenland barnacle goose and little tern) with the Monach Isles a SSSI (for machair, sand dunes, black guillemot, breeding bird assemblage and Greenland barnacle goose) National Nature Reserve and a MPA.

Blue carbon designation: Rock, sand/mud/gravel (geology); kelp beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Monach Islands	5 299	78	8 637	97

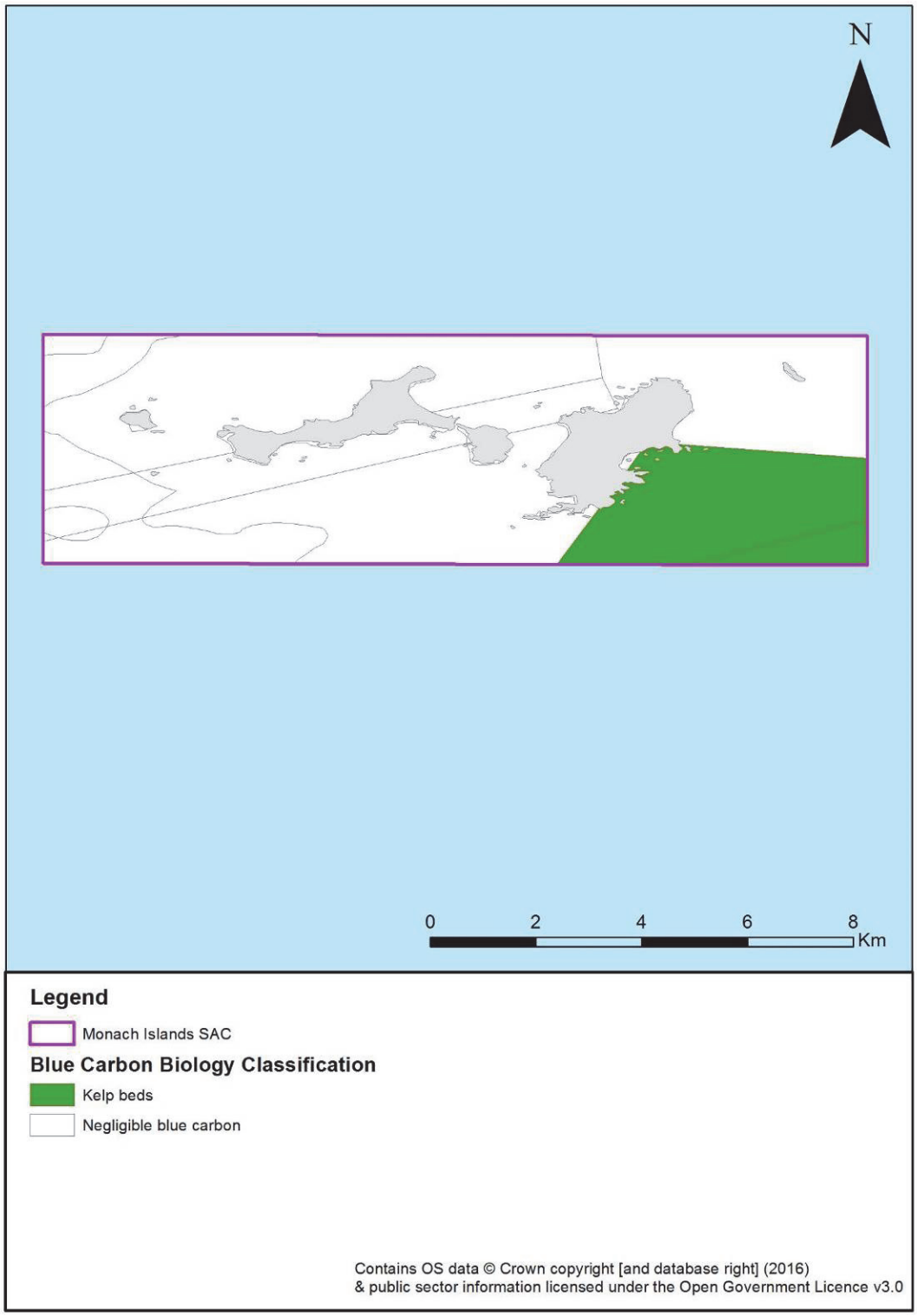
(SS: standing stock, seq: sequestration, prod: production)



Map of Monach Islands SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Monach Islands	1 080	3 942	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Monach Islands SAC showing the different biological habitats. The table above reports the calculated IC and OC

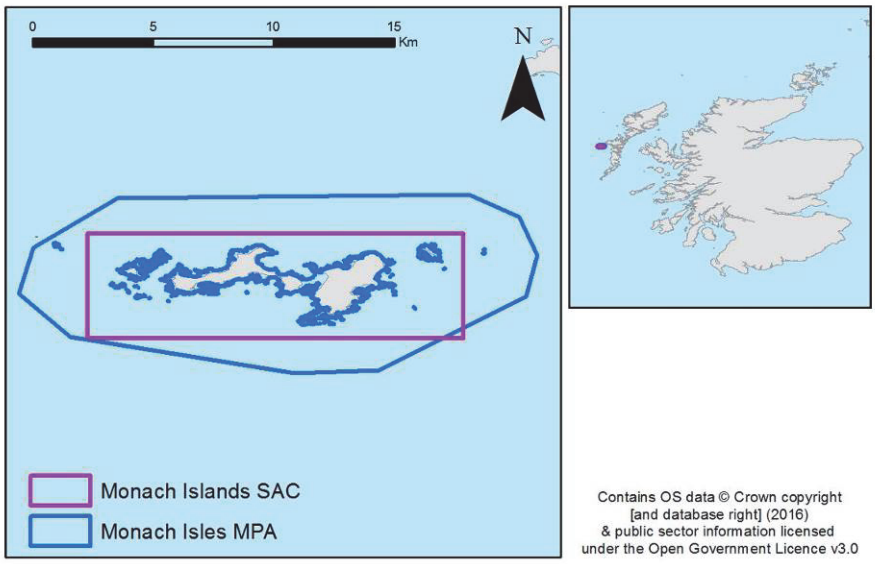
Table showing the calculated IC and OC values for each biological habitat: Monach Islands SAC

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	5.75	17.69	3941.94	100.00	0.00	-	1080.04	100.00	0.00	-	0.00	-
Negligible blue carbon	26.78	82.31	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Total	**32.54**	**100.00**	**3941.94**	**100.00**	**0.00**	**-**	**1080.04**	**100.00**	**0.00**	**-**	**0.00**	**-**

23. Monach Isles NC MPA

Location: 57°31'485 N; 007°38'281W – The Monach Isles, also known as Heisker, are a number of tiny islands five miles west of North Uist in the Outer. The Monach Isles NC MPA overlaps and build on the Monach Islands SAC, extending to cover a greater area.

Area: 62.00 km^2



Map of the location of Monach Islands SAC and Monach Isles NC MPA

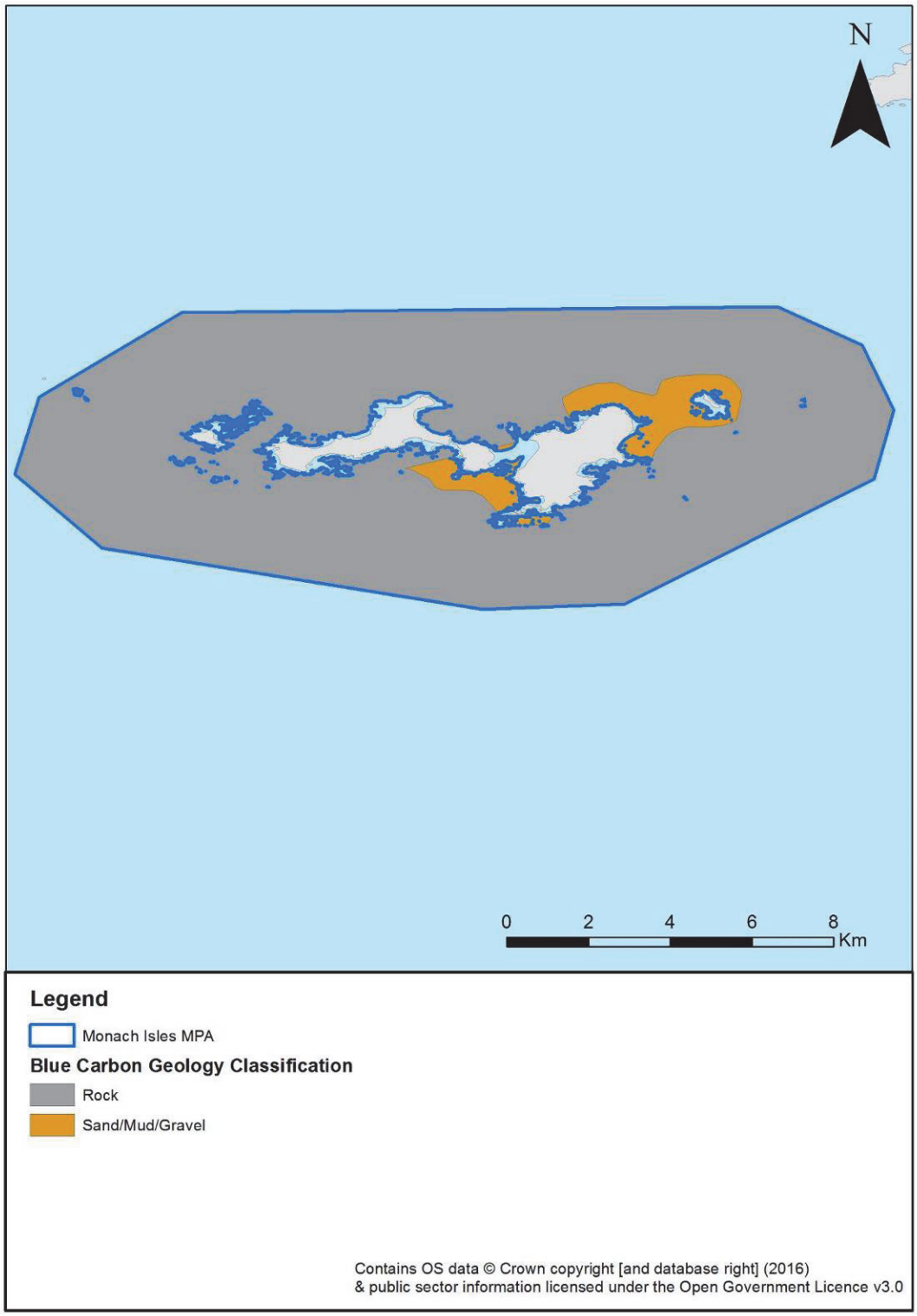
Designation: The Isles are designated an NC MPA due to the presence of black guillemots and the quaternary geology and geomorphology located at the site. The NC MPA encompasses an estimated 820 breeding black guillemots, approximately 2.2% of the British population.

The Monarch Isles are also a SSSI and a NNR. With the Monarch Islands also designated an SAC and a SPA for breeding birds including common tern, little tern and Greenland barnacle goose.

Blue carbon designation: Rock, sand/mud/gravel (geology); kelp beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Monach Isles	4 245	63	6 920	77

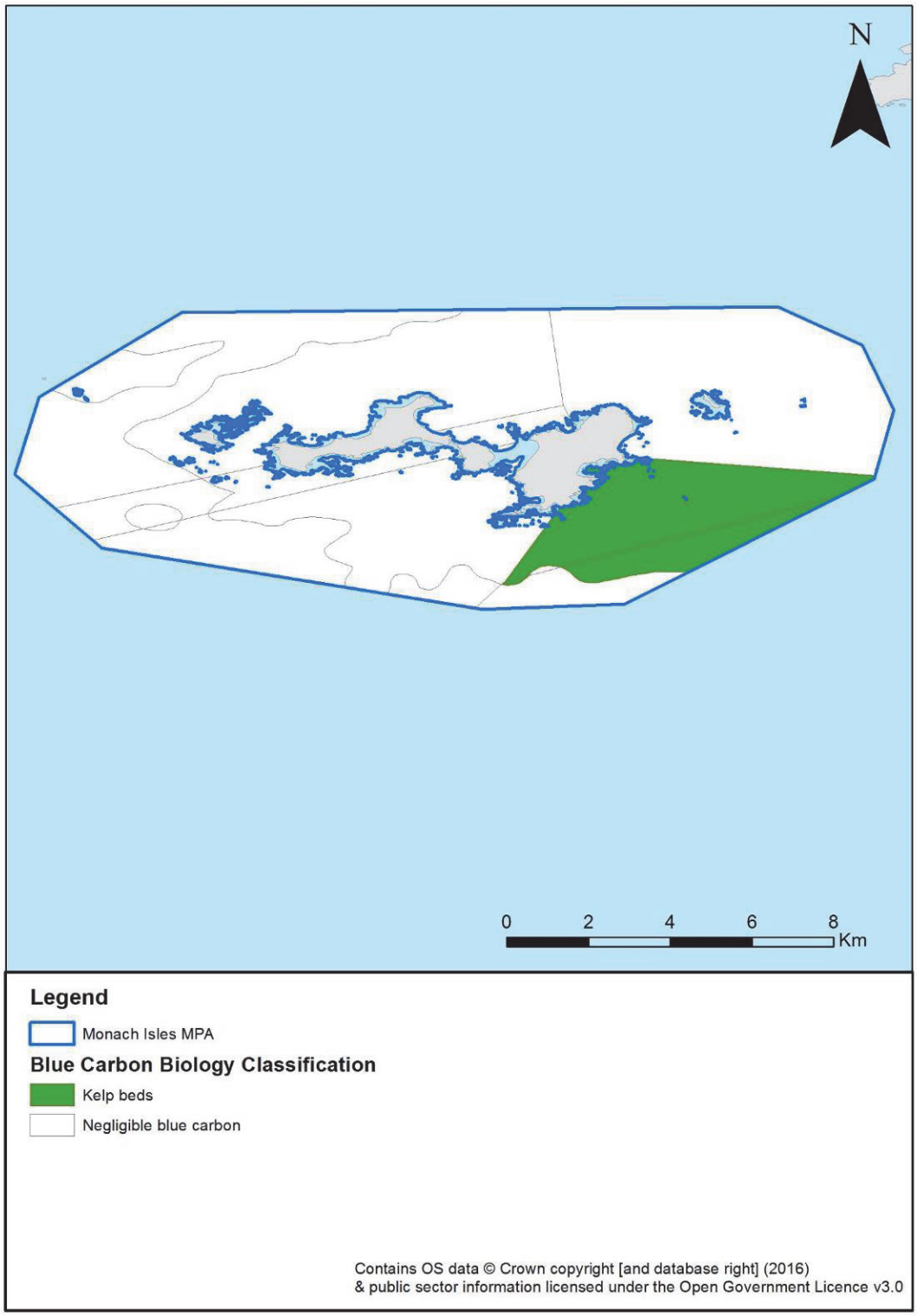
(SS: standing stock, seq: sequestration, prod: production)



Map of Monach Isles NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Monach Isles	1 553	5 667	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Monach Isles NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

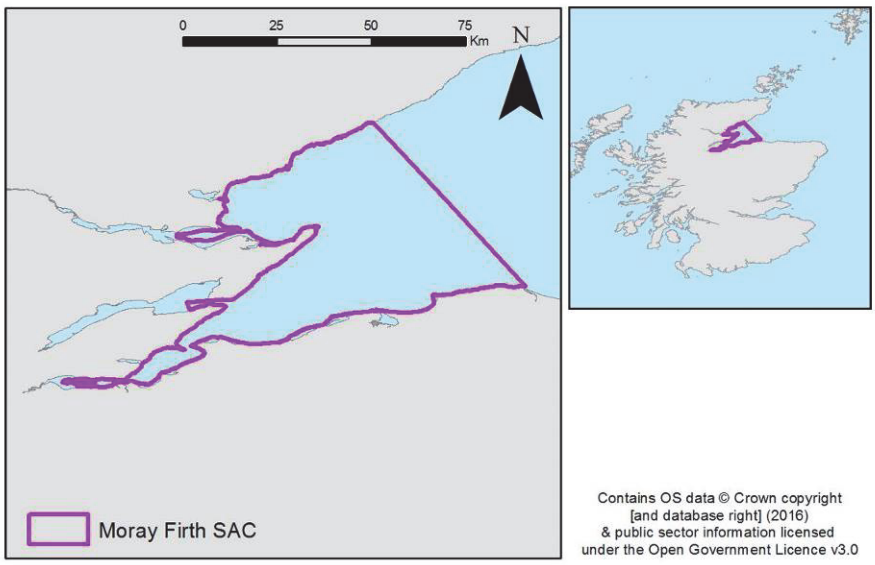
Table showing the calculated IC and OC values for each biological habitat: Monach Isles

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	8.27	13.38	5666.85	100.00	0.00	-	1552.65	100.00	0.00	-	0.00	-
Negligible blue carbon	53.54	86.62	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Total	**61.81**	**100.00**	**5666.85**	**100.00**	**0.00**	**-**	**1552.65**	**100.00**	**0.00**	**-**	**0.00**	**-**

24. Moray Firth SAC

Location: 57°49'1.00'N; 003°43'32.00'W – The Moray Firth SAC is situated in the Highlands of Scotland, north and east of Inverness. The SAC comprises the 'triangular' area of the North Sea west of a line between Helmsdale on the Sutherland coast and Lossiemouth on the Moray coast.

Area: 1513 km^2



Map of the location of Moray Firth SAC

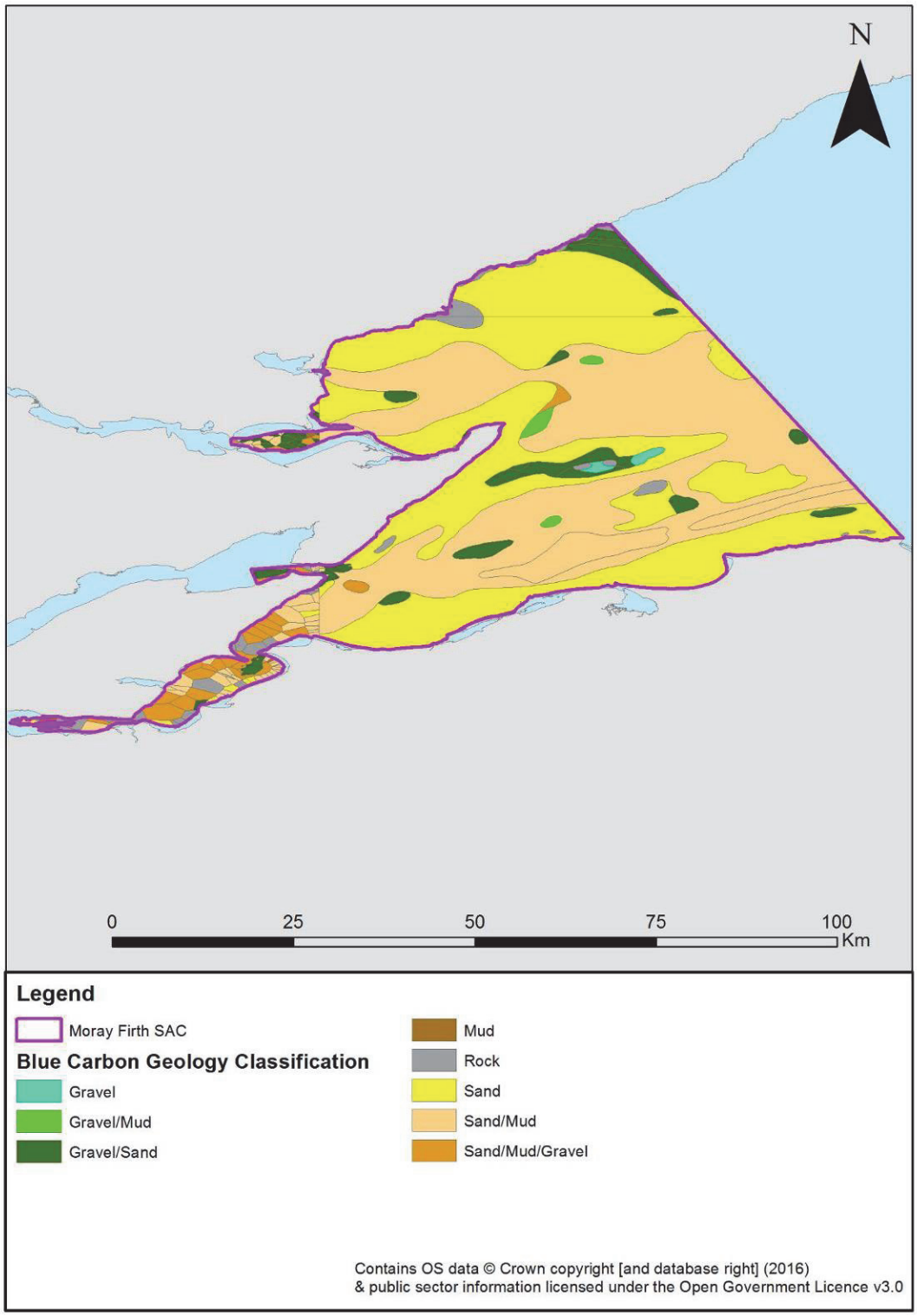
Designation: The SAC is designated for two marine habitats; subtidal sandbanks and bottlenose dolphins. The primary reason for selection of this site is the bottlenose dolphins, with the Moray Firth supporting the only resident population of bottlenose dolphin in the North Sea; approximately 130 individuals.

Situated around the Moray Firth there are a number of other designated sites including SSSIs, Ramsar Site and SPA for a range of marine and non-marine features.

Blue carbon designation: Gravel, gravel/mud, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Modiolus modiolus* beds, *Mytilus edulis* beds and seagrass beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Moray Firth	1 312 043	16 579	5 952 871	48 876

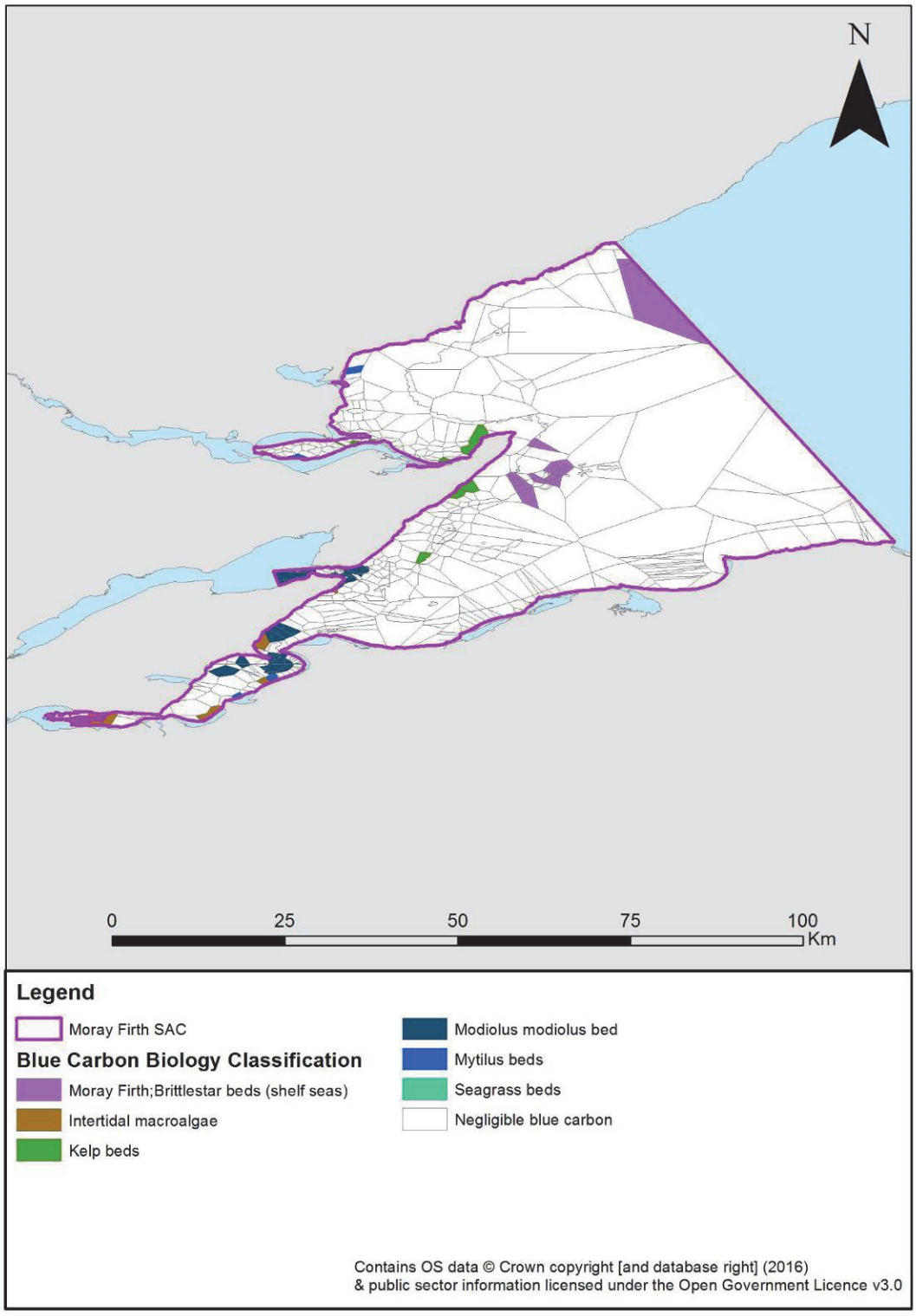
(SS: standing stock, seq: sequestration, prod: production)



Map of Moray Firth SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Moray Firth	3 031	7 110	0	66 877	4 448

(SS: standing stock, seq: sequestration, prod: production)



Map of Moray Firth SAC showing the different biological habitats. The table above reports the calculated IC and OC

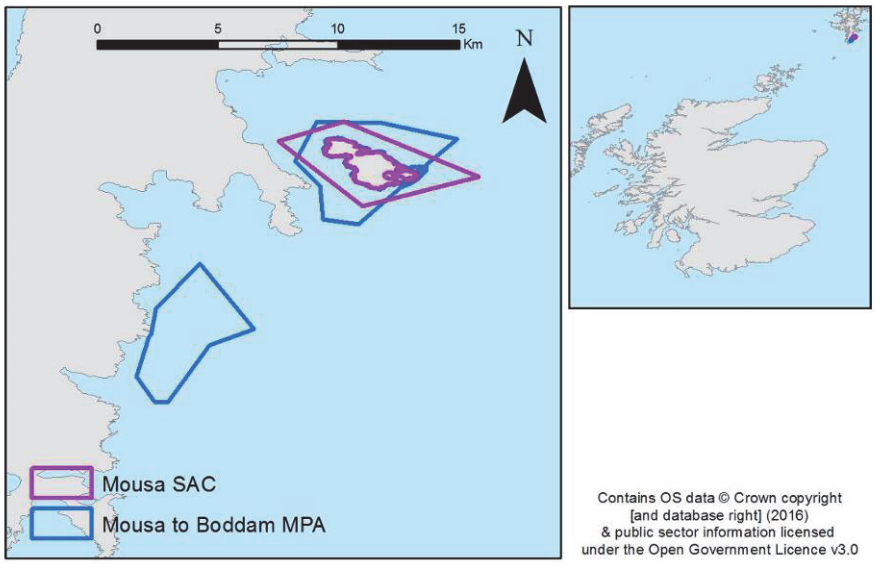
Table showing the calculated IC and OC values for each biological habitat: Moray Firth

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	45.02	3.09	0.00	0.00	3692.03	83.01	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	2.39	0.16	323.28	4.55	0.00	0.00	1171.05	38.64	0.00	0.00	0.00	-
Kelp beds	9.91	0.68	6786.79	95.45	0.00	0.00	1859.50	61.36	0.00	0.00	0.00	-
Modiolus modiolus bed	16.71	1.15	0.00	0.00	668.43	15.03	0.00	0.00	66843.07	99.95	0.00	-
Mytilus beds	2.18	0.15	0.00	0.00	87.29	1.96	0.00	0.00	33.61	0.05	0.00	-
Negligible blue carbon	1382.51	94.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**1458.73**	**100.00**	**7110.08**	**100.00**	**4447.75**	**100.00**	**3030.55**	**100.00**	**66876.68**	**100.00**	**0.00**	**-**

25. Mousa SAC

Location: 60°0'0.00'N; 1°10'20.00'W. The Island of Mousa is a small exposed rock island on the east coast of Shetland. It is approximately one mile off Mainland Shetland.

Area: 5.30 km^2



Map of the location of Mousa SAC and Mousa to Boddam MPA

Designation: The SAC is designated for three marine features; harbour seal, reefs and sea caves. The primary reason for the selection of this site is the presence of harbour seal. The island is an important breeding colony for the seal, being one of the most northerly groups in the UK. The site supports just over 1% of the UK population.

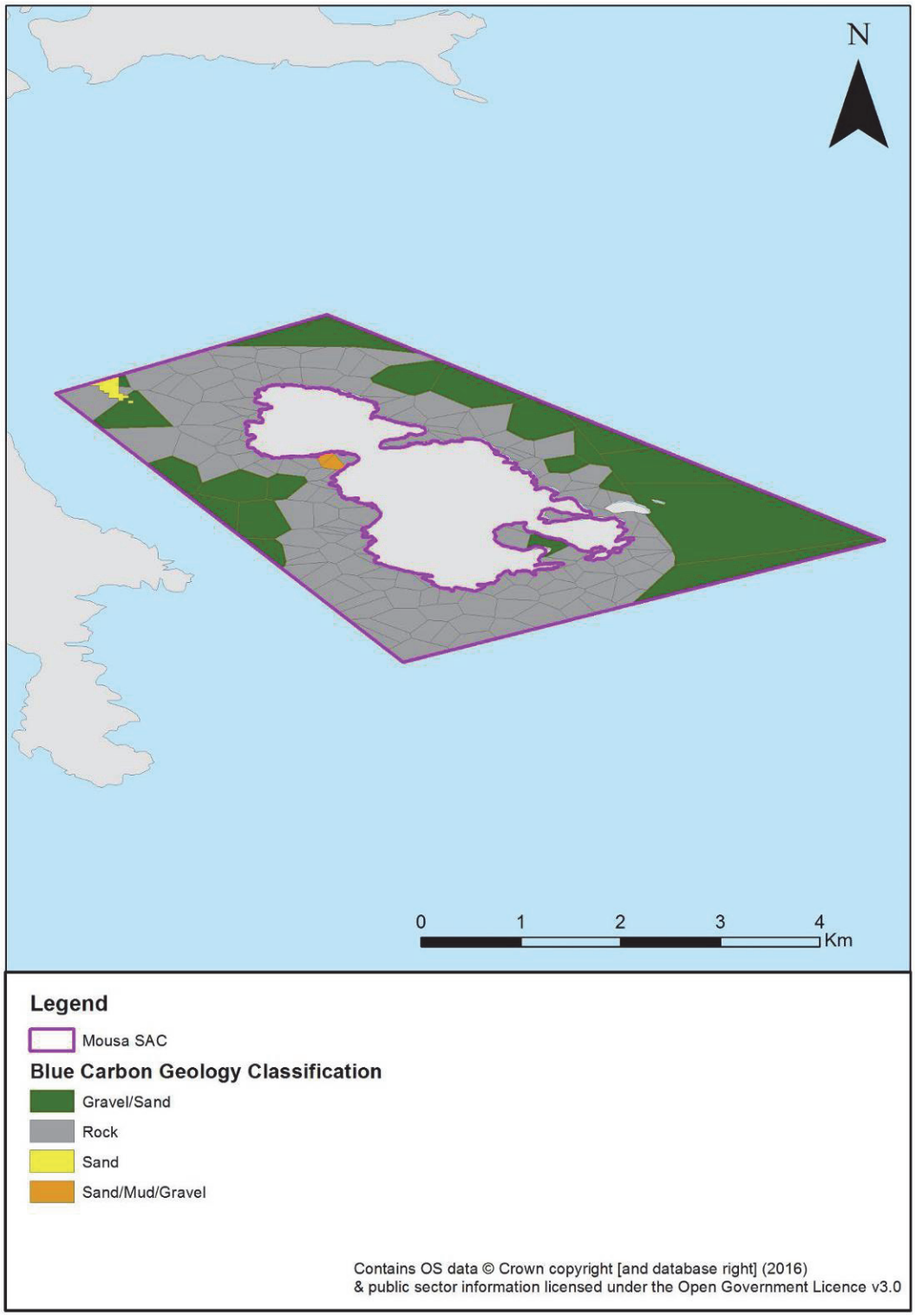
Mousa is also a SSSI (harbour seal, Arctic tern, black guillemot and storm petrel) and SPA (Arctic tern, storm petrel).

In addition Mousa to Boddam is an NC MPA for sandeels and the marine geomorphology of the Scottish Shelf Seabed.

Blue carbon designation: Gravel/sand, rock, sand and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, maerl beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mousa	1 225	9	13 822	100

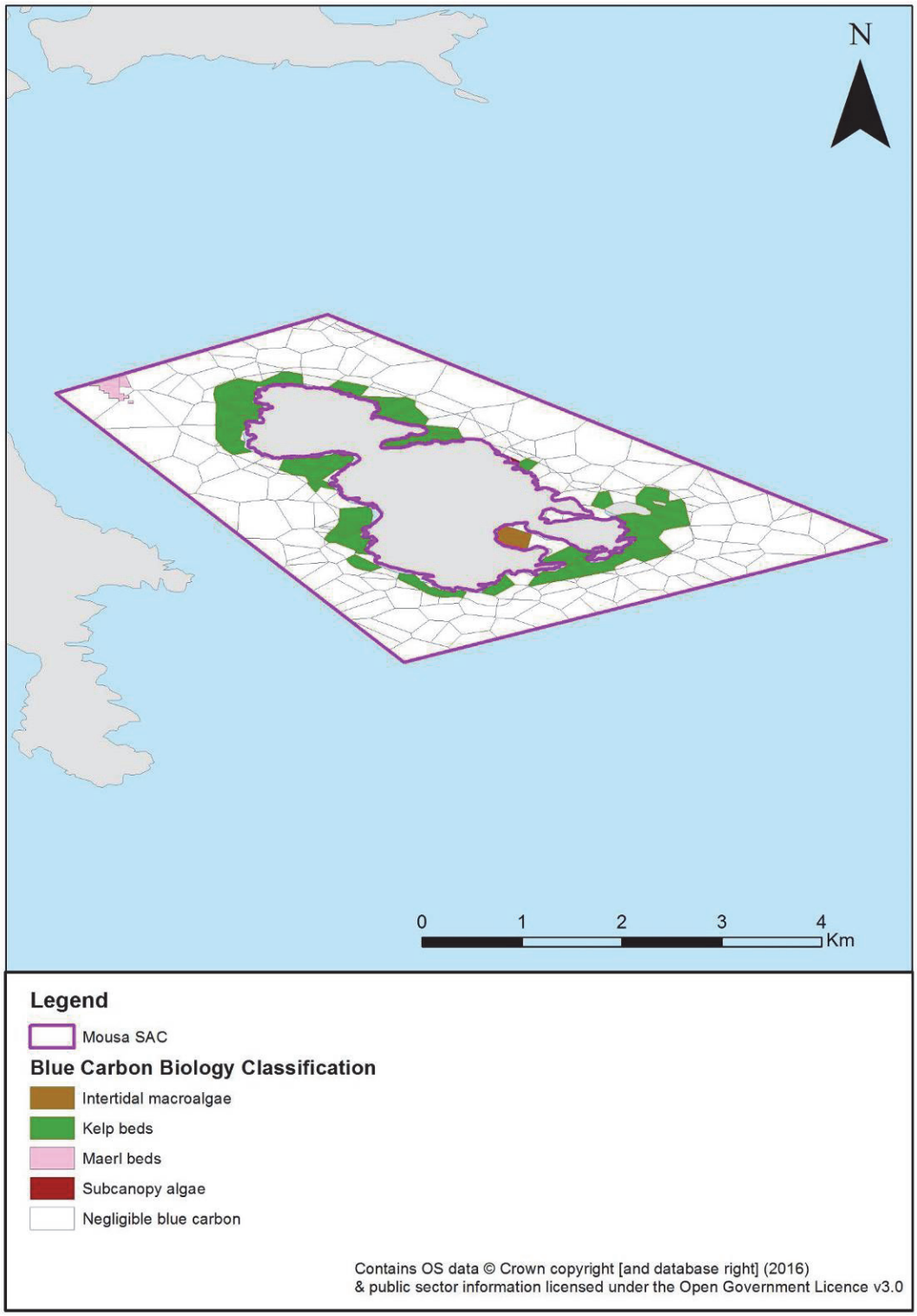
(SS: standing stock, seq: sequestration, prod: production)



Map of Mousa SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mousa	154	513	0	1 742	2

(SS: standing stock, seq: sequestration, prod: production)



Map of Mousa SAC showing the different biological habitats. The table above reports the calculated IC and OC

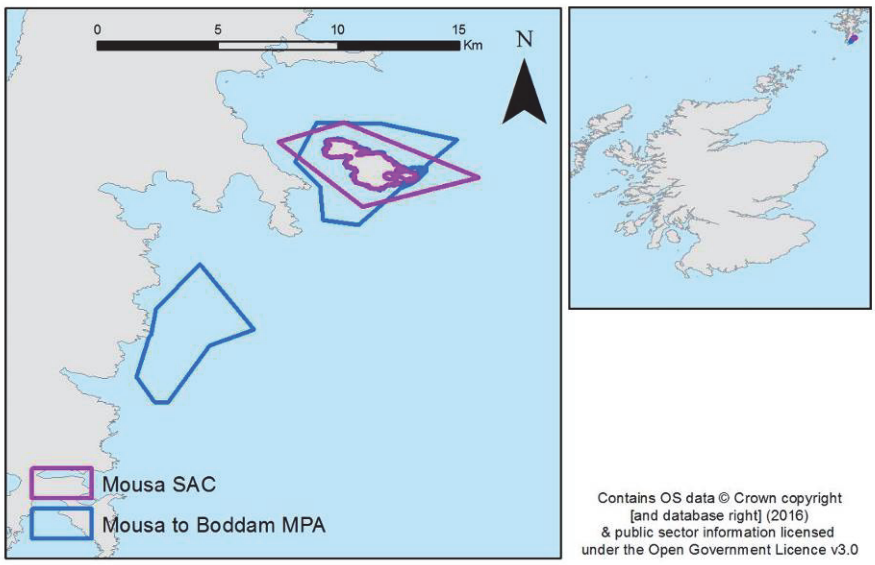
Table showing the calculated IC and OC values for each biological habitat: Mousa

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.03	0.57	3.97	0.77	0.00	0.00	14.36	**9.34**	0.00	**0.00**	0.00	-
Kelp beds	0.74	14.35	508.68	99.22	0.00	0.00	139.37	**90.63**	0.00	**0.00**	0.00	-
Maerl beds	0.03	0.54	0.0	0.00	2.07	100.00	0.00	**0.00**	1742.18	**100.00**	0.00	-
Negligible blue carbon	4.37	84.51	0.0	0.00	0.00	0.00	0.00	**0.00**	0.00	**0.00**	0.00	-
Subcanopy algae	0.00	0.03	0.0	0.01	0.00	0.00	0.00	**0.02**	0.00	**0.00**	0.00	-
Total	**5.17**	**100.00**	**512.68**	**100.00**	**2.07**	**100.00**	**153.77**	**100.00**	**1742.18**	**100.00**	**0.00**	**-**

26. Mousa to Boddam NC MPA

Location: 59°59.933'N; 001°10.722'W (Mousa), 59°56.175'N; 001°14.669'W (Boddam) located south-east of Shetland, this NC MPA includes the island of Mousa and the coastal waters off Boddam. The northern part of the NC MPA overlaps with the Mousa SAC and SPA.

Area: 13 km^2 (combined area)



Map of the location of Mousa SAC and Mousa to Boddam NC MPA

Designation: The NC MPA is designated for sandeels and the marine geomorphology of the Scottish shelf seabed. The aim is to protect habitats that provide breeding and recruitment for sandeels which are important food resources for fish, birds and marine mammals.

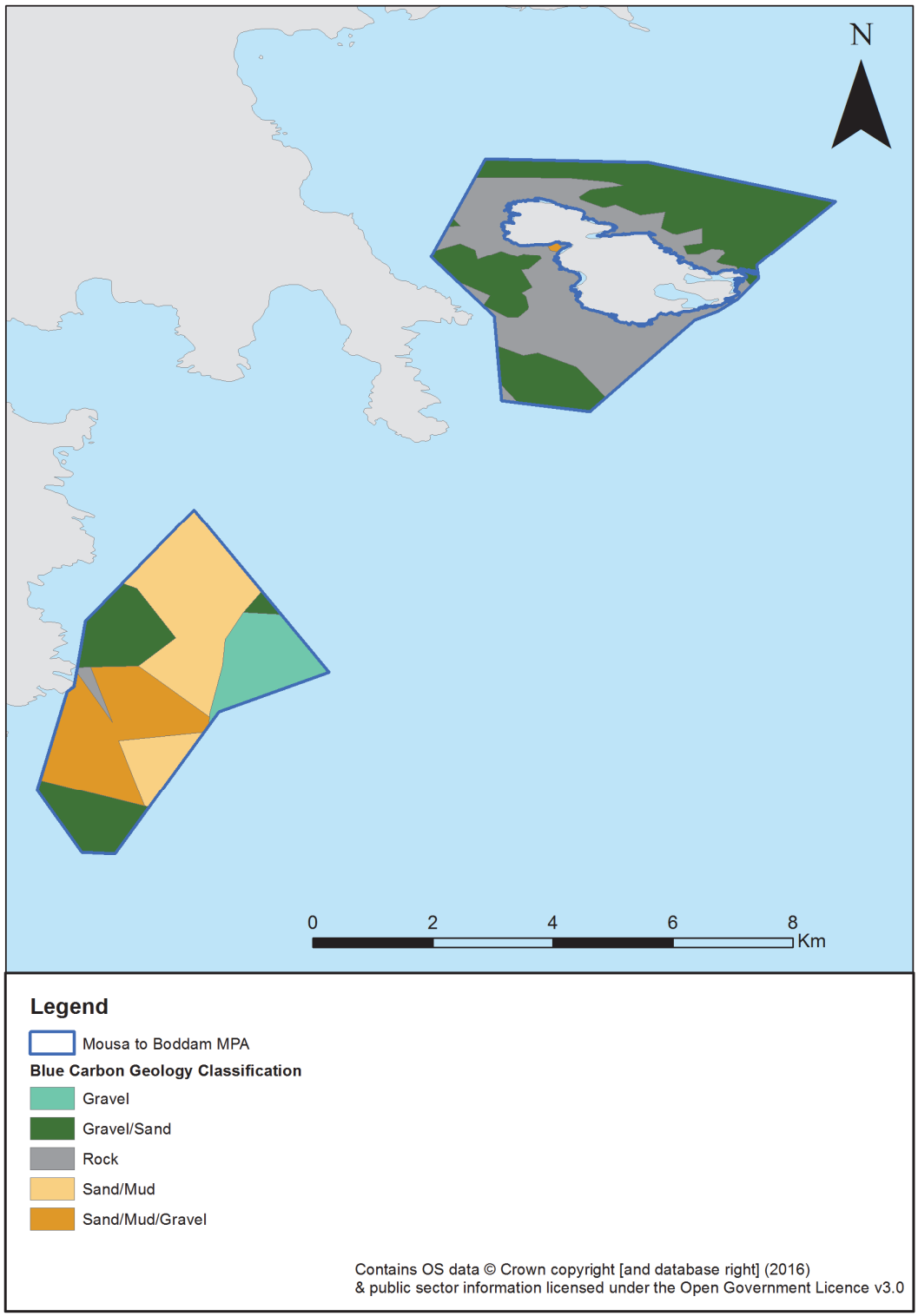
Mousa is also a designated SAC, SSSI and and SPA. The SAC was designated for reefs, sea caves and harbour seals, and the SPA protects breeding storm petrels and Arctic terns.

The MPA also lies within an internationally important carbonate production area. The subtidal banks of well flushed sands preferred by the sandeels are high in calcium carbonate because they are made of the eroded shells and skeletons of animals that lived on or in the sea bed. These sediments supply the sandy beaches of Shetland.

Blue carbon designation: Gravel, gravel/sand, rock, sand/mud and sand/mud/gravel (geology); kelp beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mousa to Boddam	7 745	96	37 202	302

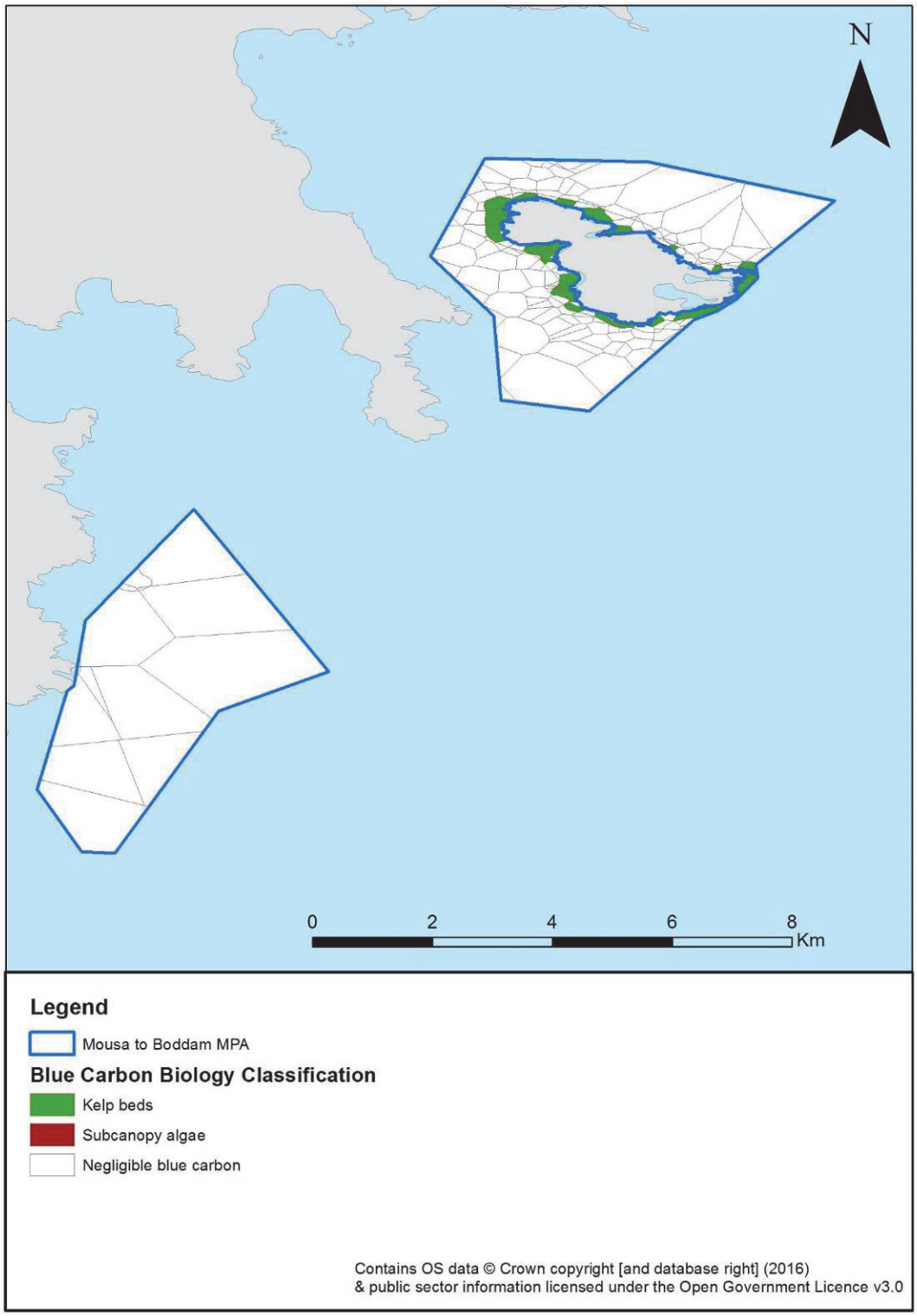
(SS: standing stock, seq: sequestration, prod: production)



Map of Mousa to Boddam NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Mousa to Boddam	106	387	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Mousa to Boddam NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

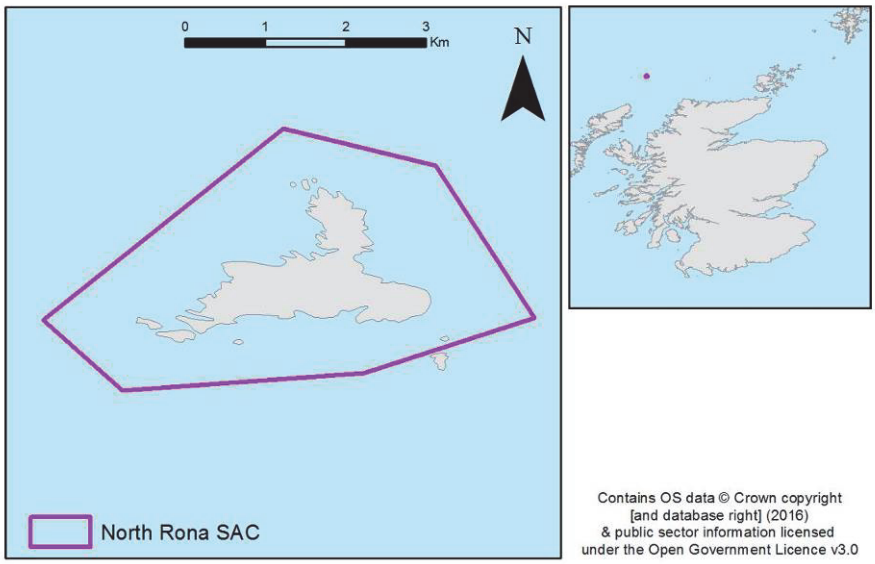
Table showing the calculated IC and OC values for each biological habitat: Mousa to Boddam

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	0.56	4.33	386.72	99.99	0.00	-	105.96	99.96	0.00	-	0.00	-
Negligible blue carbon	12.47	95.66	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Subcanopy algae	0.00	0.01	0.04	0.01	0.00	-	0.04	0.04	0.00	-	0.00	-
Total	**13.04**	**100.00**	**386.75**	**100.00**	**0.00**	**-**	**105.99**	**100.00**	**0.00**	**-**	**0.00**	**-**

27. North Rona SAC

Location: 59°7'30.00'N; 005°49'30.00'W – North Rona is located in the Atlantic Ocean, situated about 72 km's NNE of Ness, Lewis.

Area: 6.29 km^2



Map of the location of North Rona SAC

Designation: The SAC is designated for its marine features and one coastal feature. Marine features include; sea caves, reefs and grey seal. The coastal feature is vegetated sea cliffs.

The remote, very exposed, rocky island of North Rona supports one of the most important grey seal breeding groups in the UK and the EU, approximately 1,600 pups are produced annually.

North Rona with Sula Sgeir is also designated an SPA and a SSSI, North Rona and Sula Sgeir, designated for an array of birds and grey seals.

Blue carbon designation: Gravel/sand (geology); kelp beds (biology).

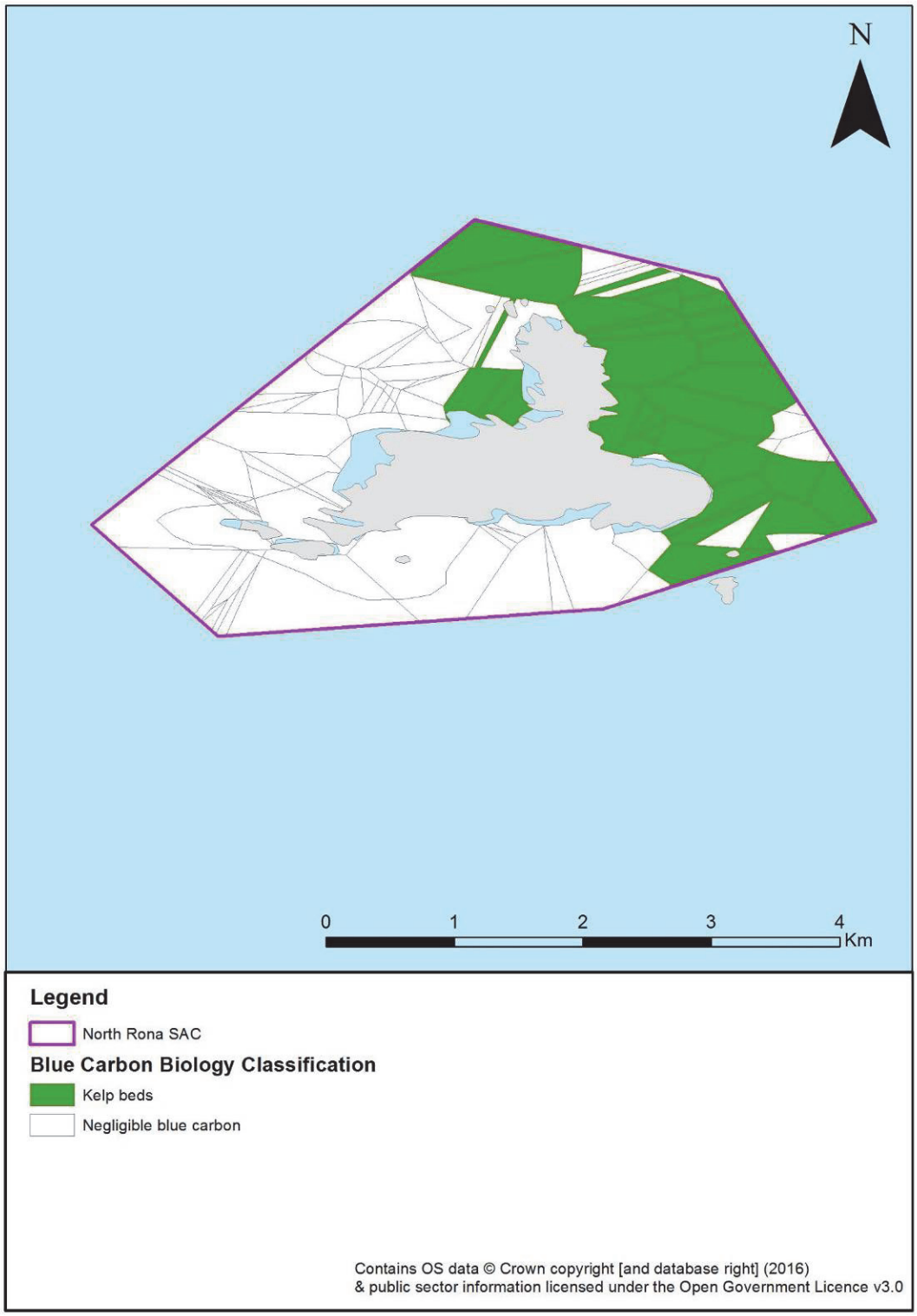
Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
North Rona	19	0	213	2

(SS: standing stock, seq: sequestration, prod: production)

Map of North Rona SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
North Rona	340	1 241	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of North Rona SAC showing the different biological habitats. The table above reports the calculated IC and OC

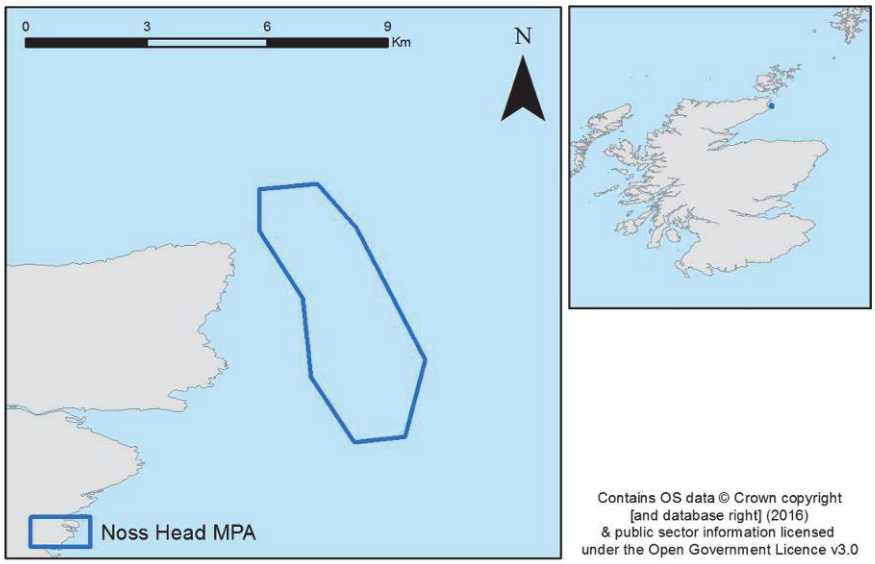
Table showing the calculated IC and OC values for each biological habitat: North Rona

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	1.81	36.70	1240.87	100.00	0.00	-	339.98	100.00	0.00	-	0.00	-
Negligible blue carbon	3.12	63.30	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Total	**4.94**	**100.00**	**1240.87**	**100.00**	**0.00**	**-**	**339.98**	**100.00**	**0.00**	**-**	**0.00**	**-**

28. Noss Head NC MPA

Location: 58°27.825'N; 003°01.439'W – Noss Head NC MPA lies to the north of Wick, in an area of explosed coastline on the north-east coast of Scotland.

Area: 8 km^2



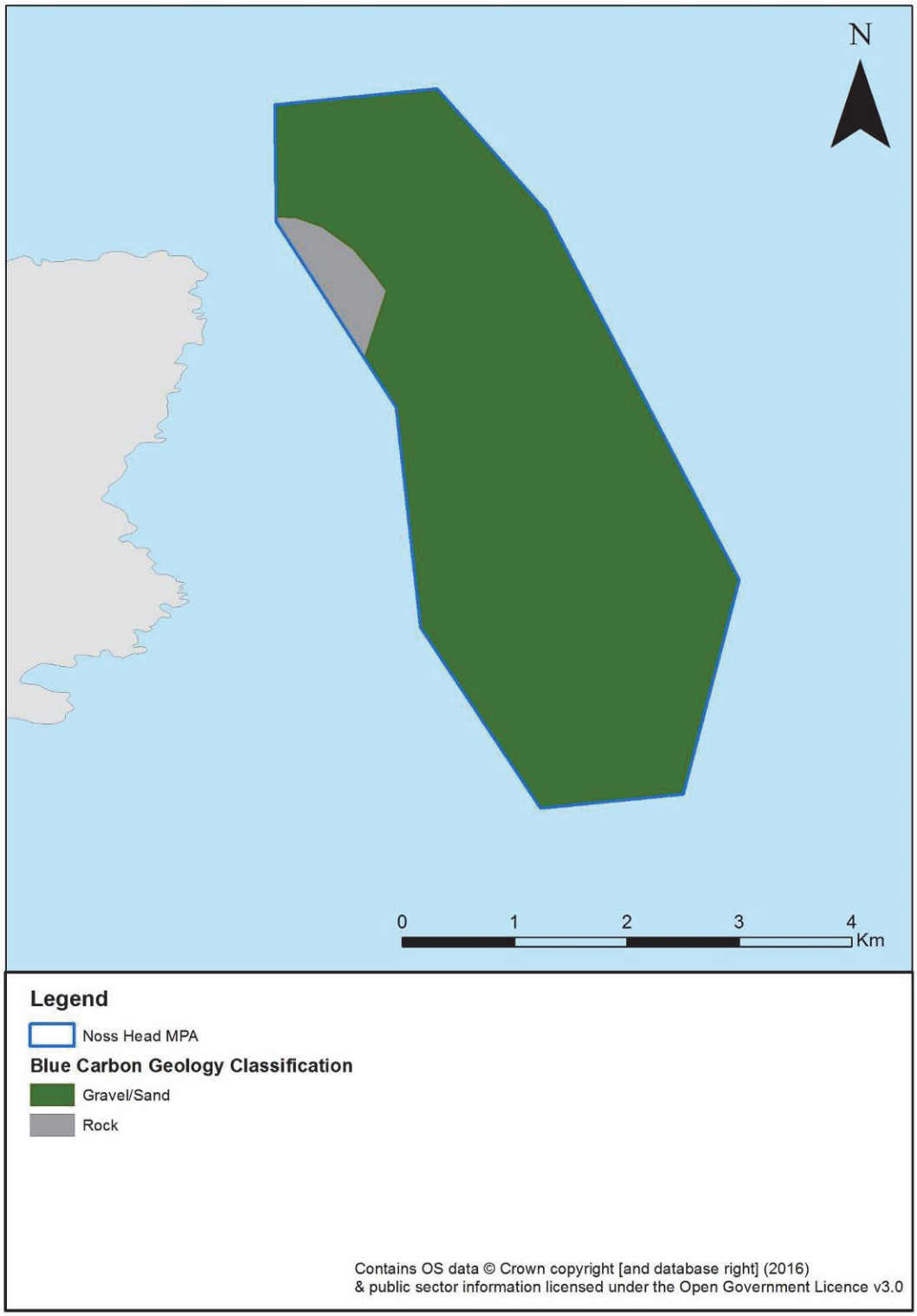
Map of the location of Noss Head NC MPA

Designation: NC MPA supports the largest Scottish horse mussel bed, which lies in depths of 35-45m of water. This provides substrata for soft corals, tubeworms, barnacles, sea firs and sea mats as well as brittlestars, crabs, worms and other molluscs.

Blue carbon designation: Gravel/sand and rock (geology); *Modiolus modiolus* bed (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Noss Head	3 906	29	44 768	323

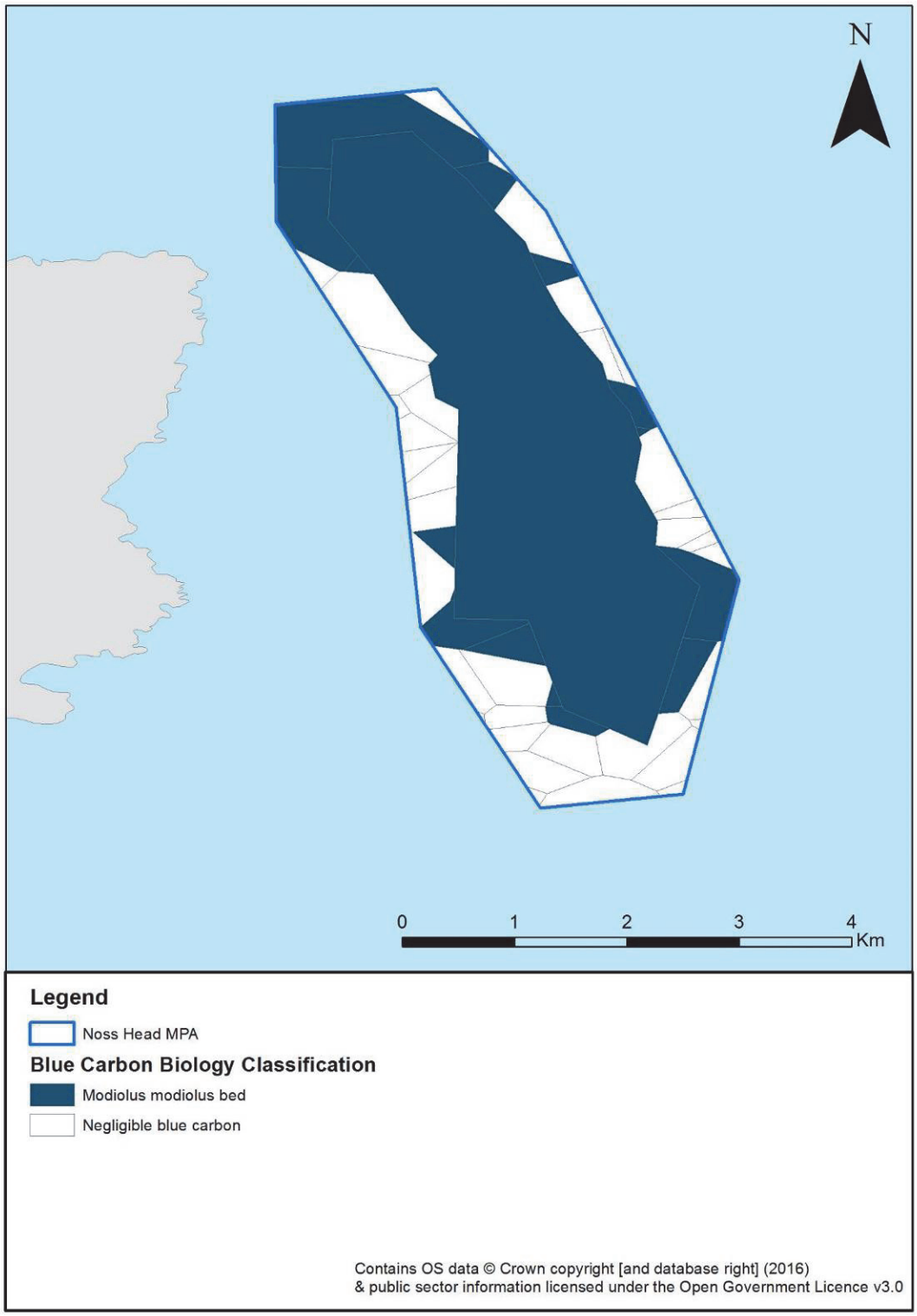
(SS: standing stock, seq: sequestration, prod: production)



Map of Noss Head NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Noss Head	0	0	0	21 514	215

(SS: standing stock, seq: sequestration, prod: production)



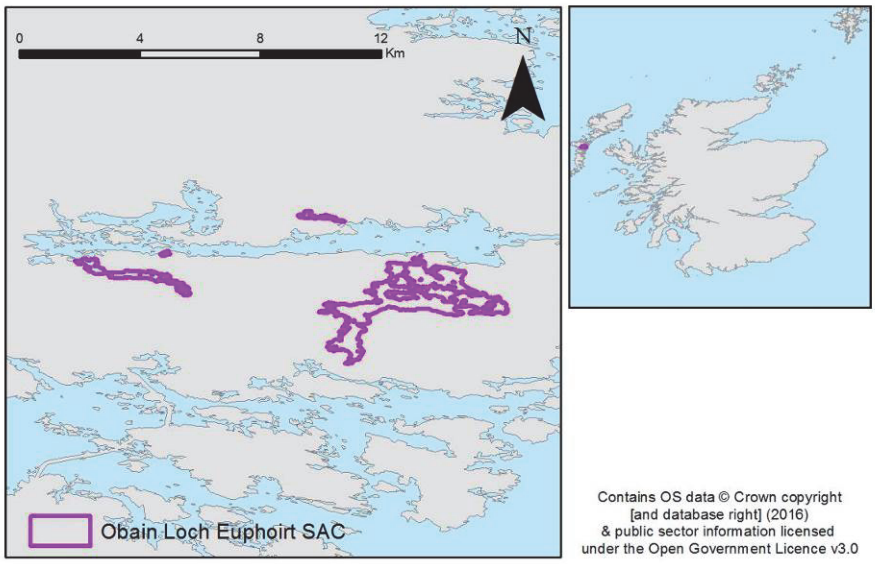
Map of Noss Head NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

Table showing the calculated IC and OC values for each biological habitat: Noss Head

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Modiolus modiolus bed	5.38	71.41	0.0	-	215.14	100.00	0.0	-	21514.23	100.00	0.00	-
Negligible blue carbon	2.15	28.59	0.0	-	0.0	0.00	0.0	-	0	0.00	0.00	-
Total	**7.53**	**100.00**	**0.00**	**-**	**215.14**	**100.00**	**0.00**	**-**	**21514.23**	**100.00**	**0.00**	**-**

29. Obain Loch Euphoirt SAC

Location: 57°32'10.00' N; 007°11'30.000' W – Obain Loch Euphoirt SAC is located on the east coast of North Uist in the Outer Hebrides.



Map of the location of Obain Loch Euphoirt SAC

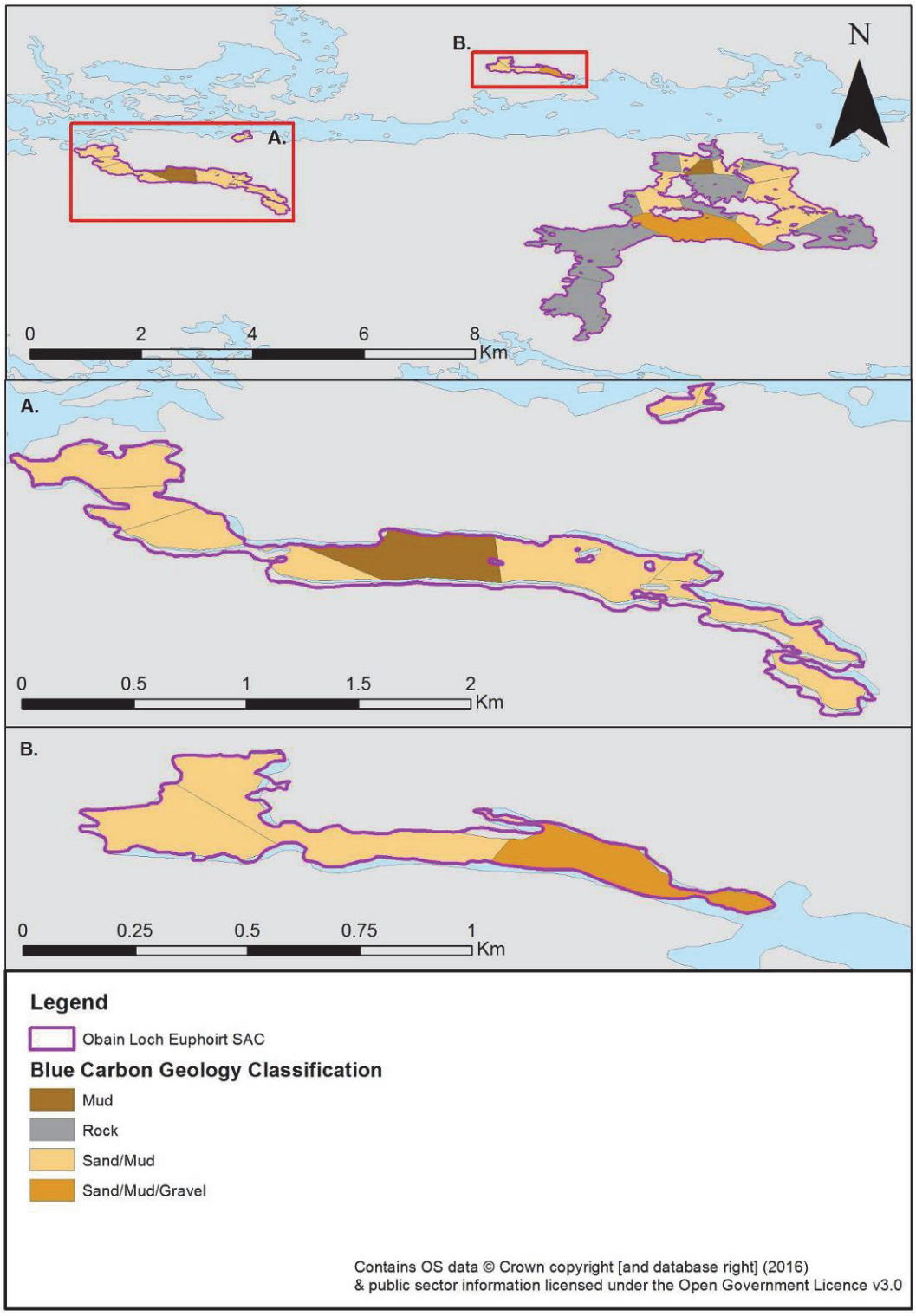
Designation: The SAC is designated for its marine feature; lagoons. Obain Loch Euphoirt SAC is comprised of four individual lagoons, forming one of the most extensive and diverse systems of coastal lagoons in the UK. The only comparable site is Loch nam Madadh, which is also a designated SAC. Collectively the lagoons support a wide range of physical conditions and unique communities.

Obain Loch Euphoirt is also a designated SSSI for its saline lagoons and the presence of foxtail stonewort (non-vascular plants).

Blue carbon designation: Mud, rock, sand/mud and sand/mud/gravel (geology); intertidal algae, kelp beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Obain Loch Euphoirt	2 338	36	3 624	40

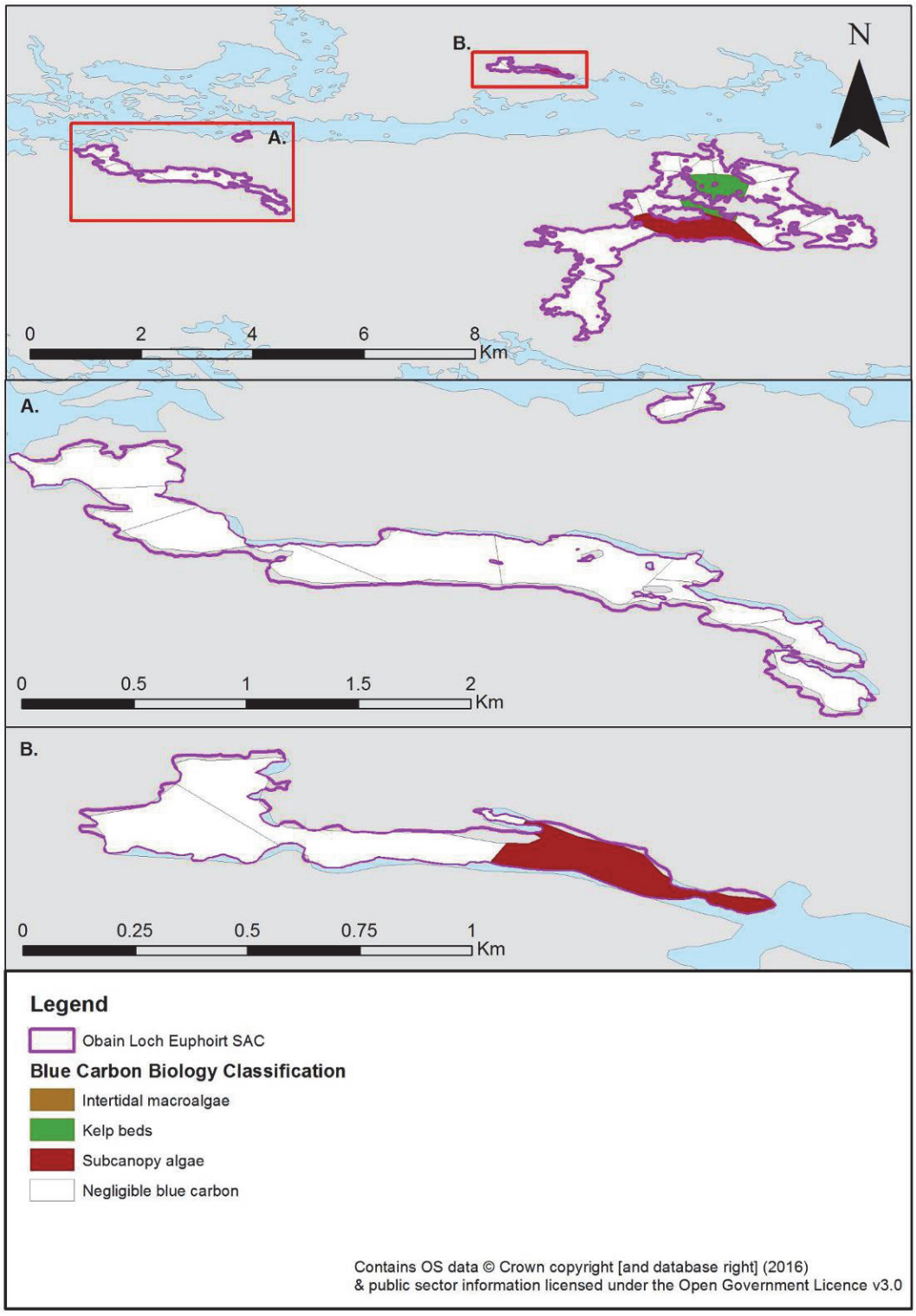
(SS: standing stock, seq: sequestration, prod: production)



Map of Obain Loch Euphoirt SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Obain Loch Euphoirt	65	205	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Obain Loch Euphoirt SAC showing the different biological habitats. The table above reports the calculated IC and OC

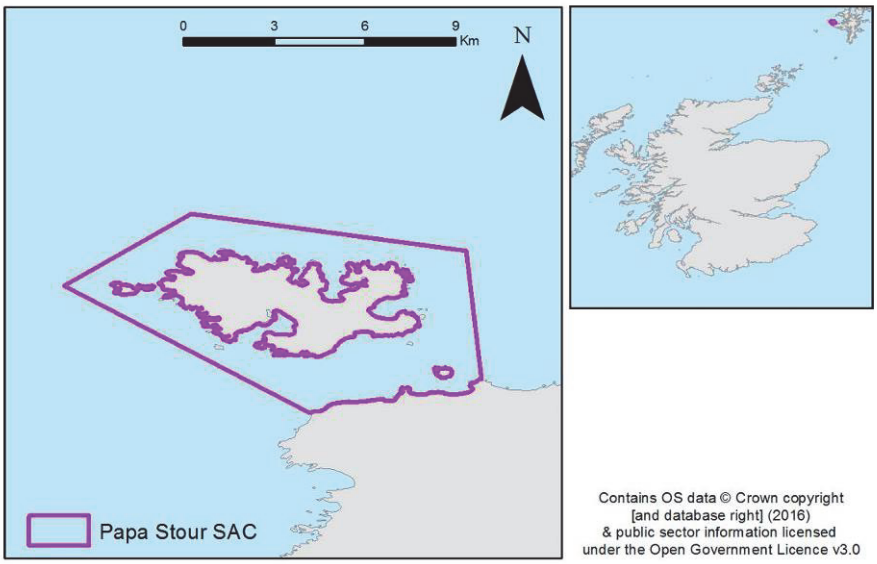
Table showing the calculated IC and OC values for each biological habitat: Obain Loch Euphoirt

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Negligible blue carbon	2.78	79.86	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Intertidal macroalgae	0.00	0.13	0.62	0.30	0.00	-	2.25	3.45	0.00	-	0.00	-
Subcanopy algae	0.41	11.78	8.62	4.20	0.00	-	9.03	13.89	0.00	-	0.00	-
Kelp beds	0.29	8.22	196.18	95.50	0.00	-	53.75	82.66	0.00	-	0.00	-
Total	**3.48**	**100.00**	**205.42**	**100.00**	**0.00**	**-**	**65.03**	**100.00**	**0.00**	**-**	**0.00**	**-**

30. Papa Stour SAC

Location: 60°19'60.00'N; 001°41'30.00'W– Papa Stour is located on the west coast of mainland Shetland

Area: 20.73 km^2



Map of the location of Papa Stour SAC

Designation: The SAC is designated for its marine features; reefs and sea caves. The site has some of the most exposed reef communities in the UK, representing a variety of exposures and shore types in a relatively small area, including northerly reef communities, which are limited to the north of the UK.

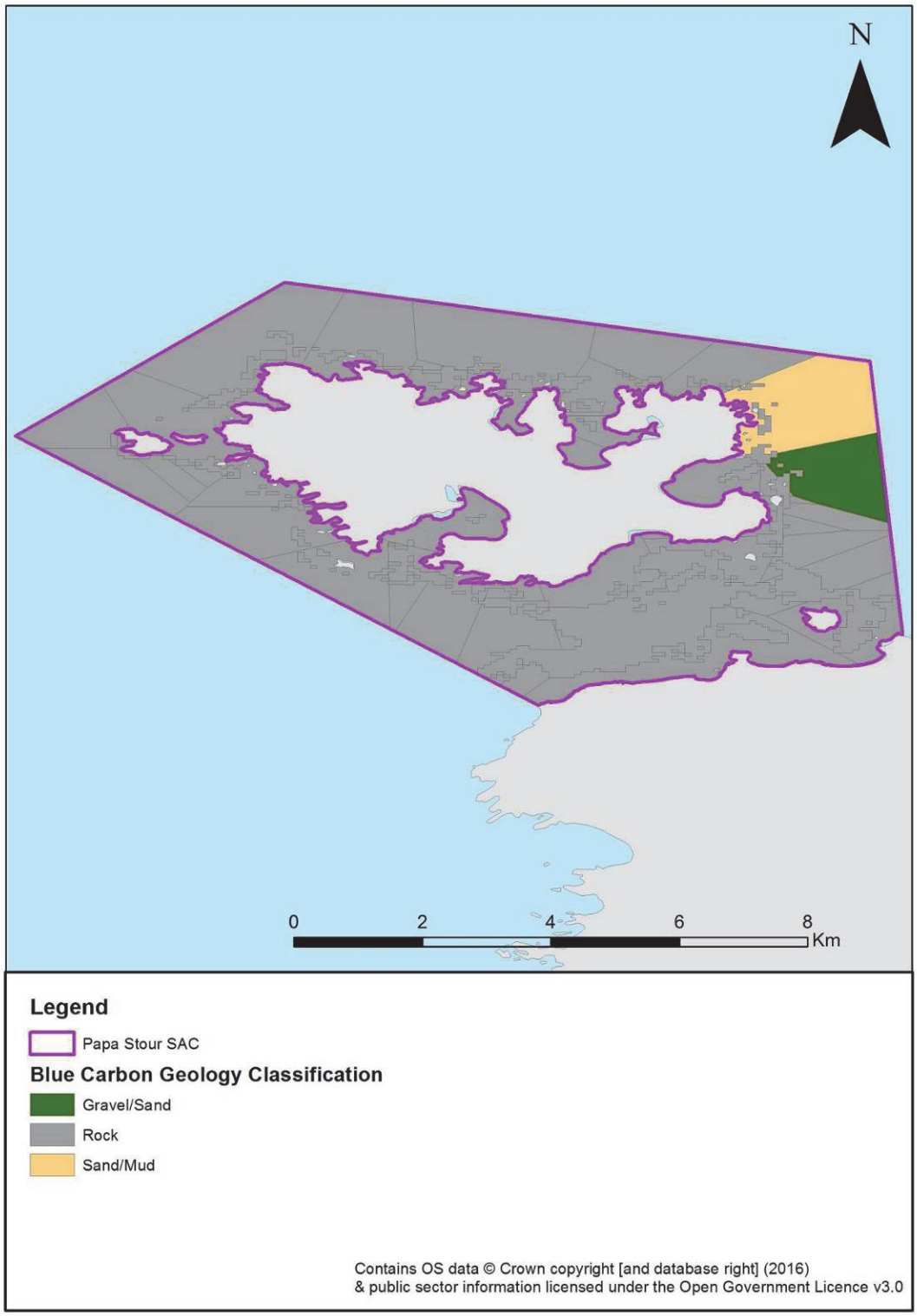
Papa Stour also has numerous and extensive caves, both submerged and partially submerged, with varying sea cave communities depending on a range of physical factors i.e. structure, size and exposure.

Papa Stour is also a designated SPA, for its birds (Arctic tern and ringed plover) and a SSSI for birds, maritime cliff, coastal geomorphology of Scotland, rocky shore and Silurian-Devonian Chordata.

Blue carbon designation: Gravel/sand, rock and sand/mud (geology); kelp beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Papa Stour	2 168	28	8 642	73

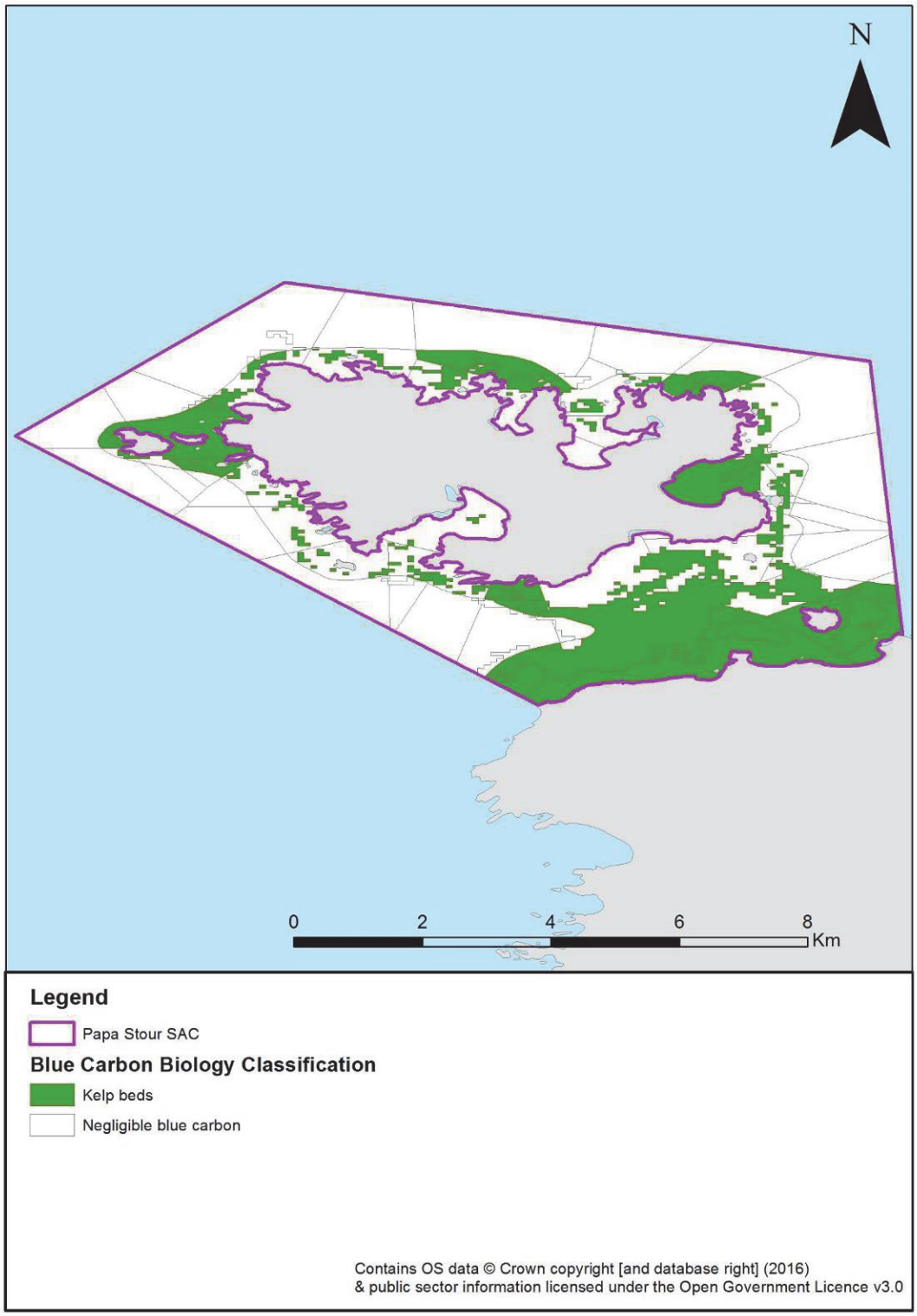
(SS: standing stock, seq: sequestration, prod: production)



Map of Papa Stour SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Papa Stour	1 183	4 318	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Papa Stour SAC showing the different biological habitats. The table above reports the calculated IC and OC

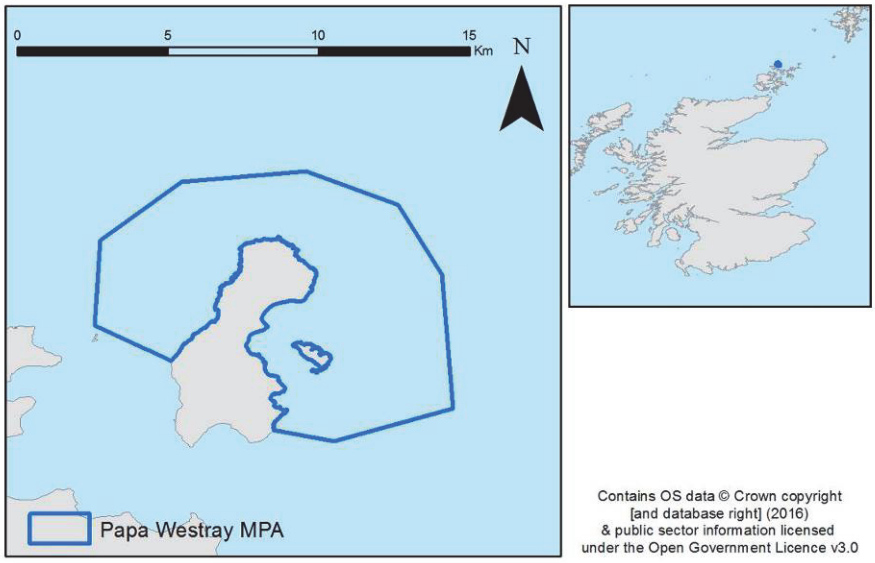
Table showing the calculated IC and OC values for each biological habitat: Papa Stour

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	6.30	30.84	4317.59	100.00	0.00	-	1182.97	100.00	0.00	-	0.00	-
Negligible blue carbon	14.13	69.15	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Total	**20.43**	**100.00**	**4317.59**	**100.00**	**0.00**	**-**	**1182.97**	**100.00**	**0.00**	**-**	**0.00**	**-**

31. Papa Westray NC MPA

Location: 59°22.121'N; 002°52.509'W – Papa Westray NC MPA in Orkney encompasses the shallow coastal waters around the islands of Papa Westray and the Holm of Papa Westray in the north, and borders two existing Sites of Special Scientific Interest (SSSI) on the Holm of Papa Westray and North Hill.

Area: 33 km^2



Map of the location of Papa Westray NC MPA

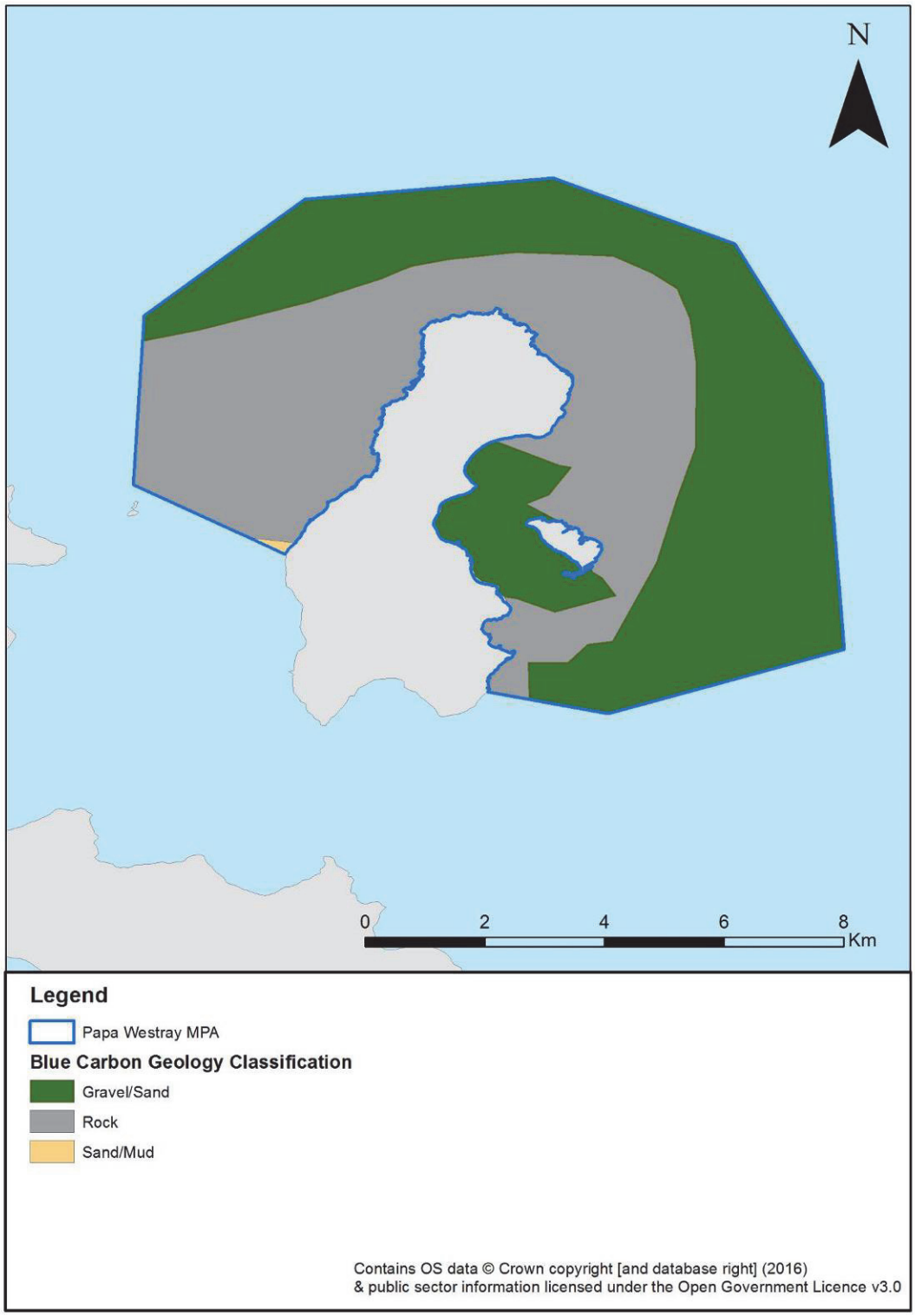
Designation: The MPA is set up to protect the foraging area for a resident breeding population of black guillemots in the adjacent SSSI's. In addition the MPA is designated for the marine geomorphology, namely sand wave fields.

The MPA also lies within the Orkney carbonate production area. This is an internationally important example of a shelf carbonate system. The sand here is rich in calcium carbonate that comes from the eroded shells and skeletons of plants and small animals that once lived in or on the sea bed, such as maerl and bivalve molluscs.

Blue carbon designation: Gravel/sand, sand/mud and rock (geology) (geology); kelp beds and *Mytilus edulis* beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Papa Westray	9 578	72	109 659	791

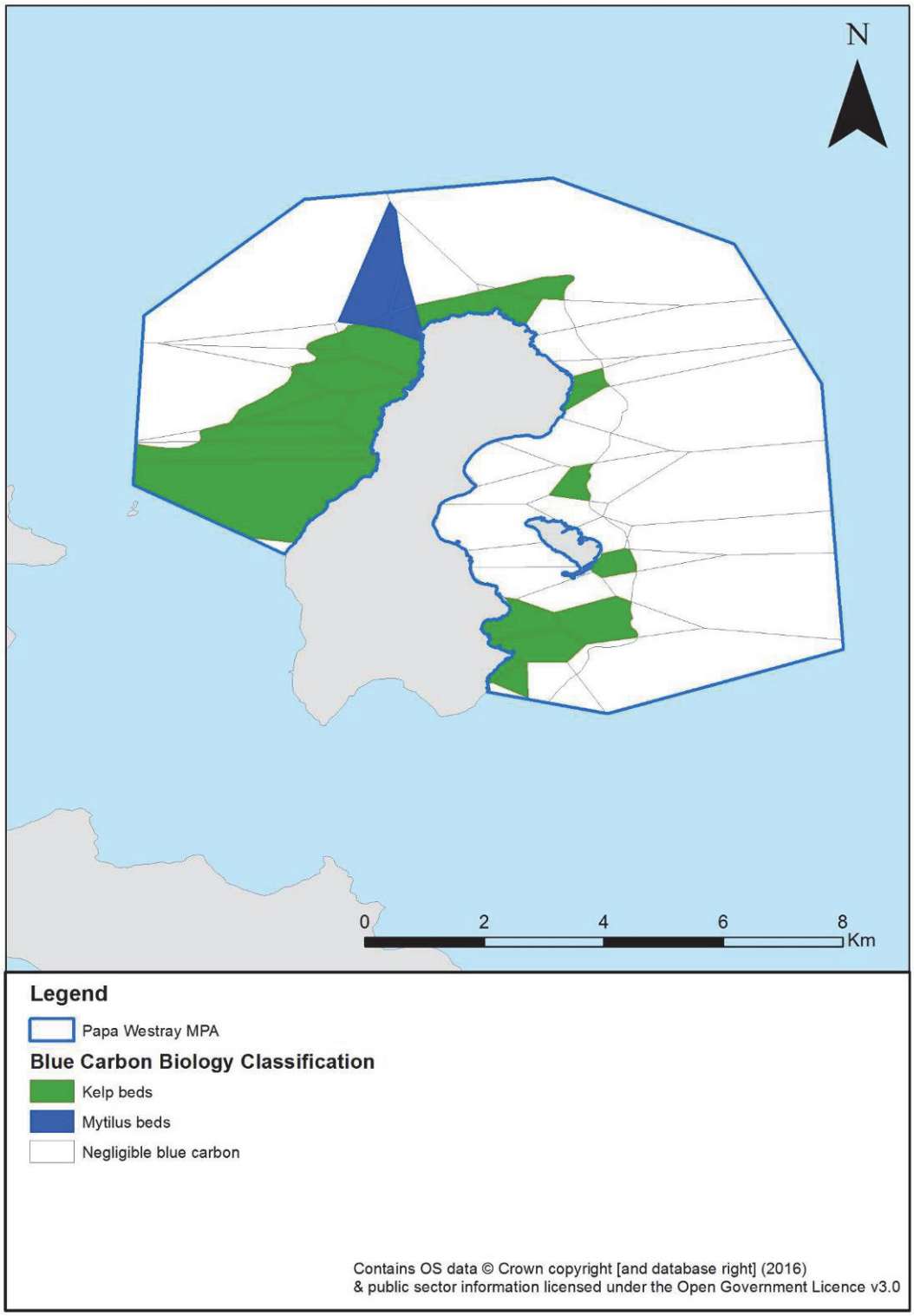
(SS: standing stock, seq: sequestration, prod: production)



Map of Papa Westray NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Papa Westray	1 234	4 504	0	13	33

(SS: standing stock, seq: sequestration, prod: production)



Map of Papa Westray NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

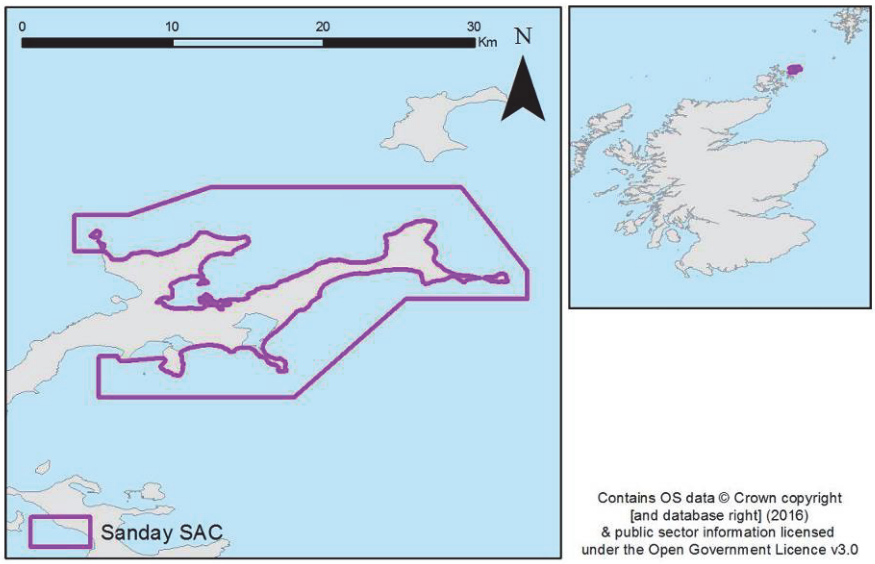
Table showing the calculated IC and OC values for each biological habitat: Papa Westray

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Kelp beds	6.57	19.82	4503.78	100.00	0.00	0.00	1233.98	100.00	0.00	0.00	0.00	-
Mytilus beds	0.82	2.48	0.00	0.00	32.92	100.00	0.00	0.00	12.67	100.00	0.00	-
Negligible blue carbon	25.77	77.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**33.17**	**100.00**	**4503.78**	**100.00**	**32.92**	**100.00**	**1233.98**	**100.00**	**12.67**	**100.00**	**0.00**	**-**

32. Sanday SAC

Location: 59°16'60.00' N; 002°30'0.00'W – Sanday is a large, low lying island to the north-east of the Orkney Islands.

Area: 110 km^2



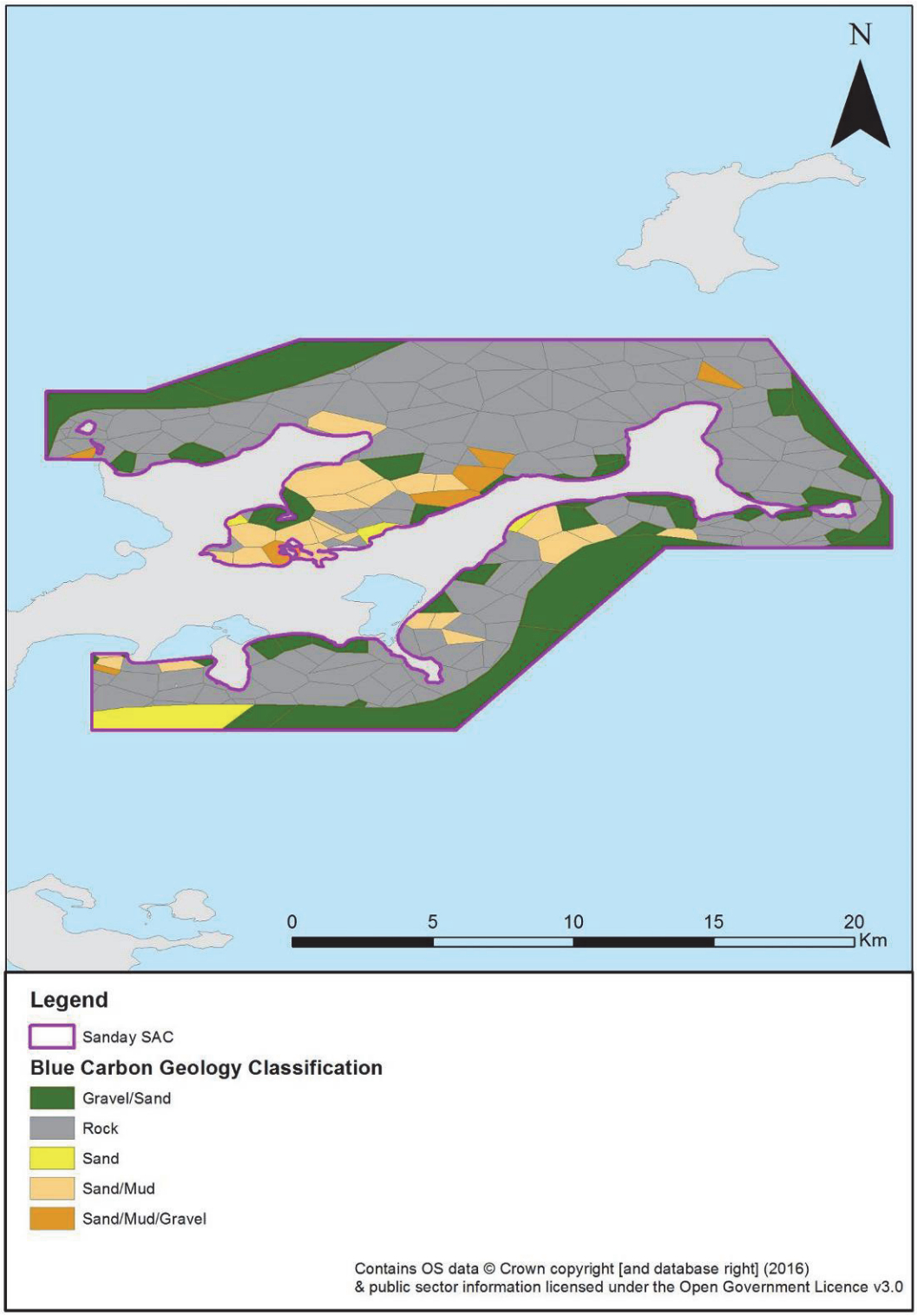
Map of the location of Sanday SAC

Designation: The SAC is designated for its marine feature; harbour seal, intertidal mudflats and sandflats, reefs and subtidal sandbanks. The primary reasons for selection of this site include reefs and harbour seals. The island supports the largest group of harbour seal at any discrete site in Scotland, representing 4% of the total UK population. In addition Sanday has extensive subtidal bedrock reefs that surround the island.

Blue carbon designation: Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sanday	31 253	339	216 462	1 654

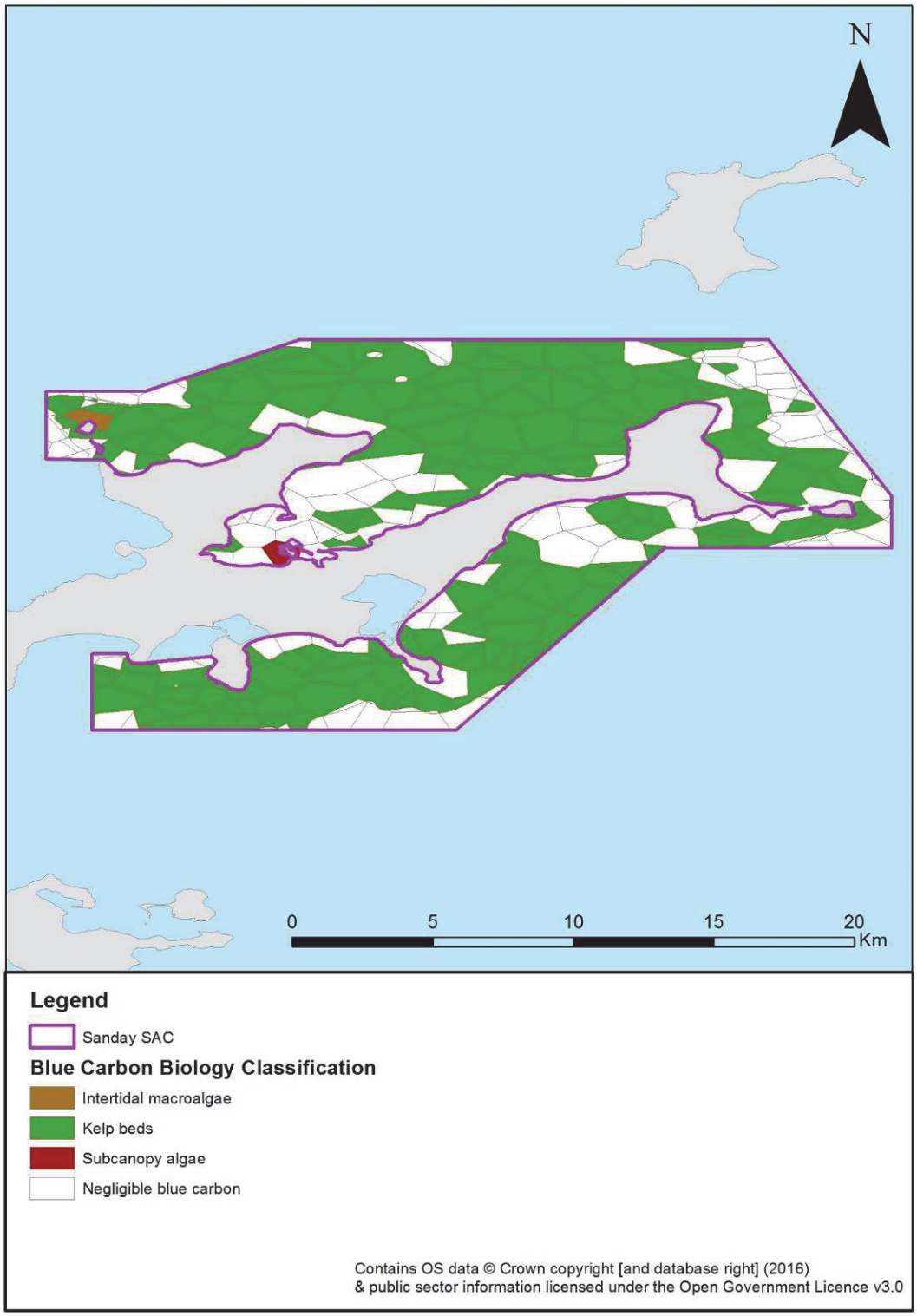
(SS: standing stock, seq: sequestration, prod: production)



Map of Sanday SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sanday	13 843	49 894	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of Sanday SAC showing the different biological habitats. The table above reports the calculated IC and OC

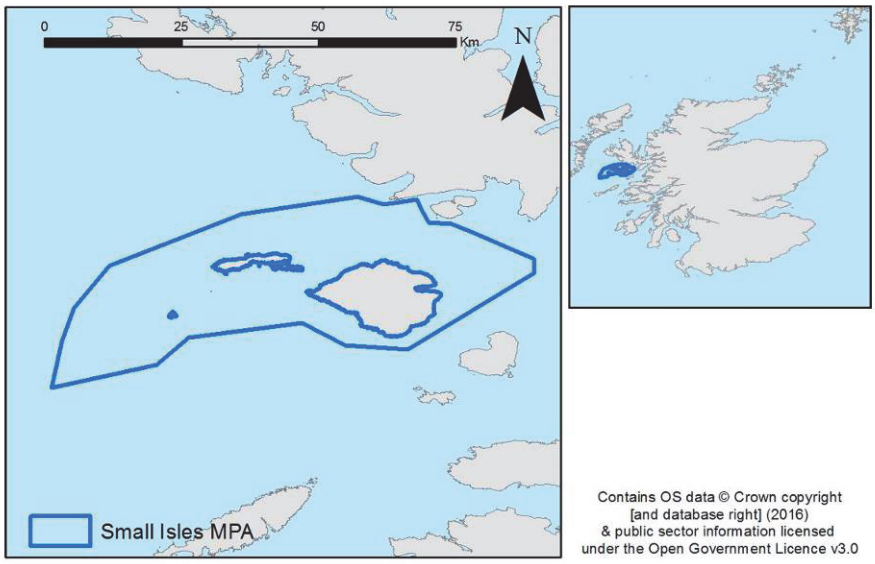
Table showing the calculated IC and OC values for each biological habitat: Sanday

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.37	0.34	50.02	0.10	0.00	-	181.19	1.31	0.00	-	0.00	-
Kelp beds	72.76	66.84	49837.44	99.89	0.00	-	13654.84	98.64	0.00	-	0.00	-
Negligible blue carbon	35.42	32.54	0.00	0.00	0.00	-	0.00	0.00	0.00	-	0.00	-
Subcanopy algae	0.32	0.29	6.62	0.01	0.00	-	6.93	0.05	0.00	-	0.00	-
Total	**108.86**	**100.00**	**49894.08**	**100.00**	**0.00**	**-**	**13842.96**	**100.00**	**0.00**	**-**	**0.00**	**-**

33. Small Isles NC MPA

Location: 57°01.435'N; 006°30.456'W – one of the largest inshore MPAs, the Small Isles MPA off the west coast of Scotland envelopes the Sound of Canna by the isles of Rum and Canna. The NC MPA overlaps the Rum, and Canna and Sanday SPAs.

Area: 110 km^2



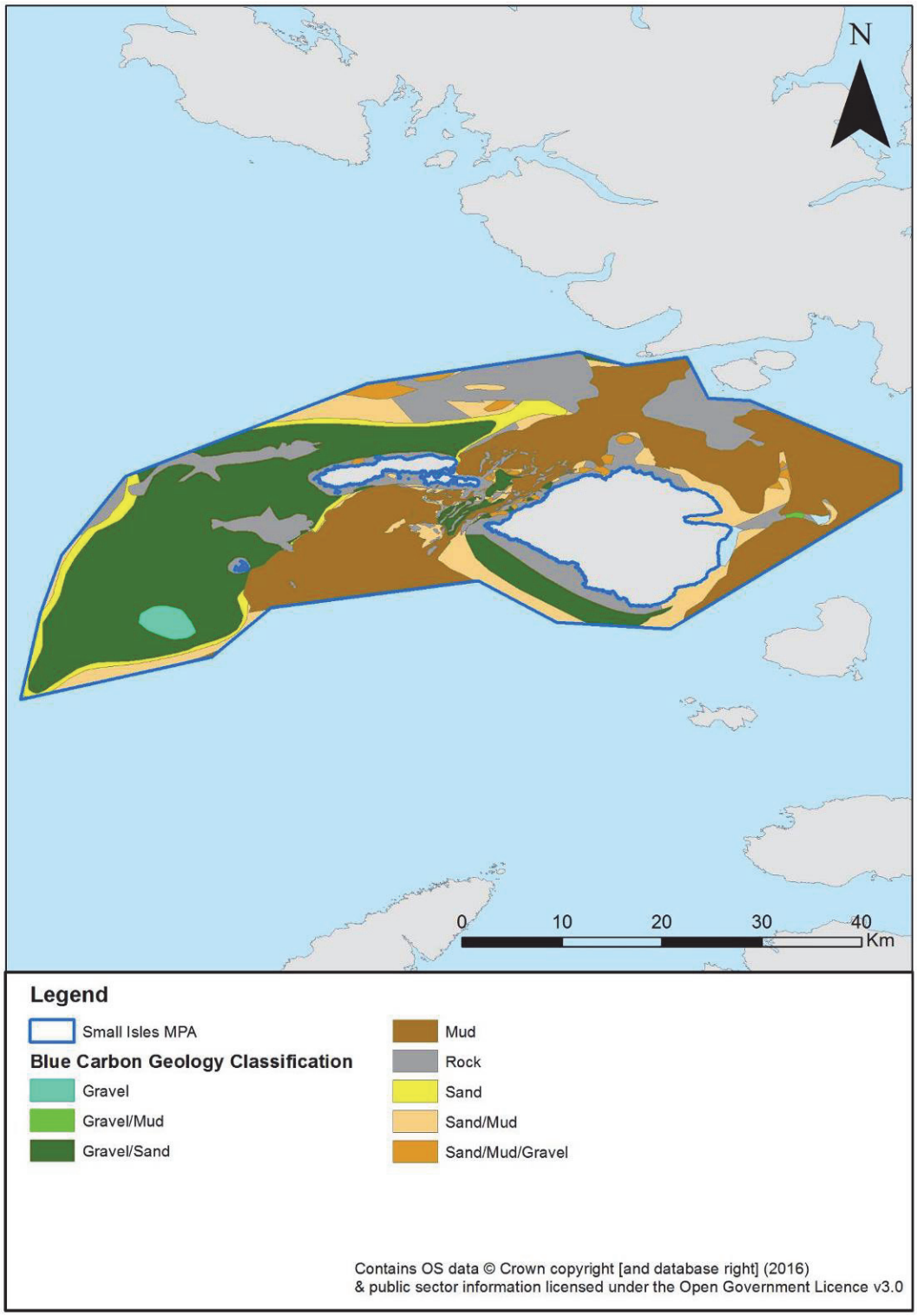
Map of the location of Small Isles NC MPA

Designation: The NC MPA covers a diverse and complex seabed habitat, and protects the only known UK aggregation of fan mussels (discovered in 2009), as well as the deepest known horse mussel bed in Scotland. The vertical slopes of a deep valley in the seabed supports northern sea fans, dead man's fingers, sponges and white cluster anemones. The base of the underwater cliffs is covered in mixed muddy sediments, providing a habitat for Norway lobsters and phosphorescent seapens.

Blue carbon designation: Gravel, gravel/mud, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, maerl beds, *Modiolus modiolus* beds, *Mytilus edulis* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Small Isles	769 965	14 034	2 428 121	19 479

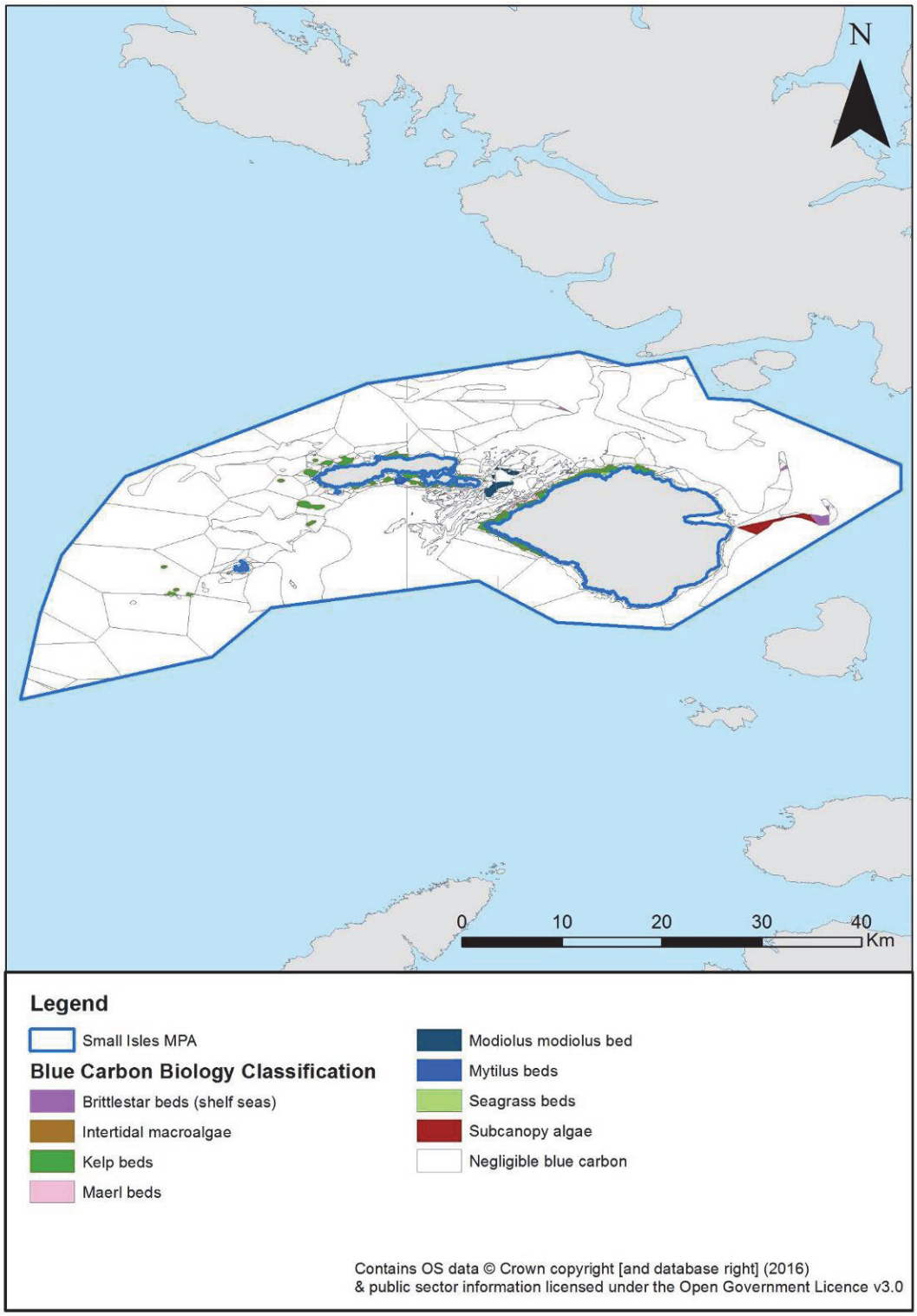
(SS: standing stock, seq: sequestration, prod: production)



Map of Small Isles NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Small Isles	2 282	8 246	15	36 487	200

(SS: standing stock, seq: sequestration, prod: production)



Map of Small Isles NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

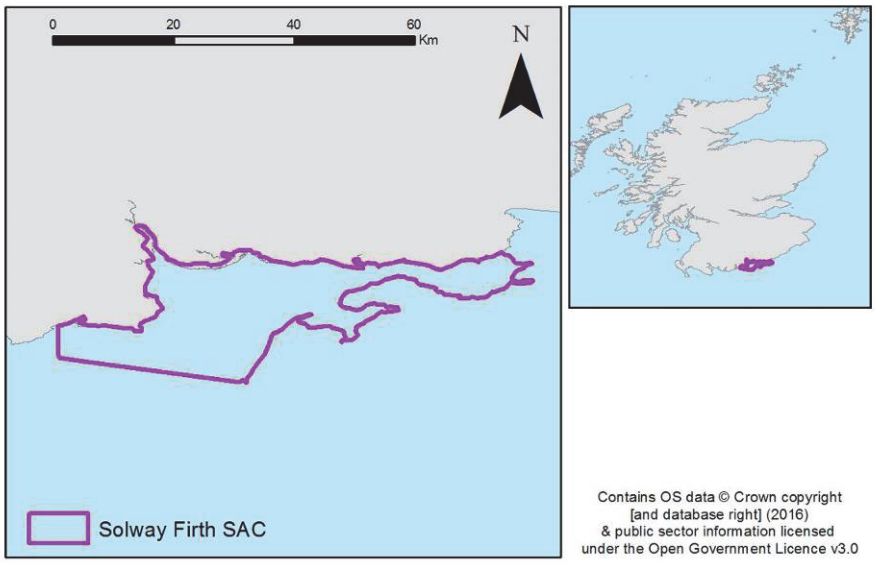
Table showing the calculated IC and OC values for each biological habitat: Small Isles

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	1.03	0.13	0.00	0.00	84.23	42.11	0.00	0.00	0.00	0.00	0.00	0.00
Intertidal macroalgae	0.00	0.00	0.64	0.01	0.00	0.00	2.32	0.10	0.00	0.00	0.00	0.00
Kelp beds	11.90	1.48	8154.56	98.89	0.00	0.00	2234.25	97.89	0.00	0.00	0.00	0.00
Maerl beds	0.48	0.06	0.00	0.00	35.68	17.84	0.00	0.00	30089.24	82.47	0.00	0.00
Modiolus modiolus bed	1.60	0.20	0.00	0.00	63.91	31.95	0.00	0.00	6391.46	17.52	0.00	0.00
Mytilus beds	0.40	0.05	0.00	0.00	16.20	8.10	0.00	0.00	6.24	0.02	0.00	0.00
Negligible blue carbon	785.12	97.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.18	0.02	46.69	0.57	0.00	0.00	0.00	0.00	0.00	0.00	14.85	100.00
Subcanopy algae	2.09	0.26	43.79	0.53	0.00	0.00	45.87	2.01	0.00	0.00	0.00	0.00
Total	**802.81**	**100.00**	**8245.68**	**100.00**	**200.02**	**100.00**	**2282.44**	**100.00**	**36486.94**	**100.00**	**14.85**	**100.00**

34. Solway Firth SAC

Location: 54°58'15.00'N; 003°20'12.00'W – The Solway Firth is a large body of water proximal to the marine border between England and Scotland, comprising part of the Irish Sea.

Area: 437 km^2



Map of the location of Solway Firth SAC

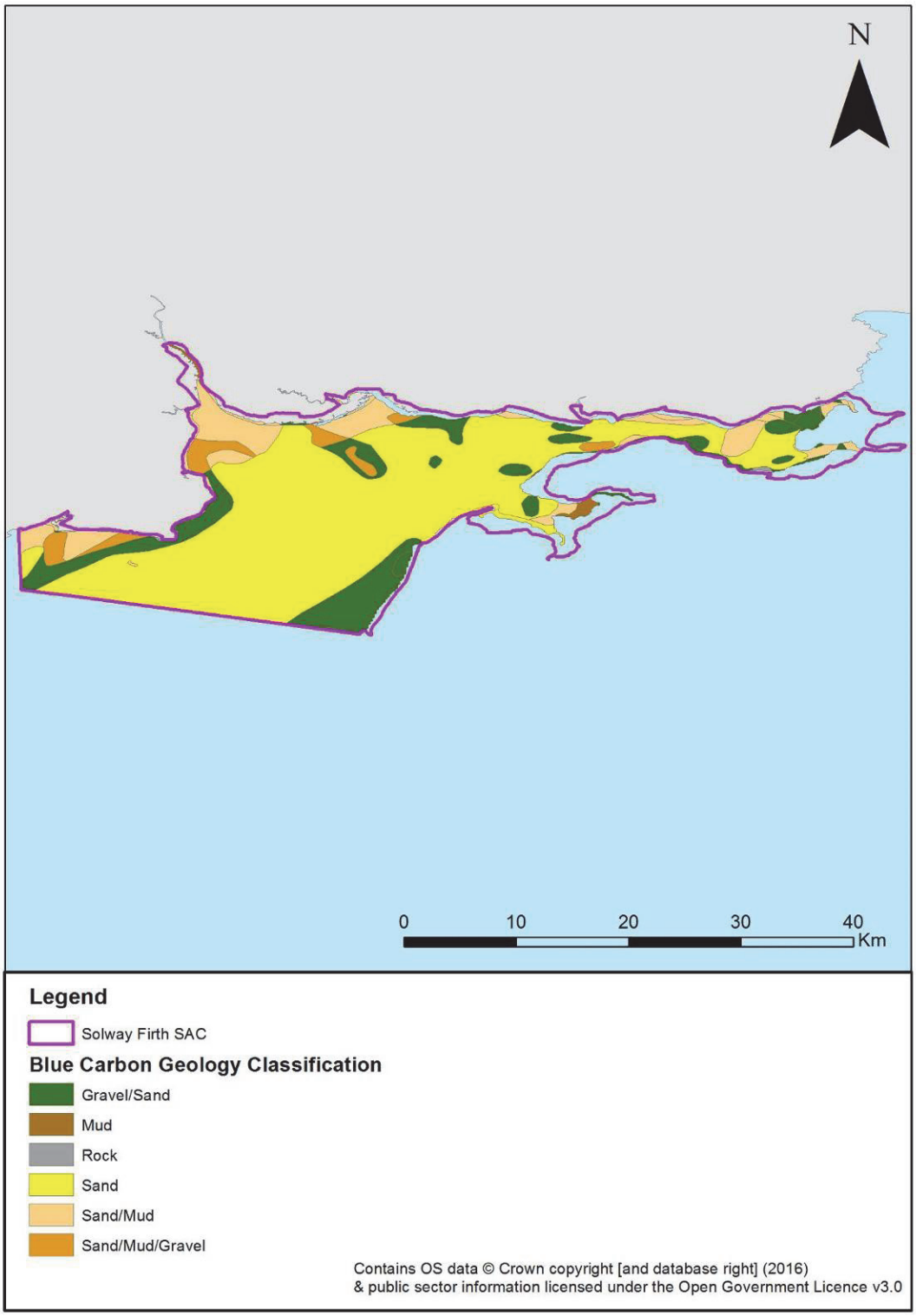
Designation: The Solway Firth area has been designated an SAC for a range of features including coastal, marine, and fish (Sea and River Lamprey). Marine features include estuaries, intertidal mudflats and sandflats, reefs and subtidal sandbanks. Coastal features include Atlantic salt meadows, coastal shingle vegetation outside the reach of waves, dune grassland, glasswort and other annuals colonising mud and sand and subtidal sandbanks.

In addition the Solway Firth carries multiple other national and international conservation designations including, SPA, SSSI and Ramsar wetlands, some of which span the national boundary.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae and *Modiolus modiolus* bed (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Solway Firth	244 659	2 461	2 003 090	14 947

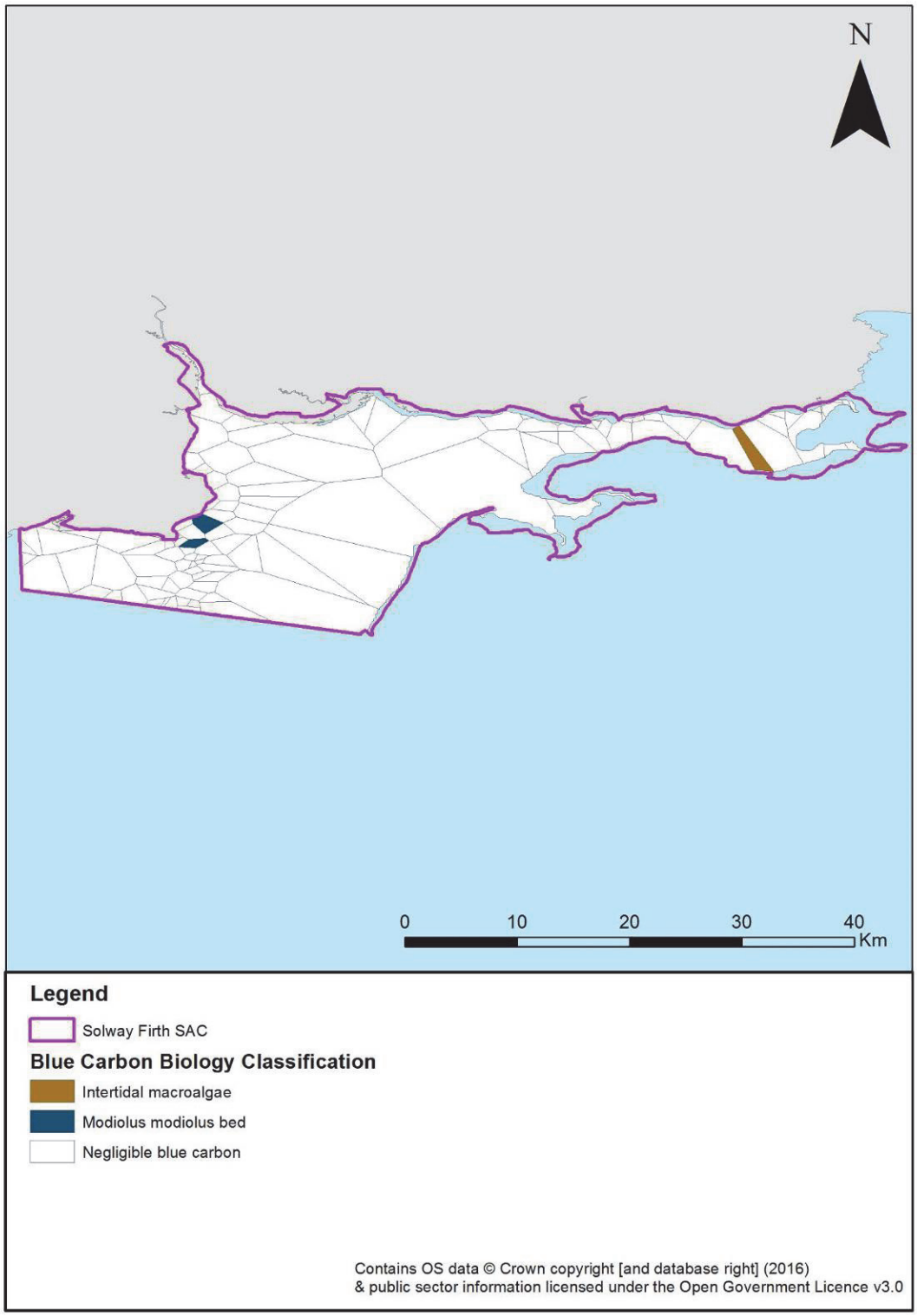
(SS: standing stock, seq: sequestration, prod: production)



Map of Solway Firth SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Solway Firth	1 350	373	0	32	97

(SS: standing stock, seq: sequestration, prod: production)



Map of Solway Firth SAC showing the different biological habitats. The table above reports the calculated IC and OC

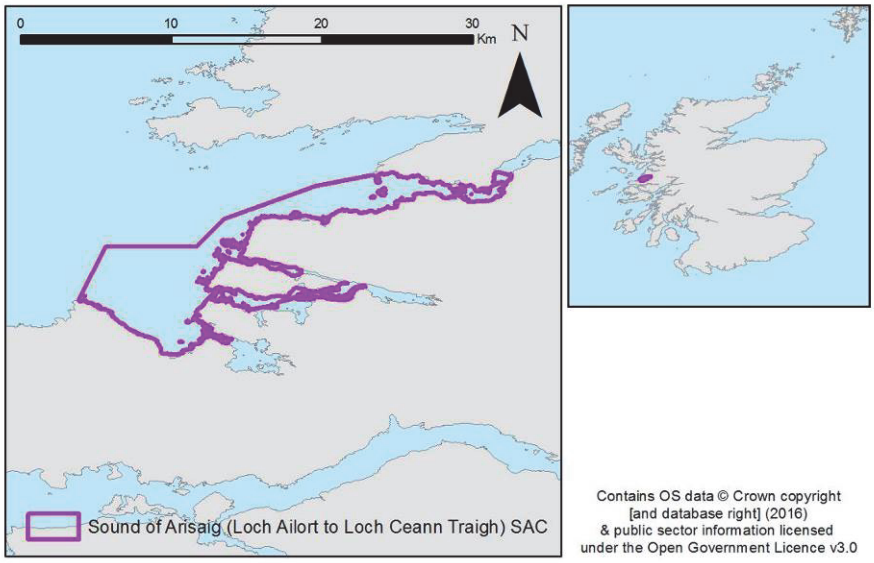
Table showing the calculated IC and OC values for each biological habitat: Solway Firth

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	2.76	0.74	372.57	100.00	0.00	0.00	1349.60	100.00	32.48	100.00	0.00	-
Modiolus modiolus bed	2.43	0.65	0.00	0.00	97.29	100.00	0.00	0.00	0.00	0.00	0.00	-
Negligible blue carbon	368.76	98.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Total	**373.95**	**100.00**	**372.57**	**100.00**	**97.29**	**100.00**	**1349.60**	**100.00**	**32.48**	**100.00**	**0.00**	**-**

35. Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC

Location: 56°48'30.00' N; 005°52'15.00'W – The Sound of Arisaig SAC, is situated off the west coast of Scotland, between the Ardnish and Ardnamurchan peninsulas. The SAC incorporates the outer parts of Loch Ailort, Loch Moidart and most of Loch Ceann Traigh, along with the adjoining open fringe of coastal waters in West Lochaber.

Area: 45.44 km^2



Map of the location of Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC

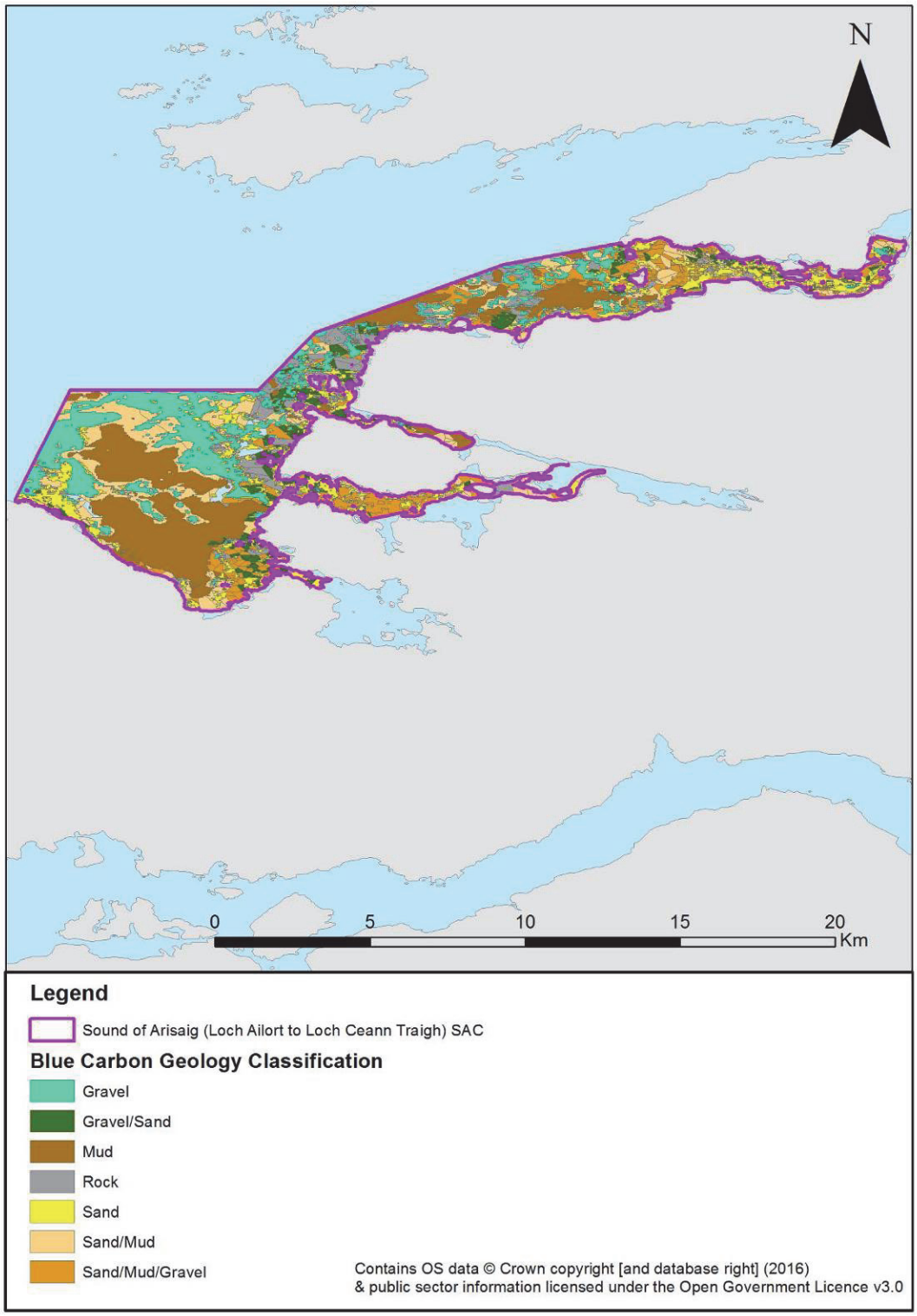
Designation: The Solway Firth area has been designated an SAC for a range of features including coastal, marine, and fish (Sea and River Lamprey). Marine features include estuaries, intertidal mudflats and sandflats, reefs and subtidal sandbanks. Coastal features include Atlantic salt meadows, coastal shingle vegetation outside the reach of waves, dune grassland, glasswort and other annuals colonising mud and sand and subtidal sandbanks.

In addition the Solway Firth carries multiple other national and international conservation designations including, SPA, SSSI and Ramsar wetlands, some of which span the national boundary.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae and *Modiolus modiolus* bed (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	47 656	1 194	95 467	1 034

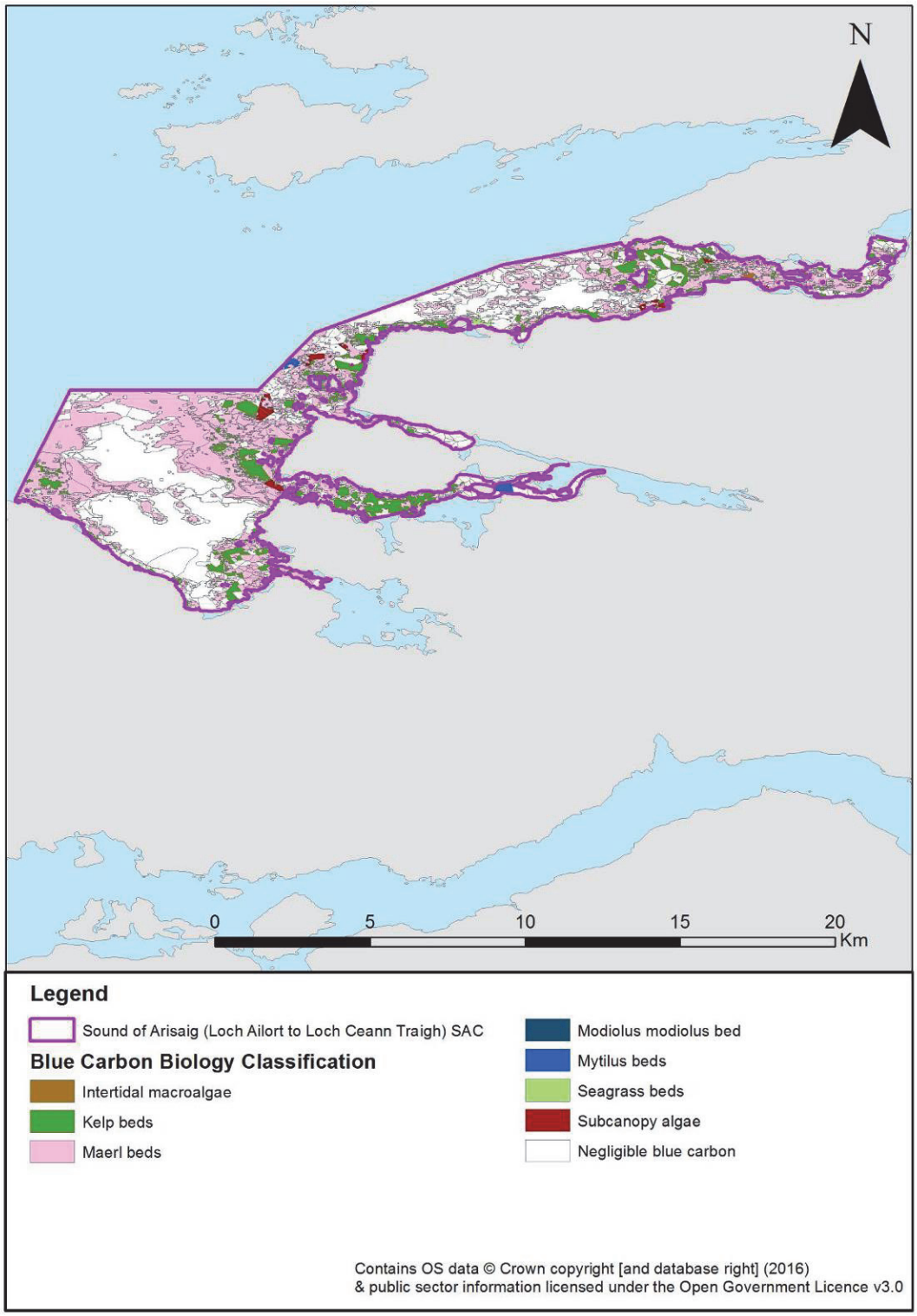
(SS: standing stock, seq: sequestration, prod: production)



Map of Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	1 004	3 533	11	1 082 865	1 290

(SS: standing stock, seq: sequestration, prod: production)



Map of Sound of Arisaig (Loch Ailort to Loch Ceann Traigh) SAC showing the different biological habitats. The table above reports the calculated IC and OC

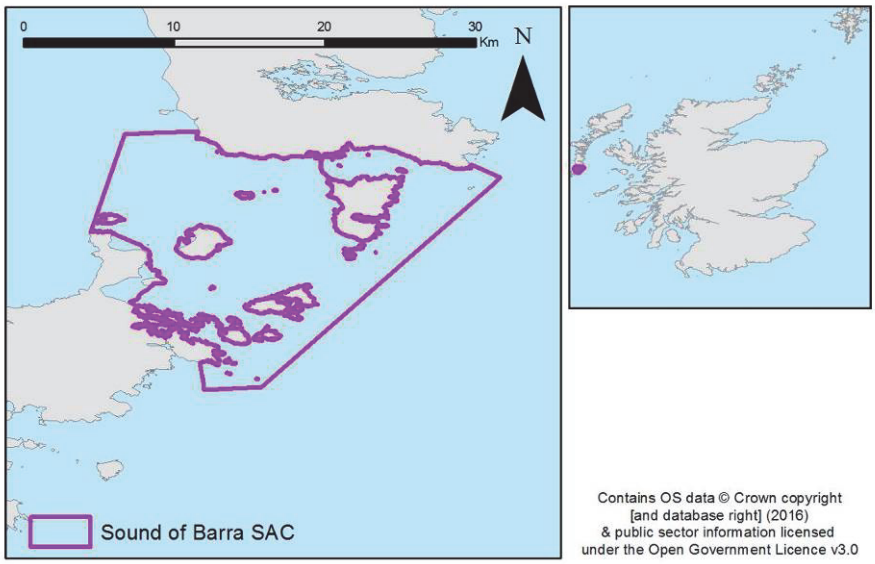
Table showing the calculated IC and OC values for each biological habitat: Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.08	0.19	11.33	0.32	0.00	0.00	41.03	4.09	0.00	0.00	0.00	0.00
Kelp beds	5.08	11.27	3477.50	98.42	0.00	0.00	952.79	94.89	0.00	0.00	0.00	0.00
Maerl beds	17.35	38.51	0.00	0.00	1284.11	99.52	0.00	0.00	1082859.66	100.00	0.00	0.00
Modiolus modiolus bed	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	3.24	0.00	0.00	0.00
Mytilus beds	0.15	0.34	0.00	0.00	6.15	0.48	0.00	0.00	2.37	0.00	0.00	0.00
Negligible blue carbon	21.79	48.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.13	0.29	34.60	0.98	0.00	0.00	0.00	0.00	0.00	0.00	11.00	100.00
Subcanopy algae	0.47	1.04	9.85	0.28	0.00	0.00	10.32	1.03	0.00	0.00	0.00	0.00
Total	**45.06**	**100.00**	**3533.27**	**100.00**	**1290.30**	**100.00**	**1004.14**	**100.00**	**1082865.27**	**100.00**	**11.00**	**100.00**

36. Sound of Barra SAC

Location: 57°3'14.04'N; 007°21'6.12'W – The Sound of Barra SAC is situated in the Outer Hebrides to the south of the Island of South Uist.

Area: 125 km^2



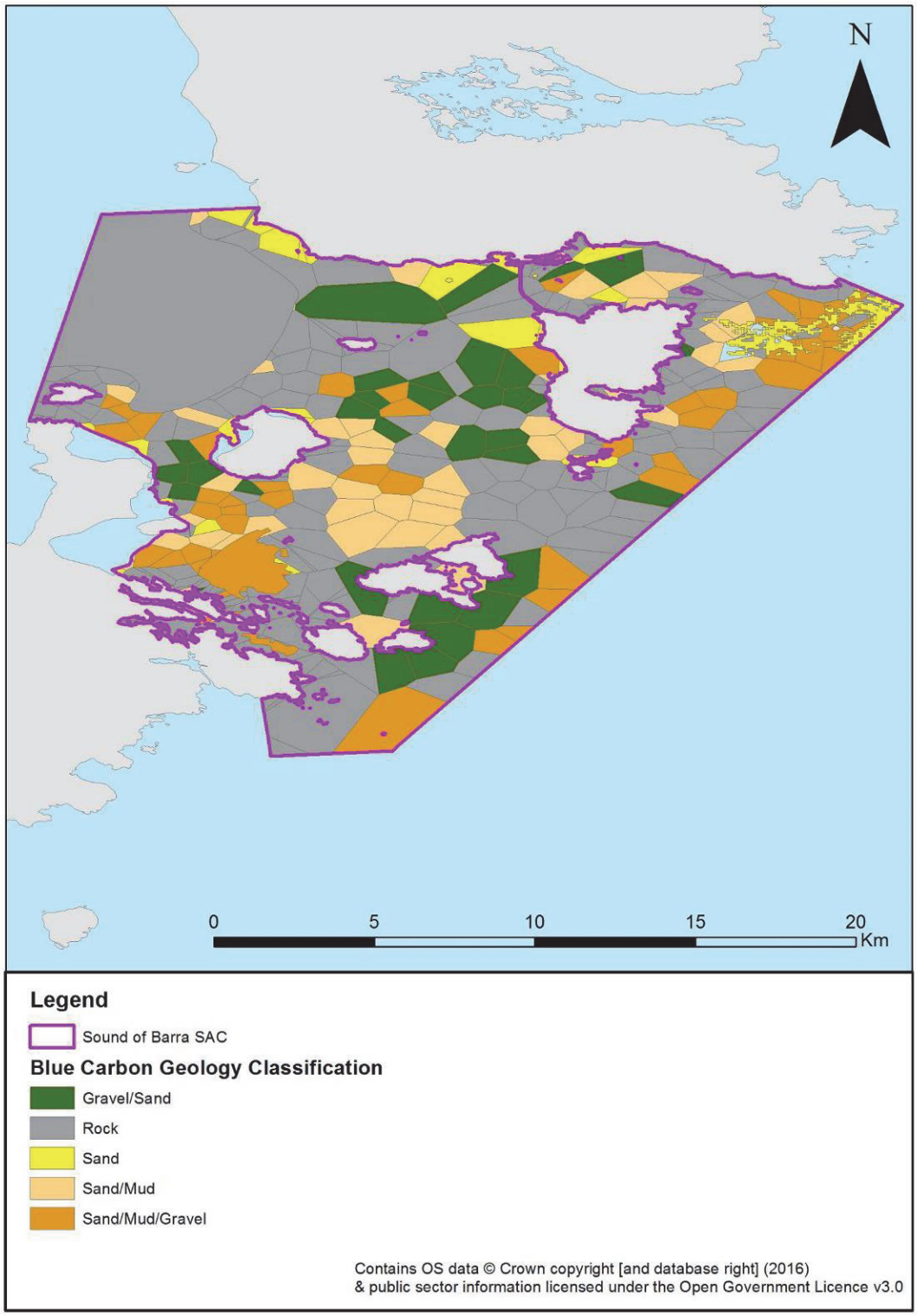
Map of the location of Sounds of Barra SAC

Designation: The SAC is designated for its marine features namely: Reefs, subtidal sandbanks and harbour seal. The Sound of Barra comprises a mixture of islands, extensive rocky reefs, sandbanks and shallow channels in a broad stretch between the southern end of South Uist and the north eastern shore of the island of Barra in the Outer Hebrides, off the west coast of Scotland.

Blue carbon designation: Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, maerl beds, *Mytilus edulis* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sounds of Barra	51 929	676	206 190	1 743

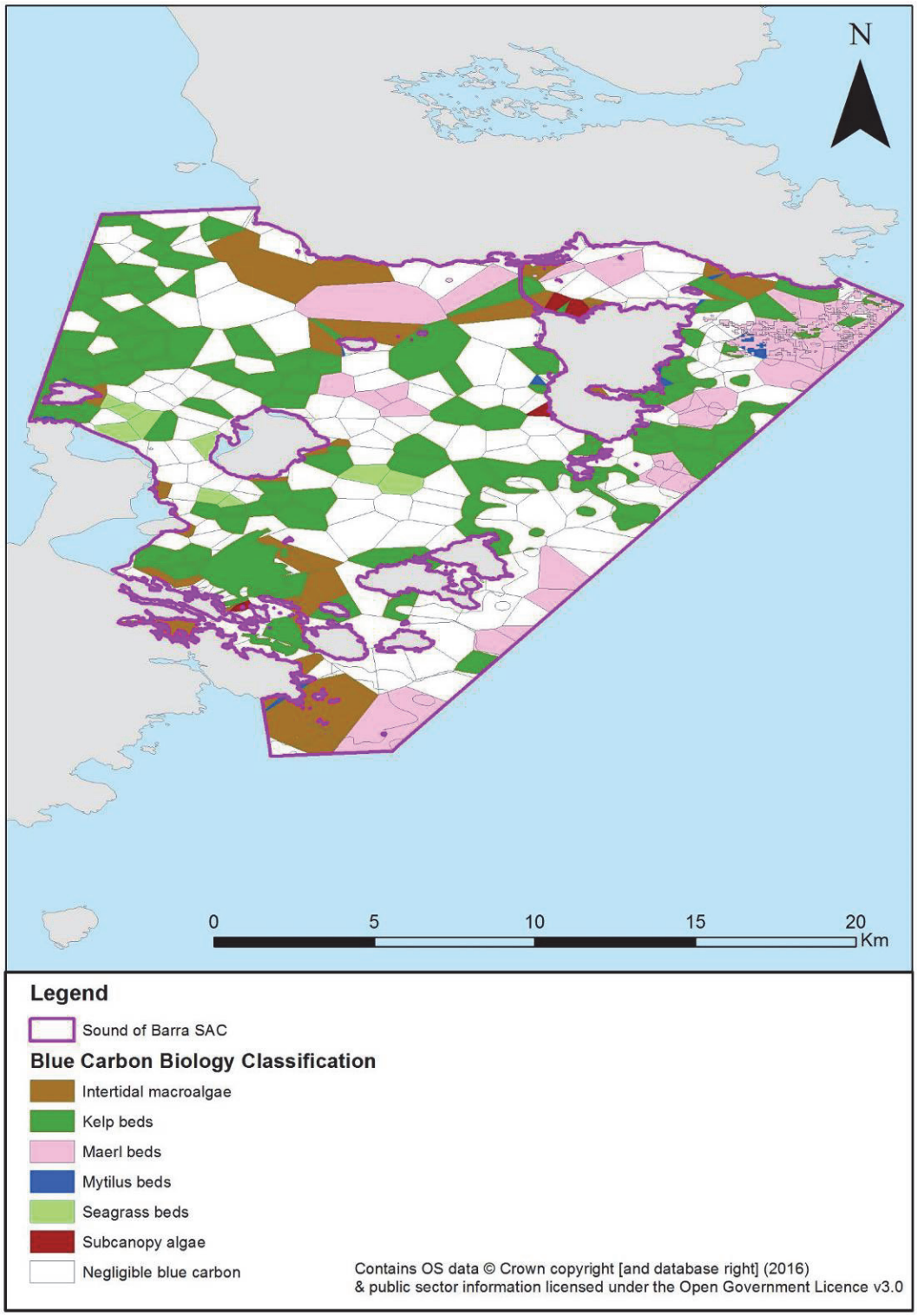
(SS: standing stock, seq: sequestration, prod: production)



Map of Sounds of Barra SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sounds of Barra	12 680	26 648	191	980 519	1 178

(SS: standing stock, seq: sequestration, prod: production)



Map of Sounds of Barra SAC showing the different biological habitats. The table above reports the calculated IC and OC

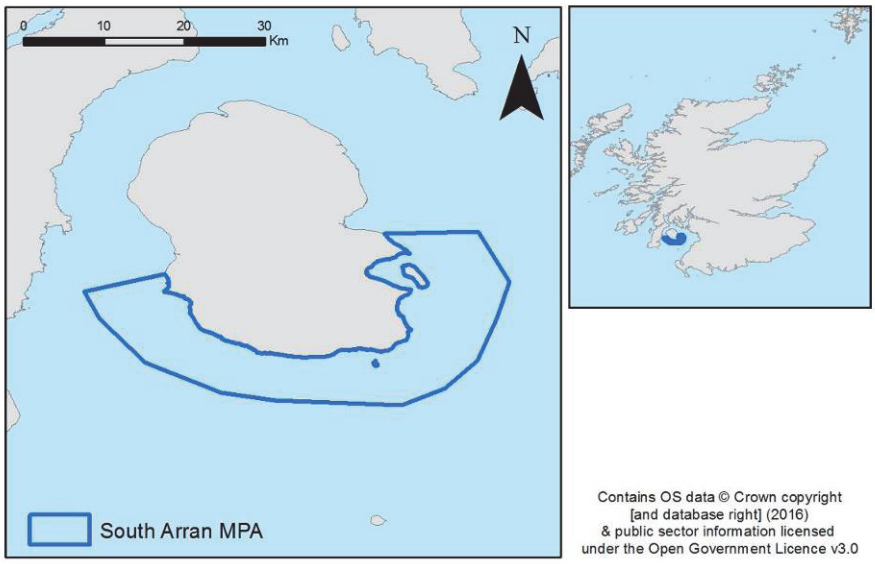
Table showing the calculated IC and OC values for each biological habitat: Sound of Barra

Biology habitats	Sum of Area Km^2	% Total area	Production OC ($t\ yr^{-1}$)	% Total production OC	Production IC ($t\ yr^{-1}$)	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC ($t\ yr^{-1}$)	% Total Sequestration OC
Intertidal macroalgae	12.24	9.88	1652.88	6.20	0.00	0.00	5987.38	47.22	0.00	0.00	0.00	0.00
Kelp beds	35.59	28.72	24381.93	91.50	0.00	0.00	6680.35	52.68	0.00	0.00	0.00	0.00
Maerl beds	15.71	12.68	0.00	0.00	1162.74	98.69	0.00	0.00	980512.75	100.00	0.00	0.00
Mytilus beds	0.38	0.31	0.00	0.00	15.40	1.31	0.00	0.00	5.93	0.00	0.00	0.00
Negligible blue carbon	57.13	46.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	2.30	1.86	601.29	2.26	0.00	0.00	0.00	0.00	0.00	0.00	191.21	100.00
Subcanopy algae	0.58	0.47	12.13	0.05	0.00	0.00	12.71	0.10	0.00	0.00	0.00	0.00
Total	**123.95**	**100.00**	**26648.23**	**100.00**	**1178.14**	**100.00**	**12680.44**	**100.00**	**980518.68**	**100.00**	**191.21**	**100.00**

37. South Arran NC MPA

Location: 55°27.763'N; 005°10.112'W – South Arran NC MPA is located within the Clyde Sea on the west coast of Scotland, and encompasses the southern coastal waters off the Isle of Arran.

Area: 280 km^2



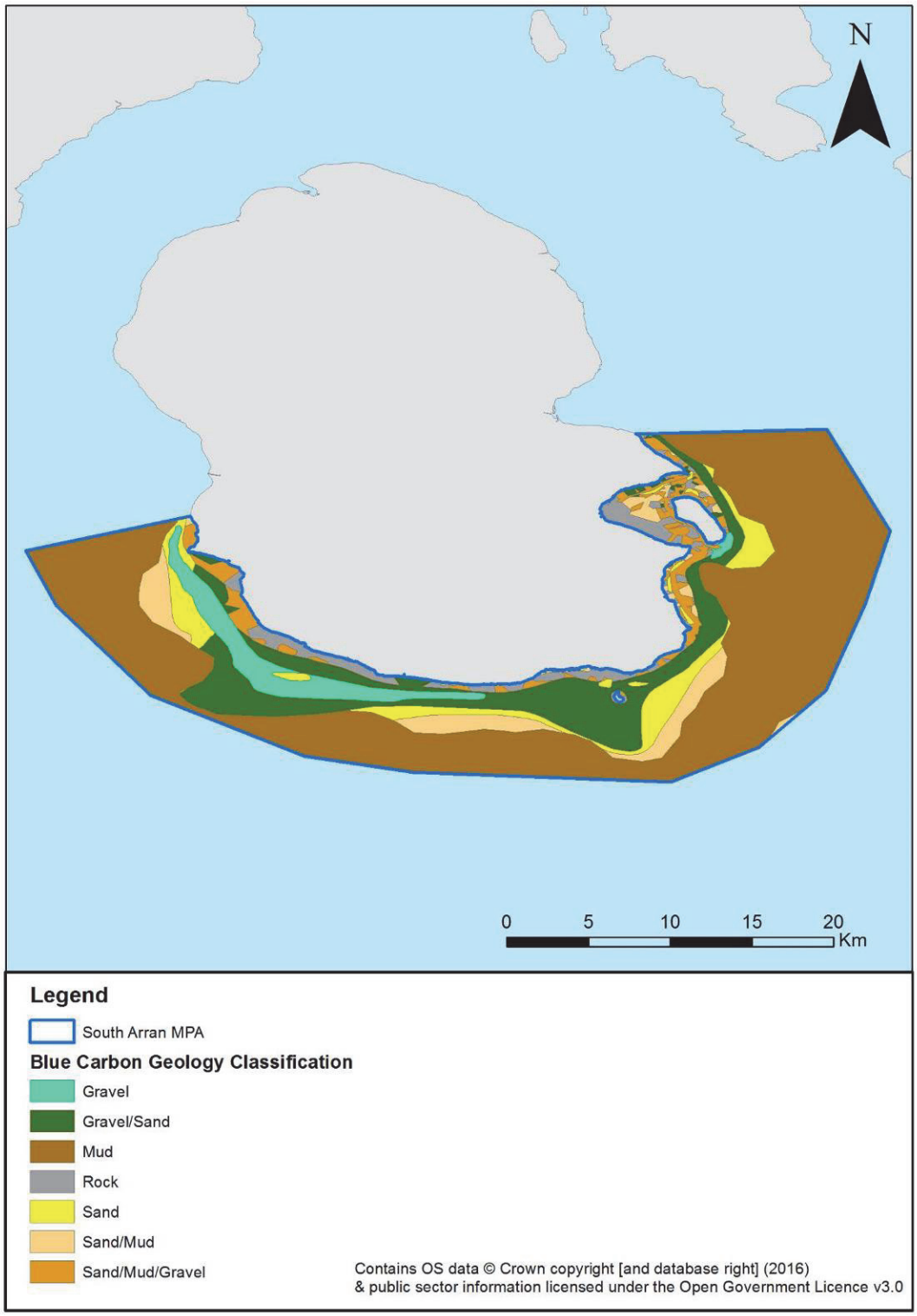
Map of the location of South Arran NC MPA

Designation: NC MPA set up to recover and conserve existing maerl beds. Maerl beds interspersed with coarse gravel, and kelp and seaweed communities are found alongside burrowing sea cucumbers, ocean quahog congregations and burrowing bivalves. The outer regions of the MPA consist of burrowed mud and support Norway and squat lobsters, crabs and the slender seapen.

Blue carbon designation: Gravel, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, kelp beds, maerl beds, *Modiolus modiolus* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
South Arran	373 208	7 599	709 238	6 092

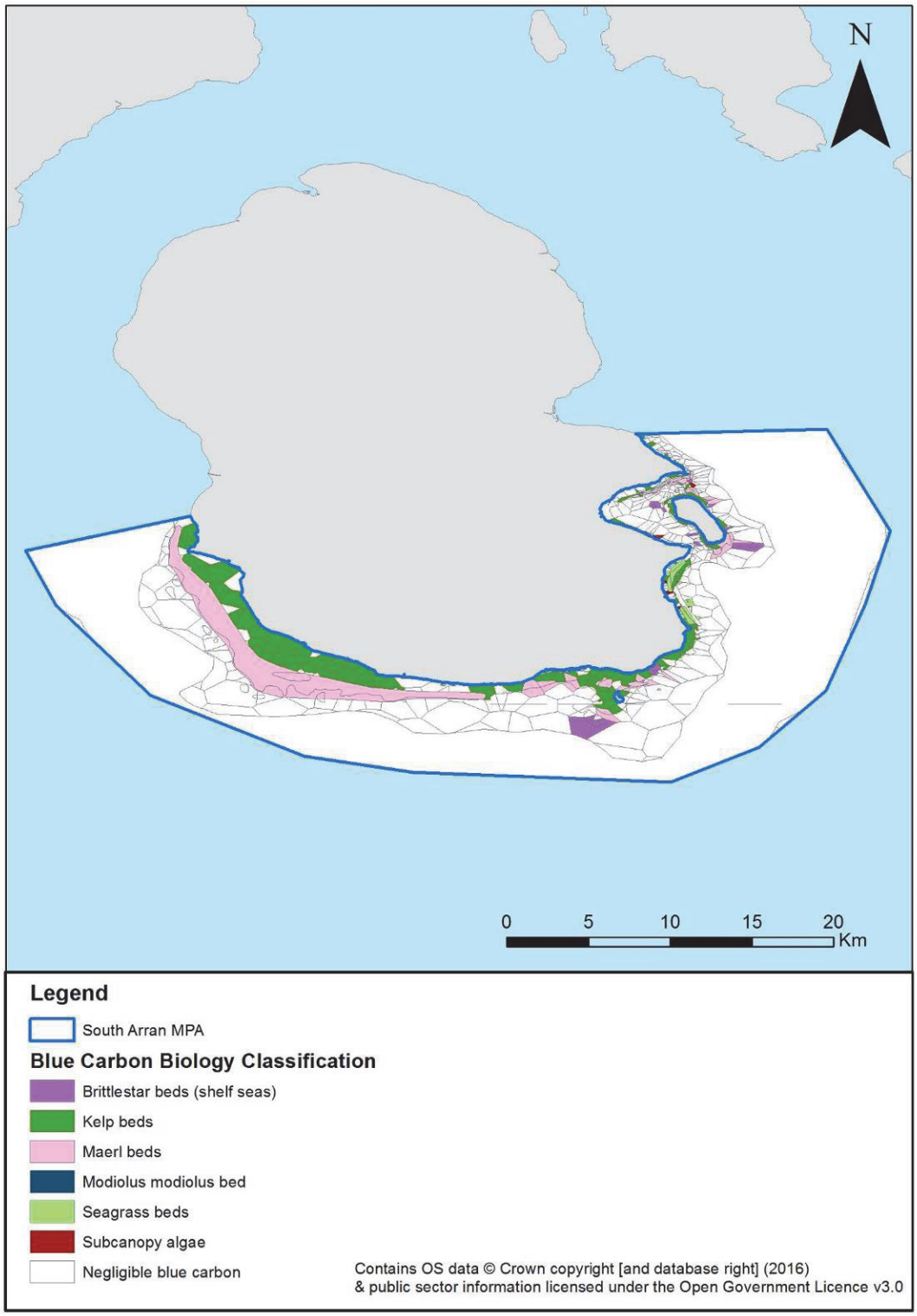
(SS: standing stock, seq: sequestration, prod: production)



Map of South Arran NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
South Arran	3 827	14 242	92	1 167 774	1 598

(SS: standing stock, seq: sequestration, prod: production)



Map of South Arran NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

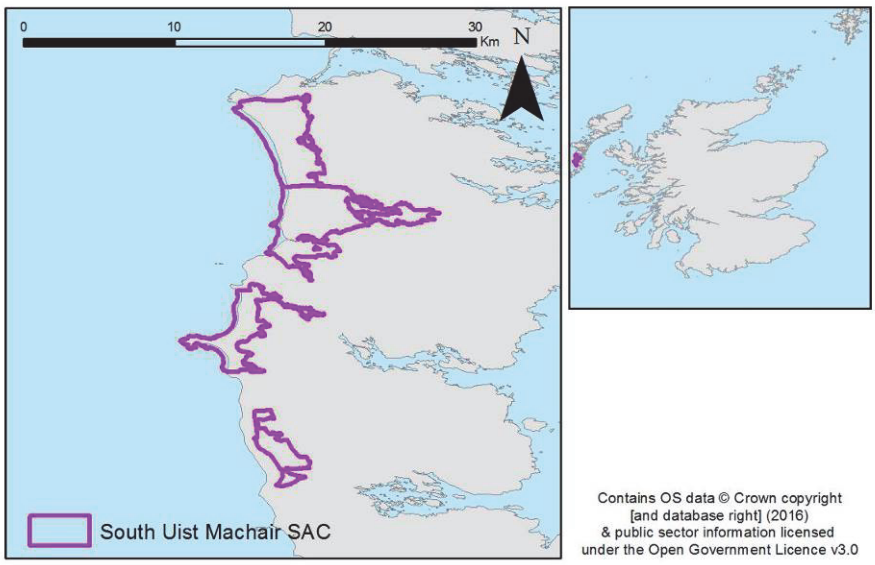
Table showing the calculated IC and OC values for each biological habitat: Sound of Arran

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	2.59	0.92	0.00	0.00	212.19	13.28	0.00	0.00	0.00	0.00	0.00	0.00
Kelp beds	20.36	7.26	13948.90	97.94	0.00	0.00	3821.83	99.87	0.00	0.00	0.00	0.00
Maerl beds	18.71	6.67	0.00	0.00	1384.67	86.65	0.00	0.00	1167659.91	99.99	0.00	0.00
Modiolus modiolus bed	0.03	0.01	0.00	0.00	1.14	0.07	0.00	0.00	114.44	0.01	0.00	0.00
Negligible blue carbon	237.48	84.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	1.11	0.39	288.43	2.03	0.00	0.00	0.00	0.00	0.00	0.00	91.72	100.00
Subcanopy algae	0.22	0.08	4.60	0.03	0.00	0.00	4.82	0.13	0.00	0.00	0.00	0.00
Total	**280.49**	**100.00**	**14241.93**	**100.00**	**1598.01**	**100.00**	**3826.64**	**100.00**	**1167774.35**	**100.00**	**91.72**	**100.00**

38. South Uist Machair SAC

Location: 57°18'50.00'N; 007°19'60.00'W – The SAC is located on the western edge of South Uist in the Outer Hebrides. Machair is a Gaelic word meaning fertile low lying grassy plain. This is the name given to one of the rarest habitats in Europe which only occurs on exposed western coasts of Scotland and Ireland.

Area: 34.38 km^2



Map of the location of South Uist Machair SAC

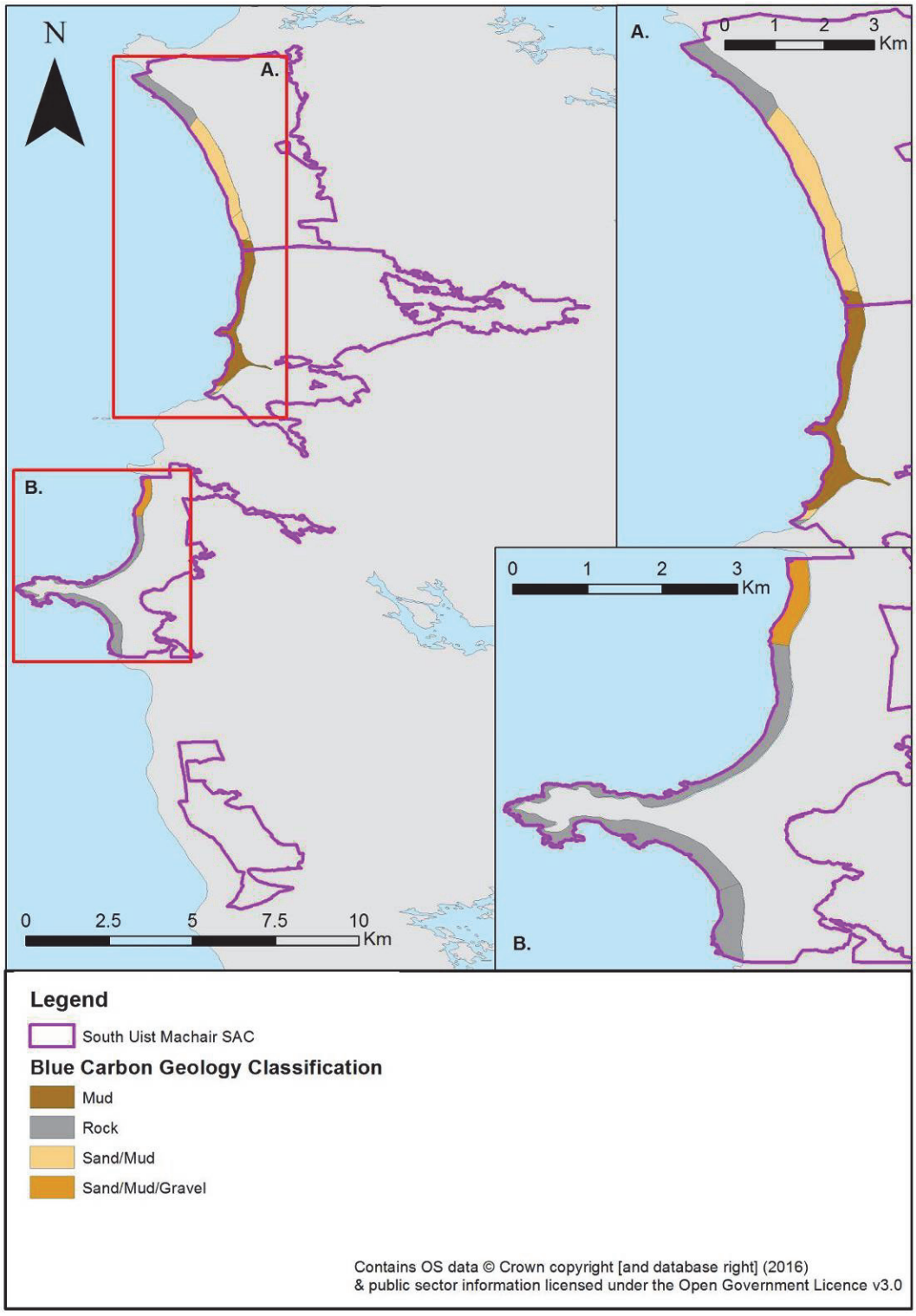
Designation: South Uist Machair has been designated an SAC for a range of features including coastal, marine, freshwater habitats, mammals (otters) and vascular plants (slender naiad). The marine feature is lagoons. Coastal features include annual vegetation of drift lines, dune grassland, humid dune slacks, machair and shifting dunes with marram. Freshwater habitats include calcium-rich nutrient-poor lakes, lochs and pools, clear-water lakes or lochs with aquatic vegetation and poor to moderate nutrient levels, naturally nutrient-rich lakes or lochs which are often dominated by pondweed, nutrient-poor shallow waters with aquatic vegetation on sandy plains.

In addition South Uist Machair is also a National Scenic Area, with South Uist Machair and Lochs also been a SPA and a Ramsar Site.

Blue carbon designation: Mud, rock, sand/mud and sand/mud/gravel (geology), negligible (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
South Uist Machair	1 985	37	2 444	26

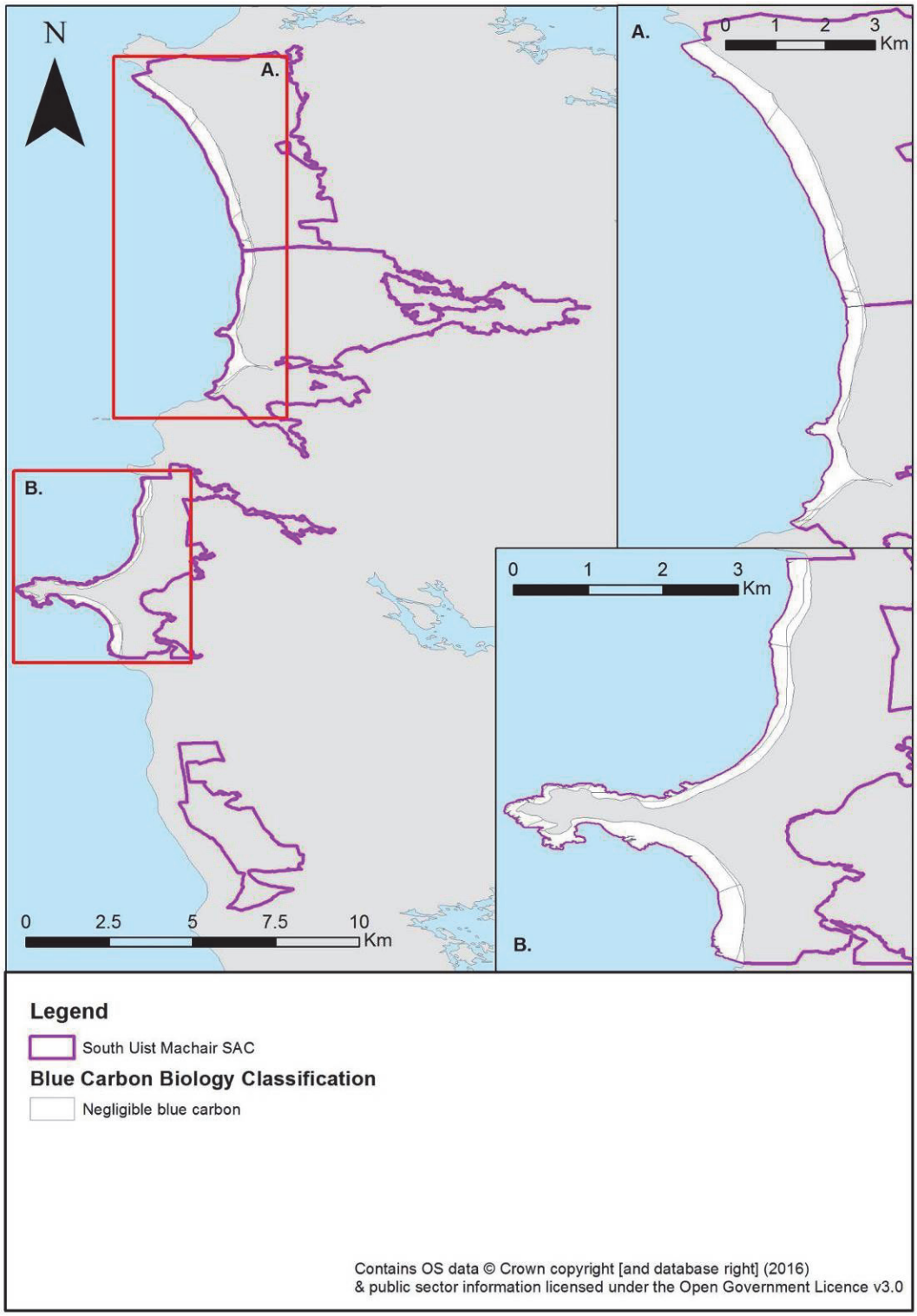
(SS: standing stock, seq: sequestration, prod: production)



Map of South Uist Machair SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
South Uist Machair	0	0	0	0	0

(SS: standing stock, seq: sequestration, prod: production)



Map of South Uist Machair SAC showing the different biological habitats. The table above reports the calculated IC and OC

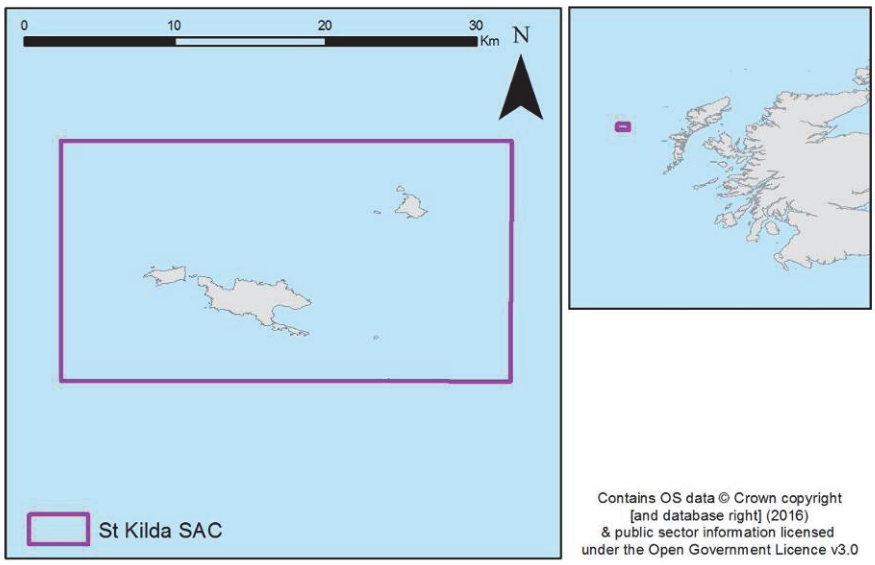
Table showing the calculated IC and OC values for each biological habitat:
South Uist Machair SAC

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	2.67	100.00	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
Total	**2.67**	**100.00**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**	**0.00**	**-**

39. St Kilda SAC

Location: 57°49'0.00'N; 8°34'60.00'W – The archipelago of St Kilda, consists of four islands, Hirta, Soay, Boreray and Dun. It is located 41 miles west of Benbecula in the Outer Hebrides of Scotland. Formed from the caldera of an ancient volcano, it is the remotest part of the British Isles.

Area: 255 km^2



Map of the location of St Kilda SAC

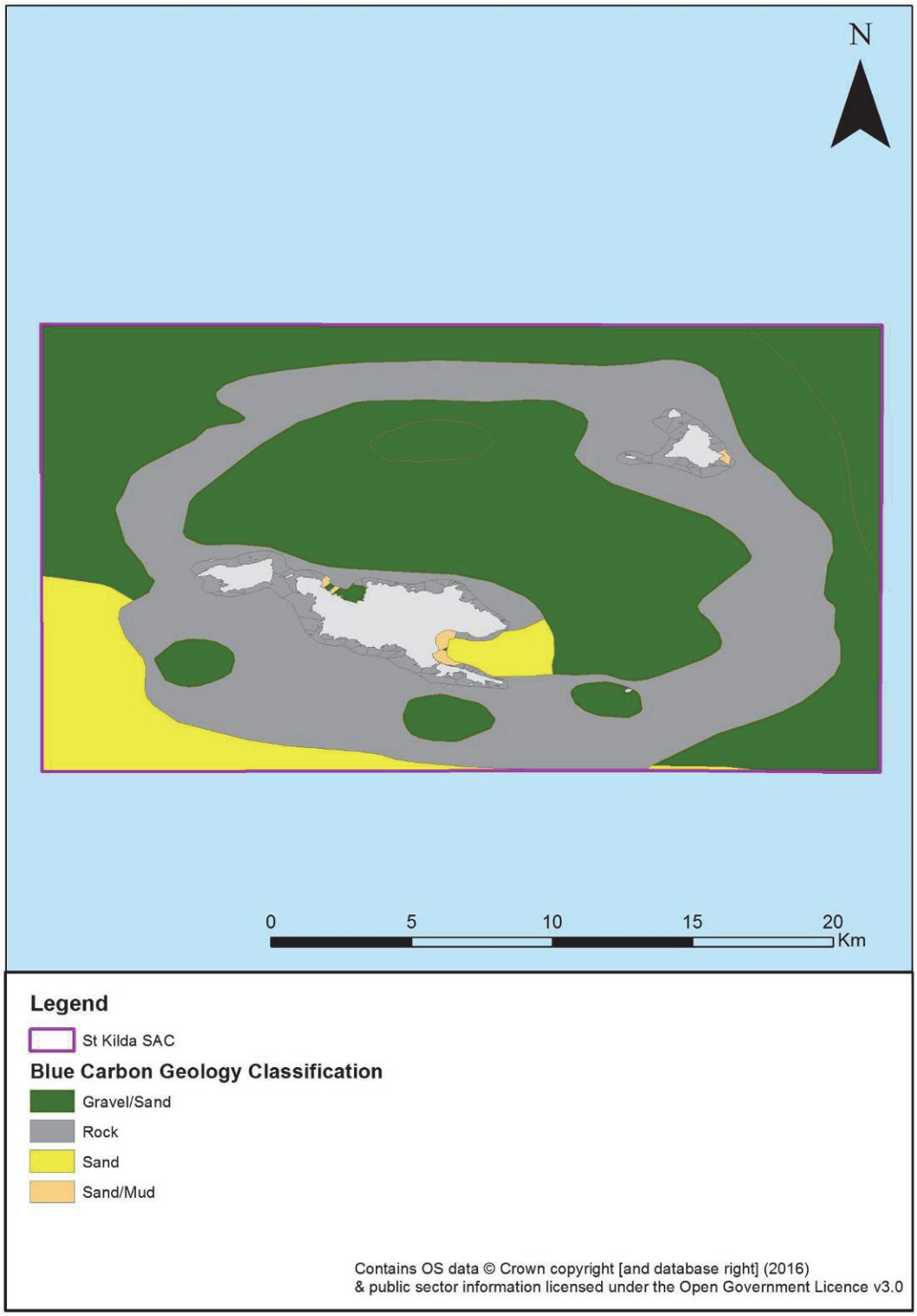
Designation: St Kilda is a designated SAC due to its marine and coastal features (vegetated sea cliffs). The marine features include reefs and sea caves. The islands are formed of hard, igneous rock, which forms steep and vertical reefs around the entire island group, along with one of the most extensive sea cave systems in the UK.

St Kilda is also a National Nature Reserve, a SSSI a SPA and a National Scenic Area. It is one of only 29 global locations to be awarded 'mixed' World Heritage Status in recognition of both its natural and cultural significance.

Blue carbon designation: Gravel/sand, rock, sand and sand/mud (geology); kelp, *Modiolus modiolus* bed and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
St Kilda	82 597	624	940 919	6 788

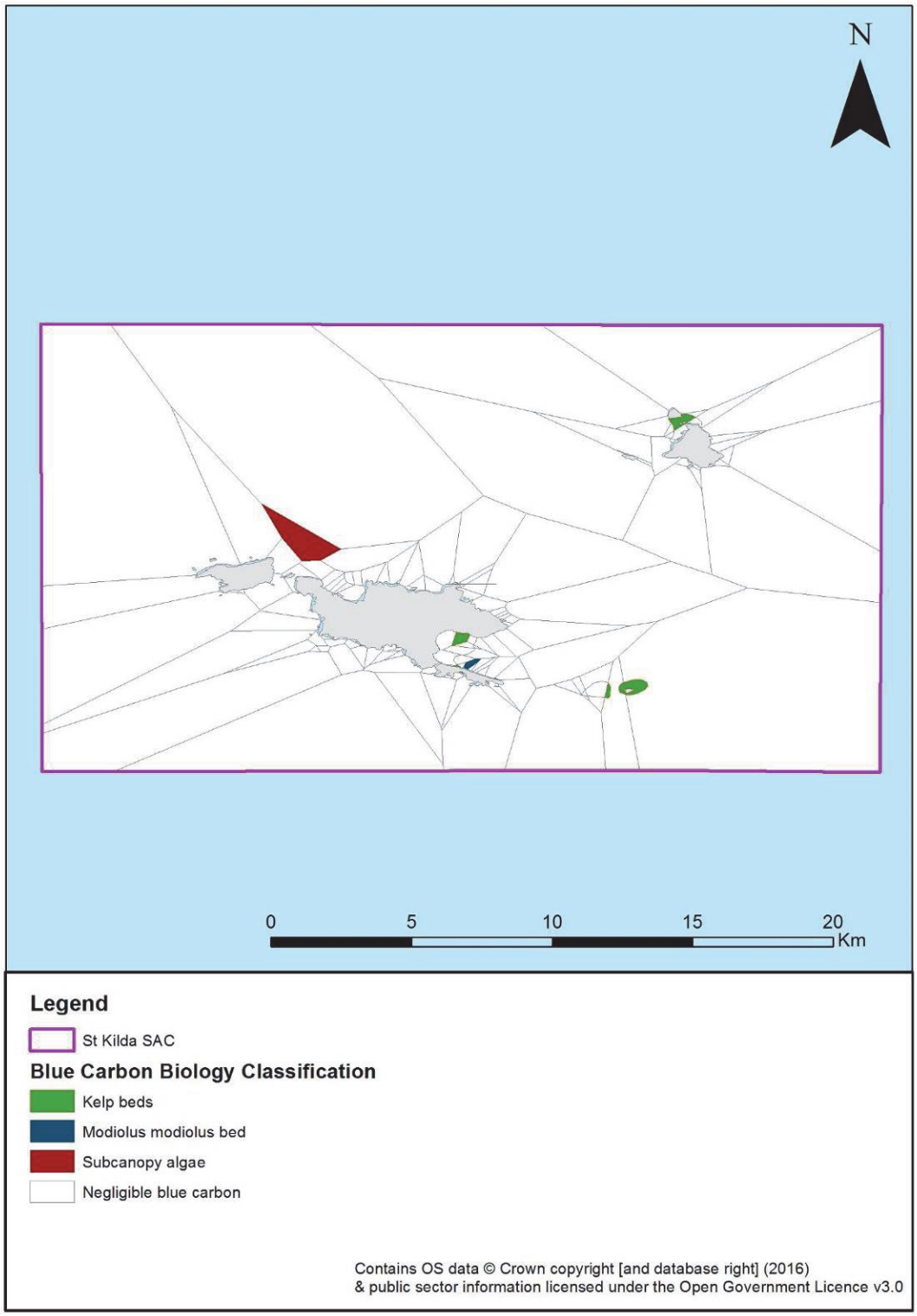
(SS: standing stock, seq: sequestration, prod: production)



Map of St Kilda SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
St Kilda	115	357	0	236	2

(SS: standing stock, seq: sequestration, prod: production)



Map of St Kilda SAC showing the different biological habitats. The table above reports the calculated IC and OC

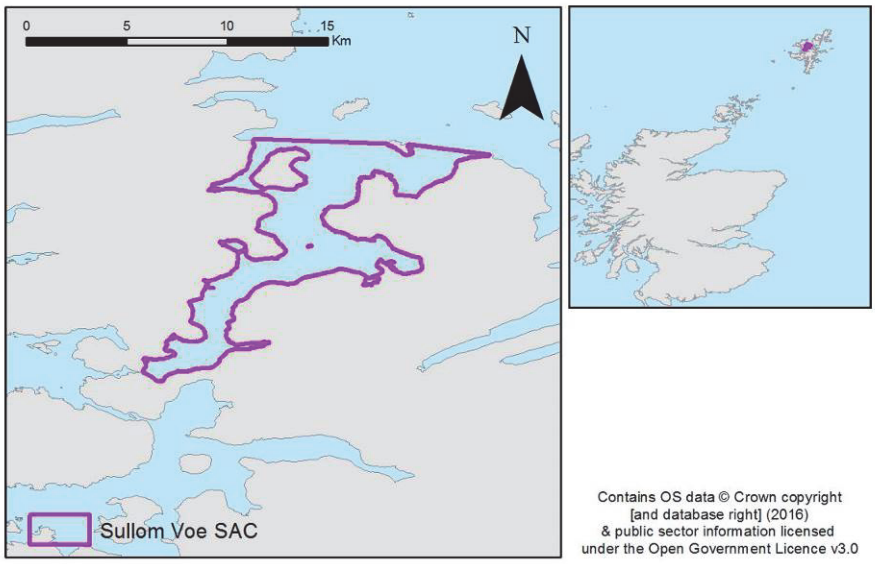
Table showing the calculated IC and OC values for each biological habitat: St Kilda

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	0.49	0.20	334.48	93.67	0.00	0.00	91.64	79.46	0.00	0.00	0.00	-
Modiolus modiolus bed	0.06	0.02	0.00	0.00	2.36	100.00	0.00	0.00	235.53	100.00	0.00	-
Negligible blue carbon	243.85	99.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	1.08	0.44	22.61	6.33	0.00	0.00	23.69	20.54	0.00	0.00	0.00	-
Total	**245.47**	**100.00**	**357.10**	**100.00**	**2.36**	**100.00**	**115.34**	**100.00**	**235.53**	**100.00**	**0.00**	**-**

40. Sullom Voe SAC

Location: 60°27'50.00' N; 001°18'35.00'W – The Sullom Voe SAC lies to the south of Yell Sound in Mainland Shetland. The site includes Gluss Voe, Sullom Voe, Orka Voe and a number of other smaller embayments and subsidiary arms.

Area: 26.91 km^2



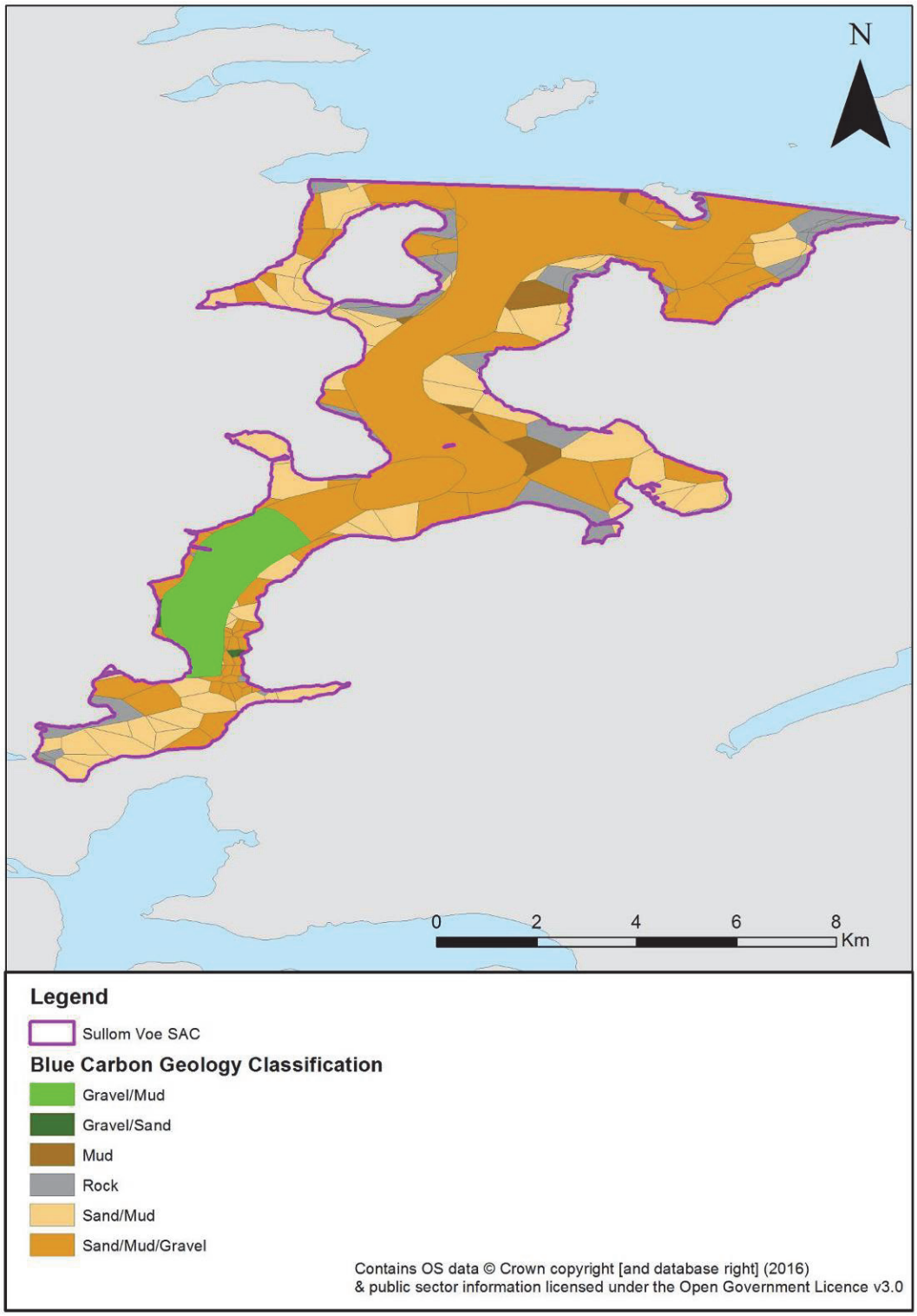
Map of the location of Sullom Voe SAC

Designation: Sullom Voe is a designated SAC due to its marine features namely: Lagoons, reefs and shallow inlets and bays. Sullom Voe SAC includes the most northerly, in terms of geographical range and ecological variation, of large shallow inlets and bays within the UK. The boreal-arctic species-rich communities are restricted to Shetland voes and are not found in any other area within the UK.

Blue carbon designation: Gravel/mud, gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, *Modiolus modiolus* beds, *Mytilus edulis* beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sullom Voe	29 581	444	47 525	530

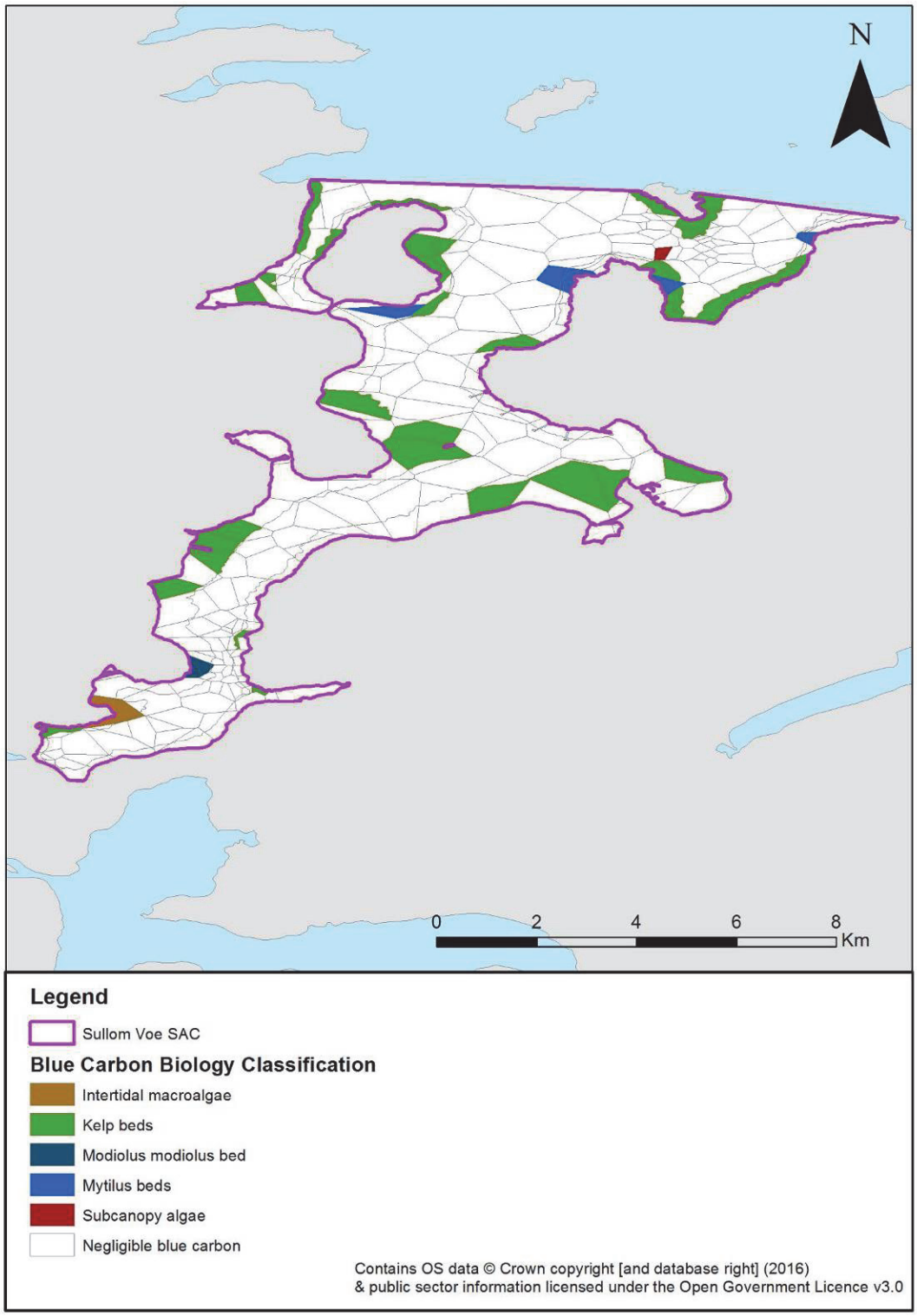
(SS: standing stock, seq: sequestration, prod: production)



Map of Sullom Voe SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sullom Voe	830	2 754	0	307	18

(SS: standing stock, seq: sequestration, prod: production)



Map of Sullom Voe SAC showing the different biological habitats. The table above reports the calculated IC and OC

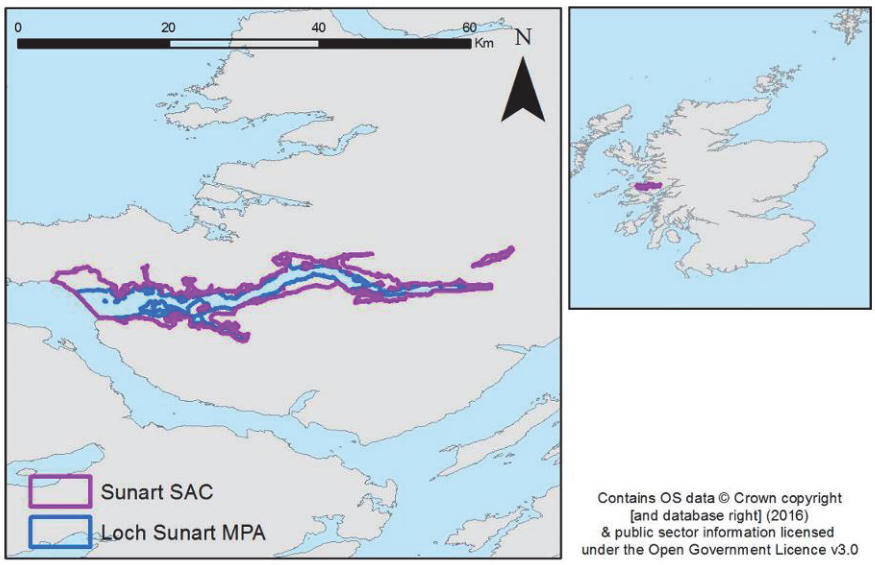
Table showing the calculated IC and OC values for each biological habitat: Sullom Voe SAC

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.17	0.62	22.40	0.81	0.00	0.00	81.15	9.77	0.00	0.00	0.00	-
Kelp beds	3.99	15.02	2731.24	99.16	0.00	0.00	748.33	90.13	0.00	0.00	0.00	-
Modiolus modiolus bed	0.08	0.28	0.00	0.00	3.01	16.54	0.00	0.00	300.92	98.09	0.00	-
Mytilus beds	0.38	1.43	0.00	0.00	15.19	83.46	0.00	0.00	5.85	1.91	0.00	-
Negligible blue carbon	21.91	82.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.04	0.13	0.74	0.00	0.00	0.00	0.77	0.09	0.00	0.00	0.00	-
Total	**26.55**	**100.00**	**2754.39**	**100.00**	**18.20**	**100.00**	**830.25**	**100.00**	**306.77**	**100.00**	**0.00**	**-**

41. Sunart SAC and Loch Sunart NC MPA

Location: 56°40'30.00'N; 005°48'30.00'W – Sunart SAC and Loch Sunart NC MPA have a very similar marine area boundary. The MPA overlaps and builds on the marine part of the SAC. Situated off the west coast of Scotland, Loch Sunart is bounded to the north by the Sunart district of Ardnamurchan and to the south by Morvern and Ardgour.

Area: Sunart SAC 102 km^2, Loch Sunart MPA 49km^2



Map of the location of Sunart SAC and Loch Sunart NC MPA

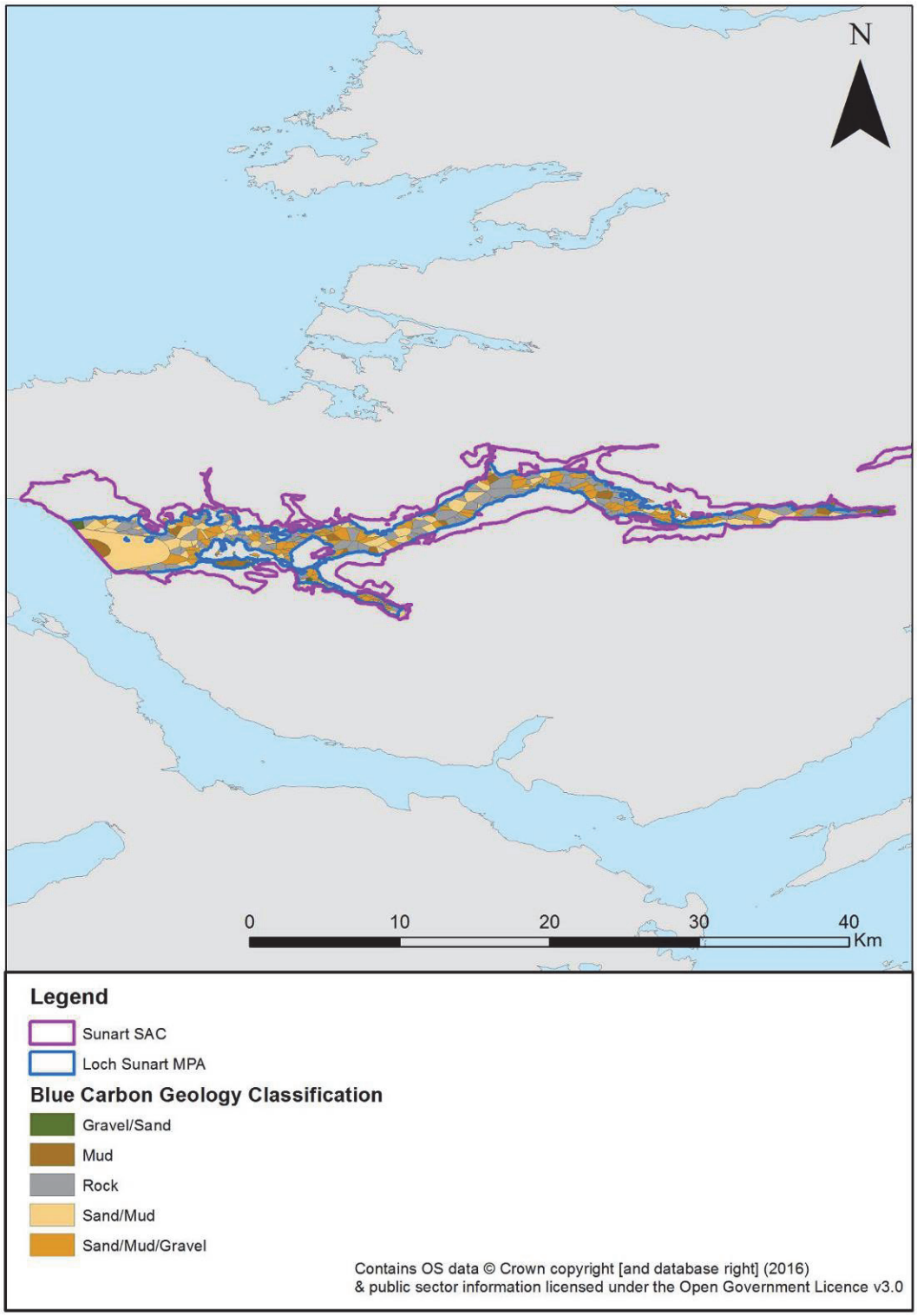
Designation: Sunart has been designated an SAC for a range of features including upland habitat, woodland, mammals (otters) and marine rocky reefs. Sunart is also a SSSI for a large range of features, including eelgrass beds and rocky shores.

Loch Sunart NC MPA designation is due to the presences of flame shell beds, serpulid aggregations and northern feather star aggregations on mixed substrata.

Blue carbon designation: Gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Limaria hians* beds, *Modiolus modiolus* beds, *Mytilus edulis* beds, *Serpula vermicularis* reefs and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sunart and Loch Sunart	47 673	877	70 352	837

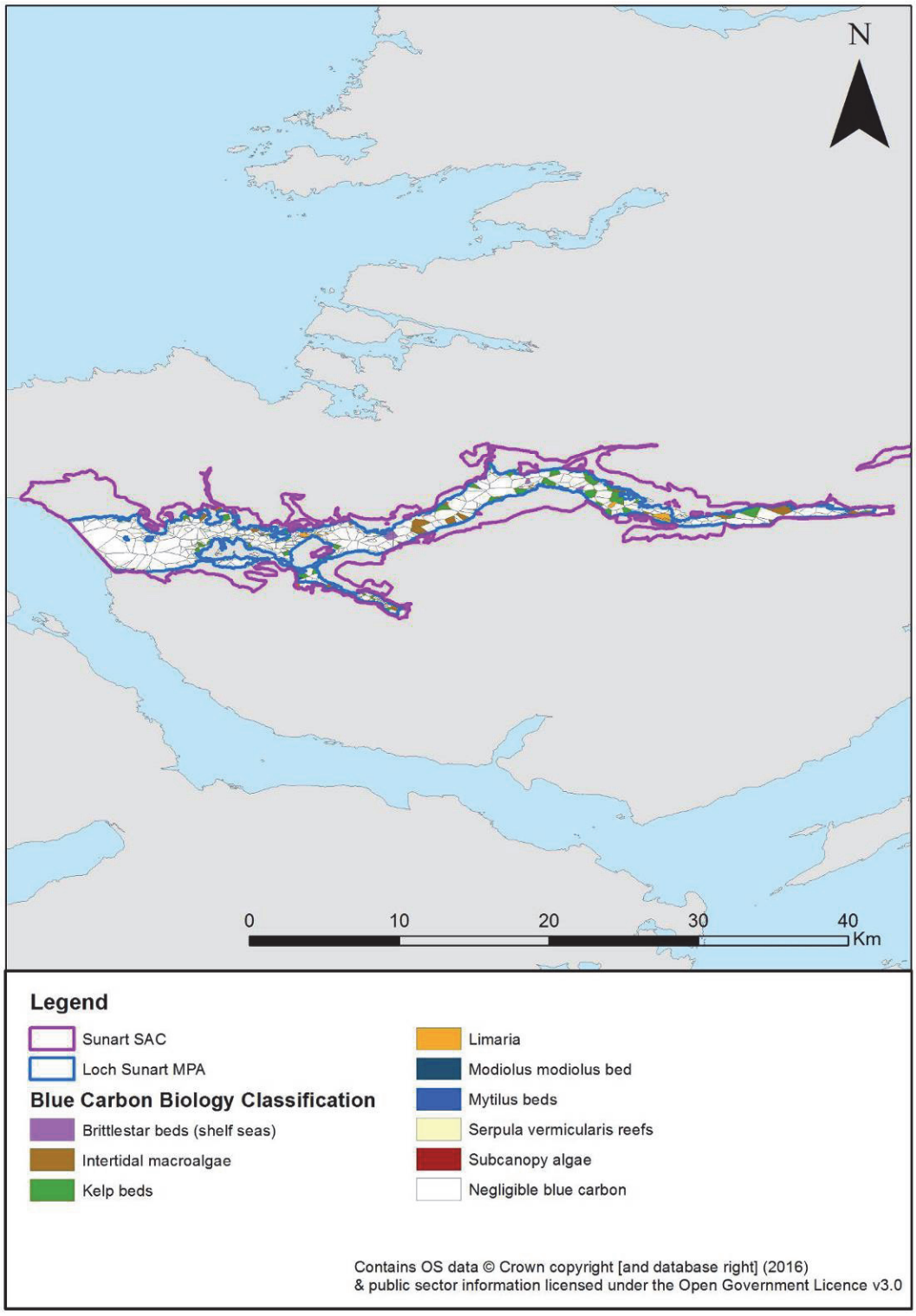
(SS: standing stock, seq: sequestration, prod: production)



Map of Sunart SAC and Loch Sunart NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Sunart and Loch Sunart	796	1 754	0	217	52

(SS: standing stock, seq: sequestration, prod: production)



Map of Sunart SAC and Loch Sunart NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

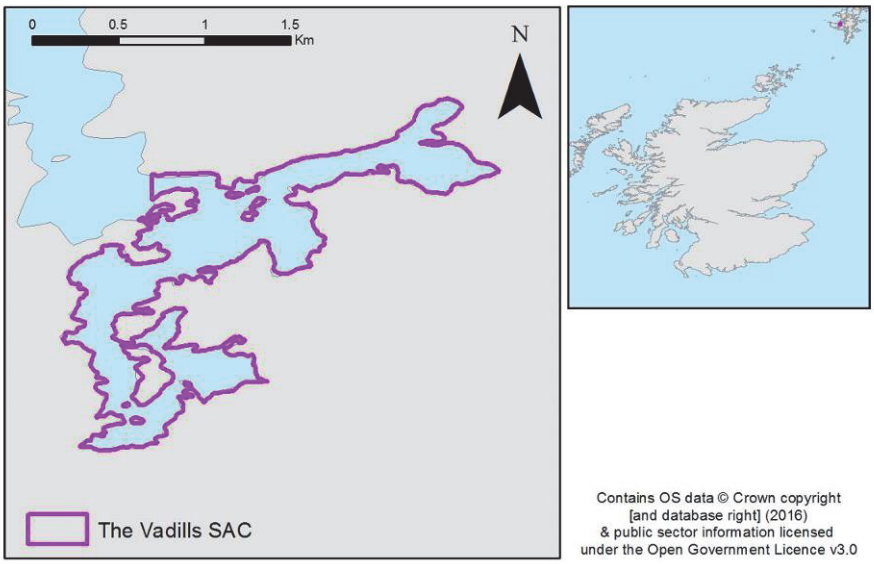
Table showing the calculated IC and OC values for each biological habitat: Sunart SAC and Loch Sunart

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.30	1.03	0.00	0.00	24.23	47.04	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.70	2.44	94.17	5.37	0.00	0.00	341.12	42.84	0.00	0.00	0.00	-
Kelp beds	2.42	8.48	1659.75	94.61	0.00	0.00	454.75	57.11	0.00	0.00	0.00	-
Limaria hians	0.24	0.83	0.00	0.00	0.00	0.00	0.00	0.00	15.16	6.99	0.00	-
Modiolus modiolus bed	0.04	0.13	0.00	0.00	1.54	2.98	0.00	0.00	153.74	70.92	0.00	-
Mytilus beds	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-
Negligible blue carbon	24.80	86.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Serpula vermicularis reefs	0.06	0.21	0.00	0.00	25.74	49.97	0.00	0.00	47.88	22.09	0.00	-
Subcanopy algae	0.02	0.07	0.43	0.02	0.00	0.00	0.45	0.06	0.00	0.00	0.00	-
Total	**28.58**	**100.00**	**1754.35**	**100.00**	**51.52**	**100.00**	**796.32**	**100.00**	**216.79**	**100.00**	**0.00**	**-**

42. The Vadills SAC

Location: 60°27'50.00' N; 001°18'35.00'W – The Vadills SAC is located on the Shetland Islands mainland.

Area: 0.62 km^2



Map of the location of The Vadills SAC

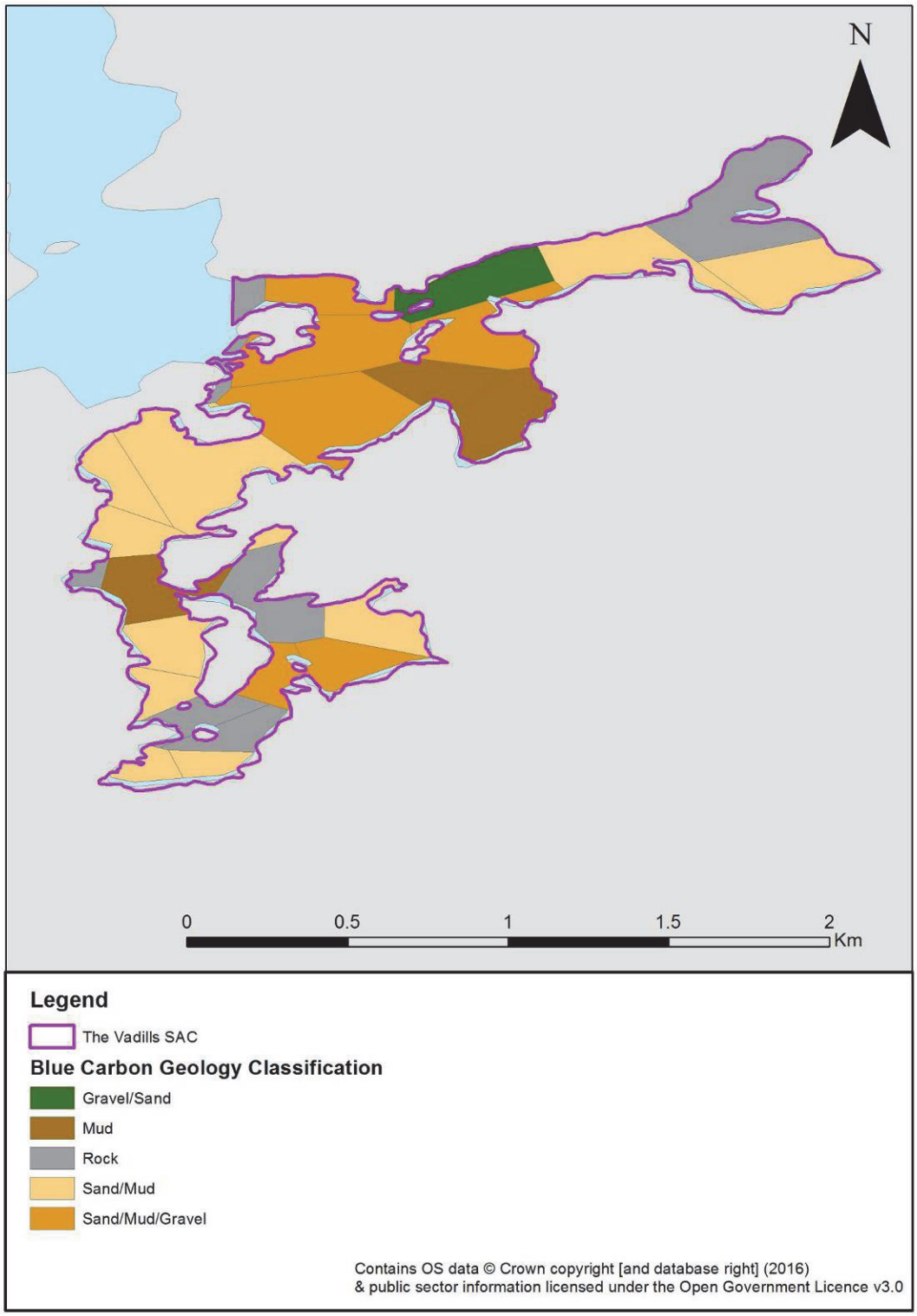
Designation: The SAC is designated for its marine feature namely: Lagoons. The Vadills SAC contains is an excellent example of a complex lagoon system, containing lagoonal inlets and silled lagoons. The graduation in the salinity throughout the lagoons, promotes a wide range of communities, with a high diversity of species.

The Vadills is also a SSSI, designated for egg wrack (non-vascular plants), saline lagoon and tidal rapids.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, maerl beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
The Vadills	311	6	634	7

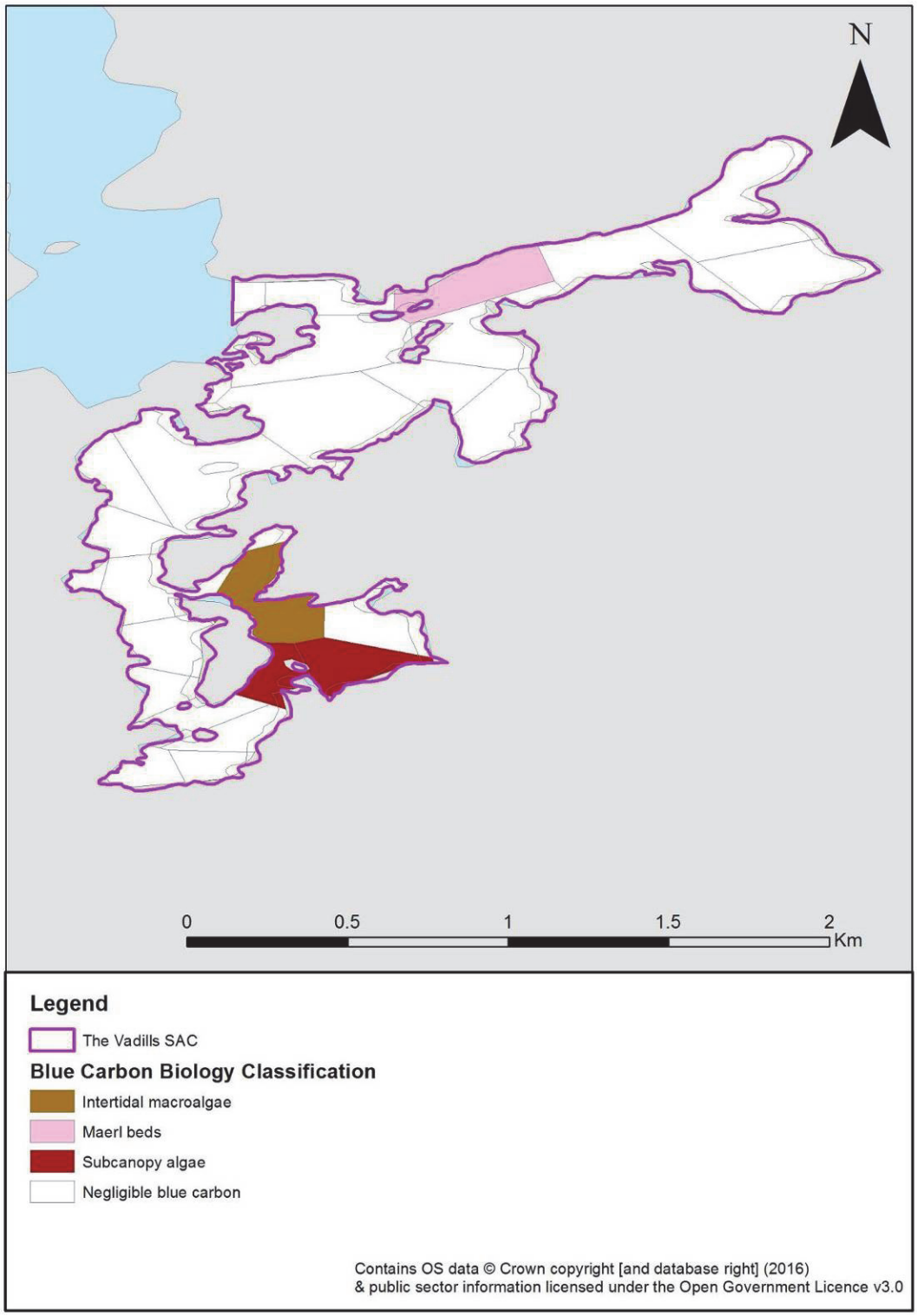
(SS: standing stock, seq: sequestration, prod: production)



Map of The Vadills SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
The Vadills	12	4	0	1 626	2

(SS: standing stock, seq: sequestration, prod: production)



Map of The Vadills SAC showing the different biological habitats. The table above reports the calculated IC and OC

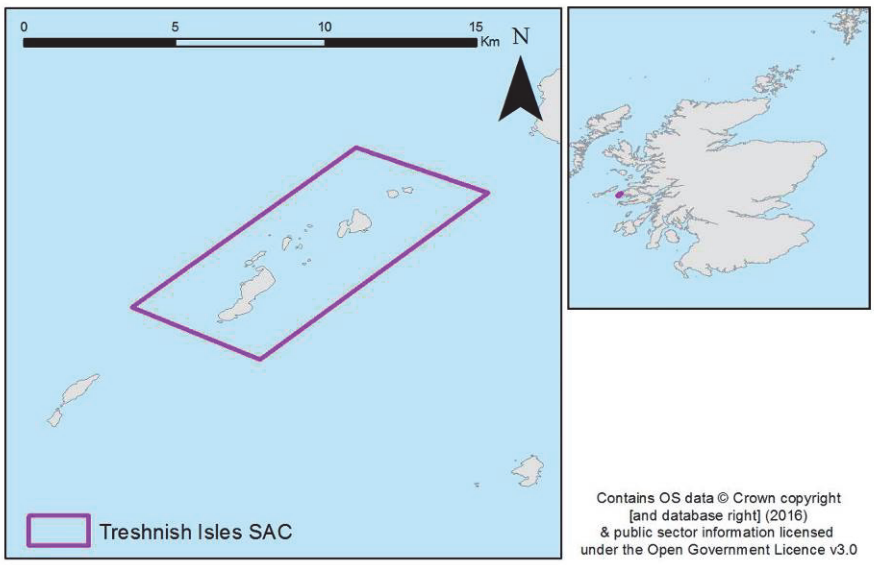
Table showing the calculated IC and OC values for each biological habitat: The Vadills

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.02	4.39	3.13	84.67	0.00	0.00	11.34	95.02	0.00	0.00	0.00	-
Maerl beds	0.03	4.93	0.00	0.00	1.93	100.00	0.00	0.00	1626.14	100.00	0.00	-
Negligible blue carbon	0.45	85.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.03	5.11	0.57	15.33	0.00	0.00	0.59	4.98	0.00	0.00	0.00	-
Total	**0.53**	**100.00**	**3.70**	**100.00**	**1.93**	**100.00**	**11.93**	**100.00**	**1626.14**	**100.00**	**0.00**	**-**

43. Treshnish Isles SAC

Location: 56°30'0.00'N; 006°24'24.00'W – The Treshnish Isles are an archipelago of several small uninhabited volcanic islands, situated between Coll and the Island of Mull in south-west Scotland. The Treshnish Isles SAC encompasses Lunga, Fladda and the Cairn na Burgh Islands.

Area: 19.63 km^2



Map of the location of Treshnish Isles SAC

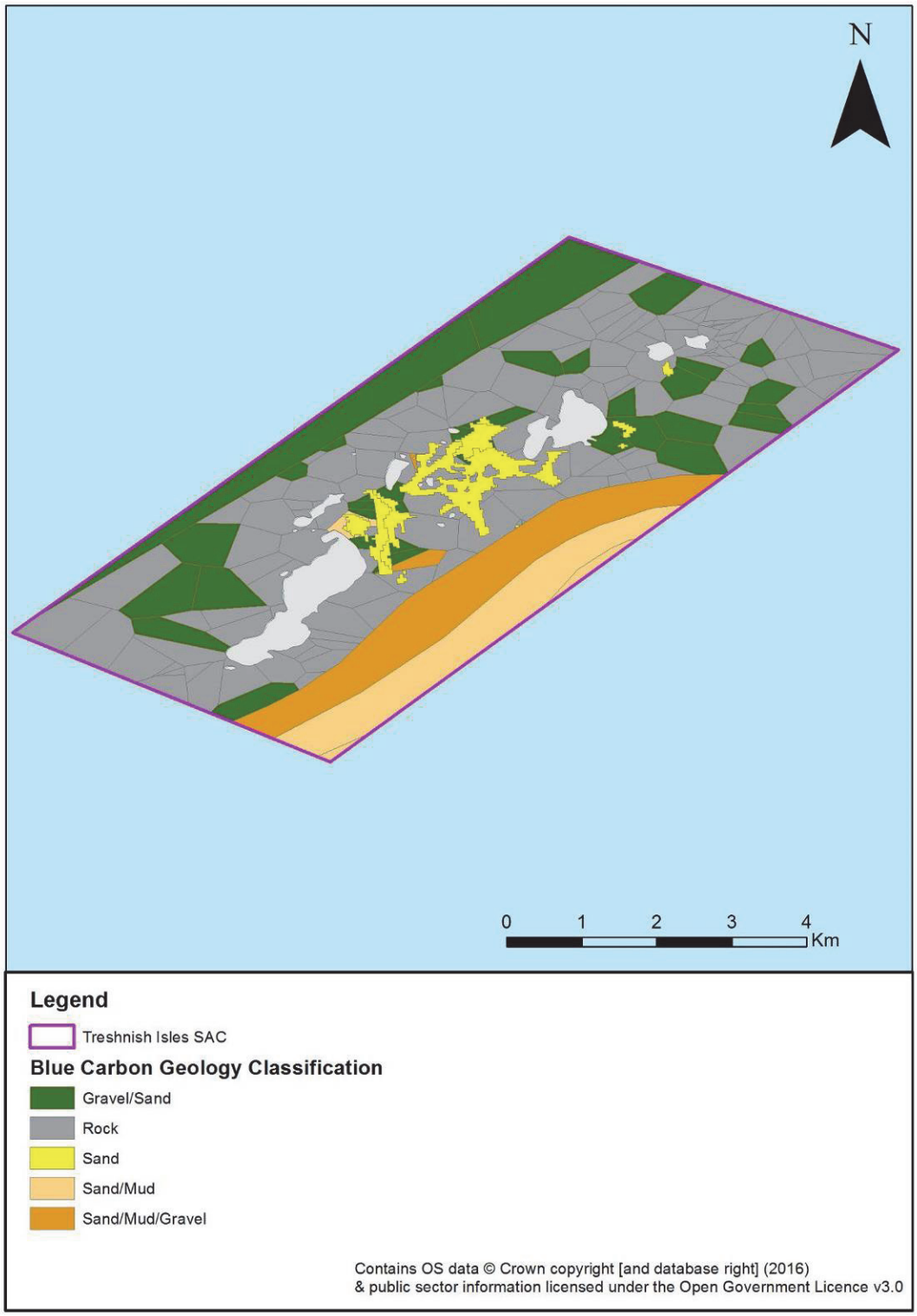
Designation: The SAC is designated for its marine feature namely: Grey seal and reefs. The primary reason for selection of this site is the breeding colony of grey seals, contributing just under 3% of annual UK pup production.

In addition the Treshnish Isles are also designated a SSSI and a SPA, with the SPA designation due to the presence of Greenland Barnacle geese and storm petrel.

Blue carbon designation: Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); kelp beds, maerl beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Treshnish Isles	7 592	92	39 545	316

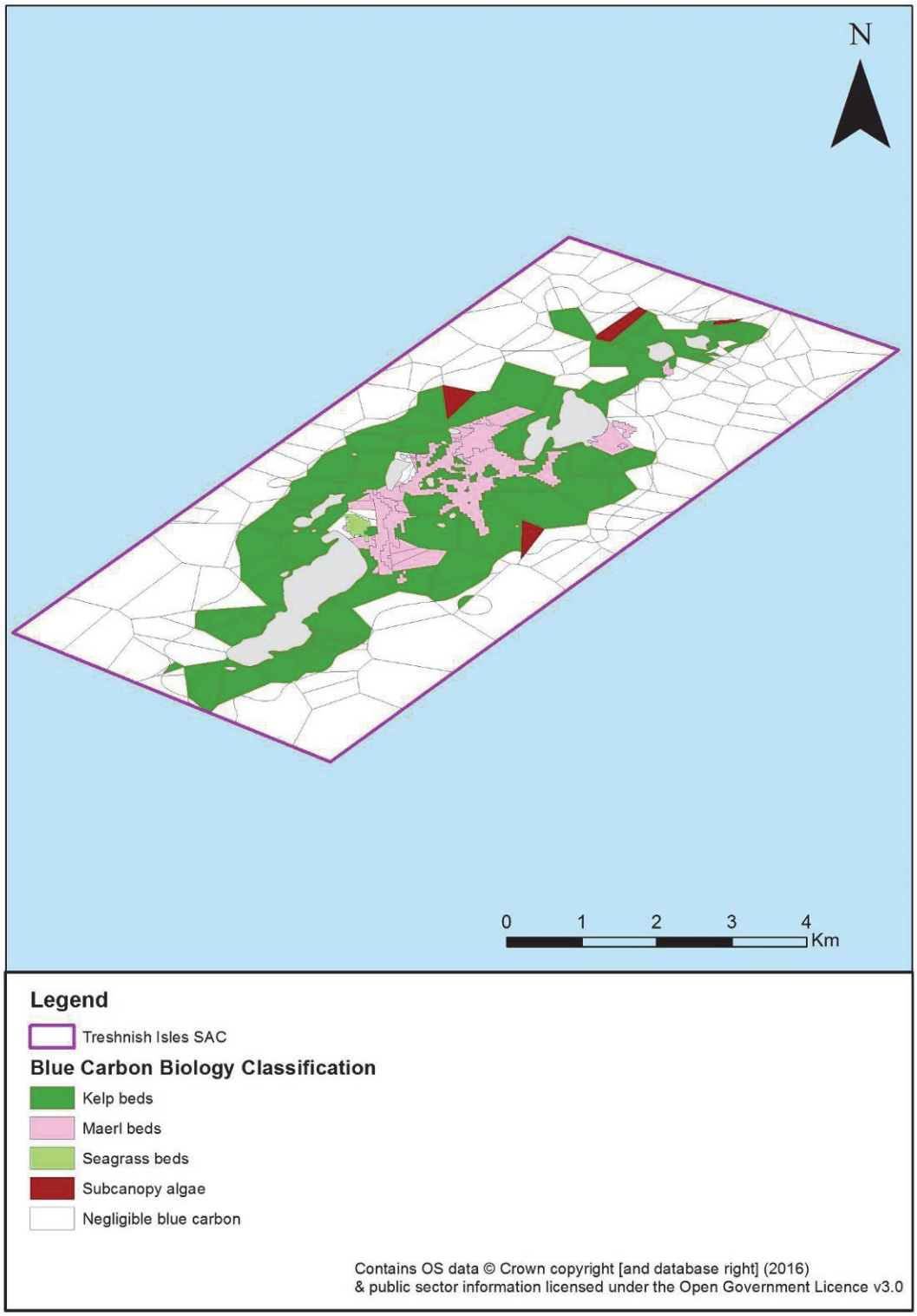
(SS: standing stock, seq: sequestration, prod: production)



Map of Treshnish Isles SAC showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Treshnish Isles	1 018	3 716	3	69 444	82

(SS: standing stock, seq: sequestration, prod: production)



Map of Treshnish Isles SAC showing the different biological habitats. The table above reports the calculated IC and OC

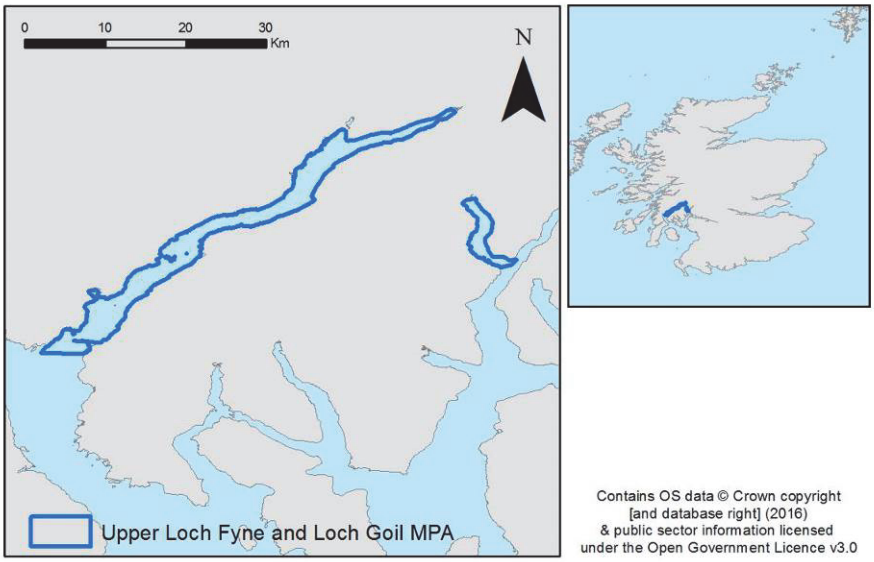
Table showing the calculated IC and OC values for each biological habitat: Treshnish Isles

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Kelp beds	5.40	29.32	3702.41	99.62	0.00	0.00	1014.42	99.63	0.00	0.00	0.00	0.00
Maerl beds	1.11	6.04	0.00	0.00	82.35	100.00	0.00	0.00	69444.06	100.00	0.00	0.00
Negligible blue carbon	11.70	63.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.04	0.22	10.40	0.28	0.00	0.00	0.00	0.00	0.00	0.00	3.31	100.00
Subcanopy algae	0.17	0.94	3.64	0.10	0.00	0.00	3.81	0.37	0.00	0.00	0.00	0.00
Total	**18.44**	**100.00**	**3716.45**	**100.00**	**82.35**	**100.00**	**1018.23**	**100.00**	**69444.06**	**100.00**	**3.31**	**100.00**

44. Upper Loch Fyne and Loch Goil NC MPA

Location: 56°07.529'N; 005°11.459'W (Upper Loch Fyne), 56°07.682'N; 004°53.632'W (Loch Goil) – The Upper Loch Fyne and Loch Goil NC MPA is on the west west coast of Scotland in Argyll and Bute. Loch Fyne extends 65 km inland from the Sound of Bute, making it the longest of the sea lochs. Loch Goil is comparatively small and is an arm of Loch Long.

Area: 88 km^2 (combined area)



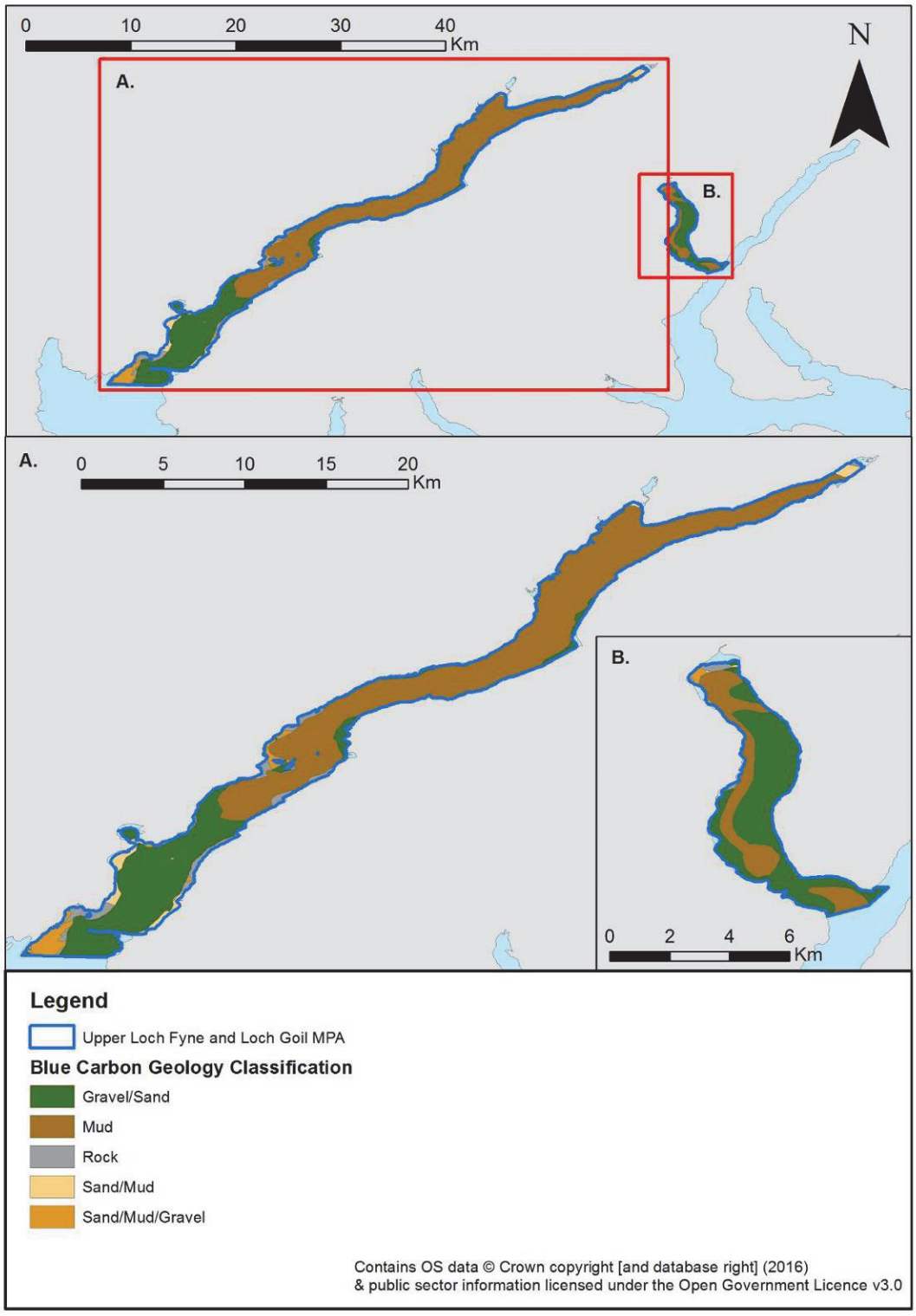
Map of the location of Upper Loch Fyne and Loch Goil MPA

Designation: This diverse NC MPA protects a series of different seabed habitats, including the ocean quahog. The NC MPA aims to recover the flame shell bed, and protect the burrowed mud, horse mussel beds, brittlestars, elegant peacock worms, sea squirts, sea cucumbers, tube dwelling sea anemones, squat lobsters and slender seapens, which inhabit the sublittoral mud and specific mixed sediment communities.

Blue carbon designation: gravel/sand, mud, rock, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae, kelp beds, *Limaria hians* beds, maerl beds, *Modiolus modiolus* beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Upper Loch Fyne and Loch Goil	156 096	4 653	332 011	3 586

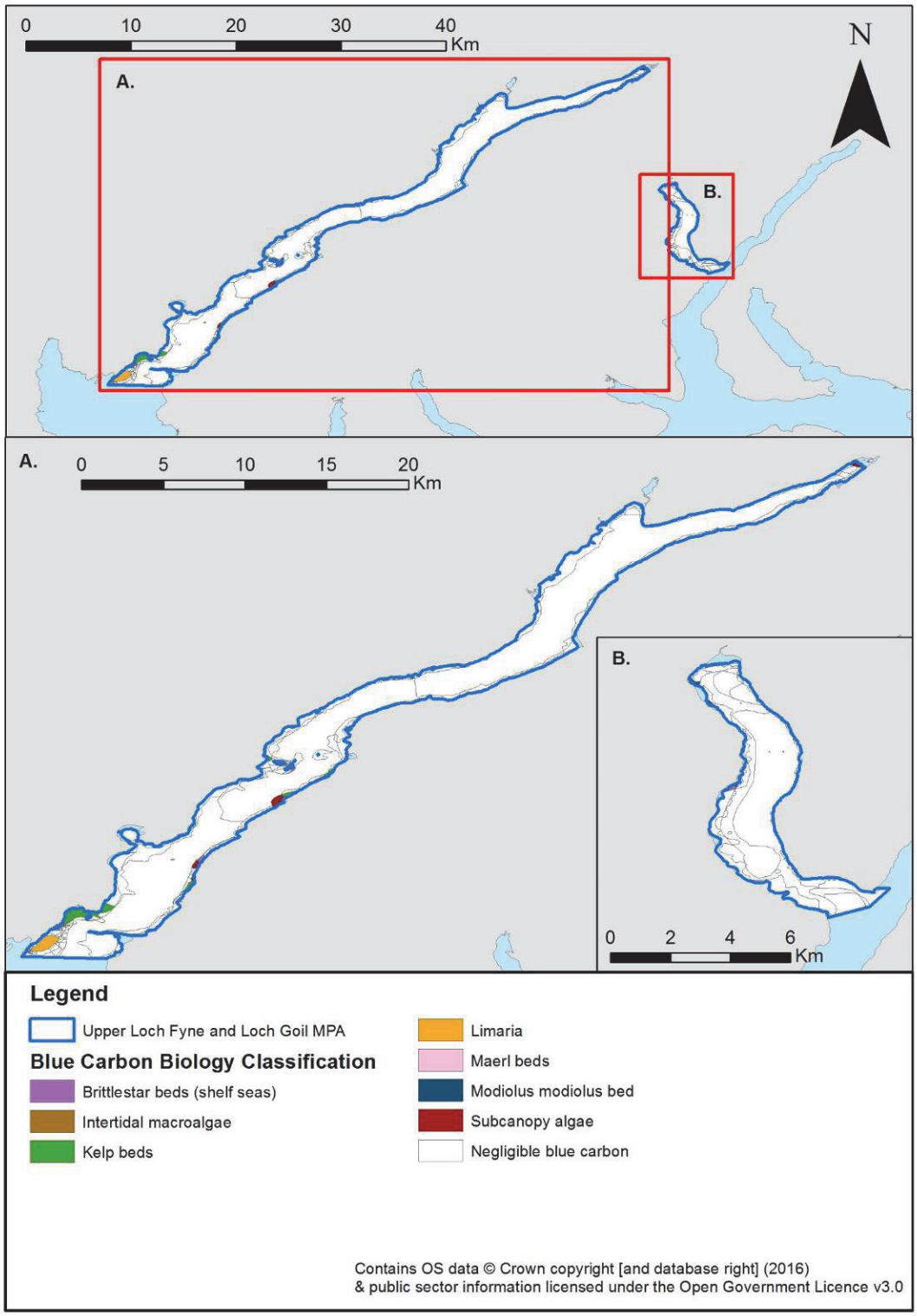
(SS: standing stock, seq: sequestration, prod: production)



Map of Upper Loch Fyne and Loch Goil NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Upper Loch Fyne and Loch Goil	265	933	0	3 672	30

(SS: standing stock, seq: sequestration, prod: production)



Map of Upper Loch Fyne and Loch Goil NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

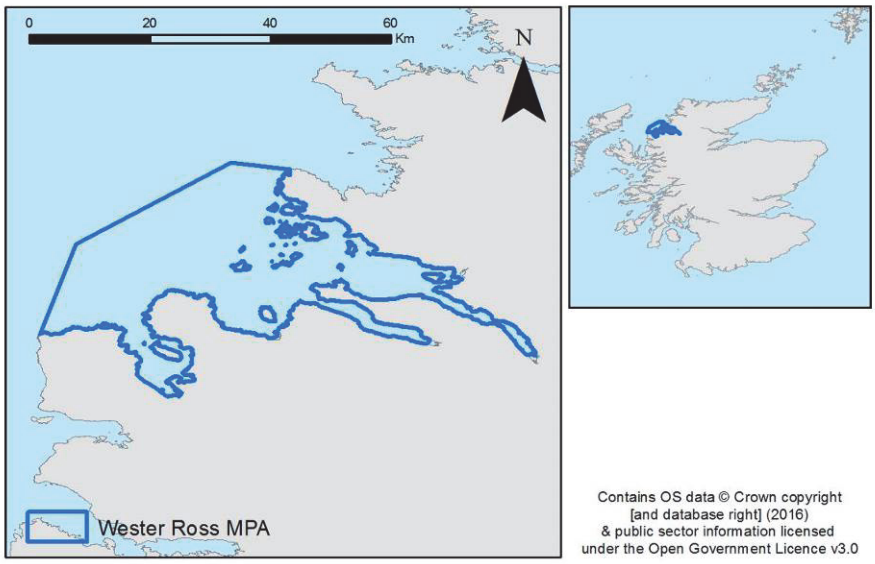
Table showing the calculated IC and OC values for each biological habitat: Upper Loch Fyne and Loch Goil

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	0.27	0.31	0.00	0.00	22.33	73.71	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	0.00	0.01	0.67	0.07	0.00	0.00	2.43	0.92	0.00	0.00	0.00	-
Kelp beds	1.35	1.54	923.10	98.91	0.00	0.00	252.92	95.31	0.00	0.00	0.00	-
Limaria hians	0.50	0.57	0.00	0.00	0.00	0.00	0.00	0.00	31.71	0.86	0.00	-
Maerl beds	0.05	0.06	0.00	0.00	3.83	12.63	0.00	0.00	3226.39	87.87	0.00	-
Modiolus modiolus bed	0.10	0.12	0.00	0.00	4.14	13.66	0.00	0.00	413.85	11.27	0.00	-
Negligible blue carbon	84.88	96.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.45	0.52	9.55	1.02	0.00	0.00	10.00	3.77	0.00	0.00	0.00	-
Total	**87.61**	**100.00**	**933.32**	**100.00**	**30.30**	**100.00**	**265.35**	**100.00**	**3671.95**	**100.00**	**0.00**	**-**

45. Wester Ross NC MPA

Location: 57°57.380'N; 005°31.457'W – The Wester Ross NC MPA is found off the north west coast of Scotland by Ullapool, and encompasses Loch Ewe and Loch Broom.

Area: 599 km^2



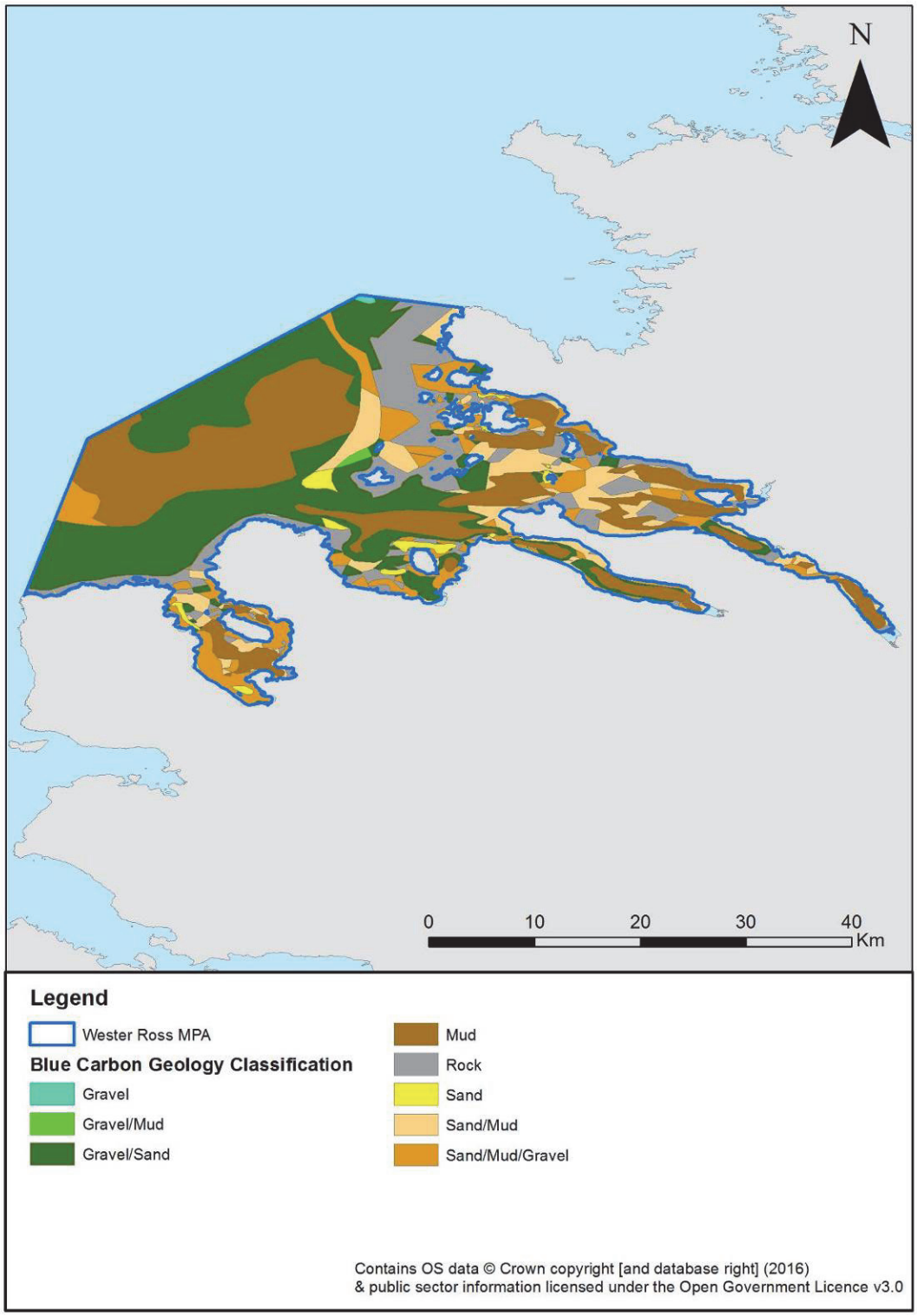
Map of the location of Wester Ross NC MPA

Designation: NC MPA protects a diverse range of seabed habitats, as well as the underlying complex geodiversity. Seapens, flame shell beds, kelp forests and northern feather stars inhabit the burrowed mud and sublittoral course sediment, together with burrowing sea cucumbers between maerl and coarse shell gravel.

Blue carbon designation: Gravel, gravel/mud, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds, *Limaria hians* beds, maerl beds, *Modiolus modiolus* beds, *Mytilus edulis* beds, seagrass beds and subcanopy algae (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Wester Ross	605 823	10 786	1 749 297	14 489

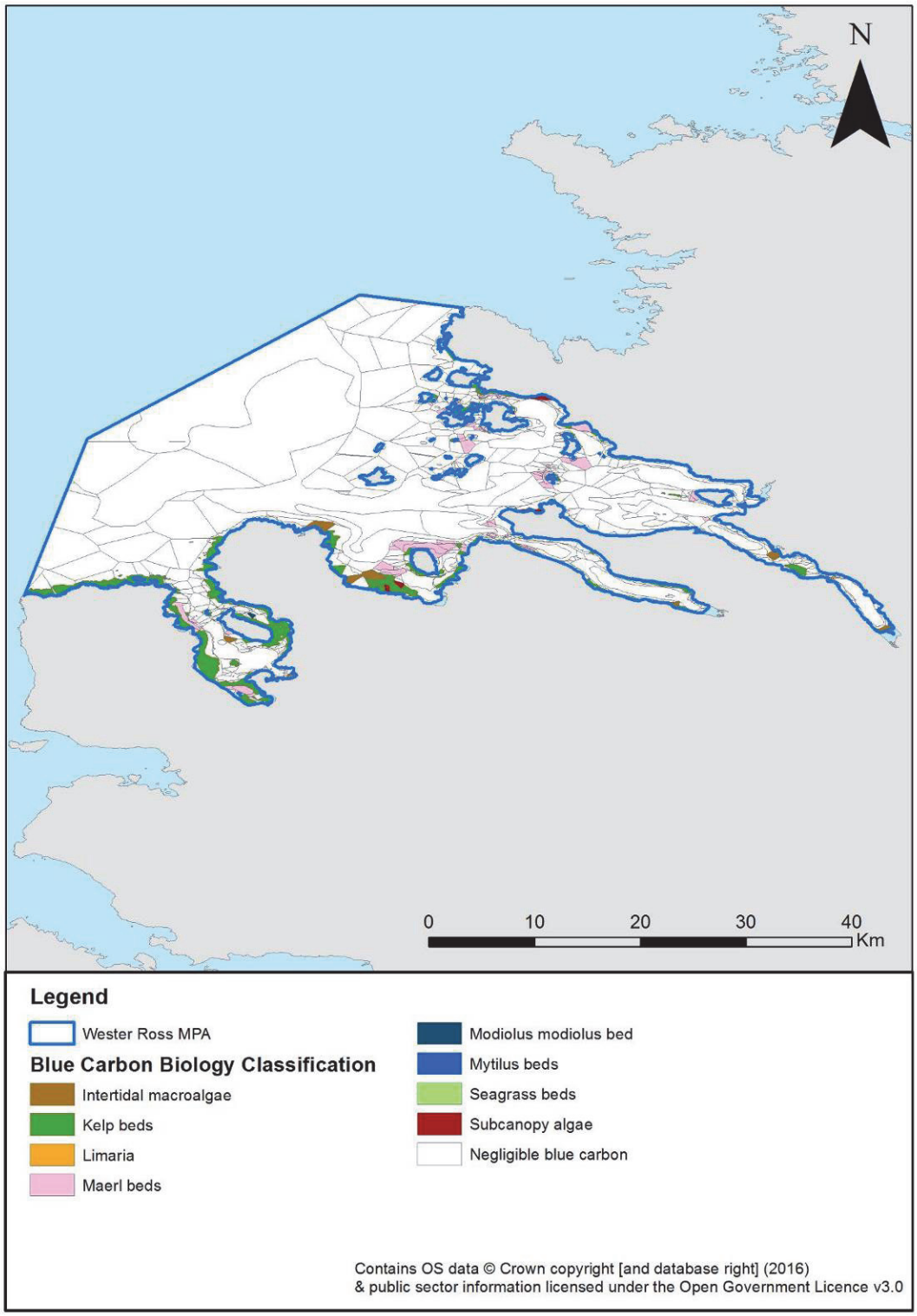
(SS: standing stock, seq: sequestration, prod: production)



Map of Wester Ross NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Wester Ross	7 862	22 114	6	891 678	1 069

(SS: standing stock, seq: sequestration, prod: production)



Map of Wester Ross NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

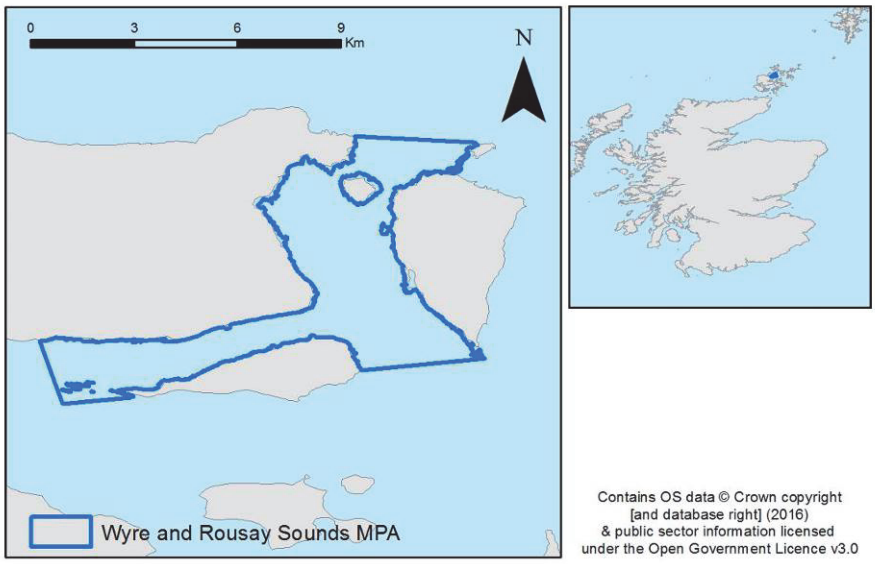
Table showing the calculated IC and OC values for each biological habitat: Wester Ross

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	3.96	0.66	534.34	2.42	0.00	0.00	1935.59	24.62	0.00	0.00	0.00	0.00
Kelp beds	31.44	5.23	21534.37	97.38	0.00	0.00	5900.15	75.04	0.00	0.00	0.00	0.00
Limaria hians	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	4.41	0.00	0.00	0.00
Maerl beds	14.28	2.38	0.00	0.00	1056.83	98.85	0.00	0.00	891199.46	99.95	0.00	0.00
Modiolus modiolus bed	0.12	0.02	0.00	0.00	4.71	0.44	0.00	0.00	471.09	0.05	0.00	0.00
Mytilus beds	0.19	0.03	0.00	0.00	7.62	0.71	0.00	0.00	2.94	0.00	0.00	0.00
Negligible blue carbon	549.66	91.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seagrass beds	0.08	0.01	19.73	0.09	0.00	0.00	0.00	0.00	0.00	0.00	6.27	100.00
Subcanopy algae	1.20	0.20	25.26	0.11	0.00	0.00	26.46	0.34	0.00	0.00	0.00	0.00
Total	**600.99**	**100.00**	**22113.69**	**100.00**	**1069.17**	**100.00**	**7862.20**	**100.00**	**891677.89**	**100.00**	**6.27**	**100.00**

46. Wyre and Rousay Sounds NC MPA

Location: 59°08.467'N; 002°57.952'W – The Wyre and Rousay Sounds NC MPA sits where the Atlantic and North Sea meet off the Orkney isles, covering the water between the islands of Rousay, Wyre and Egilsay.

Area: 16 km^2



Map of the location of Wyre and Rousay Sounds NC MPA

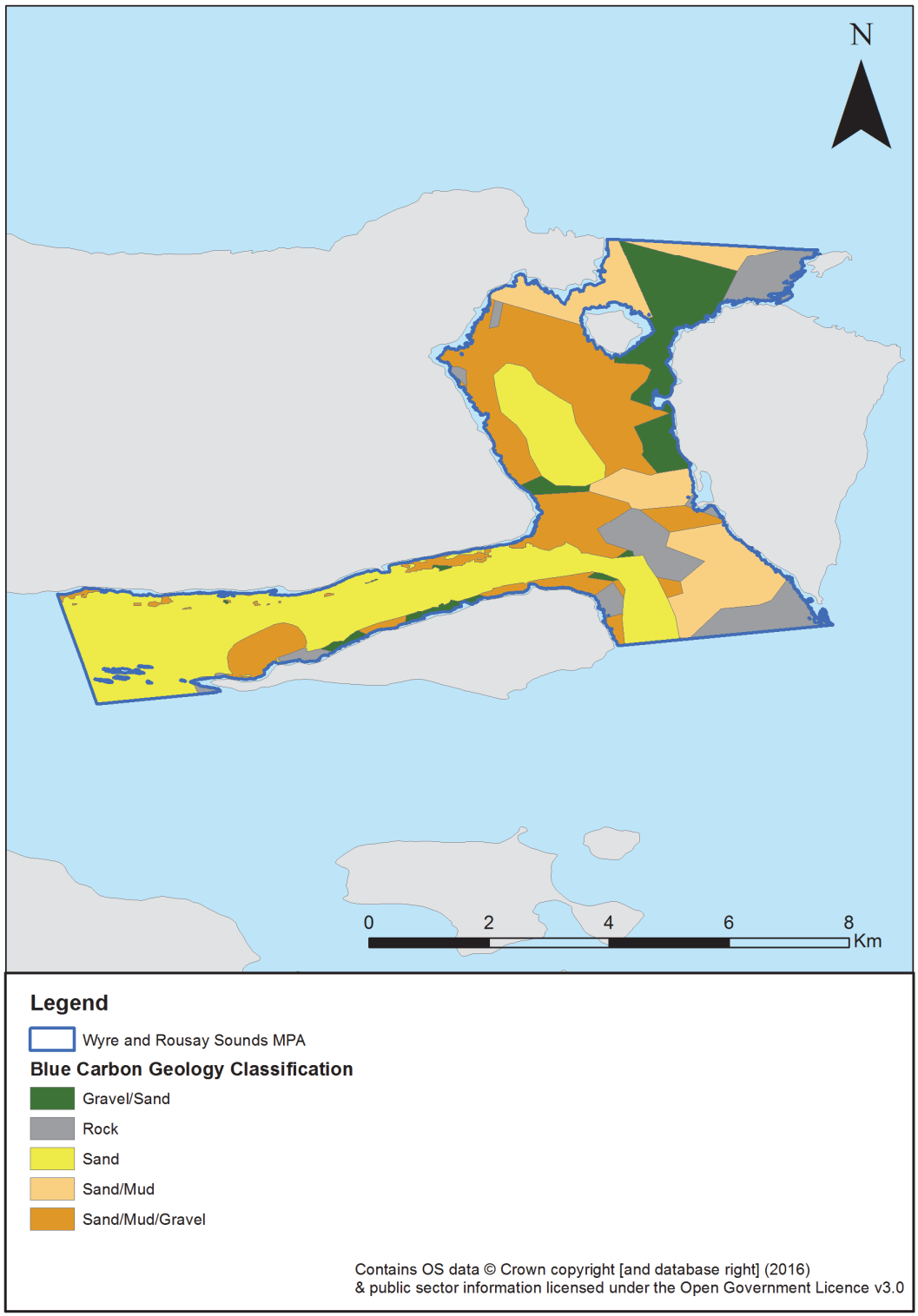
Designation: NC MPA designated to protect maerl beds, and kelp and (red) seaweed communities. Sponges and sea squirts are found in the kelp forests, alongside blue-rayed limpets and topshells. The sea bed is rich in carbonate sediments, and provides a base for the coastal machair to grow in.

The MPA lies within the Orkney carbonate production area, an internationally important example of a non-tropical shelf carbonate system.

Blue carbon designation: Gravel/sand, rock, sand, sand/mud and sand/mud/gravel (geology); intertidal macroalgae, kelp beds and maerl beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Wyre and Rousay Sounds	12 499	154	61 370	496

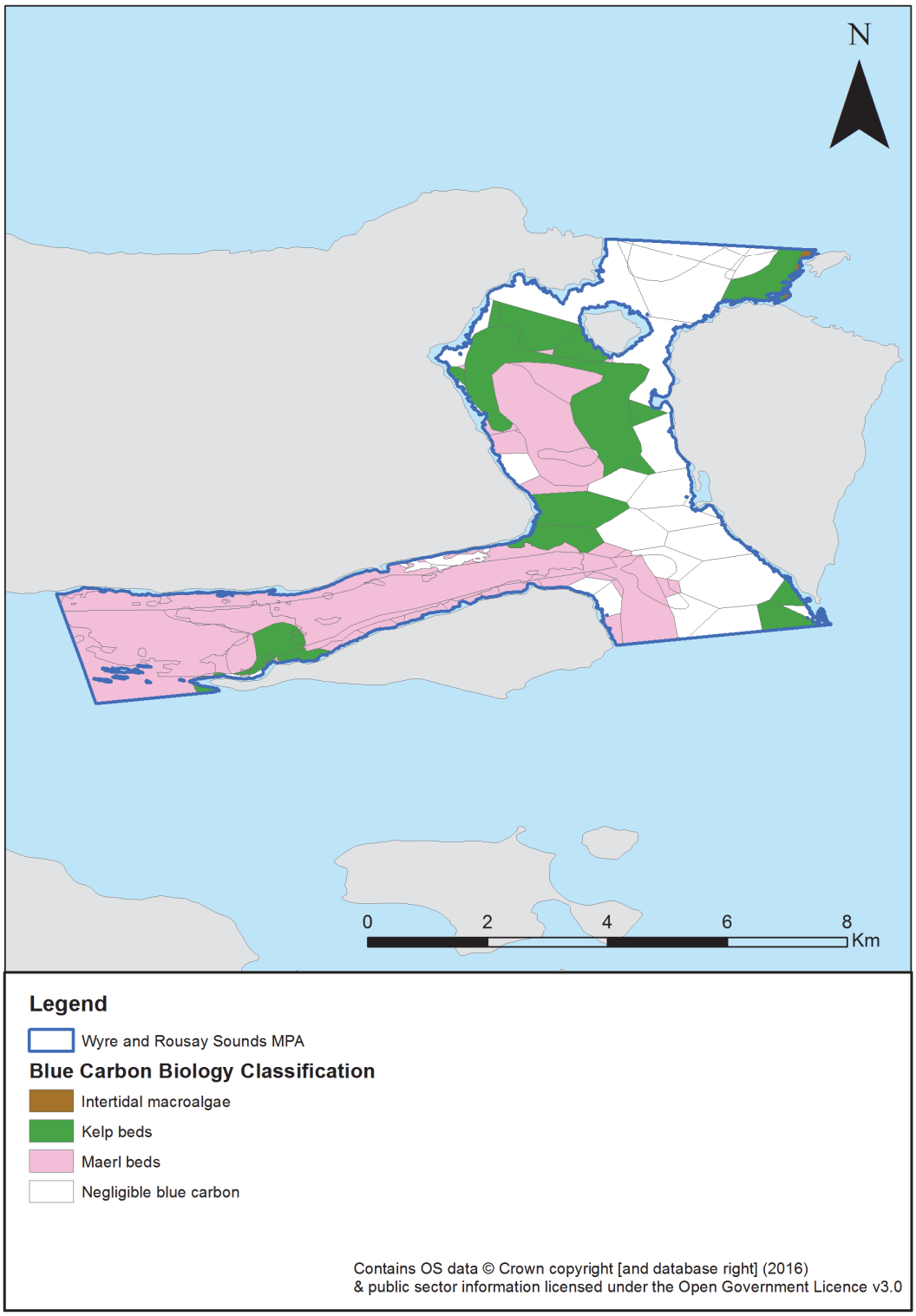
(SS: standing stock, seq: sequestration, prod: production)



Map of Wyre and Rousay Sounds NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Wyre and Rousay Sounds	747	2 669	0	442 291	524

(SS: standing stock, seq: sequestration, prod: production)



Map of Wyre and Rousay Sounds NC MPA showing the different biological. The table above reports the calculated IC and OC habitats

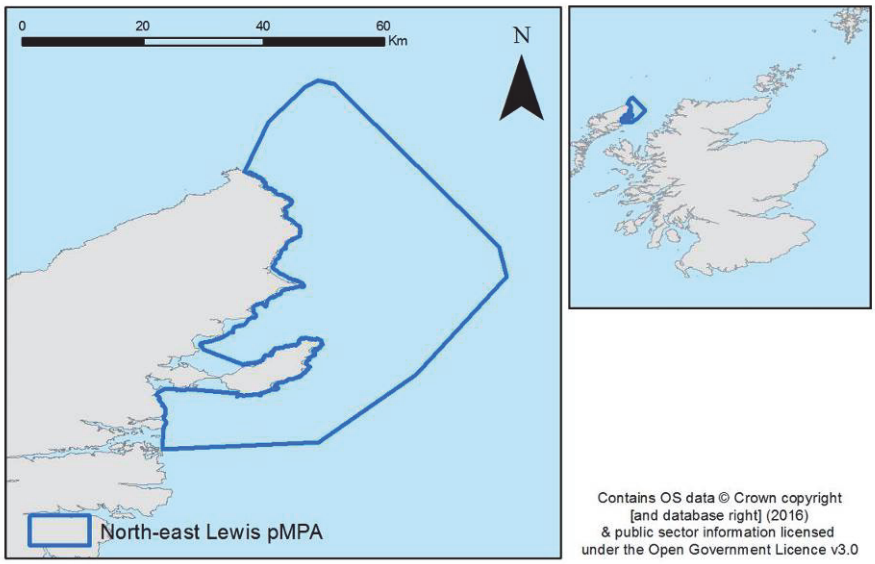
Table showing the calculated IC and OC values for each biological habitat: Wyre and Rousay Sounds

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Intertidal macroalgae	0.03	0.21	4.68	0.18	0.00	0.00	16.96	2.27	0.00	0.00	0.00	0.00
Kelp beds	3.89	23.43	2664.43	99.82	0.00	0.00	730.02	97.73	0.00	0.00	0.00	0.00
Maerl beds	7.09	42.70	0.00	0.00	524.49	100.00	0.00	0.00	442291.33	100.00	0.00	0.00
Negligible blue carbon	5.59	33.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.31	100.00
Total	**16.60**	**100.00**	**2669.11**	**100.00**	**524.49**	**100.00**	**746.98**	**100.00**	**442291.33**	**100.00**	**3.31**	**100.00**

47. North-east Lewis Proposed NC MPA

Location: The proposed NC MAP is located to the north east of the Isle of Lewis, extending from the Butt of Lewis to the South and the Eye Peninsula.

Area: 884 km^2



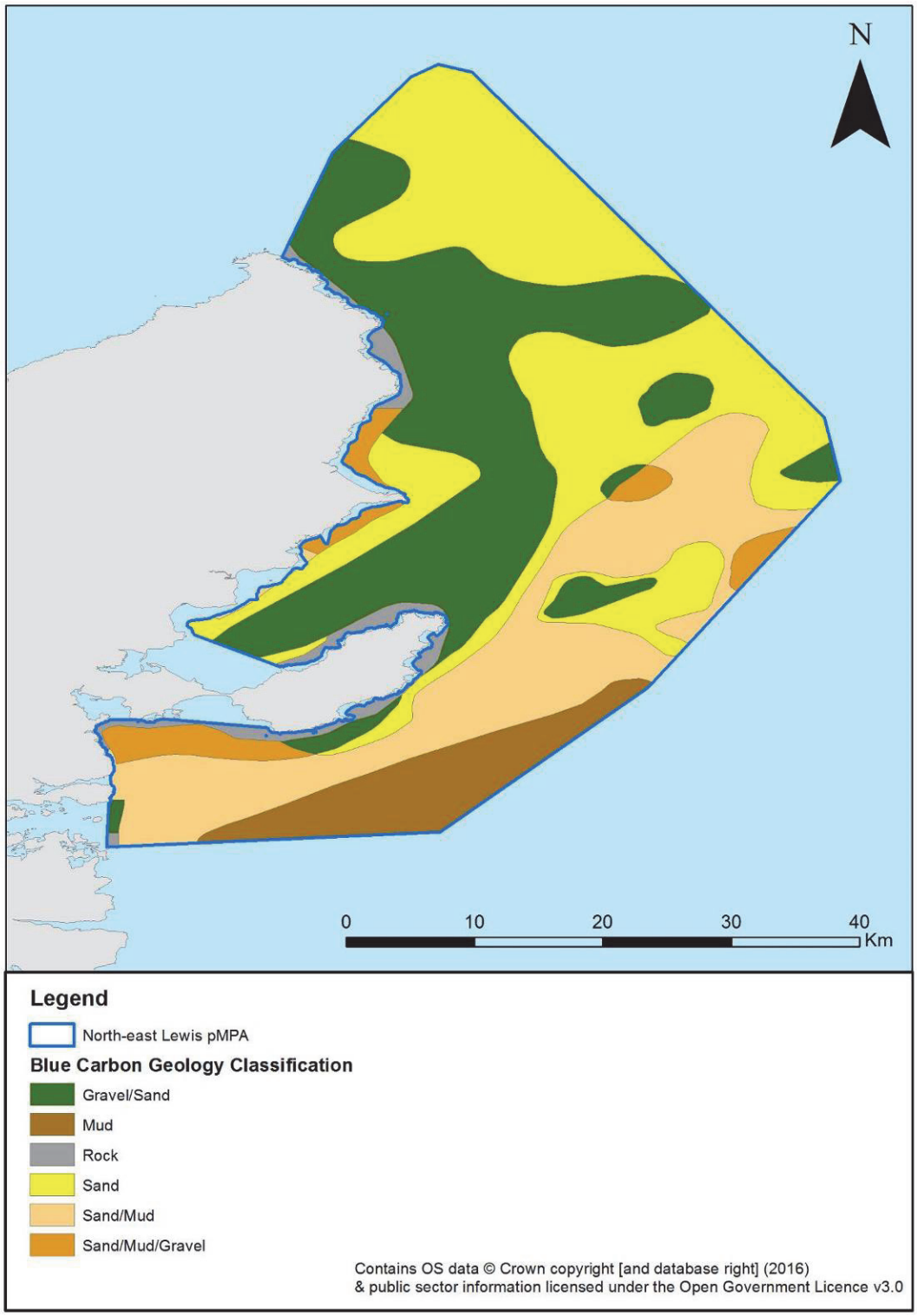
Map of the location of North-east Lewis Proposed NC MPA

Designation: The NC MPA proposal is for four protected features, Risso's dolphin, sandeels and geodiversity features associated with the Quaternary of Scotland and Marine Geomorphology of the Scottish Shelf Seabed.

Blue carbon designation: Gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae and kelp beds (biology).

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
North-east Lewis Proposed	711 131	9 271	4 023 325	31 160

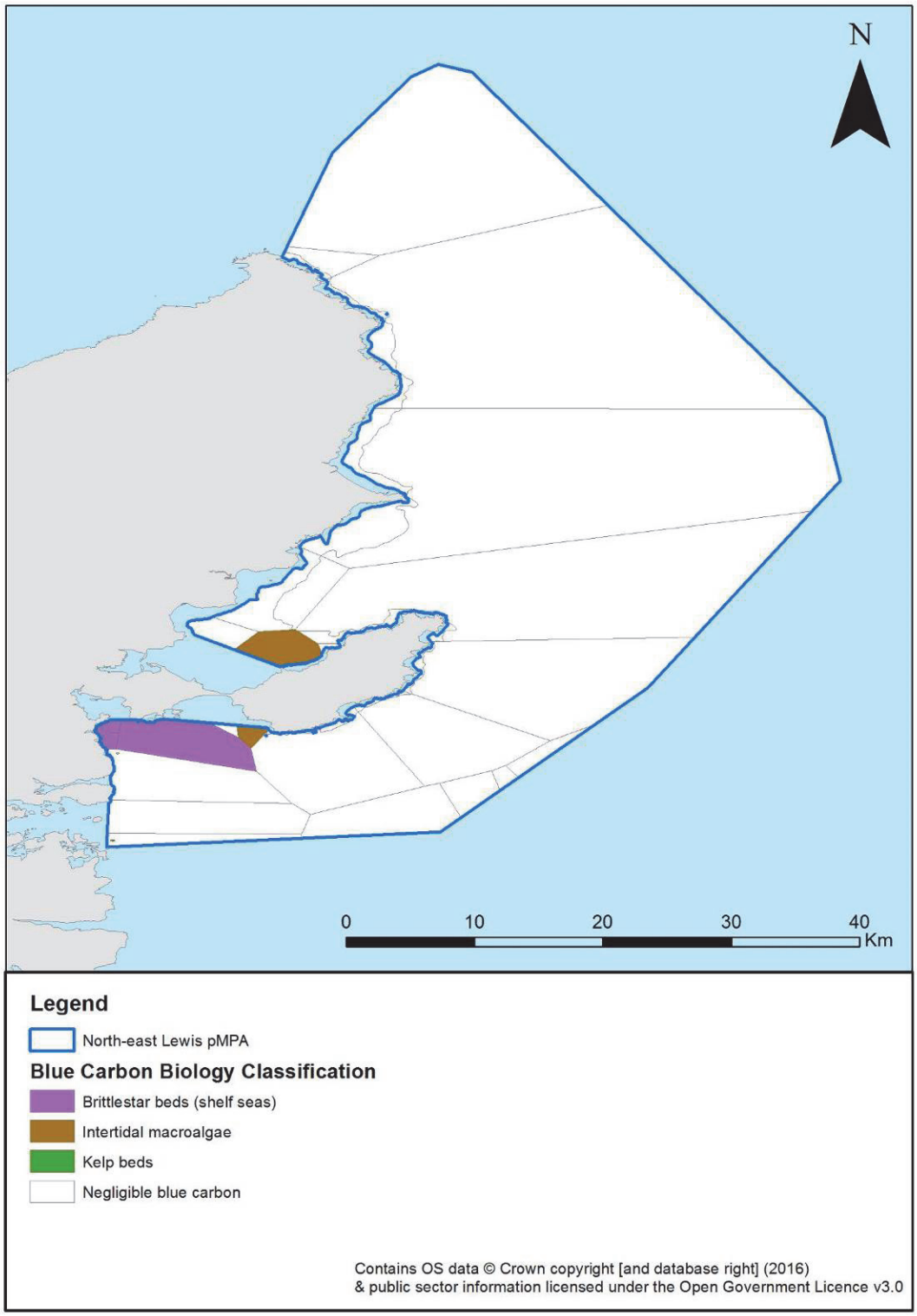
(SS: standing stock, seq: sequestration, prod: production)



Map of North-east Lewis Proposed NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
North-east Lewis Proposed	4 110	1 150	0	0	1 374

(SS: standing stock, seq: sequestration, prod: production)



Map of North-east Lewis Proposed NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

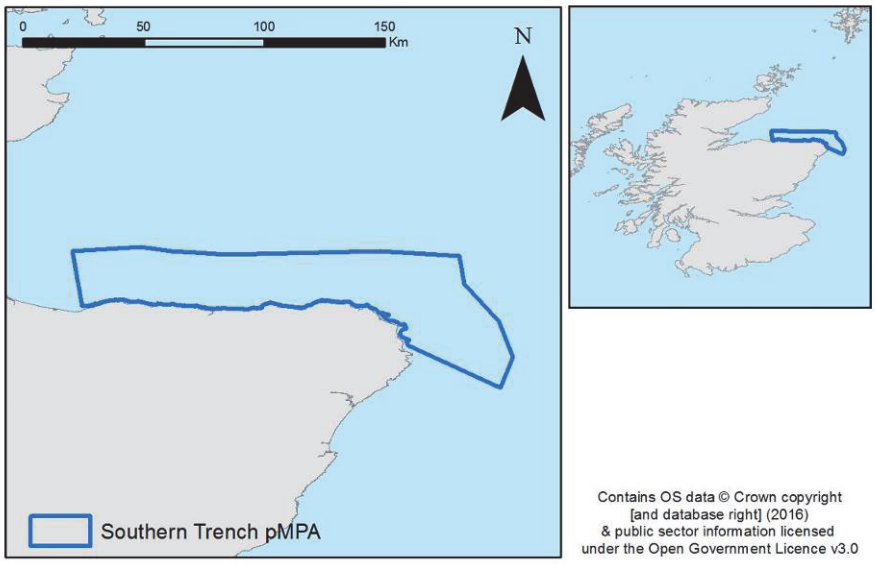
Table showing the calculated IC and OC values for each biological habitat: North-east Lewis

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	16.75	1.90	0.00	0.00	1373.79	100.00	0.00	0.00	0.00	-	0.00	-
Intertidal macroalgae	8.39	0.95	1133.18	98.51	0.00	0.00	4104.82	99.89	0.00	-	0.00	-
Kelp beds	0.03	0.00	17.17	1.49	0.00	0.00	4.70	0.11	0.00	-	0.00	-
Negligible blue carbon	858.61	97.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	-
Total	**883.79**	**100.00**	**1150.34**	**100.00**	**1373.79**	**100.00**	**4109.52**	**100.00**	**0.00**	**-**	**0.00**	**-**

48. Southern Trench Proposed NC MPA

Location: The NC MPA is shaped around the Southern Trench, a large undersea valley consisting of an area of deep water (~200 m), extending along the south of the outer Moray Firth.

Area: 2487 km^2



Map of the location of Southern Trench Proposed NC MPA

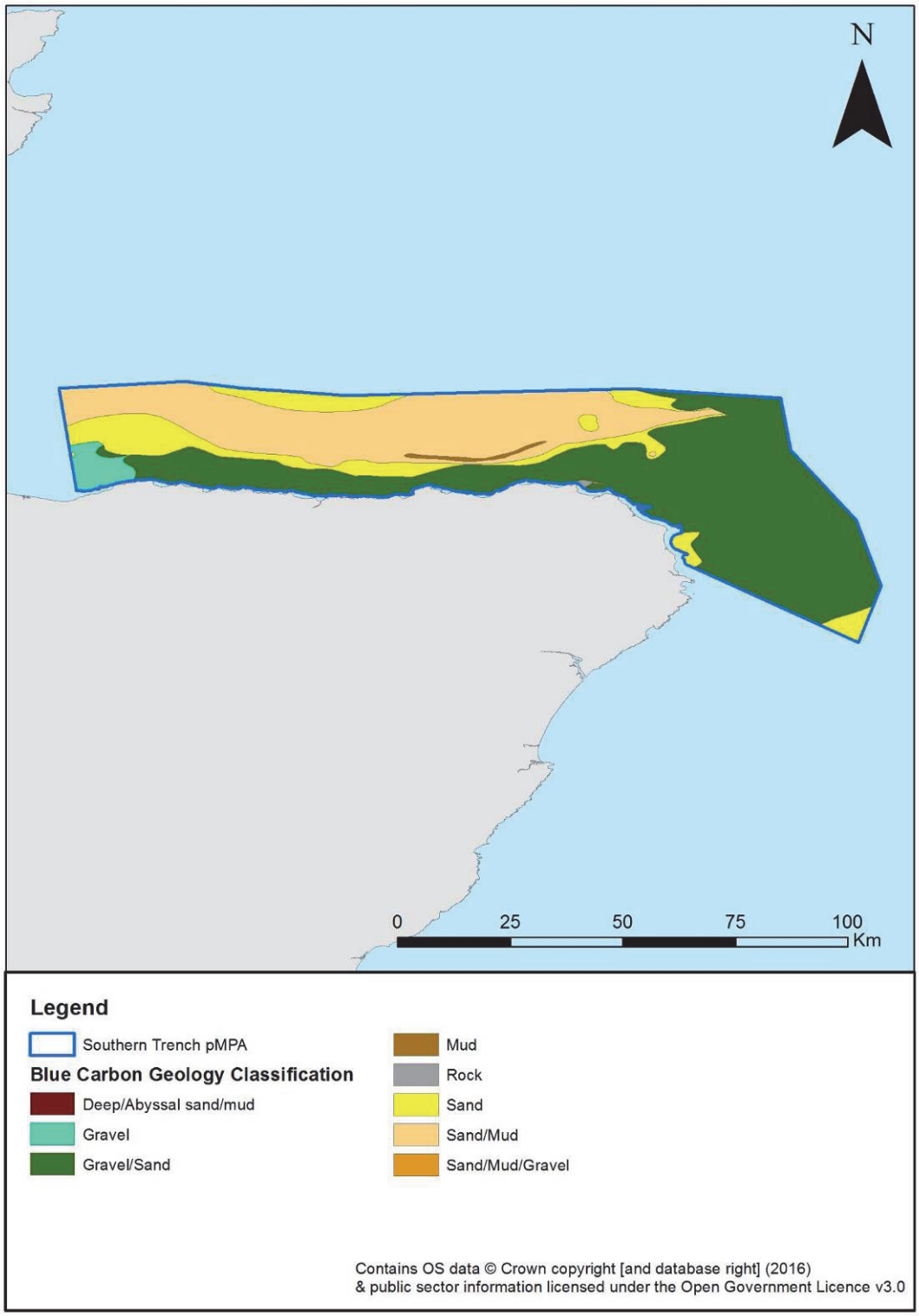
Designation: The NC MPA is a unique example of an enclosed glacial seabed basin, considered important in the understanding of ice sheet drainage patterns. The designation is related to features associated with the Quaternary of Scotland and submarine mass movements. From a biological prospective the NC MPA forms a backdrop for four protected features, minke whale, burrowed mud, fronts and shelf deeps. Frontal zones are produced in the waters off Fraserburgh, these fronts can concentrate nutrients and plankton and are often associated with pelagic biodiversity hotspots.

The NC MPA proposal also overlaps the marine part of the Troup, Pennan and Lion's Heads SPA.

Blue carbon designation: Deep/Abyssal sand/mud, gravel, gravel/sand, mud, rock, sand, sand/mud and sand/mud/gravel (geology); brittlestar beds, intertidal macroalgae,kelp beds. *Mytilus edulis* beds and subcanopy algae (biology

Geology	SS OC (t)	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Southern Trench Proposed	1 883 175	21 729	11 474 976	89 293

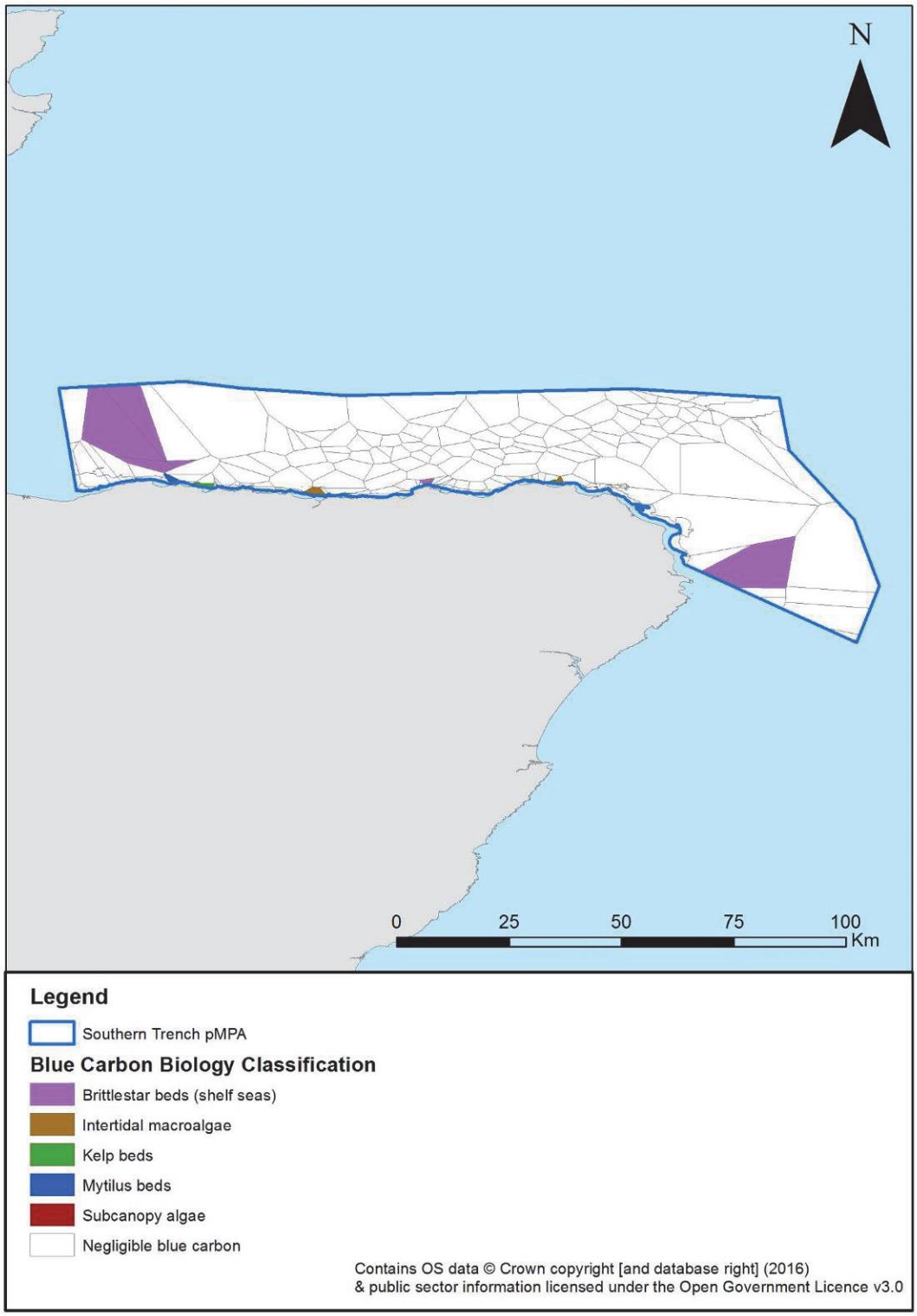
(SS: standing stock, seq: sequestration, prod: production)



Map of Southern Trench Proposed NC MPA showing the different geological habitats. The table above reports the calculated IC and OC

Biology	SS OC (t)	Prod. OC (t yr^{-1})	Seq. OC (t yr^{-1})	SS IC (t)	Prod. IC (t yr^{-1})
Southern Trench Proposed	3 361	3 721	0	30	18 250

(SS: standing stock, seq: sequestration, prod: production)



Map of Southern Trench Proposed NC MPA showing the different biological habitats. The table above reports the calculated IC and OC

Table showing the calculated IC and OC values for each biological habitat: Southern Trench

Biology habitats	Sum of Area Km^2	% Total area	Production OC (t yr^{-1})	% Total production OC	Production IC (t yr^{-1})	% Total production IC	Standing Stock OC t	% Total Standing Stock OC	Standing Stock IC t	% Total Standing Stock IC	Sequestration OC (t yr^{-1})	% Total Sequestration OC
Brittlestar beds (shelf seas)	221.61	8.91	0.00	0.00	18171.63	99.57	0.00	0.00	0.00	0.00	0.00	-
Intertidal macroalgae	5.18	0.21	699.36	18.80	0.00	0.00	2533.35	75.37	0.00	0.00	0.00	-
Kelp beds	4.41	0.18	3021.27	81.20	0.00	0.00	827.79	24.63	0.00	0.00	0.00	-
Mytilus beds	1.95	0.08	0.00	0.00	77.90	0.43	0.00	0.00	29.99	100.00	0.00	-
Negligible blue carbon	2253.38	90.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Subcanopy algae	0.01	0.00	0.20	0.01	0.00	0.00	0.21	0.01	0.00	0.00	0.00	-
Total	**2486.53**	**100.00**	**3720.83**	**100.00**	**18249.54**	**100.00**	**3361.35**	**100.00**	**29.99**	**100.00**	**0.00**	**-**

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