Joint Nature Conservation Committee

Ecological Overview

WEST OF SCOTLAND DEEP-SEA MARINE RESERVE

MARCH 2020

This Ecological Overview of the West of Scotland deep-sea marine reserve provides an overview of our ecological understanding of the deep-sea marine reserve; both in terms of the protected features and the geographic area more broadly with regards to its functional significance. The following documents provide further information about the West of Scotland deep-sea marine reserve and should be read in conjunction with this Ecological Overview:

Data Confidence Assessment – provides an overview of JNCC's confidence in the data underpinning presence and extent for the protected features of the deep-sea marine reserve.

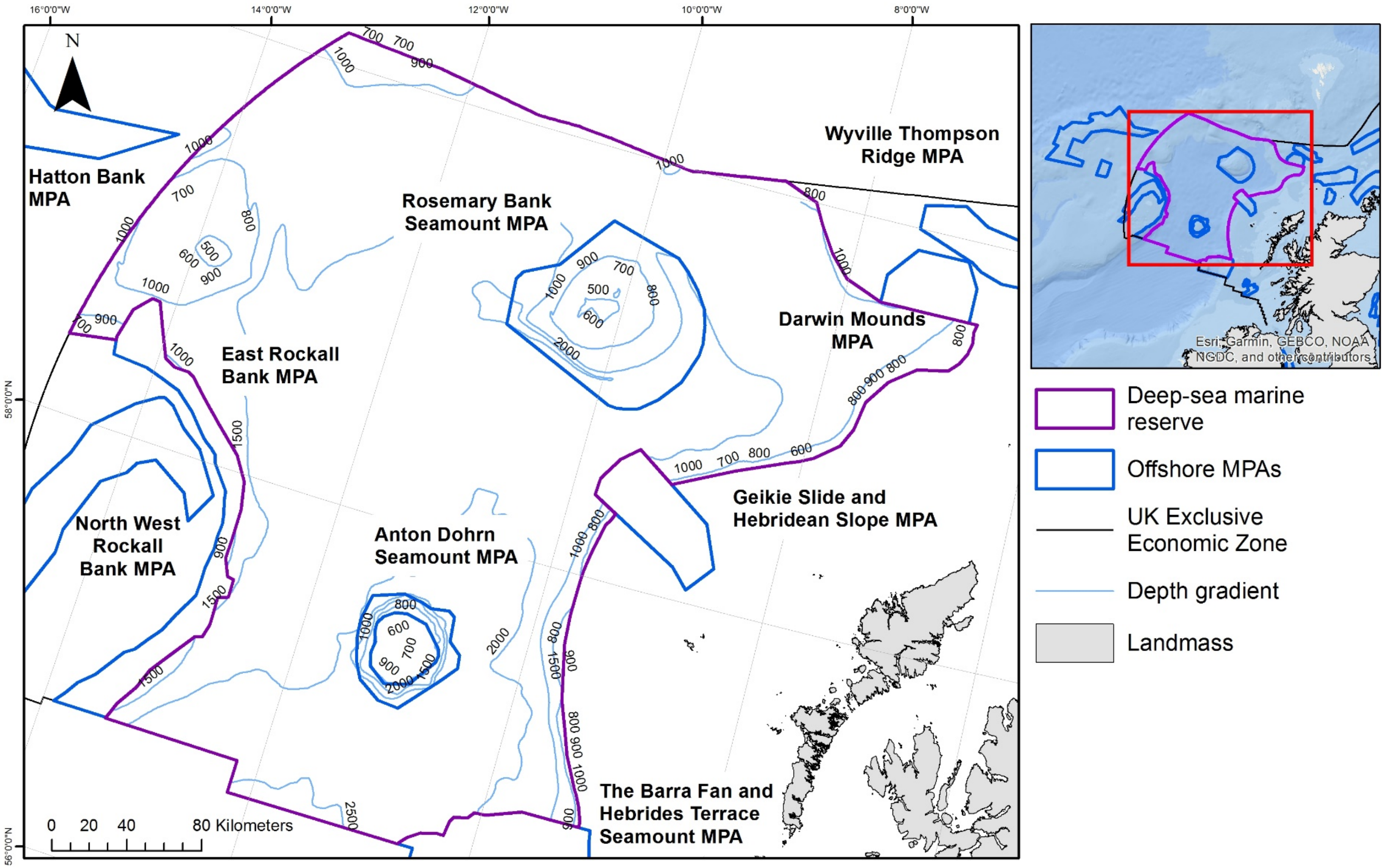
Conservation and Management Advice - provides an overview of the conservation objectives for the protected features of the deep-sea marine reserve and the management measures considered necessary to best achieve those objectives.

1. Background

The West of Scotland deep-sea marine reserve has been identified to support the Scottish Government's commitment to further the protection of deep-sea ecosystems in the seas around Scotland. This document provides an overview of our ecological understanding of the West of Scotland deep-sea marine reserve; both in terms of the protected features and the geographic area more broadly with regards to its functional significance. The boundary of the deep-sea marine reserve follows approximately the 800m depth contour and extends to the edge of British Fisheries Limits out to 200 nautical miles (see Figure 1).

The deep-sea marine reserve boundary excludes most of the existing MPAs within the Rockall Trough area. Although Anton Dohrn Seamount Special Area of Conservation (SAC) does fully overlap with the West of Scotland deep-sea marine reserve, as a different type of site designation with different underlying legislation it will remain an MPA in its own right. The top of Anton Dohrn Seamount falls outwith the SAC boundary however and is encompassed by this deep-sea marine reserve.

Details of the evidence base underpinning the protected features of this deep-sea marine reserve are provided in the Data Confidence Assessment. Conservation Objectives and Management Advice has also been produced outlining the conservation objectives of the protected features of the deep-sea marine reserve and the management measures considered necessary to best achieve those.



Map Projection: Europe Albers Equal Area Conic.

Figure 1. Location of the West of Scotland deep-sea marine reserve

2. Overview of ecological significance

The West of Scotland deep-sea marine reserve is 107,718km^2 in size. It covers a diverse marine landscape to the west of Scotland; from the steep gradient of the continental slope across the sediment plains of the Rockall Trough, to the slopes of George Bligh Bank and Rockall Bank with two isolated seamounts (Anton Dohrn and Rosemary Bank) (Figure 1). It is the geological and geomorphological features of the deep-sea marine reserve that define this marine landscape, with volcanic igneous rock protrusions forming the seamounts and the large banks at the western extent of the deep-sea marine reserve. Slide deposits are a characteristic feature along the Scottish continental slope, while other geomorphological and glacial remnant features such as sediment wave fields, scour moats, turbidite accumulations and iceberg plough marks form the landscape of the seabed (Brooks *et al.,* 2011). The interaction of these features with ocean currents determines the sediment types we find across the seabed, and these are represented by the protected sedimentary habitat features of the deep-sea marine reserve; **offshore deep-sea muds** and **offshore subtidal sands and gravels** and the biological communities that inhabit them. A particular type of muddy habitat, **burrowed mud** is also a protected feature of the deep-sea marine reserve. Burrowed mud supports a range of burrowing megafauna such as mud shrimps (*Calocaris macandreae* and *Callianassa subterranean*). The 'bioturbation' or burrowing activity of these species (amongst others such as polychaete worms) mixes the sediment and allows oxygen to penetrate deeper into otherwise anoxic layers (Hughes, 1998). This habitat is important for nutrient exchange between the water column and sediments. Where bioturbation occurs at larger scales, it can result in the fixing of carbon that may assist in climate regulation (Doggett *et al.,* 2018).

All of the protected biodiversity features of the deep-sea marine reserve (including the sedimentary features described above) are Priority Marine Features (PMFs); these are habitats and species considered to be of conservation priority in Scotland's seas. **Coral gardens, cold-water coral reefs** (including *Lophelia pertus*a reefs), **deep-sea sponge aggregations**, **seamount communities**, **Leafscale gulper shark** (*Centrophorus squamosus*), **Gulper shark** (*Centrophorus granulosus*), **Orange roughy** (*Hoplostethus atlanticus*) and **Portuguese dogfish** (*Centroscymnus coelolepis*) are also listed as OSPAR Threatened and/or Declining habitats or species in the North-East Atlantic region[1]. **Burrowed mud** (including sea-pens), **coral gardens**, **cold-water coral reefs** (including *Lophelia pertus*a reefs), **deep-sea sponge aggregations** and **seamount communities** are all Vulnerable Marine Ecosystems (VMEs) as identified by the joint International Council for the Exploration of the Sea (ICES) / North-west Atlantic Fisheries Organisation (NAFO) Working Group on Deep-Water Ecology (WGDEC) for the North-east Atlantic[2]. These are habitats/ecosystems that are classified as vulnerable due to the characteristics they possess e.g. they maybe fragile and susceptible to damage.

Deep-sea sponge aggregations, **cold-water coral reefs** and **coral gardens** are known as 'habitat formers'. The physical structures they create provide an environment that other species can colonise, and they support a diverse community of associated species (OSPAR 2009, 2010 a and b). Sponges may also play a significant role in silicon regulation by providing a long-term sink for silicon (Maldonado *et al.,* 2012, Tréguer and Rocha, 2013), while coral skeletons act as a long-term store of carbon (OSPAR, 2009).

---

[1] Available at: https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

[2] Available at: http://ices.dk/marine-data/data-portals/Pages/vulnerable-marine-ecosystems.aspx

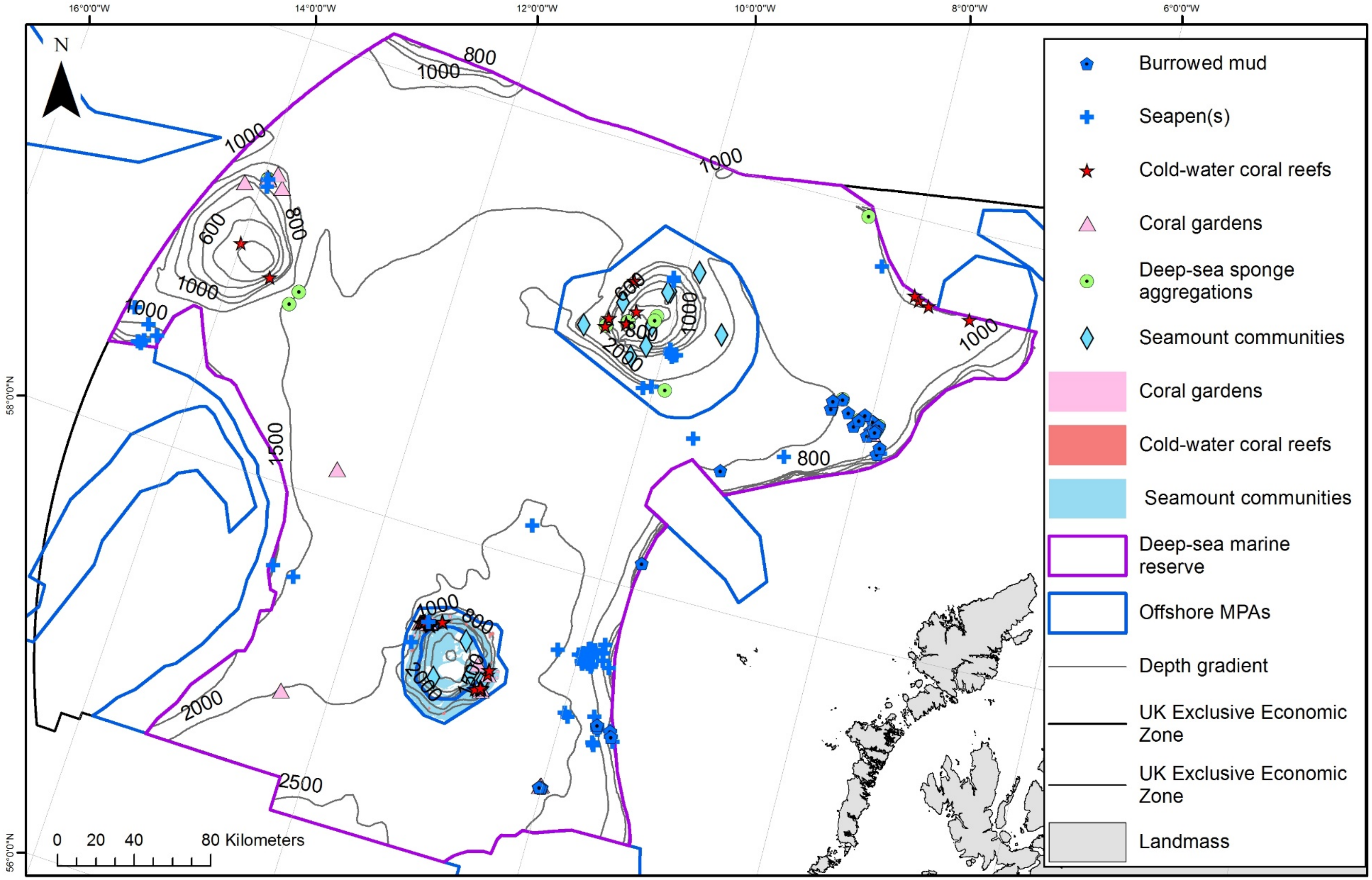
The deep-sea marine reserve has six deep-sea fish species as protected features (**Blue ling** (*Molva dypterygia*)**, Orange roughy, Leafscale gulper shark / Gulper shark**[3]**, Portuguese dogfish** and **Round-nose grenadier** (*Coryphaenoides rupestris*). The deep-sea marine reserve contains characteristic habitat for **Round-nose grenadier, Leafscale gulper shark, Gulper shark,** and **Portuguese dogfish. Round-nose grenadier** can be considered resident within the deep-sea marine reserve, and it is one of only 17 locations globally where **Gulper shark** has been reported (White *et al.,* 2013). Studies have documented that the Rockall Trough is important to the life cycle of **Portuguese dogfish**, but current scientific understanding remains unclear as to whether this is for the full life cycle of the species (Moura *et al.*, 2014) or if this species migrates south along the continental slope of Europe to give birth, before returning to the more northern feeding areas (Verissimo *et al.,* 2011). Moreover, there is limited understanding as to the specific locations within the deep-sea marine reserve that may be of importance to the life history of this species and further scientific research is required. The deep-sea marine reserve contains (spawning) areas important to the life history of **Blue ling** (Large *et al*., 2010). Adult **Orange roughy** form large spawning congregations around seabed features such as summits and steep slopes; the deep-sea marine reserve includes two seamounts features and areas of the continental slope at suitable depths for **Orange roughy**. Spawning aggregations had not been identified at these locations prior to the cessation of the **Orange roughy** fishery, but the habitat protected is similar to that in locations where large spawning aggregations have been recorded e.g. at the Hebrides Terrace Seamount (Priede, 2018).

The two **seamounts** (Rosemary Bank and Anton Dohrn) are protected as large-scale features of the deep-sea marine reserve and for the rich **seamount communities** they support. The seamounts create a very different environment to the sedimentary plains of the Rockall Trough. The dynamic hydrographic environment surrounding the seamounts increases food availability to suspension feeders such as sponges and corals that colonise the **seamounts**. Many fish species such as **blue ling**, Black scabbard (*Aphanopus carbo*) and mesopelagic lantern fish (*Lampanyctus* sp.) are attracted to seamounts for feeding or spawning. The concentrations of fish and other prey species around **seamounts** also attracts larger predators and marine mammals such as Atlantic white-sided dolphin (*Lagenorhynchus acutus*) and Sperm whale (*Physeter macrocephalus*), which have been observed in high numbers around these features (Clarke 2007, Macleod *et al.,* 2003, Weir *et al.,* 2001).

[3] Due to historical difficulty in identifying Gulper shark and consequent difficulty distinguishing between records of Leafscale Gulper Shark and Gulper Shark both of these species considered together as proposed protected features of the West of Scotland deep-sea marine reserve.

3. Protected biodiversity features

Protected biodiversity features (see figures 2 – 4)	**Priority Marine Feature** *Presence of features of exceptional scientific importance for which Scotland is considered to be a stronghold and/or are characteristic (i.e. distinctive or representative) of Scotland's marine environment*	**OSPAR Threatened and Declining** *Presence of features under threat and/or subject to decline across the North-east Atlantic*	**Vulnerable Marine Ecosystem** *Presence of ICES Vulnerable Marine Ecosystem*
Burrowed mud (including Sea-pens)	**Y**	**Y**	**Y**
Coral gardens	**Y**	**Y**	**Y**
Cold-water coral reefs (including *Lophelia pertus*a reefs)	**Y**	**Y**	**Y**
Deep-sea sponge aggregations	**Y**	**Y**	**Y**
Offshore deep-sea muds	**Y**		
Offshore subtidal sands and gravels	**Y**		
Seamount communities	**Y**	**Y**	**Y**
Seamounts	**Y**	**Y**	
Blue Ling (*Molva dypterygia*)	**Y**		
Leafscale gulper shark (*Centrophorus squamosus*) / Gulper shark (*Centrophorus granulosus*)	**Y**	**Y**	
Orange roughy (*Hoplostethus atlanticus*)	**Y**	**Y**	
Portuguese dogfish (*Centroscymnus coelolepis*)	**Y**	**Y**	
Round-nose grenadier (*Coryphaenoides rupestris*)	**Y**		



Map Projection: Europe Albers Equal Area Conic.

JNCC

marine scotland

Scottish Government
Riaghaltas na h-Alba
gov.scot

Figure 2. The West of Scotland deep-sea marine reserve and the distribution of protected Vulnerable Marine Ecosystem (VME) features

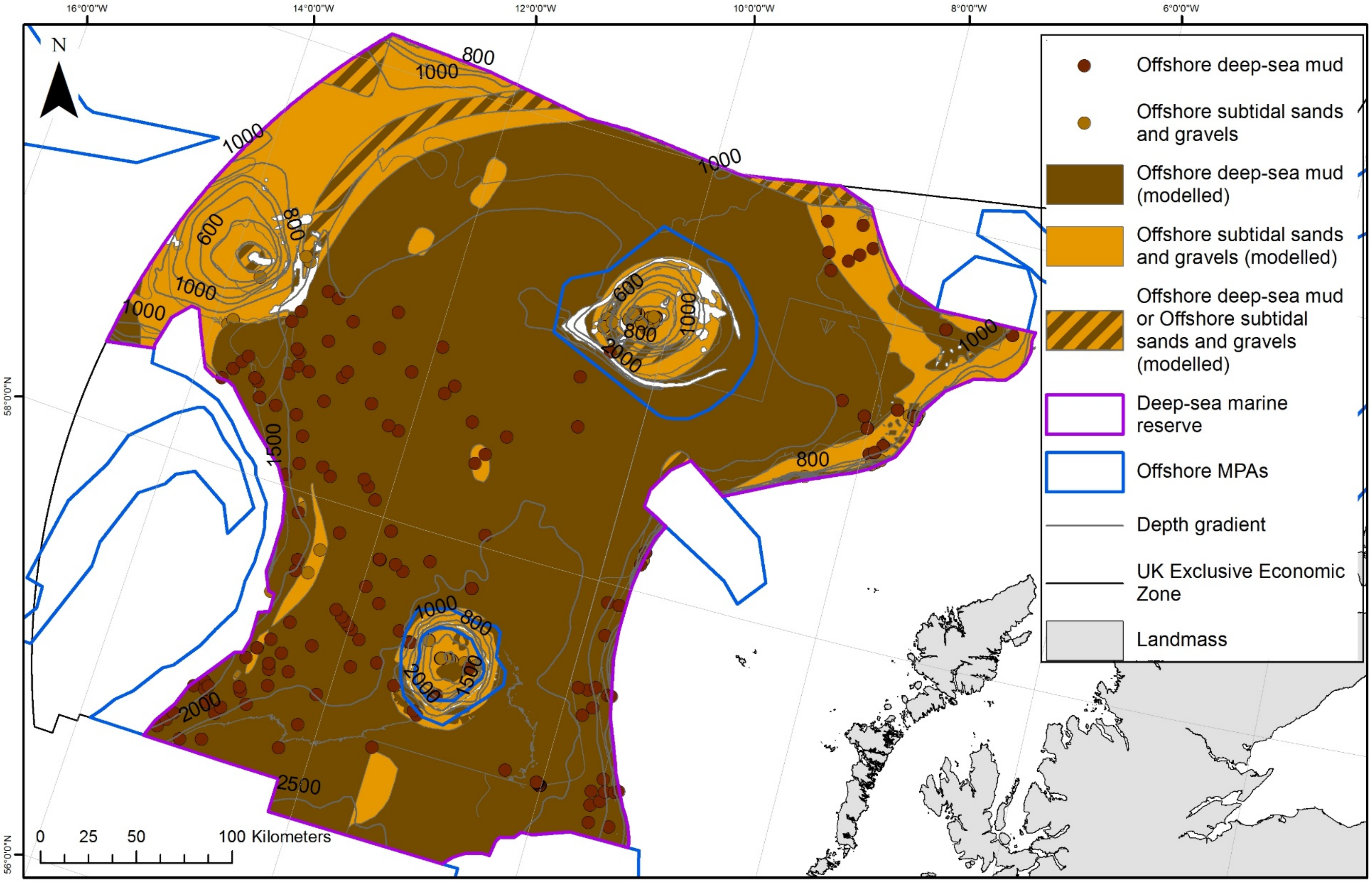
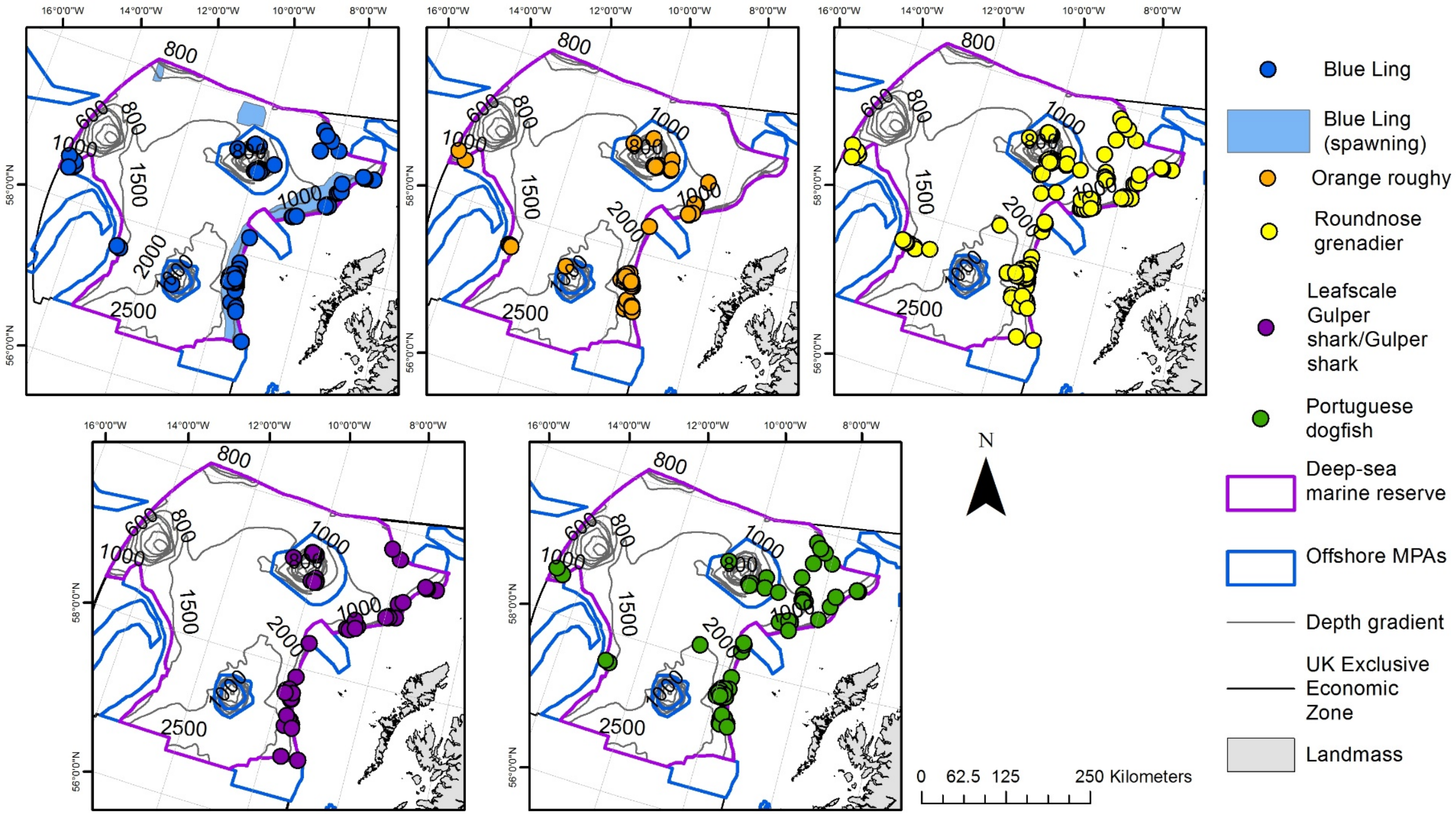


Figure 3 The West of Scotland deep-sea marine reserve and the distribution of protected sedimentary habitat features



Map Projection: Europe Albers Equal Area Conic.

JNCC marine scotland Scottish Government Riaghaltas na h-Alba gov.scot

Figure 4 The West of Scotland deep-sea marine reserve and the distribution of protected deep-sea fish species

4. Protected geodiversity features

Protected geodiversity features	**Key Geodiversity Areas** (see figure 5)	**Signficance of Key Geodiversity Areas** (after Brooks *et al.,* 2011)
Scour moats, sediment drifts, sediment wave field, bioherm reefs, biogenic sediment mounds, parasitic cones, slide scars, cliff, slide deposit, seamount (Palaeogene igneous centre).	Anton Dohrn Seamount (and adjacent basin floor)	Large Palaeogene deep ocean bathymetric rises such as Anton Dorn seamount are a characteristic feature of the deep-waters to the west of Scotland. Dating evidence obtained from Anton Dohrn has been scientifically important in advancing understanding of the volcanic history of the North Atlantic.
Scour moats, erosional scour fields, sediment drifts, bioherm reefs, parasitic cones, iceberg ploughmarks, slide scars, large bank (Palaeogene igneous centre).	George Bligh Bank (and adjacent basin floor)	This area contains representative examples of bedforms produced by deep-ocean currents. Core data from this area also contain scientifically important information regarding the influence of North Atlantic Deep Water (NADW) flow stretching back to Eocene times.
Erosional scour fields, sediment drifts, sediment wave fields, parasitic cones, slide scars, slide deposits, small scale ridges, large bank (Palaeogene igneous centre).	North-east Rockall Bank (and adjacent basin floor)	This area contains a number of representative examples of geodiversity interest features which are commonly associated with deep ocean rise settings. Investigations from this area looking at the relationship between sedimentation patterns and palaeoceanographic changes have a key role to play in furthering scientific understanding of ocean circulation and the wider global climate system.
Iceberg ploughmarks, sediment wave field, turbidite accumulations, scour moat, bioherm reefs, slide scars, parasitic cones, seamount (Palaeogene igneous centre).	Rosemary Bank Seamount (and adjacent seafloor)	Rosemary Bank seamount is scientifically important because it forms a large obstacle to the flow of deep-ocean currents, producing a drift-moat complex surrounding the seamount. Geological investigations into the origins of Rosemary Bank seamount have been instrumental in furthering scientific understanding of the volcanic history of the North Atlantic volcanic province.
Prograding wedge, iceberg ploughmarks, slide deposits, ice-proximal and ice-contact	Summer Isles to Sula Sgeir Fan	This is a classic glacial landscape formed by repeated glaciation over at least the last 500,000 years. The outstanding

facies (e.g. mega-scale glacial lineations), sub-glacial tills, ice-distal and glacimarine facies.		range of glacial interests coupled with the exceptional detail of the record means this region should be regarded as internationally important. It is also a scientifically important area for developing understanding of Quaternary ice sheet dynamics, deglaciation of the last British-Irish Ice Sheet, Lateglacial climate change, and the style and rates of fjord sedimentation. Numerous representative examples of various different glacial moraine types are contained within this area.
Slide deposits, continental slope turbidite canyons, turbidite accumulations, scour moat, sediment wave field.	The Barra Fan	The Barra Fan may be regarded as a key geodiversity area because the morphology and sedimentary sequences identified on the fan are scientifically important in furthering understanding of regional-scale palaeoceanographic changes as well as fluctuations in the extent of the last British Irish Ice Sheet. Is also contains several other features representative of key features and earth system processes in the region.
Slide scars.	The Peach Slide Complex	Large-scale slides are a characteristic feature along the Scottish continental slope the Peach Slide Complex is one of five examples that are considered broadly representative of the range of slides found in Scottish offshore waters.

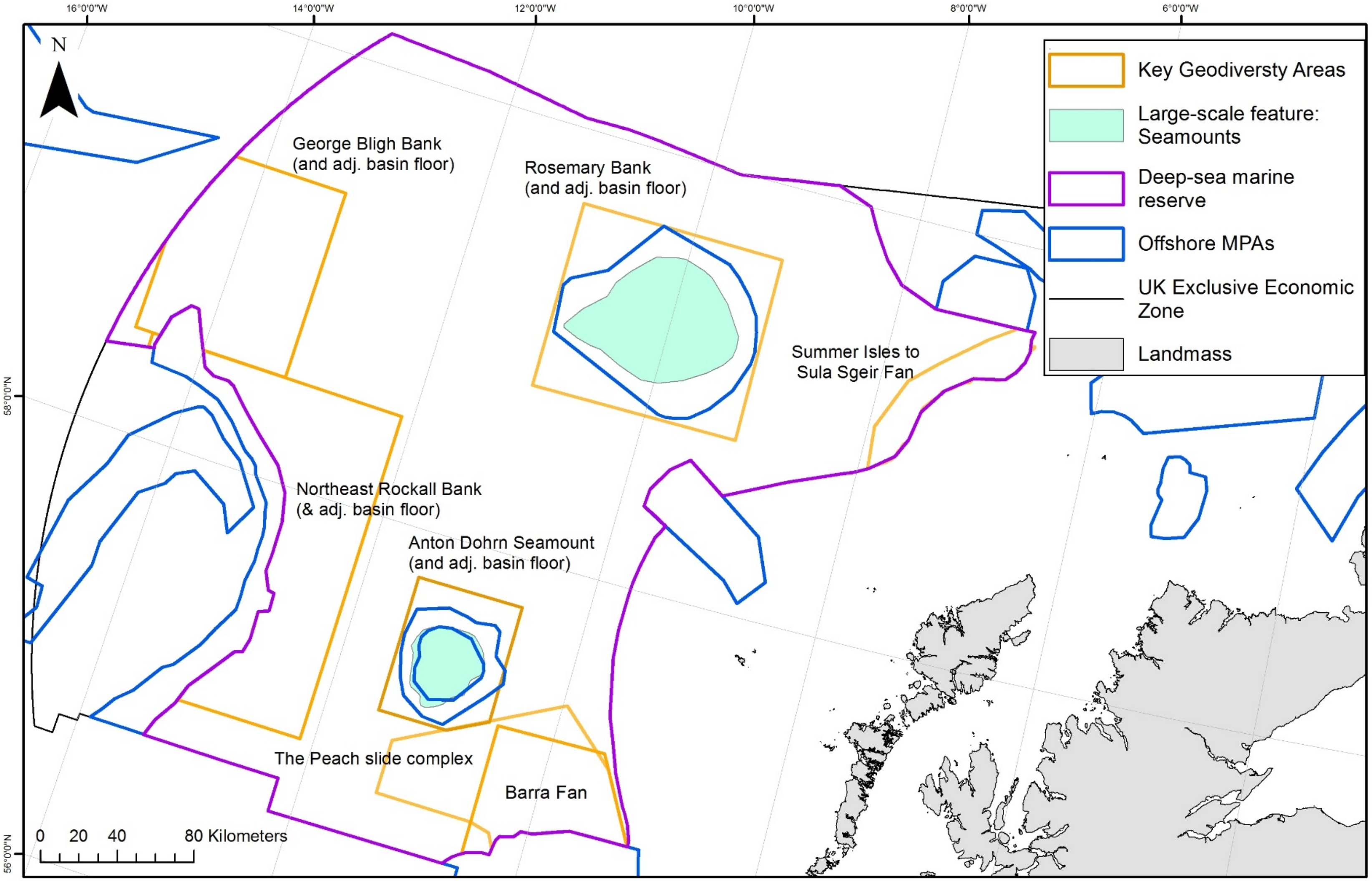


Figure 5 The West of Scotland deep-sea marine reserve and the distribution of protected Key Geodiversity Areas, and large-scale features (seamounts)

5. Ecological significance of the protected features of the West of Scotland deep-sea marine reserve

The West of Scotland deep-sea marine reserve protects five different types of VME habitat across its extent[2]. These are habitats that have been identified as particularly vulnerable to impacts from human activities due to their life history traits and characteristics such as slow growth rates, late age of maturity, low or unpredictable recruitment, and structural fragility (FAO, 2009). The three-dimensional structures formed by these habitats as they grow provides habitat and refugia for other species to colonise. In addition, they often play a functional role within the ecosystem providing spawning or nursery grounds for fish species or provide ecosystem services such as biogeochemical cycling.

Deep-sea sponge aggregations are found in many parts of the world's oceans, but the community composition of these habitats varies in different regions (OSPAR 2010a). Four different sub-types of deep-sea sponge aggregations occur in UK waters, the West of Scotland deep-sea marine reserve contains examples of three of these: encrusting sponge dominated aggregations; Boreal ostur aggregations and stalked sponge grounds (Henry and Roberts, 2014b). The biogeographic boundary formed by the Wyville Thompson ridge results in different communities present in the West of Scotland deep-sea marine reserve to the west compared with the area to the north of this geographic boundary, and therefore it is important to protect the diversity of the sponge aggregations found within the West of Scotland deep-sea marine reserve (OSPAR 2010a). **Deep-sea sponge aggregations** are particularly sensitive to impacts from human activities due to their longevity, slow growth, unknown reproductive patterns and slow recovery from physical damage (OSPAR, 2010a). Of the anthropogenic pressures that are known to severely impact deep-sea sponge aggregations, fishing and climate change are considered to present the highest degree of threat, both of which operate over large spatial scales. In addition, sponge grounds may be locally disturbed by activities such as oil drilling and, in the future, potentially seabed mining (Colaço and Osinga 2018). Based on annual growth rates, it is predicted that individual structural sponges can take decades to reach average sizes within the population (Leys and Lauzon, 1998; Klitgaard and Tendal, 2004). The large upright structures formed by many of the species that form these sponge aggregations makes them vulnerable to damage from any activity that comes into contact with the seafloor but in particular bottom contact fishing gears (OSPAR, 2010a). Sponges are a highly diverse group of organisms and have a range of different morphotypes depending on species and/or environmental conditions (Schönberg and Fromont, 2014). It is this structural complexity that creates habitat and refugia for other benthic organisms. Rockfish, especially Sebastes species, live in sponge openings and in between individual sponges, (OSPAR, 2010a). Filter feeders use the sponges as an elevated perch, while other species such as hydroids, zoanthrians, bryozoans, and ascidians live on the surface of sponges themselves or within the canals in the sponge's tissue (Klitgaard and Tendal, 2004). Sponges also perform other functional roles within the ecosystem. They filter feed organic matter out of the water column and are potentially an important link in the flow of nutrients between the pelagic and benthic environment (Maldonado *et al.,* 2012; Cathalot *et al.,* 2015). They may also play a role in silicon regulation by providing a long-term sink for silicon (Maldonado *et al.,* 2012, Tréguer and Rocha, 2013).

The subtypes of **coral garden** found in the UK were described by Henry and Roberts (2014a). These can occur across a wide range of substrata from hard to soft sediments which will determine the species present. The species composition of **coral gardens** varies at a regional or biogeographic scale but will also vary across the deep-sea marine reserve due to the range of environmental conditions that occur on the seamounts, George Bligh Bank and across the Rockall Trough (Henry and Roberts, 2014a). The West of Scotland deep-sea marine reserve represents examples of four of the five coral garden subtypes found in UK waters: soft-bottom bamboo coral garden characterised by *Acanella arbuscular*, deep cup coral gardens characterised by *Caryophyllia spp*. cup corals, lace coral gardens characterised by *Pliobothrus* or *Stylaster spp*. and gorgonian coral garden characterised by large gorgonians. Analysis of the life span of octocorals indicates that some of the large colony forming species can live for centuries (OSPAR, 2010b). The presence of coral garden habitat adds structural complexity to the marine environment OSPAR (2010b), however **coral gardens** function differently to other VMEs such as **cold-water coral reefs** and **deep-sea sponge aggregations,** for example they do not form reefs or baffle sediments (Henry and Roberts, 2014a). **Coral garden** taxa exhibit critical differences in ecological functioning, for example there are much higher incidences of obligate and parasitic symbioses associated with gorgonians than with reef forming corals (OSPAR, 2010b). This means coral gardens are likely to host assemblages that are distinct from those found at **cold-water coral reefs** or **deep-sea sponge aggregations** (Henry and Roberts, 2014a). The large upright structure of some coral garden species means they are vulnerable to physical damage. OSPAR (2010b) consider **coral gardens** very sensitive to impacts from human activities due to their longevity, unknown reproductive patterns and uncertain recovery from damage.

Cold-water coral reefs records in the OSPAR north-east Atlantic region are considered globally important because 92% of global records of *Lophelia pertusa* coral reefs occur in this region (OSPAR, 2009). This habitat has a fragile structure and slow growth rate. The growth rate is thought to be about 6 mm per year implying that reefs of about 1.5 m high are about 250 years old (OSPAR, 2009). However, successful recruitment events may occur only once a decade (Stone *et al.,* 2015), which limits the ability of this habitat to recover from damage. The growth of **cold-water coral reefs** forms a complex structural habitat that is utilised by many other species. The biological diversity of the reef community can be three times as high as the surrounding soft sediment (OSPAR, 2009). Reefs commonly harbour abundant sessile suspension feeders and a multitude of grazing, scavenging and predatory invertebrates such as echiurans (e.g. *Bonellia* sp.), molluscs (e.g. *Acesta excavata*), crustaceans (*Pandalus* spp., *Munida* spp.) and echinoderms (e.g. *Cidaris* spp., *Gorgonocephalus* sp.) (OSPAR, 2009). This habitat also provides other ecosystem functions and services within the marine environment; coral skeletons are a long-term store of carbon (OSPAR, 2009), although the coral calcification process emits carbon dioxide.

The habitat **burrowed mud** is created by the activity of burrowing species such as the mud shrimp (*Calocaris macandreae* and *Callianassa subterranean*). Burrowing activity and bioturbation of the sediment allows oxygen to penetrate deep into otherwise anoxic layers of sediment. This influences the rate at which nutrients such as nitrate and phosphate, and metals such as manganese are recycled (Hughes, 1998). The mosaic of disturbance patches created by the burrowing activity across the sediment supports diversity in the sediment communities, and the burrows themselves are often colonised. For example, numerous small bivalves and polychaete worms have been observed on the walls of large spoon worm (*Maxmuelleria lankesteri* and *Echiurus echiurus*) burrows (Nickell *et al.,* 1995a). These are not obligate burrow residents but probably benefit from the spoon worms' irrigation activities which supply both oxygenated water and food and they may additionally gain some refuge from predators (Hughes, 1998). This habitat contributes to food web dynamics as the species creating or utilising burrows can be found in the stomachs of benthic-feeding fish species, some of which will be exploited by commercial fisheries (Fletcher *et al.,* 2011) and the habitat is also known to provide nursery areas for a number of fish including hake (*Merluccius merluccius*) (OSPAR, 2010c). Sea-pens are frequently associated with burrowed mud habitat. Relatively little is known about the population dynamics of sea-pens in UK waters but data from other species suggest that they are likely to be long-lived and slow-growing, with patchy and intermittent recruitment (Hughes, 1998, MarLIN, 2019). The tall sea-pen *Funiculina quadrangularis* is likely to be the most vulnerable to physical damage because of its brittle stalk and inability to retract into the sediment (Hughes, 1998). Studies in the North Sea have shown that where bioturbation occurs on large scales it can result in the fixing of carbon that may assist in climate regulation (Doggett *et al.,* 2018).

The West of Scotland deep-sea marine reserve protects **offshore deep-sea muds** and **offshore subtidal sands and gravels** where they occur across the extent of the deep-sea marine reserve. These are representative of deep sea (Atlantic bathyal and upper abyssal zone) sedimentary habitats in the wider North-east Atlantic region. Water depths within the study area range between 800m and approximately 2,500m at the deepest point (Doggett *et al.,* 2018). The deep-sea areas to the west of Scotland support large expanses of mud and fine clay with a variety of coarse sediments present in places. The distribution of sediment types within the study area is influenced by the presence of geological and topographic features e.g. seamounts, the continental slope, ridges, troughs and banks and their associated oceanic currents (Doggett *et al.,* 2018). The broad deep-sea sedimentary communities of this region were described by Davies *et al.,* (2006): between 800-1,000m communities may be characterised by burrowed muds and include brittlestars (ophiuroids), anemones and cut-throat eels, from 1,000 – 1,400m communities can be characterised by the hexactinellid sponge *Pheronema carpenteri* which is often restricted to this depth band and can overlap with high abundances of the brittlestar *Ophiocten gracilis,* from 1,000 – 1,400m in areas with high surface productivity and particle flux, multinucleate xenophyophores may also occur. Xenophyophores are the world's largest single celled organisms and are only found in deep-sea environments. And finally, from 1,500 – >2,000m high abundances of the octocoral *Acanella arbuscula* and brittlestars are found (Doggett *et al.,* 2018). Microbial communities found within these sedimentary habitats play a role in the cycling and retention mechanisms of carbon, nitrogen, silica, sulphur, phosphorous and methane in the deep sea (Doggett *et al.,* 2018). Throughout the deep-sea the biological, physical, and chemical properties of the ecosystem operate in combination, forming complex processes that result in globally important ecosystem services (Doggett *et al.,* 2018). Species characteristic of **offshore deep-sea muds** include polychaete worms, brittlestars (ophiuroids), bivalves, sea-pen and crustaceans. **Offshore subtidal sands and gravels** are characterised by urchins, brittlestars (ophiuroids), sea cucumbers (holothurians), gastropods and polychaete worms. Many fish species, including commercial species are directly linked to deep-sea sedimentary habitats, for feeding, reproductive or nursery areas, for example Anglerfish (*Lophius piscatorius*) and Atlantic halibut (*Hippoglossus hippoglossus*) inhabit sandy and muddy substrates and **blue ling** feed on benthic fish species of flatfish, gobies and rockling (Doggett *et al.,* 2018).

Six species of deep-water fish are protected features of the West of Scotland deep-sea marine reserve; **Blue ling** (*Molva dypterygia*); the **Gulper shark** (*Centrophorus* granulosus) and **Leafscale Gulper shark** (*Centrophorus squamosus*); **Orange roughy** (*Hoplostethus atlanticus*); **Portuguese dogfish** (*Centroscymnus coelolepis*); and the **Round-nose grenadier** (*Coryphaenoides rupestris*).

Blue ling is endemic to the North Atlantic, though is more frequently encountered in the east, from the SW Barents Sea to the SW of Ireland, than the west (Priede, 2018). In the Rockall Trough, **Blue ling** occur between depths of 500 to 1250 m. Important spawning areas for this species have been identified within the deep-sea marine reserve, lying along the continental slope, to the north of Rosemary Bank and to the south-west of Lousy Bank. Other areas within the deep-sea marine reserve have been suggested as important for spawning through the tracking of fishing vessels (Large *et al.,* 2010) but remain to be corroborated by observational data.

The **Gulper shark** is a globally distributed deep-water shark species, which has been reported from depths of 98 – 1700 m around the margins of the world's oceans (Bañón *et al.,* 2008; White *et al.,* 2013). Historically, however, there has been confusion over the identification of the species in the *Centrophorus* genus at the latitudes of the deep-sea marine reserve, leading to uncertainty in some of the records arising from this area (see Priede, 2018, for a review). Nonetheless, several confirmed records exist and given the gulper shark is probably under-represented in scientific deep-water trawls, due to its large size and ability to actively avoid nets, it is likely that it is present within the deep-sea marine reserve. Indeed, the deep-sea marine reserve is one of only 17 areas globally from which the species has been reported (White *et al.,* 2013) and the deep-sea marine reserve encompasses a large area of potentially suitable habitat for the **Gulper shark**.

The **Leafscale gulper shark** is atypical for the *Centrophorus* genus in that it is comparatively straightforward to identify due to unique features of its dermal denticles (Veríssimo *et al.,* 2014). It shares the same worldwide distribution as the **Gulper shark** and is found at depths between 415 – 2400 m (Froese and Pauly, 2017). In the NE Atlantic it is found from the Barents Sea and around Iceland to the waters of the NW African coast. The **Leafscale gulper shark** is caught in more deep-water hauls, though at low abundances, than any other elasmobranch within the deep-sea marine reserve (Neat *et al.,* 2015). In the NE Atlantic, areas around Iceland have been suggested as important for pupping (Moura *et al.,* 2014). However, the importance of the deep-sea marine reserve in the **Leafscale gulper shark's** life cycle remains unclear due to a lack of juveniles and pregnant females in samples from taken from this area (Moura *et al.,* 2014; Priede, 2018). The **Leafscale gulper shark** is potentially resident throughout the deep-waters of the deep-sea marine reserve which covers the centre of the species distribution in the north-east Atlantic (Priede, 2018). Neat *et al.*, (2015) found **Leafscale gulper shark** to be distributed throughout the deep-sea marine reserve with peak abundance at around 800 m depth. A proportion of the population (shallower than 800 m) may fall outwith the deep-sea marine reserve, particularly on the continental slope to the west of Scotland (Priede, 2018).

The **Orange roughy** has a global distribution, but in the northern hemisphere it is confined mostly to the continental slopes, offshore banks, ridges and seamounts of the NE Atlantic at its preferred depth range (180 -1800 m) (Branch, 2001). It is best known for the sequential depletions experienced by its fisheries during the 1980s and 1990s (e.g. Ryan, 2017). In the Rockall Trough they were found on slopes between 500 – 1750 m and were one of the most commonly caught species in the 1000 – 1250 m depth zone (Gordon and Duncan 1987; Mauchline and Gordon 1984a). However, they were essentially rendered commercially extinct in the deep-sea marine reserve due to fishing of spawning aggregations around the Hebrides Terrace Seamount in the early 1990s (Priede, 2018). Given the longevity of the **Orange roughy** (150 years) and the age of first maturity (28 years), even under the current management regime of a zero-total allowable catch, stock recovery is likely to be slow (Priede, 2018). Nevertheless, the deep-sea marine reserve provides suitable habitat for this species at appropriate depths including the continental slope and submarine features (e.g. the two seamount features), which may be important areas for spawning aggregations; the protection of which will help support any population recovery.

The **Portuguese dogfish** has a global distribution and is the world's deepest-living shark species, being reported down to a depth of 3700 m (Forster, 1973). In the NE Atlantic, they are found from Eastern Greenland to West Africa, including throughout the deep-sea marine reserve, where they have been reported from depths of 700 – 1900 m, with a peak abundance at 1300 – 1400 m (Neat *et al.,* 2015). No evidence of genetic differentiation has been found at the scale of the NE Atlantic for **Portuguese dogfish**, perhaps due to large-scale migrations linked to their reproductive cycle; with areas to the west of the British Isles hypothesised as important for breeding (Veríssimo *et al.,* 2011). The deep-sea marine reserve provides suitable habitat where **Portuguese dogfish** occur and may also be important for significant events in their life cycle.

The **Round-nose grenadier** is endemic to the North Atlantic Ocean, being found associated with slopes and banks between depths of 180 – 2600 m in the east and west Atlantic (Priede, 2018). It is one of the more abundant deep-sea fish in the deep-sea marine reserve and amounted to 28% of the entire fish catch at depths from 750 – 1750 m (Mauchline and Gordon 1984b), with all sizes classes from 4 cm and up being present. It is a relatively well studied species in the deep-sea marine reserve, with research beginning in the 1970s and continuing to the present day (see Priede, 2018 for a review). Recent work that used otolith microchemistry on **Round-nose grenadier** sampled from the Rosemary Bank seamount and adjacent areas on the continental slope suggests high levels of post-settlement site fidelity (Regnier *et al.,* 2017). Information such as this on spatial population structure supports the use of area based management tools for this species. **Round-nose grenadier** can be considered resident within the deep-sea marine reserve, where the population contributes towards the economically important wider European deep continental margin stock (Priede, 2018).

Deep-sea fish species are often characterised by slow growth rates and late maturity therefore the recovery of populations from impacts such as overexploitation or bycatch can be slow, for example **Leafscale gulper shark** have been recorded up to 70 years old and estimates for Round-nose grenadier are between 38-70 years old (Priede, 2018).

The deep-sea marine reserve has two **seamounts** as protected features: Anton Dohrn and Rosemary Bank seamount. These large-scale features are OSPAR Threatened and/or Declining habitats and create a different environment to the sedimentary plains of the Rockall Trough. Rising above the seabed to 1,800m and over 1,000m respectively, these large volcanic structures disrupt the flow of oceanographic currents to create a dynamic hydrographic environment. This increases the food availability to suspension feeders such as sponges and corals supporting the growth of habitats such as **cold-water coral reefs**, **coral gardens**, and **deep-sea sponge aggregations**. Anton Dohrn seamount supports **cold-water coral reefs**, and **coral gardens;** and Rosemary Bank seamount supports **cold-water coral reefs, deep-sea sponge aggregations,** and sea-pens. The different environmental conditions found on the summits, flanks and base of seamounts increase the diversity of the communities that are found here. The structural complexity of **cold-water coral reefs**, **coral gardens**, and **deep-sea sponge aggregations** in turn provides a habitat for other species increasing the species diversity of these ‘hot spot’ locations. Many different fish species are attracted to seamounts for feeding or spawning. **Orange roughy** and **Blue ling** both use seamounts as spawning locations, **Blue ling** use the north-west slope Rosemary Bank seamount for spawning (Large *et al.,* 2010). **Orange roughy** occur at both seamounts although it is not known if they spawn here, large spawning aggregations are known to occur at the Hebrides Terrace seamount just south of this deep-sea marine reserve. Other fish species also aggregate here; black scabbardfish occur in higher abundance on Anton Dohrn Seamount than surrounding areas (Neat *et al.,* 2008), and several mesopelagic fish spawn over Anton Dohrn Seamount including Mueller’s pearlside (*Maurolicus muelleri*), glacier lanternfish (*Benthosema glaciale*) and other lanternfish. The complex hydrographic systems around seamounts can have a role in the supply and dispersal of larvae to the wider marine ecosystem (McClain *et al.,* 2009). The concentration of fish around these topographic features also attracts larger predators such as Atlantic white-sided dolphin (*Lagenorhynchus acutus*), which have been observed to aggregate in high numbers around Rosemary Bank seamount (Weir *et al.,* 2001; Macleod *et al.,* 2003). Sperm whale (*Physeter macrocephalus*) have been observed around both seamounts. It is thought the presence of Sperm whale here may indicate higher abundances of cephalopod prey (such as squid), concentrated near seamounts (Weir *et al.,* 2001, Clarke 2007). Many marine mammal species have also been recorded as frequent visitors to seamounts (Evans 1997; Charif *et al.,* 2001; Swift *et al.,* 2002; Macleod *et al.,* 2003).

6. Wider benefits of the West of Scotland deep-sea marine reserve

Ecosystem services

MPAs also have an important role to play in conserving our seas. They enable the focused protection of habitats and species which are essential to the marine ecosystem. This facilitates an increase in ecosystem resilience and recovery of habitats and species where required. Some examples of the ecosystem functions and services provided by the protected features of the West of Scotland deep-sea marine reserve are described below:

Offshore deep-sea muds and **offshore subtidal sands and gravels**

- Microbial communities found within these sedimentary habitats play a role in the cycling and retention mechanisms of carbon, nitrogen, silica, sulphur, phosphorous, methane and nutrients in the deep sea (Danovaro *et al*., 2008; Thurber *et al*., 2014; Corinaldesi 2015). For example:

    - The nitrogen cycle - Microbially mediated processes including nitrification, nitrogen fixation, denitrification and anaerobic ammonium oxidation occur within these sedimentary habitats, providing sources, sinks, and transformation of nitrogen. Nitrogen cycling in the benthos releases nutrients such as nitrate, nitrite and ammonia back into the water column. Nutrients regenerated at the seafloor are ultimately recycled and returned back to the surface through thermohaline circulation (often in areas of upwelling) for the process to start again (Thurber *et al*., 2014 and references within).

    - Methane storage - Vast stores of methane exist in the deep-sea, most of which is trapped either as or by hydrates, one of the key services by deep-sea communities is the rapid consumption of the small proportion that is released. The majority of this happens in the sedimentary environments (Thurber *et al*., 2014 and references within).

- Many fish species, including those of commercial importance, are directly linked to deep-sea sedimentary habitats; for feeding, reproductive or nursery services. For example, Anglerfish and Atlantic halibut inhabit sandy and muddy substrates and **Blue ling** feed on benthic fish species of flatfish, gobies and rockling (FAO, 2018). Indirectly, global fisheries are linked to the deep-sea through nutrient regeneration. Some of the most productive fisheries occurring in areas of strong upwelling, where deep-sea nutrients recycled in the sedimentary habitats are brought back to the surface fuelling primary production and feeding of larger marine species (Thurber et al., 2014)

Burrowed mud

- The ‘bioturbation’ or burrowing activity of animals within the sediment allows oxygen to penetrate deeper into the sediment and influences the rate at which nutrients such as nitrate and phosphate, and metals such as manganese are recycled (Hughes, 1998). Where bioturbation occurs on large scales it can result in the fixing of carbon that may assist in climate regulation (Doggett *et al.,* 2018).

- Bioturbation can also facilitate bioremediation, helping to regulate the decomposition and/or sequestration of organic wastes (Armstrong et al., 2012).

Deep-sea sponge aggregations, cold-water coral reefs and **coral gardens**

- The three-dimensional structures formed by these habitats as they grow provide habitats and refugia for other species to colonise, e.g. deep-water skate species including *Bathyraja richardsoni* have been found to lay their eggs within the framework of cold-water corals (Henry *et al*., 2016).

- Sponges are important in the turnover of energy, organic matter, and inorganic nutrients in the deep-sea including playing a role in silicon regulation by providing a long-term sink for silicon (Maldonado *et al.,* 2012, Tréguer and Rocha, 2013).

- Coral skeletons are a long-term store of carbon (Armstrong *et al.,* 2014).

- Chemicals extracted from both sponges and corals have been investigated for pharmaceutical or biotechnical applications e.g. chitin networks from one species of sponge are effective at absorbing uranium contamination (Ebada *et al.,* 2010, Indraningrat *et al.,* 2016, Laport *et al.,* 2009, Sawadogo *et al.,* 2015, Schleuter *et al.,* 2013 and Ruiz-Torres *et al.,* 2017).

- Sponges might have evolved 100 million years earlier than their oldest recognizable fossils and can contribute to shedding light on the early steps of animal evolution (Zunberge *et al*., 2018).

Climate change resilience

The designation of the West of Scotland deep-sea marine reserve supports resilience of the protected features against the impacts of climate change by removing or limiting other pressures as a result of human activities. Removing the pressures from human impacts will reduce the stress on the features and allow them more capacity to cope with impacts from climate change (Jackson *et al.,* 2014, MCCIP, 2018).

The large scale of the deep-sea marine reserve incorporates replication of the protected features across the deep-sea marine reserve e.g. a range of feature sub-types are protected for deep-sea sponge aggregations and coral gardens, and different sediment communities where environmental conditions vary across the deep-sea marine reserve; protected features occur at a number of locations across the deep-sea marine reserve increasing resilience. As far as possible this builds capacity for the features to adapt to climate change e.g. where species distribution may shift northwards. Fox *et al.* (2016) found coral on seamounts and offshore banks within the deep-sea marine reserve may play a critical role in connectivity and maintaining larval supply; and seamounts may act as refugia from ocean acidification for cold-water corals (Tittensor *et al.,* 2010).

Some of the protected features of the deep-sea marine reserve have functional roles within the ecosystem that contribute to climate change regulation and resilience e.g. suspension feeders such as sponges extract food from the water column and expel it as pseudofaeces, which is then available to benthic feeders; this process enhances biogeochemical cycling and likely plays a role in climate regulation by extracting carbon from the water column and eventually transferring it to the sediments (Fletcher *et al.,* 2011). Bioturbation (e.g. in **burrowed mud** habitat) where it occurs at large scales can result in the fixing of carbon that may assist in climate regulation (Doggett *et al.,* 2018).

Blue carbon

Blue carbon, or carbon stored and sequestered in marine ecosystems, is increasingly being recognised as an important factor in mitigating climate change. Around a quarter of the carbon dioxide released through the burning of fossil fuels is absorbed by the oceans each year (Laffoley *et al.,* 2014). Carbon dioxide is converted into living matter through photosynthesis in surface waters, while most of this carbon is recycled within food webs, around 20% is transferred from surface waters to the deep sea as dead organisms, faecal material and carbonate skeletons where the carbon is stored for decades to geological timescales (Laffoley *et al.,* 2014). These processes form the basis of the biological carbon pump.

Diel vertical migration, the synchronised movement of zooplankton from surface waters to greater depths during daylight hours, is also important in linking surface production to deeper ecosystems. In the Rockall Trough, a rich concentration of pelagic prey organisms are found on the continental slope at depths of 800 – 1500 m during their diel vertical migrations, providing food for fish species such as the **Round-nose grenadier** (Mauchline and Gordon, 1991). Fish in turn make a large contribution to oceanic carbonate production through the production of high magnesium calcite crystals continuously excreted by the gut, which contributes to regulating the acidity/alkalinity of surface waters (Laffoley *et al.,* 2014).

Below the photic zone (the depth to which light penetrates the sea), the only form of primary production is chemosynthesis. Chemosynthetic bacteria use chemical energy to produce biomass by oxidizing reduced inorganic compounds to obtain both energy and fix inorganic carbon (Das *et al.,* 2011). About half of the total oceanic chemosynthetic carbon fixation occurs in sediments and represents an important ecosystem function in the deep sea (Sweetman *et al.,* 2018). However, in terms of long-term climate mitigation, deep-sea ecosystems are thought to be less important than those of coastal systems (Laffoley *et al.,* 2014). Nonetheless, maintaining a healthy, productive and diverse marine ecosystem will support the functioning of the carbon cycle and the ability of the ocean to function as a carbon sink.

Marine mammals

Over 20 species of whale, dolphin and porpoise can be found in Scottish waters. Eleven of these species were considered as potential features for this deep-sea marine reserve, but insufficient data were available to determine if the deep-sea marine reserve supported important life history areas for these species. However, the broad ecosystem approach taken to the protection of marine habitats and species within the deep-sea marine reserve will support a healthy ecosystem and food availability to the cetacean species that utilise this area. These cetacean species and others may use this area for feeding, breeding or as part of their migration routes (Charif and Clarke, 2009; Pollock *et al.,* 2000; Stone, 2015 and Reid *et al.,* 2003); for example, the waters off the west coast of Scotland are likely important feeding grounds and migration routes for Fin whale (*Balaenoptera physalus*) (Macleod *et al.,* 2003). Long-finned pilot whale (*Globicephela melas*) and sperm whale (*Physeter macrocephalus*) have frequently been recorded around both seamounts in the deep-sea marine reserve (Weir *et al.,* 2001; Macleod *et al.,* 2003; Boisseau *et al.,* 2011)

Seabirds

Scotland hosts internationally important numbers of seabirds (Mitchell *et al.,* 2004, Kober *et al.,* 2010). Seabirds are important indicators of the state of the marine environment as they respond to a range of environmental factors such as food availability, weather, predation and pollution (Mitchell *et al.,* 2004). Kober *et al.,* (2010) analysed the numbers and distribution of seabirds within the British Fishery Limit and the distribution maps produced show the deep-sea marine reserve is utilised by these seabird populations in both the breeding and non-breeding season.

The deep-sea marine reserve is within the foraging range (Thaxter *et al.,* 2012) of some of the largest breeding colonies for seabirds in the UK. European storm-petrel (*Hydrobates pelagicus*) and Leach's storm (*Oceanodroma leucorhoa*) are truly oceanic species (Mitchell *et al.*, 2014). Ninety-four percent of the UK population of Leach's storm petrel breeds on four islands in the St. Kilda archipelago, with the remainder in the western isles and two islands in Shetland (Mitchell *et al.,* 2004). During the breeding season foraging is concentrated in deeper waters over the shelf edge (Stone *et al.,* 1995; Pollock *et al.,* 2000 and Reid *et al.,* 2001). All Leach's storm-petrel colonies are within 37-67km of the shelf break and 65-119km from the bottom of the continental slope (200m-1000m) (Mitchell *et al.,* 2004). The UK supports 5.2% of the biogeographic population of European storm petrel, the largest UK colony, is on Mousa (Shetland) (Mitchell *et al.*, 2004). Almost all European storm petrel colonies in Scotland are found on offshore islands to the west and north of the mainland. Density surface distributions (Kober *et al.*, 2010) show European storm petrel utilise the area of the deep-sea marine reserve during the breeding season.

St. Kilda supports the largest colonies in the UK for northern fulmar (*Fulmar glacialis*) and northern gannet (*Morus bassanus*), with large colonies also present in the Orkney and Shetland islands (Mitchell *et al.,* 2004). The north-west coast of Scotland also supports some of the UK's largest colonies of great-blacked gull (*Larus marinus*) and kittiwake (*Rissa tridactyla*) (Mitchell *et al.,* 2004). Foraging range (Thaxter *et al.* 2012, not available for Great black-backed gull) and density surface distribution maps (Kober *et al.* 2010) indicate these species utilise the deep-sea marine reserve in both the breeding and non-breeding season. However, for some of these species (particularly during the breeding season) the deep-sea marine reserve may be at the edge of their foraging range (Thaxter *et al.* 2012), and area's closer to shore may be more important for foraging during this season (Wakefield *et al*. 2013, 2017; Cleasby *et al*. 2018). Long-tailed skua and Pomarine skua are passage migrants transiting through the area of the deep-sea marine reserve to and from their breeding grounds in the high arctic.

Insufficient data were available to determine the regular occurrence of seabird density hotspots in the deep-sea marine reserve that exceeded the relevant population threshold, compared with other areas of Scotland’s seas. However, the broad ecosystem approach taken to the protection of marine habitats and species within the deep-sea marine reserve will support a healthy ecosystem and food availability to the many seabird species that utilise this area.

7. Contribution of the West of Scotland deep-sea marine reserve to the Marine Protected Area network in the seas around Scotland and beyond.

The MPA network supports the Scottish Government's vision of clean, healthy, safe, productive, biologically diverse marine and coastal environment, managed to meet the long-term needs of nature and people. The creation and maintenance of the MPA network is an integral part of achieving the vision by safeguarding marine biodiversity. The Scottish MPA network contributes to international MPA networks at European, North-east Atlantic and global scales, and meeting international commitments under the OSPAR Convention, and the United Nation's Convention on Biological Diversity and Sustainable Development Goals. Since a key aim of the Scottish Government has been to make a significant contribution to the OSPAR MPA network in the North-east Atlantic, the protection of additional replicates of listed habitats will help further that aim.

The deep-sea marine reserve will protect large swaths of deep-sea sediments representative of Atlantic influenced offshore subtidal sands and gravels and offshore deep-sea muds in the bathyal region, with both **offshore deep-sea muds** and **offshore subtidal sands and gravels** representative of the deep-sea habitat in Scottish waters and the wider regional NE Atlantic. These deep sedimentary habitats support a wide range of communities which can greatly differ from shallower locations and enhance the protection of deep-sea sedimentary habitats across the wider network.

The deep-sea marine reserve ensures that all known examples of **burrowed mud** (including sea-pens), **coral gardens, cold-water coral reefs, deep-sea sponge aggregations**, and **seamount communities** occurring in Scotland's deep sea between the continental shelf break and Rockall Bank are protected with the Scottish MPA network. As OSPAR Threatened and/or Declining habitats, it is considered important to have greater replication for **deep-sea sponge aggregations, coral gardens, cold-water coral reefs** and **seamount communities** on the grounds of increasing resilience to pressures or impacts.

This deep-sea marine reserve will ensure Scotland makes a significant contribution towards the OSPAR MPA network for the protection of deep-water fish species. All of the protected deep-water fish species of the deep-sea marine reserve are OSPAR Threatened and/or Declining species, apart from round-nose grenadier, which is a Scottish PMF species. This deep-sea marine reserve will also add significantly to the large-scale and geodiversity features protected within Scotland's seas.

8. Bibliography

Armstrong, C. W., Foley, N. S., Tinch, R., and van den Hove, S. (2012). Services from the deep: Steps towards valuation of deep sea goods and services, Ecosyst. Serv., **2**, 2–13,

Armstrong, C.W., Foley, N.S, Kahui, V. and Grehan, A. (2014). Cold water coral reef management from an ecosystem service perspective. *Marine Policy*, **50**: 126-134.

Bañón, R., Piñeiro, C. & Casas M. (2008). Biological observations on the gulper shark Centrophorus granulosus (Chondrichthyes: Centrophoridae) off the coast of Galicia (northwestern Spain, eastern Atlantic). *Journal of the Marine Biological Association of the United Kingdom*, **88**(2): 411–414 doi:10.1017/S0025315408000787.

Boisseau, O., Moscrop, A., Cucknell, A., McLanaghan, R., and Wall, D. (2011). An acoustic survey for beaked whales in the Rockall Trough. *International Whaling Commission*, **SC/63/SM2.**

Branch T.A. (2001). A Review of Orange Roughy *Hoplostethus atlanticus* Fisheries, Estimation Methods, Biology and Stock Structure. South African *Journal of Marine Science* **23**: 181–203.

Brooks, A.J. Kenyon, N.H. Leslie, A., Long, D. and Gordon, J.E. (2011). Characterising Scotland's marine environment to define search locations for new Marine Protected Areas. Part 2: The identification of key geodiversity areas in Scottish waters (interim report July 2011). Scottish Natural Heritage Commissioned Report No.430. Available from: https://www.researchgate.net/publication/279440166

Cathalot, C., Van Oevelen, D., Cox, T.J.S., Kutti, T., Lavaleye, M., Duineveld, G. and Meysman, F.J.R. (2015). Cold-water coral reefs and adjacent sponge grounds: hotspots of benthic respiration and organic carbon cycling in the deep sea. *Frontiers in Marine Science*, **2**: 37. [online] Available at: https://doi.org/10.3389/fmars.2015.00037

Charif, R.A., Clapham, P.J., and Clark, C.W. (2001). Acoustic detections of singing humpback whales in deep waters off the British Isles. *Marine Mammal Science*, **17**. 751–768.

Charif, R.A., and Clark, C.W. (2009). Acoustic monitoring of large whales in deep waters north and west of the British Isles: 1996 – 2005. Technical report 08-07. Bioacoustics research programme, Cornell University. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/196484/OES_UK_SOSUS_10year_report.pdf

Clarke, M. (2007). Seamounts and cephalopods. In: *Seamounts: Ecology, Fisheries and Conservation*. Pitcher, T.J., Morato, T., Hart, P.J.B., Clark, M.R., Haggan, N., and Santos, R.S. (Eds). Blackwell Publishing, Oxford. 207–229.

Cleasby I.R., Owen E., Wilson L.J, Bolton M. (2018). Combining habitat modelling and hotspot analysis to reveal the location of high density seabird areas across the UK: Technical Report. RSPB Research Report no. 63. RSPB Centre for Conservation Science, RSPB, The

8. Bibliography

Lodge, Sandy, Bedfordshire, SG19 2DL Available at: https://www.rspb.org.uk/globalassets/downloads/documents/conservation-science/cleasby_owen_wilson_bolton_2018.pdf

Colaço, A. and Osinga, R. (2018). Threats and impacts to sponge grounds. FAO. Available at: http://www.deepseasponges.org/?page_id=1197

Corinaldesi, C. (2015). New perspectives in benthic deep-sea microbial ecology. *Frontiers in Marine Science* **2**(17). doi:10.3389/fmars.2015.00017

Danovaro, R., Gambi, C., Dell'Anno, A., Corinaldesi, C., Fraschetti, S., Vanreusel, A., Vincx, M. & Gooday, A.J. (2008). Exponential decline of deep-sea ecosystem functioning linked to benthic biodiversity loss. *Current Biology*, **18**, 1-8.

Das A., Sujith P.P., Mourya B.S., Biche S.U., and LokaBharathi P.A. (2011). Chemosynthetic activity prevails in deep-sea sediments of the Central Indian Basin. *Extremophiles*, **15**, 177–189.

Davies, A.J., Narayanaswamy, B.E., Hughes, D.J. & Roberts, J.M. (2006). An introduction to the benthic ecology of the Rockall – Hatton Area (SEA 7). A Report for the Department of Trade and Industry. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197028/SEA7__Benthos_SRSL.pdf

Doggett, M., Baldock, B. and Goudge, H. (2018). A review of the distribution and ecological importance of seabed communities in the deep waters surrounding Scotland. JNCC Report No. 625, JNCC, Peterborough, ISSN 0963-8091. Available at: http://jncc.defra.gov.uk/page-2132

Ebada, S.S., Lin, W.H. and Proksch, P. (2010). Bioactive Sesterterpenes and Triterpenes from marine sponges: Occurrence and pharmacological significance. *Marine Drugs*, **8**: 313- 346.

Evans, P.G.H. (1997). Ecology of sperm whales (*Physeter macrocephalus*) in the Eastern North Atlantic, with special reference to sightings and strandings records from the British Isles. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie*, **67** (Supplement). 37–46.

FAO (2009). International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, FAO. 2009. 73p. Available at: http://www.fao.org/docrep/011/i0816t/i0816t00.HTM

FAO (2018). Species Fact Sheet: Molva dipterygia. Food and Agriculture Organisation of the United Nations. Available online at: http://www.fao.org/fishery/species/2221/en

Fletcher, S., Saunders, J., Herbert, R. & Roberts, C. (2011). Description of the ecosystem services provided by broad-scale habitats and features of conservation importance that are likely to be protected by Marine Protected Areas in the Marine Conservation Zone Project area. Report to Natural England.

8. Bibliography

Forster, G.R. (1973). Line fishing on the continental slope: the selective effect of different hook patterns. *Journal of the Marine Biological Association of the UK* **53**, 749–751.

Fox, A., Henry L-A., Corne, D. and Roberts, J. (2016). Sensitivity of marine protected area network connectivity to atmospheric variability. *R. Soc. Open sci.* **3**:160494. doi:10.1098/rsos.160494.

Froese, R. & Pauly, D. (Eds) (2017). FishBase. World Wide Web electronic publication. www.fishbase.org, version (10/2017).

Gordon, J.D.M. & Duncan, J.A.R. (1987). Aspects of the biology of *Hoplostethus atlanticus* and *H. mediterraneus* (Pisces: Berycomorphi) from the slopes of the Rockall Trough and the Porcupine Sea Bight (north-eastern Atlantic). *J. mar. biol. Ass. U.K.* **67**: 119–133.

Henry, L.A. and Roberts, J.M. (2014a). Developing an interim technical definition for Coral Gardens specific for UK waters and its subsequent application to verify suspected records. JNCC Report No. 507. Available at: http://jncc.defra.gov.uk/PDF/507_web.pdf

Henry, L.A. and Roberts, J.M. (2014b). Applying the OSPAR habitat definition of deep-sea sponge aggregations to verify suspected records of the habitat in UK waters. JNCC Report No. 508. Available at: http://jncc.defra.gov.uk/PDF/508_web.pdf

Henry, L. A., Stehmann, M. F. W., De Clippele, L., Findlay, HS., Golding, N. and Roberts, J. M. (2016). Seamount egg-laying grounds of the deep-water skate *Bathyraja richardsoni*. *Journal of fish biology*, **89**, 1473-1481.

Hughes, D.J. (1998). Sea pens and burrowing megafauna (volume III). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project). 105 Pages. Available at: http://www.ukmarinesac.org.uk/pdfs/seapens.pdf

Indraningrat, A.A.G., Smidt, H. and Sipkema, D. (2016). Bioprospecting sponge-associated microbes for antimicrobial compounds. *Marine Drugs*, **14**: doi:10.3390/md14050087. [online]. Available at: http://www.mdpi.com/1660-3397/14/5/87

Jackson, E. L., Davies, A. J., Howell, K. L., Kershaw, P. J., and Hall-Spencer, J. M. (2014). Future-proofing marine protected area networks for cold water coral reefs. *ICES Journal of Marine Science: Journal du Conseil*, **71**, 2621-2629

Klitgaard, A.B. and Tendal, O.S. (2004). Distribution and species composition of mass occurrences of large-sized sponges in the northeast Atlantic. *Progress in Oceanography*, **61**: 57-98.

Kober, K., Webb, A., Win, I., Lewis, M., O'Brien, S., Wilson, L.J., Reid, J.B. (2010). An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs. JNCC report No. 431. Available at: http://jncc.defra.gov.uk/PDF/jncc431_mainreport.pdf

Laffoley, D., Baxter, J. M., Thevenon, F. and Oliver, J. (editors). (2014). The Significance and Management of Natural Carbon Stores in the Open Ocean. Full report. Gland, Switzerland: *IUCN*. 124 pp

8. Bibliography

Laport, M.S., Santos, O.C.S. and Muricy, G. (2009). Marine Sponges: Potential sources of new antimicrobial drugs. *Current Pharmaceutical Biotechnology*, **10**: 86-105.

Large, P. A., Diez, G., Drewery, J., Laurans, M., Pilling, G. M., Reid, D. G., Reinert, J., South, A. B., and Vinnichenko, V. I. (2010). Spatial and temporal distribution of spawning aggregations of blue ling (Molva dypterygia) west and northwest of the British Isles. – *ICES Journal of Marine Science*, **67**: 494–501.

Leys, S.P. and Lauzon, N.R.J. (1998). Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges. *Journal of Experimental Marine Biology and Ecology*, **230**: 111-129.

Macleod, K., Simmonds, M.P., and Murray, E. (2003). Summer distributions and relative abundance of cetacean populations off north-west Scotland. *Journal of the Marine Biological Association of the UK*, **83**. 1187–1192.

Maldonado, M., Ribes, M. and van Duyl, F.C. (2012). Nutrient Fluxes Through Sponges: Biology, Budgets, and Ecological Implications. In Mikel A. Becerro, Maria J. Uriz, Manuel Maldonado and Xavier Turon, editors: *Advances in Marine Biology*, **62**: 113-182.

Maldonado, M., Aguilar, R., Bannister, R.J., Bell, J.J., Conway, K.W., Dayton, P.K., Díaz, C., Gutt, J., Kelly, M.R., Kenchington, E.L.R., Leys, S.P., Pomponi, S.A., Rapp, H.T., Rützler, K., Tendal, O.S., Vacelet, J. and Young, C.M. (2016). Sponge Grounds as Key Marine Habitats: A Synthetic Review of Types, Structure, Functional Roles, and Conservation Concerns. S. Rossi (ed.), Marine Animal Forests, Springer International Publishing Switzerland.

Marine Climate Change Impacts Partnership, (2018). Climate change and marine conservation, supporting management in a changing environment, coral gardens. Available at: http://www.mccip.org.uk/media/1810/mccip-coral-gardens-report-card_second-run_v5.pdf

Marine Life Information Network. Accessed February (2019). Available at: https://www.marlin.ac.uk/

Marine Scotland (2013). Features, Activities, Sensitivities Tool (FEAST) online resource. Available at: www.marine.scotland.gov.uk/FEAST/. *Version 1.0 (August 2013).*

Mauchline, J. and Gordon, J.D.M. (1984a). Occurrence and feeding of berycomorphid and percomorphid teleost fish in the Rockall Trough. *Journal du Conseil*, **41**, 239-247 DOI10.1093/icesjms/41.3.239.

Mauchline, J. and J.D.M. Gordon, (1991). Oceanic pelagic prey of benthopelagic fish in the benthic boundary layer of a marginal oceanic region. *Marine Ecology Progress Series* **74**:109-115.

McClain, C.R., Lundsten, L., Ream, M., Barry, J., and DeVogelaere, A. (2009). Endemicity, biogeography, composition, and community structure on a northeast Pacific seamount. *PLoS One*, **4**. e4141.

8. Bibliography

Mitchell, P.I., Newton, S.F., Ratcliffe, N. & Dunn, T.E., (2004). Seabird Populations of Britain and Ireland, 511 pages, hardback, colour photos, figures, maps, ISBN 0 7136 6901 2.

Moura, T., Jones, E., Clarke, M.W., Cotton, C.F., Crozier, P., Daley, R.K., Diez, G., Dobby, H., Dyb, J.E., Fossen, I., Irvine, S.B., Jakobsdottir, K., López-Abellán, L.J., Lorance, P., Pascual-Alayón, P., Severino, R.B. and Figueiredo, I. (2014). Large- scale distribution of three deep-water squaloid sharks: integrating data on sex, maturity and environment. *Fisheries Research*, **157**: 47–61.

Neat, F., Burns, F., and Drewery, J. (2008). The deepwater ecosystem of the continental shelf slope and seamounts of the Rockall Trough: a report on the ecology and biodiversity based on FRS scientific surveys. *Fisheries Research Services Internal Report*, **No.02/08**.

Neat, F.C., Burns, F., Jones, E. and Blasdale, T. (2015). The diversity, distribution and status of deep-water elasmobranchs in the Rockall Trough, north-east Atlantic Ocean. *Journal of Fish Biology* **87**: 1469–1488 doi:10.1111/jfb.12822.

Nickell, L.A., Atkinson, R.J.A., Hughes, D.J., Ansell, A.D. & Smith, C.J. (1995a). Burrow morphology of the echiuran worm Maxmuelleria lankesteri (Echiura: Bonelliidae), and a brief review of burrow structure and related ecology of the Echiura. *Journal of Natural History*, **29**: 871-885.

OSPAR Commission. (2008a). *List of Threatened and/or Declining Species and Habitats*. Reference Number: 2008-6. <http://www.ospar.org/documents/DBASE/DECRECS/Agreements/08-06e_OSPAR%20List%20species%20and%20habitats.doc>.

OSPAR Commission. (2008b). *Case Reports for the OSPAR List of Threatened and/or Declining Species and Habitats*. OSPAR Commission. Biodiversity Series. <http://qsr2010.ospar.org/media/assessments/p00358_case_reports_species_and_habitats_2008.pdf>.

OSPAR Commission. (2009). Background Document for *Lophelia pertusa* reefs. Available at: https://www.ospar.org/documents?d=7182

OSPAR Commission. (2010a). Background Document for Deep-sea sponge aggregations. Available at: https://www.ospar.org/documents?d=7234

OSPAR Commission. (2010b). Background Document for Coral gardens. Available at: https://www.ospar.org/documents?d=7217

OSPAR Commission. (2010c). Background Document for Seapen and Burrowing megafauna communities. Available at: https://www.ospar.org/documents?d=7261

Pollock, CM, R Mavor, CR Weir, A Reid, RW White, ML Tasker, A Webb, and JB, Reid. (2000). The distribution of seabirds and marine mammals in the Atlantic Frontier, north and west of Scotland. Joint Nature Conservation Committee, Aberdeen, Scotland.

Priede, I.G. (2018). Deep-sea Fishes Literature Review. JNCC Report No. 619. JNCC, Peterborough. ISSN 0963-8091. Available at: http://jncc.defra.gov.uk/page-2132

8. Bibliography

Régnier T., Augley J., Devalla S., Robinson C.D., Wright P.J., and Neat F.C. (2017). Otolith chemistry reveals seamount fidelity in a deepwater fish. *Deep Sea Research Part I: Oceanographic Research Papers*, **121**, 183–189.

Reid, J.B., Pollock, C.M. & Mavor, R. (2001). Seabirds of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research*, **21**, 1029-1045.

Reid, J.B., Evans, P.G.H., and Northridge, S.P. (2003). *Atlas of cetacean distribution in north-west European waters*. Joint Nature Conservation Committee, Peterborough.

Ruiz-Torres, V., Encinar, J.H., Lopez, M-H., Pérez-Sánchez, A., Galiano, V., BarrajónCatalán, E. and Micol, V. (2017). An Updated Review on Marine Anticancer Compounds: The Use of Virtual Screening for the Discovery of Small-Molecule Cancer Drugs. *Molecules*. **22**. 1037. 10.3390/molecules22071037.

Ryan, H. (2017). Big Read: Return of the Roughy. New Zealand Herald. Available at: http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11868056 . Accessed 15 March 2018.

Sawadogo, W.R., Boly, R., Cerella, C., Teiten, M.H., Dicato, M. and Diederich, M. (2015). A survey of marine natural compounds and their derivatives with anti-cancer activity reported in 2012. *Molecules*, **20**: 7097-7142.

Schleuter, D., Günther, A., Paasch, S., Ehrlich, H., Kljajić, Z., Hanke, T., Bernhard, G. and Brunner, E. (2013). Chitin-based renewable materials from marine sponges for uranium absorption. *Carbohydrate Polymers*, **92**: 712-718.

Schönberg, C.H.L., and Fromont, J. (2014). Sponge functional growth forms as a means for classifying sponges without taxonomy. Australian Institute Marine Science [online]. Available at: http://ningaloo-atlas.org.au/content/sponge-functional-growth-forms-means-classifyingspo

SNH and JNCC (2014). *Assessment of the adequacy of the Scottish MPA network for MPA search features: summary of the application of the stage 5 selection guidelines.* Final report produced by Scottish Natural Heritage, the Joint Nature Conservation Committee and Marine Scotland for the Scottish Marine Protected Areas Project.

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J. & Pienkowski, M.W. (1995). An atlas of seabird distribution in northwest European waters. Peterborough, UK.

Stone, C.J. (2015). Marine mammal observations during seismic surveys from 1994-2010. JNCC report, No. 463. Available at: http://jncc.defra.gov.uk/pdf/JNCC%20Report%20463a_Final.pdf

Stone, R.P., Masuda, M.M. and Karinen, J.F. (2015). Assessing the ecological importance of red tree coral thickets in the eastern Gulf of Alaska. ICES *Journal of Marine Science*, **72**: 900–915.

8. Bibliography

Sweetman A.K., Smith C.R., Shulse C.N., Maillot B., Lindh M., Church M.J., Meyer K.S., van Oevelen D., Stratmann T., and Gooday A.J. (2018). Key role of bacteria in the short-term cycling of carbon at the abyssal seafloor in a low particulate organic carbon flux region of the eastern Pacific Ocean: Key role of benthic bacteria in abyssal food webs. *Limnology and Oceanography.*

Swift, R.J., Hastie, G.D., Barton, T.R., Clark, C.W., Tasker, M.L., and Thompson, P.M. (2002). Studying the distribution and behaviour of cetaceans in the northeast Atlantic using passive acoustic techniques. Report for the Atlantic Frontier Environmental Network.

Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S., Roos, S., Bolton, M., Langston, R.H. & Burton, N.H., (2012). Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation*, **156**, 53-61

Thurber, A.R., Sweetman, A.K., Narayanaswamy, B.E., Jones, D.O.B., Ingels, J. & Hansman, R.L. (2014). Ecosystem function and services provided by the deep sea. *Biogeosciences*, **11**, 3941–3963, 2014 www.biogeosciences.net/11/3941/2014/.

Tittensor, DP. Baco, AR. Hall Spencer, JM. Orr, JC. and Rogers, AD. (2010). Seamounts as refugia from ocean acidification for cold water stony corals. *Marine Ecology*, **31**, 212–225

Tréguer, P.J. and De La Rocha, C.L. (2013). The world ocean silica cycle. *Annual Review of Marine Science*, **5**: 477-501.

Veríssimo, A., McDowell, J.R. and Graves, J.E. (2011). Population structure of a deep-water squaloid shark, the Portuguese dogfish (*Centroscymnus coelolepis*). *ICES Journal of Marine Science* **68**: 555–563. doi:10.1093/icesjms/fsr003.

Veríssimo, A., Cotton, C.F., Buch, R.H., Guallart, J. & Burgess, G.H. (2014). Species diversity of the deep-water gulper sharks (Squaliformes: Centrophoridae: Centrophorus) in North Atlantic waters-current status and taxonomic issues. *Zoological Journal of the Linnean Society* **172** (4):803-830.

Wakefield, E.W., Bodey, T.W., Bearhop, S. *et al*. (2013). Space partitioning without territoriality in gannets. *Science*, **341**, 68– 70.

Wakefield, E.D., Owen, E., Baer, J., Carroll, M.J., Daunt, F., Dodd, S.G., Green, J.A., Guilford, T., Mavor, R.A., Miller, P.I. & Newell, M.A. (2017). Breeding density, fine-scale tracking, and large-scale modelling reveal the regional distribution of four seabird species. *Ecological Applications*, *27*, 2074-2091.

Weir, C.R., Pollock, C., Cronin, C., and Taylor, S. (2001). Cetaceans of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research*, **21**. 1047–1071.

White, W.T., Ebert, D.A., Naylor, G.J.P., Ho, H.-C., Clerkin, P., Veríssimo, A. & Cotton, C.F. (2013). Revision of the genus *Centrophorus* (Squaliformes: Centrophoridae): Part 1 — Redescription of *Centrophorus granulosus* (Bloch & Schneider), a senior synonym of *C. acus* Garman and C. niaukang Teng. *Zootaxa* **3752**(1): 35-72.

8. Bibliography

Zumberge, J. A., Love, G. D., Cárdenas P., Sperling E. A., Gunasekera, S., Rohrssen, M., Grosjean, E., Grotzinger, J.P., and Summons, R. E. (2018). Demosponge steroid biomarker 26-methylstigmastane provides evidence for Neoproterozoic animals, *Nature Ecology and Evolution* **2**:1709–1714. http://doi.org/10.1038/s41559-018-0676-2.