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PROTECTING THE NORTH SEA: ABERDEENSHIRE

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Credits

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Cover: Plumose anemones (*Metridium senile*). © OCEANA/ Juan Cuetos

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Table of contents

The sea surrounding Aberdeenshire is home to a rich diversity of seabed ecosystems, ranging from kelp forests along the coast to burrowed mud within the Southern Trench, a deep seabed incision that is both geologically and ecologically important. The value of the Southern Trench as a biodiversity hotspot has been recognised by the Scottish government, which proposed the creation of the *Southern Trench* Nature Conservation Marine Protected Area (NCMPA) to protect four biodiversity features (burrowed mud, fronts, minke whale, and shelf deeps) and two geodiversity features (Quaternary of Scotland and submarine mass movement). However, it is not yet known whether the site will in fact be designated, and protection of benthic ecosystems in the Aberdeenshire area area at present is limited.

In 2017, Oceana carried out a research expedition in the waters of Aberdeenshire, to gather further information about the area's benthic species and communities. Surveys were conducted mainly through low-impact visual means (filming via a remotely operated vehicle and by professional divers) and were complemented with seabed grab sampling of sediments and infauna. Locations surveyed included unprotected areas, points within the area's three existing marine protected areas (none of which protect seabed ecosystems), and the proposed *Southern Trench* NCMPA. In total, Oceana documented 481 taxa (351 to the species level), in association with 14 habitat types. Among the marine features recorded were 16 species and seven habitat types that are considered priorities for conservation under Scottish or international frameworks. Key findings included reefs and other aggregations formed by ross worm (*Sabellaria spinulosa*), kelp forests, submerged caves, and sea pen and burrowing megafauna communities.

On the basis of its findings, Oceana strongly supports the designation of the *Southern Trench* NCMPA, and encourages the Scottish government to grant formal protection to other features found within the site. In particular, the Aberdeenshire area appears to be important for ross worm (*S. spinulosa*) reefs, both within the proposed *Southern Trench* site and beyond its southern boundary. Oceana urges the Scottish authorities to extend the site boundaries to encompass these vulnerable habitats, to carry out further studies to assess the extent and condition of *S. spinulosa* reefs, and to develop appropriate measures of protection. Extending the boundary of the *Southern Trench* would have the added benefit of safeguarding other features of conservation importance in the same area, including kelp forests, submerged caves, and seven species that are considered Priority Marine Features in Scottish waters.

Introduction

The waters of the North Sea surrounding Aberdeenshire (Figure 1) are characterised by a wide range of geological and geomorphological features that, in turn, host a diverse array of marine biotypes and species. One area of particular interest is the Southern Trench, located along the south coast of the Moray Firth. The origin of this large-scale seabed incision is still contentious, but it is thought to have been formed from at least two fluvial erosion events, and as such is important for increasing our understanding of ice sheet drainage in this area.[1] With an approximate length of 120 km and maximum depths of 250 m, it is one of the largest enclosed glacial seabed basins mapped in Scottish waters.[1] In addition to its geodiversity significance, it is considered ecologically important due to the occurrence of biodiversity features that include burrowed mud, fronts, shelf deeps, and minke whales. On the basis of these features, it was identified as a potential candidate for protection in 2012 and formally proposed as a Scottish Nature Conservation Marine Protected Area (NCMPA) in 2019. Although benthic communities in the area outside of the Southern Trench have been less well studied, the reef-forming polychaete *Sabellaria spinulosa* has been documented from some locations, on mixed sediment (see *Known ecological features of interest*). Additionally, there are extensive areas of burrowed mud, particularly in the Southern Trench, with associated communities that include burrowing megafauna such as Norway lobster (*Nephrops norvegicus*) and sea pens.[2]

Kelp forest (*Laminaria ochroleuca* and *L. hyperborea*).
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The seas off Aberdeenshire are also subject to intense fishing activity, oil and gas exploration, and shipping traffic. Due to the presence of commercially important Norway lobster, burrowed mud areas are a particular target for the fishing industry. The fisheries associated with Norway lobster can have a detrimental influence on muddy habitats and their associated communities.[3,4,5] Similarly, biogenic reefs formed by *S. spinulosa* are also highly vulnerable to damage as a result of trawling or dredging.[6]

In order to preserve the biodiversity and improve the state of health of Scottish waters, it is important to increase our understanding of the benthic communities that they host, especially in areas threatened by human activity. Oceana conducted biological research surveys in the waters of Aberdeenshire in 2017, to characterise the benthic species, communities, and habitats of the area. These surveys were part of a research expedition carried out across the waters of five North Sea countries, which aimed to gather critical data for improving the existing network of North Sea marine protected areas. The findings of Oceana's surveys are presented here, in the broader context of the marine biodiversity of the area, the threats it faces, and the implications for its protection.

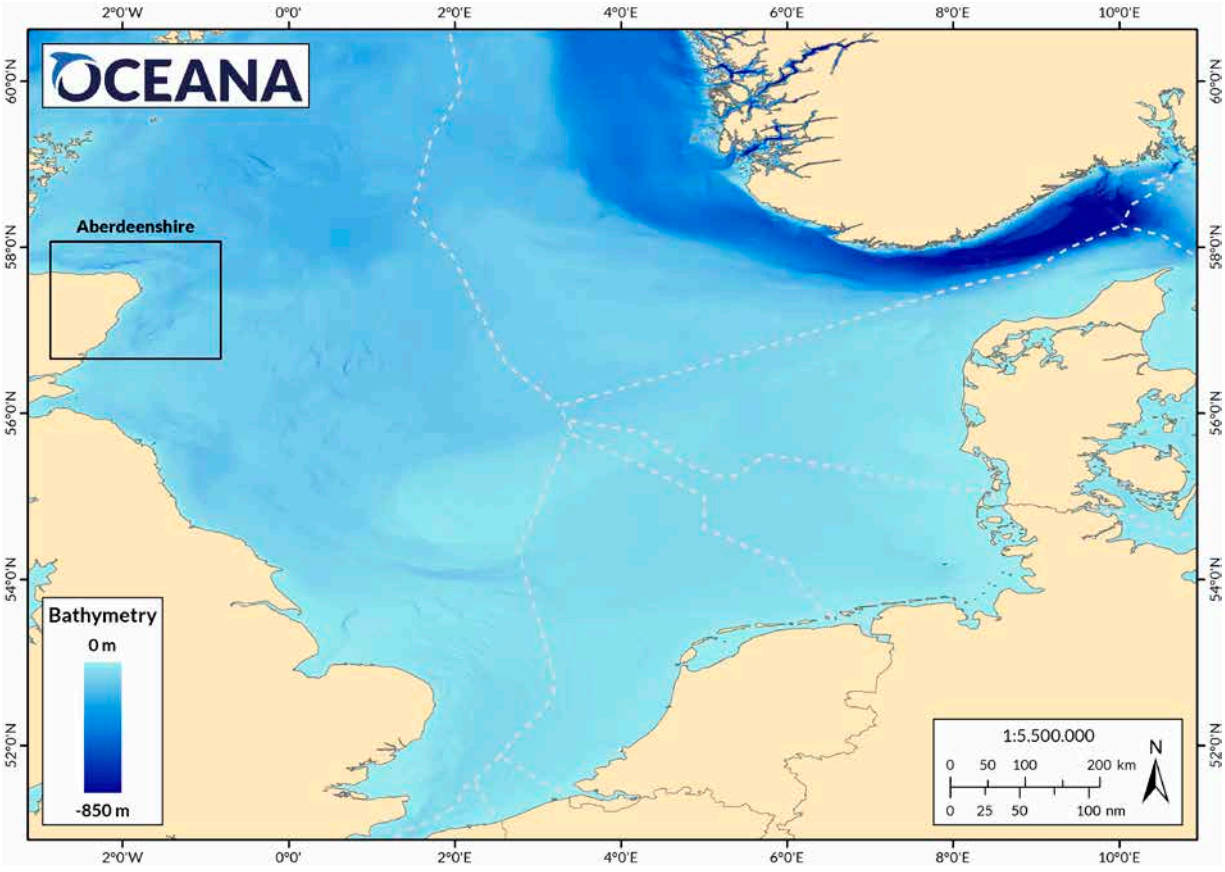

Figure 1. Location of Aberdeenshire survey area. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute.[9]

DESCRIPTION OF THE AREA

The physical environment of the Aberdeenshire area has been shaped mostly by geological and glacial processes.[10] This combination of drivers has resulted in a relatively flat seabed, with the exception of a deep area, the Southern Trench, located along the south coast of the Moray Firth between the coastal ports of Banff and Fraserburgh (Figure 2). This trench is thought to have been formed by at least two glacial erosive events from different directions,[11] although its formation is still under debate. The trench reaches depths of 244 m below sea level, with slopes ranging from as little as 2° to greater than 50°.[1,10] This deep area is of particular interest due to the irregular morphology of the trench, making it the most topographically complex region of the Moray Firth, and one of the deepest points in Scottish North Sea waters.[12]

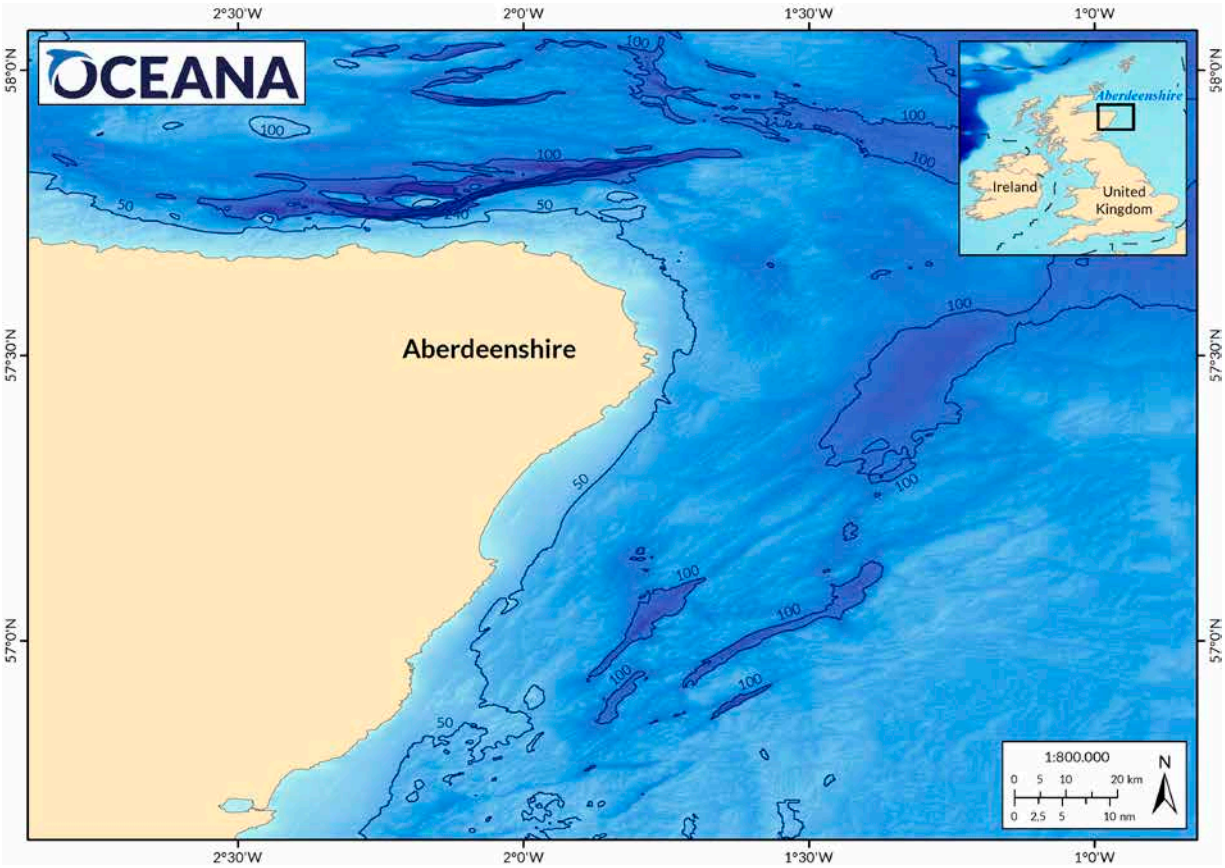

Figure 2. Detailed bathymetry of the Aberdeenshire survey area. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute.[9]

Sediments in the North Sea derive from the Holocene epoch and their distribution reflects the glacial history and hydrodynamic processes in the area.[13] In the Aberdeenshire area, the dominant substrate type is sand and coarse sand, with interspersed areas of mixed sediment, rocks and other hard substrata closer to the coastline (Figure 3). In deeper, offshore waters, finer silts and muds (such as sandy mud to muddy sand) are present, particularly in the Southern Trench area. In the deepest points of the Southern Trench, the substrate is characterised by fine mud. In contrast, shallower sandy areas along the eastern coast of Aberdeenshire are characterised by sand waves with average wave lengths of 200 m and heights reaching 17 m.[10]

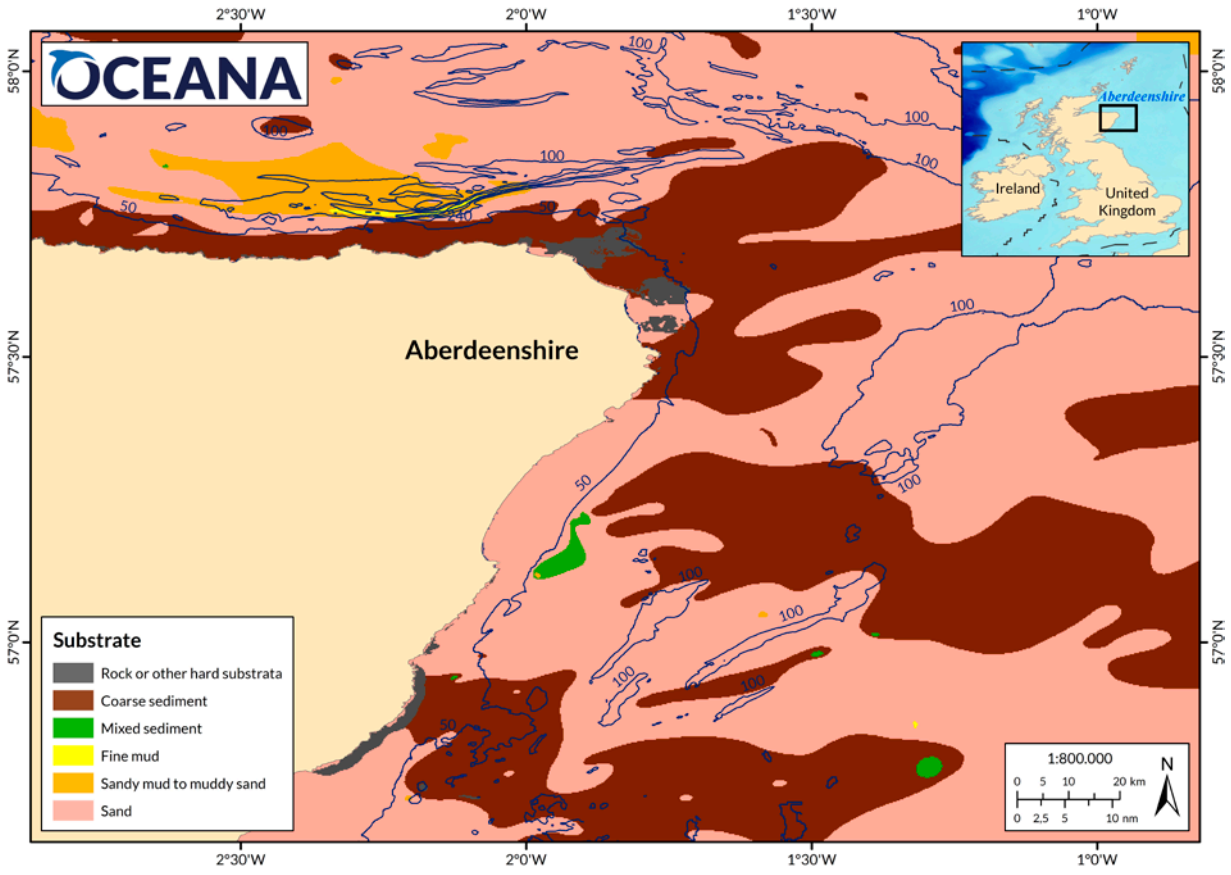

Figure 3. Substrate types and bathymetry of the Aberdeenshire survey area. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute.[9]

Known ecological features of interest

The complex bathymetry and heterogeneity of the seafloor substrates in the waters off Aberdeenshire contribute to a diverse array of habitats and thus ecological features of interest. The Aberdeenshire survey area is known to host muddy habitats that support sea pen and burrowing megafauna communities. The reef-forming polychaete known as ross

worm (*Sabellaria spinulosa*) has also been recorded in sandy and gravelly regions, with reef formations in some sites. Along the coastline, macroalgal forests have been documented on both the north and east coasts of Aberdeenshire, within the survey area. Finally, a frontal system in the Moray Firth represents an area of increased chlorophyll levels and a hotspot for marine mammals. Each of these features is described in more detail below.

Muddy habitats are extensive in the North Sea, particularly in Scottish waters, and in some areas are home to various species of sea pens.[2,14] Burrowing megafauna associated with such habitats can include Norway lobster (*N. norvegicus*), North Sea tube anemone (*Cerianthus lloydii*), and fireworks anemone (*Pachycerianthus multiplicatus*).[14] In fine sediment areas, the expected fauna includes phosphorescent sea pen (*Pennatula phosphorea*), crustaceans such as common hermit crab (*Pagurus bernhardus*) and gastropods such as slender colus (*Colus gracilis*).[13]

Edible crab (*Cancer pagurus*) and ascidians (*Clavelina lepadiformis*).
© OCEANA/ Juan Cuetos

Within the Southern Trench specifically, the biotype burrowed mud has been repeatedly reported.[15] Burrowed mud communities are expected to occur more broadly in the survey area due to the presence of muddy seabeds, and also the occurrence of Norway lobster (*Nephrops norvegicus*) and sea pens, which have been documented in previous studies and fisheries surveys.[2] Sea pens are considered an indicator of

the quality of mud habitats, due to their sensitivity to demersal fishing impacts.[16] The distributions of three sea pen species in Scottish waters, *Virgularia mirabilis*, *P. phosphorea* and *Funiculina quadrangularis* have been determined using *N. norvegicus* stock assessment video survey data.[2] During this analysis, both *V. mirabilis* and *P. phosphorea* sea pens were frequently observed in the Southern Trench area.

A study conducted in 2015 by Marine Scotland Science (MSS) and Scottish Natural Heritage (SNH)[17] documented populations of *N. norvegicus* and *P. phosphorea* on deep sandy mud (93-94 m), in the northwestern corner of the Southern Trench. The northern part of the Southern Trench was dominated by muddy sand, which was home to a burrowing megafauna community that included *N. norvegicus* and *P. phosphorea*. In 2017, additional surveys in the area further documented muddy bottoms, with burrows likely made by *N. norvegicus* and *Calocaris macandreae*, and frequent observations of *P. phosphorea*.[18]

Another known feature of interest in the waters off Aberdeenshire are biogenic reefs formed by ross worm (*S. spinulosa*). *S. spinulosa* reefs are associated with faunal levels of abundance five times higher than surrounding sedimentary habitats.[19] Such reefs have the potential to affect the topographic relief of soft sediment zones; this habitat modification in areas of otherwise little topographic relief can affect the soft sediment communities present.[20]

Various recent studies have documented the presence of this habitat type in the eastern arm of the proposed *Southern Trench* MPA. Research on *Southern Trench* habitats in 2011 found low numbers of ross worm tubes (i.e., 1-4 tubes) in grab samples at three locations, and nearly 200 tubes in a sample from the eastern part of the trench.[21] A 2013 survey conducted for Statoil documented high abundances of *S. spinulosa* in the eastern part of the proposed MPA, extending into waters further to the east.[22] *S. spinulosa* coverage was as high as 85% in some of the sites areas surveyed, and reef habitats extended over areas of up to 4,015,865 m^2.[22] Additional *S. spinulosa* reefs and tubes were observed during later research by SNH and Cefas, in areas characterised by tide-rippled medium sand, and also in the eastern arm of the proposed *Southern Trench* MPA.[17,23] These waters experience elevated tidal currents that favour the development of ross worm on bedrock, boulders and cobbles.[17] The importance of the south-eastern arm of *Southern Trench* for *S. spinulosa* was further confirmed through more recent surveys carried out by the Joint Nature Conservation Committee (JNCC) and MSS in collaboration with SNH. *S. spinulosa* reefs were widely recorded during inshore surveys, and consolidated material forming dense encrustations, probably from *Sabellaria* activity, was abundant in deeper waters.[18] Species that are considered Priority Marine Features (PMFs)[24] were also recorded during some of these surveys, such as juveniles of anglerfish (*Lophius piscatorius*) and ling (cf. *Molva molva*).

Kelp forests often dominate the rocky coasts of cold-water marine habitats and are considered to be one of the most diverse and productive ecosystems in the world.[25,26,27] They develop on shallow rocky shores where light and oceanographic conditions allow the development, growth and persistence of populations.[26] Kelp forests provide a three-dimensional habitat in coastal waters for a diverse array of marine organisms.[30] For example, tangle (*L. hyperborea*) creates a large and heterogeneous habitat owing to its height (1-2 m), and can host a large number of species, often in high densities.[28] Kelp forests in the UK provide habitat for invertebrates and nursery habitat for fishes such as cod (*Gadus morhua*) and pollack (*Pollachius pollachius*).[30] They also represent feeding grounds for fish species including *Labrus bergylta* and *Ctenolabrus rupestris*.[29] In the Aberdeenshire survey area, documented kelp species include *Alaria esculenta*, *Laminaria digitata*, *L. hyperborea* and *Saccharina latissima*.[30,31]

Additionally, another known feature of interest in the survey area is the frontal system in the Moray Firth. Fronts are narrow zones with steep gradients in temperature, salinity, density, turbidity and ocean colour.[32] In 2013, this system was identified by detecting chlorophyll front hotspots using satellite ocean colour data.[33] The front appeared to correspond to a narrow, shallow inner shelf, which indicated that it may be associated with enhanced tidal mixing.[33] Marine mammals are associated with oceanic fronts, and the Southern Trench is characterised by higher-than average predicted densities of minke whale (*Balaenoptera acutorostrata*).[34] Sightings of minke whales increase in the outer Moray Firth during front periods when phytoplankton biomass is at its greatest.[35] Other cetaceans found in the outer southern Moray Firth area include bottlenose dolphin (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), killer whale (*Orcinus orca*), long-finned pilot whale (*Globicephala melas*), humpback whale (*Megaptera novaeangliae*), Risso's dolphin (*Grampus griseus*), and Atlantic white-sided dolphin (*Lagenorhynchus acutus*).[36]

Beyond specific features, the waters of Aberdeenshire are also known to provide habitat for a wide range of commercial species, some of which have spawning and/or nursery grounds in the area. Such species include sandeels (Ammodytidae), herring (*Clupea harengus*), cod (*Gadus morhua*), lemon sole (*Microstomus kitt*), Norway lobster (*Nephrops norvegicus*), and plaice (*Pleuronectes platessa*).[37,38] The habitats that they rely upon for growth or spawning (along with other important habitats such as feeding grounds and migratory corridors) are known as essential fish habitats (EFH), because of the critical role that they play during species' life cycles.[39]

The diverse array of species that use Aberdeenshire as spawning and nursery grounds could be due to the heterogeneity of the seafloor substrate and associated habitat types in the area. Additionally, the presence of a frontal system in the survey area may influence the distribution of spawning sites and nursery grounds. Frontal systems represent a

boundary between two water masses and therefore can be characterised by steep horizontal gradients in both biological and physical properties.[40] As a result, fronts have the potential to locally retain larvae that float in the water column, thereby limiting larval dispersal.[40]

Plaice (*Pleuronectes platessa*).
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Previous surveys

Since the first large-scale survey of the North Sea in 1923,[41] the waters of Aberdeenshire have been studied extensively for geological, biological, and industrial interests (Table 1). Various academic, government, and industrial research bodies have made efforts to better understand the physical nature of the seabed, as well as benthic community composition in Aberdeenshire waters (Table 1).

Geophysical surveys have been conducted in the Oceana survey area, with particular attention having been paid to the Southern Trench. Detailed surveys were made along a section of the Southern Trench for the Strategic Environment Assessment Area 5 (SEA Area 5).[11] Data were obtained on seabed superficial geology and geological processes using multibeam bathymetry, side-scan sonar, seismic reflection profiles, seafloor photographs and samples.[11] Additional surveys have been conducted for the oil and gas industry and for potential wind farm installation sites.[22,42]

In order to improve knowledge of the benthos associated with this unique area, major UK research bodies have studied seabed communities across a range of depths. For example, MSS has made efforts to characterise the Scottish marine benthos in the Moray Firth using *Nephrops* survey video data and reported burrowed mud habitats with three species of sea pens.[2,43] MMT conducted marine geophysical research using video data and grab samples and identified areas of 'bedrock reef' and 'stony reefs', as well as aggregations of ross worm (*Sabellaria spinulosa*).[22] SNH was the first group to thoroughly examine both infaunal and epifaunal benthic communities in the Southern Trench using drop-down video camera footage and grab samples, identifying eight habitat biotypes.[21] Multiple surveys carried out by SNH during the last decade have revealed locations with burrowed muddy bottoms and of habitat formed by *S. spinulosa* (see *Known ecological features of interest*).

Table 1. Major benthic biological and geological research studies carried out in the survey area.

Year of Survey	Group	Purpose of Survey	References
1922-1925	Fishery Board for Scotland	First large-scale survey of the northern North Sea. Qualitative documentation of benthic species using grab sampler.	Stephen, 1923,[41] 1933,[44] 1934[45]
1958	Aberdeen Marine Laboratory	Study of the benthos of fishing grounds off the east coast of Scotland, Aberdeen Bay, St Andrews Bay and the Smith Bank in the Moray Firth.	McIntyre, 1958[46]
1975-1992	United Kingdom Offshore Operators Association	Numerous seabed surveys conducted for the oil and gas industry to provide information on localised impacts of offshore installations.	Kingston & Harries, 2000[42]
1980-1985	Scottish Department of Agriculture and Fisheries, International Council for the Exploration of the Seas	Survey of the entire North Sea benthos to determine species biodiversity and abundance.	Eleftheriou & Basford, 1989;[47] Heip *et al.*, 1990,[48] 1992;[49] Künitzer *et al.*, 1992;[50] Duineveld *et al.*, 1991[51]
1982	MAFF/Luton College	Surveys of the epifauna of the North Sea using a camera attached to a trawl during demersal fish surveys.	Dyer *et al.*, 1982,[52] 1983;[53] Cranmer 1985[54]
1983-present	English and Scottish Groundfish Surveys	Annual demersal fish surveys using trawls.	ICES, 2019[55]
1986	Delta Institute for Hydrobiological Research	Synoptic benthic survey across North Sea. 171 sample sites were surveyed using a Van Veen grab, concentrating on copepod communities.	Huys *et al.*, 1990, 1992[56,57]

1999	Cefas	Biological survey of epibenthic species using a small beam trawl across various sites in the North Sea.	Jennings *et al.*, 1999[58]
2001-2003	Marine Scotland Science	Determined distributions of three sea pen species, using *Nephrops norvegicus* stock assessment videos.	Greathead *et al.*, 2007[2]
2003	British Geological Survey, Department of Trade and Industry	Detailed surveys along a section of the Southern Trench for the Strategic Environment Assessment area 5 (SEA Area 5). Data obtained on seabed superficial geology and geological processes using multibeam bathymetry, side scan sonar, seismic reflection profiles, seafloor photographs and samples. Comprised both geological and biological sampling.	Holmes *et al.*, 2004[11]
2008-2010	Marine Scotland Science	Analysed sea pen abundance, using *Nephrops* stock assessment videos.	Allan *et al.*, 2012[43]
2010-2011	SEA/Marine Scotland	Shelf deeps of Southern Trench mapped during multibeam surveys.	Unpublished (see SNH, 2014)[59]
2011	British Geological Survey and Scottish Natural Heritage	Multibeam surveys adjacent to the survey area SEA5 (see above).	Hirst *et al.*, 2012[21]
2011	Heriot Watt University, Scottish Natural Heritage and Marine Scotland Science	Biological surveys of the Southern Trench, using drop-down video and grabs.	Hirst *et al.*, 2012[21]
2013	MMT	Marine geophysical seabed and environmental surveys around the then-proposed Hywind Offshore Wind farm site, off the east coast of Scotland. Environmental surveys comprised 34 sampling sites and 6 video transects.	Statoil Environmental Survey report[22]
2015	Scottish Natural Heritage and Cefas	Investigation of the distribution of protected features in the *Southern Trench* MPA proposal, using video data and grab sampling.	Moore, 2017[17]; Axelsson *et al.*, 2017[23]
2015-2018	Scottish Natural Heritage/Marine Scotland Science and JNCC/Marine Scotland Science	Research to improve knowledge of species and habitats through analysis of seabed videos and still images collected during monitoring and research cruises.	Moore, 2019[18]

The main threats to marine biodiversity in the Aberdeenshire area originate from anthropogenic activities (Figure 4). These threats include commercial fishing, oil and gas exploitation (e.g., platforms and pipelines), shipping traffic, wind farm installations, and pollution.

Fisheries represent a major industry in Scottish waters. Within the Oceana survey area, there is widespread fishing activity using dredges, harvesting machines, seine nets, traps and trawls (Table 2) to capture both pelagic and demersal species. Over 54 species are commercially fished in Aberdeenshire waters (Table 2) including crustaceans, molluscs, gadoids, and rays. In terms of total catches by weight, the fishery for scallop (*Pecten maximus*) is the greatest (with 1226 tonnes landed in the southeast part of the survey site in 2016). *Scomber scombrus*, *Loligo* spp. and *Nephrops norvegicus* are also among the most significant fisheries by weight. Offshore sites (in the eastern part of the survey area) have a greater diversity of species caught compared to nearshore coastal fisheries, potentially owing to the high fishing effort reported from these offshore sites (Table 2).

Table 2. Effort and landing data for commercial species for UK vessels over 10 m in length. Data were obtained from ICES fishing effort data sets for 2016.[63,64,65]

	ICES Statistical Rectangle					
	42E7	**42E8**	**43E7**	**43E8**	**44E7**	**44E8**
Area	SW survey area, east coast of Scotland	SE survey area	Aberdeen coast	Offshore Aberdeen	NW survey site, Moray Firth	NE survey area, offshore Peterhead
Effort (days) by UK vessels >10 m length. Annual total	1062	674	130	589	2248	1424
Gear type	Dredges, Harvesting machines, Traps, Trawls	Dredges, Harvesting machines, Seine nets, Trawls	Dredges, Traps, Trawls	Dredges, Harvesting machines, Seine nets, Traps, Trawls	Dredges, Harvesting machines, Seine nets, Traps, Trawls	Dredges, Harvesting machines, Seine nets, Traps, Trawls
Quantity of species landed (tonnes)						
Anarhichas lupus	-	-	-	0	0	0
Brachyura	0	-	-	-	-	0

Brosme brosme	-	-	-	1	0	0
Buccinum undatum	10	-	0	0	1	0
Cancer pagurus	236	5	58	167	335	380
Carcinus maenas	1	-	-	1	0	1
Chelidonichthys cuculus	-	-	-	0	1	2
Clupea harengus	1	0	-	97	2	-
Conger conger	-	-	-	-	0	0
Dicentrarchus labrax	-	-	-	-	0	-
Eutrigla gurnardus	-	-	-	0	2	8
Gadus morhua	1	0	-	4	9	11
Galatheidae	-	-	-	-	0	-
Glyptocephalus cynoglossus	0	0	-	0	8	6
Hippoglossoides platessoides	-	-	-	-	0	-
Hippoglossus hippoglossus	0	0	-	0	2	1
Homarus gammarus	129	7	6	17	25	31
Labridae	-	-	-	-	0	-
Lepidorhombus spp.	-	-	-	0	1	1
Leucoraja naevus	-	0	-	-	3	3
Limanda limanda	-	-	-	-	4	0
Loligo spp.	0	6	0	0	550	62
Lophiidae	0	0	-	4	47	67
Melanogrammus aeglefinus	0	4	-	25	233	215
Merlangius merlangus	-	0	-	2	15	33
Merluccius merluccius	-	-	-	1	2	2
Microstomus kitt	0	0	-	0	6	6
Molva molva	0	-	-	-	2	3
Mullus surmuletus	-	0	-	0	0	0
Mya arenaria	0	-	-	-	-	-
Necora puber	60	3	2	17	37	39
Nephrops norvegicus	95	2	-	7	513	113

Octopodidae	-	-	-	-	2	0
Palaemon serratus	3	-	-	-	-	-
Palinurus spp.	-	-	-	-	-	0
Pecten maximus	317	1226	4	640	160	753
Phycis blennoides	-	-	-	-	-	0
Pleuronectes platessa	0	0	-	2	34	19
Pollachius pollachius	-	-	-	0	0	0
Pollachius virens	-	0	-	-	2	4
Psetta maxima	0	-	-	0	0	0
Raja clavata	-	-	-	0	4	0
Raja montagui	-	-	-	-	-	0
Raja spp.	-	-	-	-	0	-
Scomber scombrus	20	1	3	43	147	969
Scophthalmus rhombus	-	-	-	0	0	0
Scyliorhinus canicula	-	-	-	-	31	5
Sebastes spp.	0	-	-	-	-	-
Sepiidae, Sepiolidae	-	-	-	-	0	0
Solea solea	-	-	-	-	0	-
Solen spp.	0	-	-	-	-	-
Sprattus sprattus	-	-	-	-	2	-
Squalidae, Scyliorhinidae	-	-	-	-	0	-
Triglidae	-	-	-	-	0	1

Various fishing gears used in the waters of Aberdeenshire are destructive and can have profound impacts on the seafloor. Demersal fishing activities such as dredging (used for scallop fisheries) and trawling (used for infaunal and epifaunal species) are associated with habitat loss and damage and with the capture of non-target organisms, altering benthic community structure.[3,60,61] Traps and pots are also used in Scottish waters, to capture crustaceans such as *Cancer pagurus*, *Homarus gammarus* and *N. norvegicus*. Pots and traps are less destructive than mobile fishing gear,[62] although lost pots and traps have the potential to continue to capture benthic organisms, especially if there is still bait inside: a phenomenon known as 'ghost-fishing'.

Offshore oil and gas exploitation is another major industry in the North Sea that poses multiple threats to benthic communities.[66,67,68] Scotland is considered to be the largest producer of oil in Europe, and there are numerous wells and hydrocarbon fields within and in close proximity to the Aberdeenshire survey area (Figure 4). The St Fergus terminal on the east coast of Scotland is the largest single gas importing facility in the UK, receiving nine gas pipelines;[10] to the north of Aberdeen, Cruden Bay receives oil from the Forties pipeline system. The presence of such pipelines can also cause habitat loss, due to physical disturbance of seabed substrata.

Benthic communities are also at risk from pollutants released from oil platform operations and ships. Exposure to such stressors can lead to a reduction in species abundance and diversity and an increase in opportunistic species.[67,69] During 2014, there were a total of 748 accidental discharges from vessels and releases from offshore oil and gas installations in the UK.[70] On the eastern coast of Scotland, 18 oil spill incidents were reported, 14 of which occurred in ports and harbours, three in the open sea and one on a beach.[70]

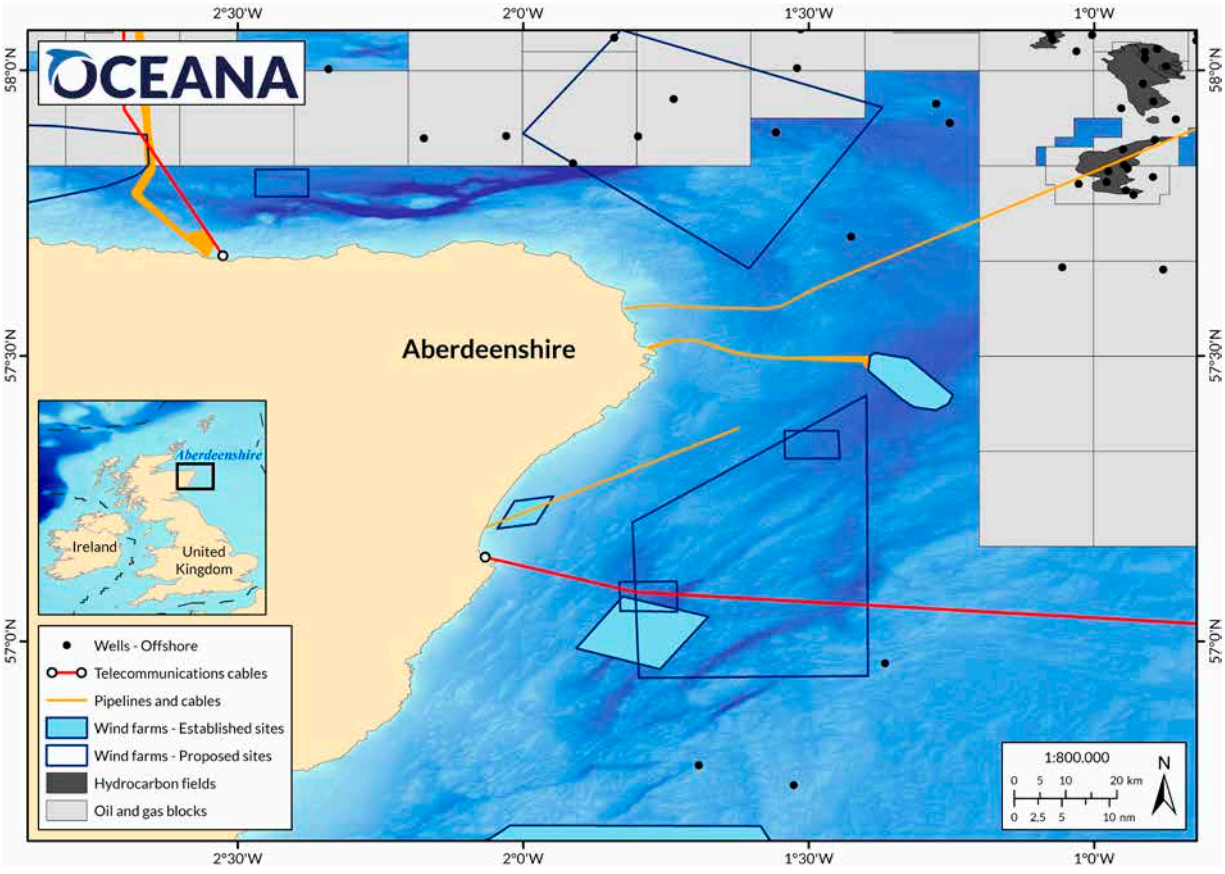

Figure 4. Oil fields, pipeline, cables and wind farm development sites in the survey area. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] Oil and Gas Authority,[71] TeleGeography,[72] The Crown Estate,[73] and 4c Offshore.[74]

Trawler off the coast of Fraserburgh.
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Along the east coast of Scotland are numerous harbours, many of which require occasional dredging to maintain navigable depths. The areas with the highest density of shipping traffic are coastal areas around Peterhead.[10] The dredge spoils from navigational dredging are disposed of around the east coast of Scotland and along the coast of the Moray Firth. There are a total of five open waste disposal sites within the survey area,[75] and five closed disposal sites, one off the coast of Stonehaven and four off the coast of Peterhead.[76] Aberdeen and Peterhead each have major ports for both oil and gas, and for fishing vessels. Various smaller harbours are also dotted along the coast of the Aberdeenshire survey area.

Additionally, the *Hywind Scotland* floating offshore wind farm is located 25 km offshore from Peterhead, with the cable landing point in Peterhead.[74] The world's first floating commercial wind farm, it began supplying electricity to Scotland in late 2017. The wind farm consists of five floating turbines anchored to the seabed, each with a connection to an export cable. Prior to the development of this wind farm, an environmental survey conducted by MMT for Statoil revealed a *Sabellaria spinulosa* reef along the export cable route, and extensive *S. spinulosa* reefs within the turbine site area that were found to have higher levels of biodiversity than sites lacking *S. spinulosa*.[22] Further wind farms are being developed off the coast of Aberdeen, with another wind farm also fully commissioned, *European Offshore Wind Deployment Centre*.[74] Additionally, *Kincardine Offshore Windfarm* is under construction, 15 km southeast of the Aberdeen coast.[74] A development zone for wind farms (named E3) partially overlaps with the survey site,

but it is 'subject to high levels of ornithological constraints' and encompasses known spawning area for some species, so development of wind farms within the zone will depend on science to reduce environmental risks.[77] The impacts of renewable energy and power cables can affect sediment or water quality, which may impact benthic communities by displacing or attracting species.[78,79] Disturbance of the seabed during construction and operation can cause habitat damage directly or indirectly, through increased suspended sediment and turbidity, which poses a particular risk to benthic filter-feeding organisms.[78] Marine mammals can be sensitive to noise created by exploration and construction activities, which may cause displacement or act as a barrier to species movement.[80,81,82]

Another significant and growing threat is marine debris. It has been estimated that 4.8-12.7 million tonnes of litter enter the oceans each year;[83] the North Sea alone has a mean litter abundance of 16.8 litter items per km^2, the majority of which are plastic.[84] Large plastics can pose a threat to marine organisms via entanglement, whereas marine organisms can ingest smaller plastics such as microplastics,[85] which have been steadily increasing in the oceans over past decades.[86] Microplastics can originate from the direct release of plastic particles and also as a result of the fragmentation of larger plastic particles.[86] A study in the North Sea sampled seven commercially important fish species, and detected microplastic in five of them (i.e., cod, herring, horse mackerel, whiting and haddock); within each of those species, the percentage of individual fish containing plastics ranged from 1-13%.[85]

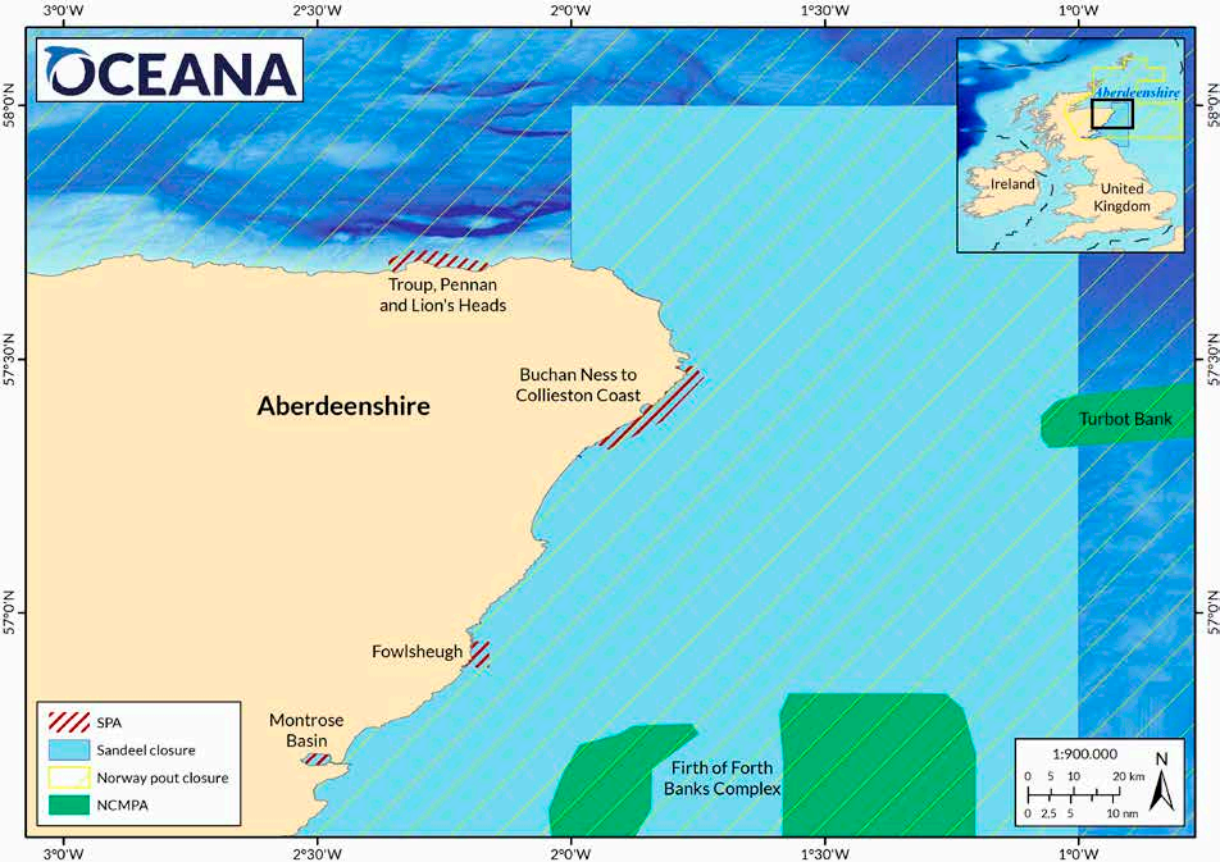
Current management measures

The Oceana survey area encompasses three sites that are designated as Special Protection Areas (SPAs), overlaps with two fisheries closures, and is near to two offshore Nature Conservation MPAs (NCMPAs) (Table 3; Figure 5). The SPAs were designated for the protection of seabird breeding sites along the coast; the fisheries closures target the recovery of sandeel (Ammodytidae) and Norway pout (*Trisopterus esmarkii*) populations. To the east of the survey area, the offshore *Turbot Bank* NCMPA was designated for the protection of sandeel, and while the *Firth of Forth Banks Complex* NCMPA was created to protect ocean quahog (*Arctica islandica*), among other features (see Figure *5*, which shows two of its three polygons). The designation of MPAs in Aberdeenshire has remained relatively stagnant, with most of the areas having been designated in the 1990s, and the two NCMPAs in 2014.

Table 3. Current spatial management measures in the survey area and vicinity.

Management measure	Details
Fowlsheugh SPA	Originally designated in 1992, under the EU Birds Directive. During the breeding season, the area regularly supports 170 000 seabirds, including: razorbill (*Alca torda*), herring gull (*Larus argentatus*), fulmar (*Fulmarus glacialis*), guillemot (*Uria aalge*), and kittiwake (*Rissa tridactyla*).[87]
Troup, Pennan and Lion's Heads SPA	Originally designated in 1997, under the EU Birds Directive. During the breeding season, the area regularly supports 150 000 seabirds, including: guillemot (*Uria aalge*), razorbill (*Alca torda*), fulmar (*Fulmarus glacialis*), herring gull (*Larus argentatus*), kittiwake (*Rissa tridactyla*).[87]
Buchan Ness to Collieston Coast SPA	Originally designated in 1998, under the EU Birds Directive. During the breeding season, the area regularly supports 95 000 seabirds, including: guillemot (*Uria aalge*), kittiwake (*Rissa tridactyla*), herring gull (*Larus argentatus*), shag (*Phalacrocorax aristotelis*) and fulmar (*Fulmarus glacialis*).[87]
Norway pout box	Designated in 1977. Norway pout fishing prohibited year-round using towed gear with a mesh size less than 32 mm. This area is closed with the intention of protecting juvenile gadoids.[88]
Northwestern North Sea Sandeel Fishery Closure	Designated in 2000. Year-round closure on sandeel fishing except for a commercial monitoring fishery with a total allowable catch limit.[89]
Turbot Bank NCMPA (outside survey area)	Designated in 2014, because of its importance for sandeels, particularly Raitt's sandeel (*Ammodytes marinus*). The site contains the type of sandy sediment with low silt and clay components that sandeels prefer.[90]
Firth of Forth Banks Complex NCMPA (outside survey area)	Designated in 2014. The site was designated to protect both biodiversity and geodiversity features, such as ocean quahog (*Arctica islandica*) aggregations, offshore subtidal sands and gravels, shelf banks and mounds, and Quaternary of Scotland – moraines.[91]

Figure 5. Current spatial management measures in the area, including SPAs, sandeel and Norway pout fisheries closures, and NCMPAs. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] SNH,[92] Wright *et al.* (1998).[93]



Previous conservation proposals

Following the enactment of the Marine (Scotland) Act 2010,[94] the process began to identify, propose, and designate Nature Conservation MPAs (NCMPAs) in Scottish waters. These MPAs are intended to conserve marine biodiversity (both species and habitats) and geodiversity (features of geological or geomorphological interest).

In 2012, as part of this process, the Whale and Dolphin Conservation Society, the Hebridean Whale and Dolphin Trust, and the Cetacean Research and Rescue Unit proposed two potential areas for protection that overlap with the Oceana survey area (Figure 6).[95] The first of these areas encompassed part of the Southern Trench, and was proposed for the protection of minke whale (*Balaenoptera acutorostrata*); the second area, along the east coast of Aberdeenshire, was put forward for the conservation of white-beaked dolphin (*Lagenorhynchus albirostris*).[95]

While the proposal for the latter area did not advance, the former contributed to the identification of the Southern Trench as an MPA search location, for which further assessment was required because the existing evidence was considered to be insufficient for making a full proposal.[96] The *Southern Trench* MPA search location was considered to be of interest for an array of Scottish MPA search features,[97] including both biodiversity features (i.e., burrowed mud, fronts, shelf deeps, minke whale, and white-beaked dolphin) and geodiversity features (i.e., Quaternary of Scotland — subglacial tunnel valleys and moraines; and submarine mass movement — slide scars).[59] The search area lay primarily in territorial (i.e., nearshore) waters, encompassing the trench and roughly following the 12 nm limit. It also overlapped with the marine part of the *Troup, Pennan and Lion's Head* SPA (see *Current protection measures*).

In 2014, SNH provided further evidence and formal advice to the Scottish government on the NCMPA proposals for *Southern Trench*, and three other areas (*North-east Lewis*, *Sea of Hebrides*, and *Shiant East Bank*).[98] At that time, modifications of the boundaries of the recommended MPA included its westward expansion, to include an area of above-average densities of minke whale (*B. acutorostrata*). White-beaked dolphin (*L. albirostris*) was also removed as a feature of the proposal, because it was not possible to identify areas considered as essential within the area.

In 2015, a network-scale assessment was carried out to evaluate the adequacy of the Scottish MPA network with respect to the MPA search features.[99] That assessment included both designated NCMPAs and the four proposed areas (including *Southern Trench*) for which government approval was still pending. The assessment concluded that the protection of *Southern Trench* was necessary in order to have sufficient representation of the feature 'burrowed mud'. It further stated the designation of *Southern Trench* was required in order to provide sufficient representation of minke whale (*Balaenoptera acutorostrata*), fronts and shelf deeps in OSPAR Region II (Greater North Sea).[99]

Following an announcement in 2018 that the Scottish government was providing additional resources for the development of the four pending NCMPAs,[100] a public consultation was launched in 2019 on the designation of the sites.[101] The official proposal for the *Southern Trench* NCMPA listed four proposed protected biodiversity features (burrowed mud, fronts, minke whale, and shelf deeps) and two geodiversity features (Quaternary of Scotland and submarine mass movement).[102,103] At least 182 participants, including Oceana, responded to the consultation.[104] At the time of writing, the analysis report from the consultation had not yet been released, and the protection of the area was still pending.

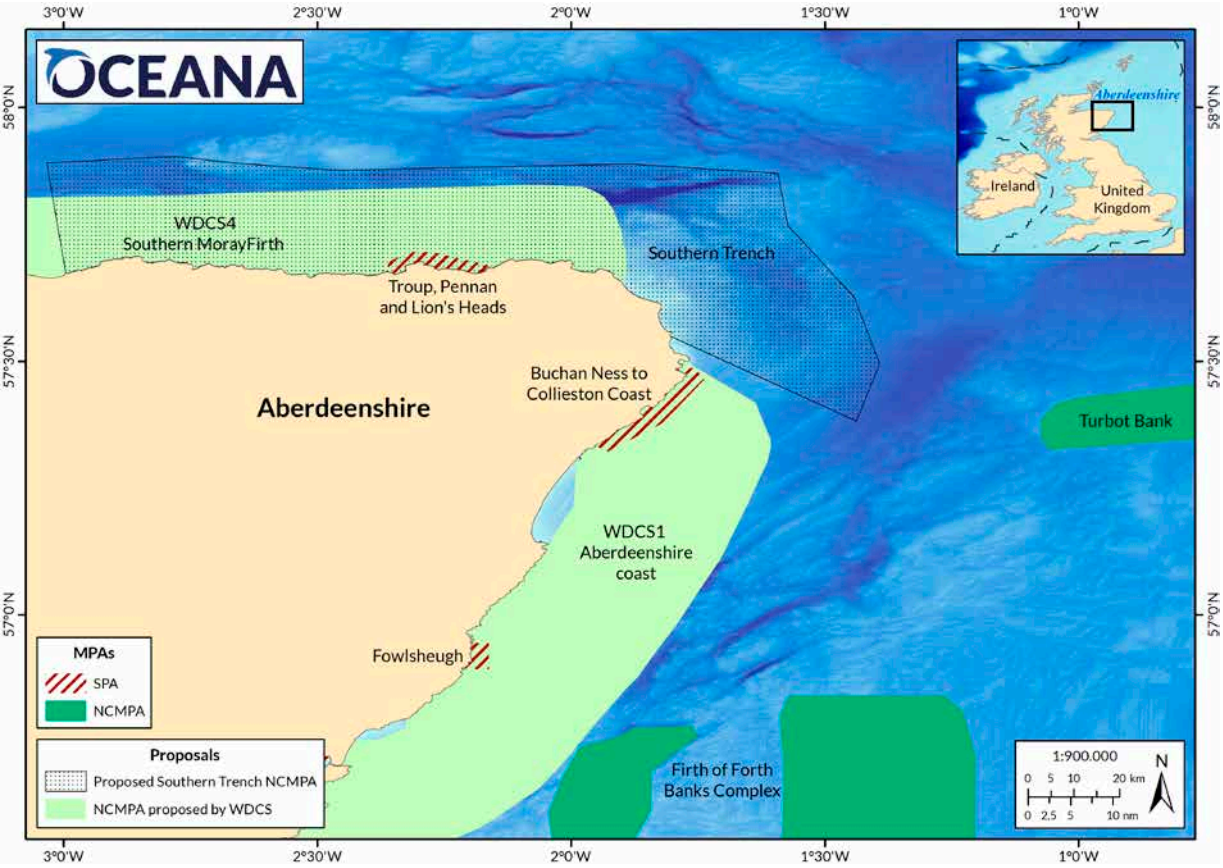


Figure 6. Designated and proposed MPAs in the Aberdeenshire area. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] SNH,[92] WDCS/ HWDT/CRRU.[95]

Lion's mane jellyfish (*Cyanea capillata*). © OCEANA/ Juan Cuetos

OCEANA SURVEYS

Methods

Oceana surveyed the waters off the Aberdeenshire coast as part of an eight-week, at-sea research expedition carried out in the North Sea in 2017. This expedition aimed to gather first-hand information from areas of known or potential ecological importance, but from which data on benthos were lacking. Surveys of these zones were carried out onboard the research survey vessel *MV Neptune*, a fully-equipped vessel of 49.85 m overall length and 10 m extreme breadth.

Research was conducted off the Aberdeenshire coast between 27 June and 3 July 2017, with a total of six days of work at sea in the area (Figure 7). Survey sites were selected based on known or potential features of interest, and also based on consultation with Marine Scotland and SNH prior to the expedition, with particular interest being paid to potential *Sabellaria spinulosa* reef sites.

Visual surveys (ROV and SCUBA)

The seabed was explored mostly by low-impact, visual means, using a remotely operated vehicle (ROV) with a high-definition camera, and via professional SCUBA divers, who produced high-definition video footage and high-resolution still images.

For ROV image recording, a Saab Seaeye Falcon DR ROV was used, equipped with a High Definition Video (HDV) camera of 1920x1080 resolution, 1/2.9" Exmor R CMOS Sensor, minimum scene illumination of 3-11 Lux, and a 4.48 mm, f/1.8 3.4 zoom lens. Images were recorded both in high definition (to film specific features of interest) and low definition (for the total duration of surveys), along with position, depth, course and time. Lasers on the ROV were used in order to estimate sizes and abundances. Considering the average speed and the wide angle of the camera (i.e., it was able to film transects of ca. 1.5 m width), the ROV allowed the observation of around 550-650 m^2 per hour of seabed.

Across the survey area the ROV was deployed in seven locations, three of which were in the proposed *Southern Trench* MPA (Figure 7). The depth range of the ROV surveys was 42-244 m. Samples of key habitat-forming species were also collected (by means of the robotic arm of the ROV) for detailed analyses to confirm preliminary identifications.

SCUBA surveys were carried out by eight professional divers, divided into two teams; each team comprised a photographer, a videographer, and two safety divers. The divers surveyed five areas: one within *Fowlsheugh* SPA, three within *Buchan Ness to Collieston Coast* SPA, and one

off the coast of Fraserburgh, ranging in depth from 8-17 m. A total of five samples were taken during two of the dives in the *Buchan Ness to Collieston Coast* area.

Following the expedition, all of the videos and still images filmed by the ROV and divers were analysed by Oceana scientists, who identified all of the visible species identified to the finest taxonomic level possible.

Infaunal sampling

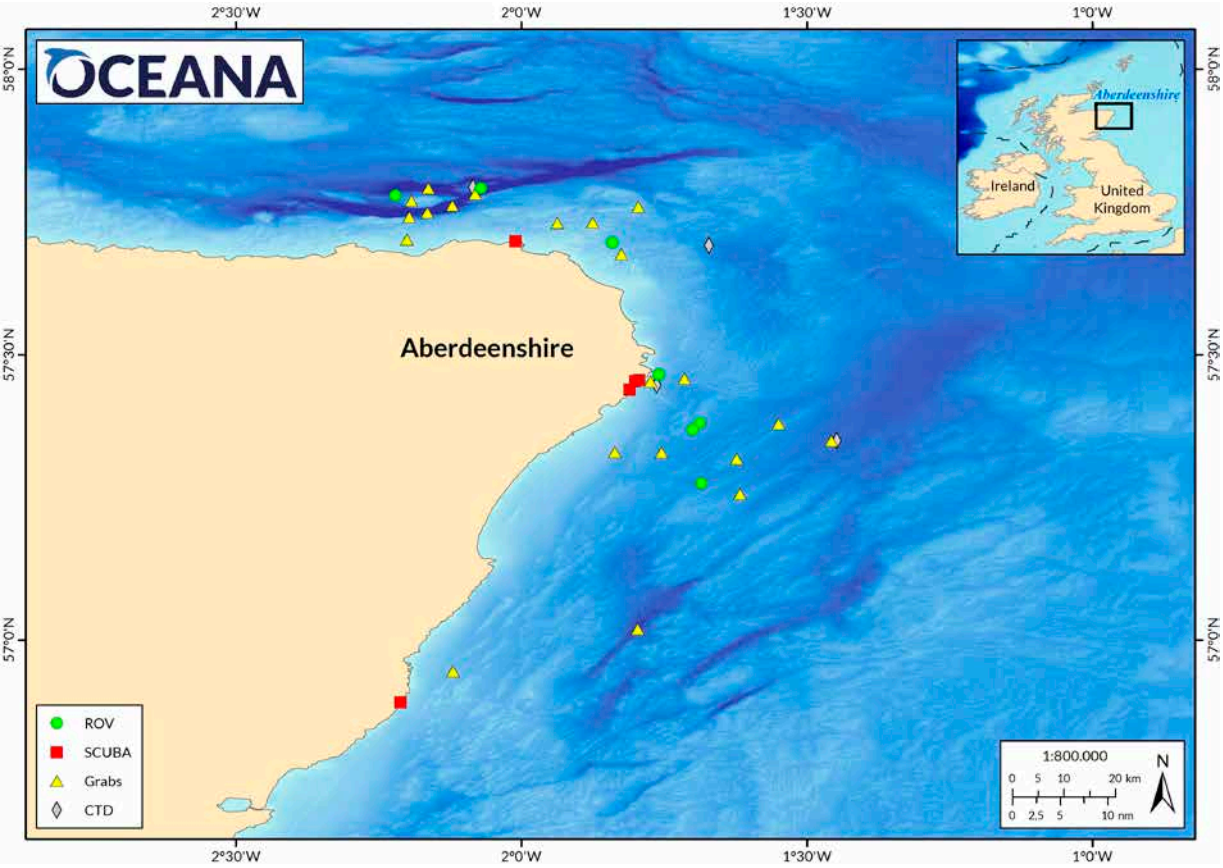
Infaunal community composition was examined using a 12 litre Van Veen grab sampler, and specimens retained on 0.5 mm and 1 mm mesh sieves were kept and identified. In total, 21 grab samples were obtained (one within the *Buchan Ness to Collieston Coast* SPA, 11 within the proposed *Southern Trench* MPA, and the rest in unprotected waters off the coast of Aberdeenshire). Surveyed sites ranged in depth from 30 m to 223 m. This provided ground-truth data for the footage observed on the ROV, and also biological and sediment samples across the survey area.

Oceanographic parameters

Water column profiles on various oceanographic parameters were obtained at four locations in the survey area, using a Valeport MIDAS Conductivity, Temperature, and Depth recorder (CTD). This CTD is capable of reaching depths of 7000 m, but in this survey the greatest depth reached with the CTD was 158 m. With the CTD, data were obtained on dissolved oxygen (% saturation), pressure (dbar), temperature (°C), conductivity (ms/cm), fluorescence (ug/L), salinity (psu) and density (kg/m^3). Parameters were measured at 1 m depth intervals during both descent and ascent, yielding 851 measurements for each parameter. One of the CTD sample locations lay off the north coast of Fraserburgh, one off the coast of Rattray Head, and the final two off the coast of Peterhead, one of which was within the *Buchan Ness to Collieston Coast* SPA.

Squat lobster (*Galathea intermedia*).
© OCEANA/ Carlos Minguell

Figure 7. Survey points in the Aberdeenshire survey area during the 2017 Oceana North Sea expedition. Points are shown according to sampling type (i.e., ROV, SCUBA, grab samples, and CTD). Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute.[9]



Results

Oceanographic parameters

Data on oceanographic parameters in the four sites are shown in Figure 8. The deepest site sampled with a CTD was off the north coast of Fraserburgh, at a depth of 158 m. The water profile here revealed a temperature range of 9.5-11.8 °C, an average salinity of 35 psu and a fluorescence range of 0.1-4.8 ug/L, with the peak fluorescence reading at 26 m. This site had the highest fluorescence concentrations of the four sites sampled. A CTD deployed off the coast of Rattray Head reached a depth of 85 m and recorded temperatures ranging from 10.9-12.6 °C, and average salinity of 33.9 psu and a fluorescence range of 1.7-4.1 ug/l peaking at 47 m depth.

The third CTD deployment was within the SPA *Buchan Ness to Collieston Coast* and was the shallowest of the CTD sites, reaching depths of 42 m. There, the temperature ranged from 11.7 to 12.0 °C with an average salinity of 34.7 psu. The fluorescence levels recorded there were lower than those recorded off Rattray Head and Fraserburgh, ranging from 0.9-2.4 ug/L. Similarly, the final CTD conducted further offshore of Peterhead revealed fluorescence concentrations ranging from 0.3-2.8 ug/L. The temperature ranged from 9.7-12.0 °C and average salinity was 34.8 psu.

Fluorescence concentration can be used to infer chlorophyll and coloured dissolved organic matter levels. The higher levels of fluorescence found in the northern survey area may have been due to two small mesoscale oceanographic features in the Moray Firth. These features are the Dooley Current, which transports cold north Atlantic water into the northern North Sea and into the Moray Firth[13] and a plume feature which consists of warmer water flowing from the inner Moray Firth out into the North Sea.[35] When the plume is more dominant than the cold-water current, there is an increase in phytoplankton biomass in the southern outer Moray Firth.[35] As such, the oceanographic regime in the northern sector of the survey area may have resulted in the higher fluorescence concentration levels compared to the eastern coast of Aberdeenshire.

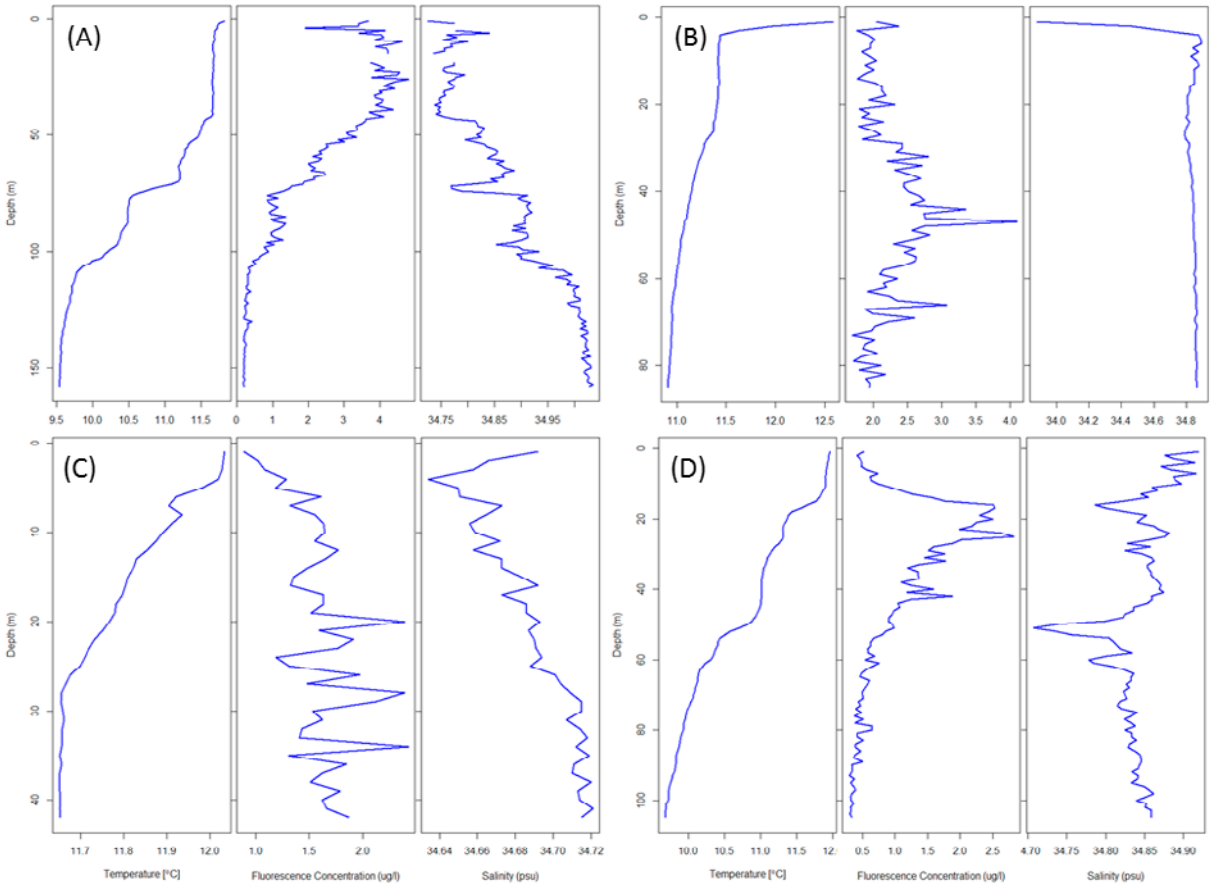


Figure 8. CTD profiles of the water column at four sites in Aberdeenshire. Parameters included are temperature (°C), fluorescence concentration (ug/L) and salinity (psu). (A) North coast of Fraserburgh, (B) off the coast of Rattray Head, (C) within *Buchan Ness to Collieston Coast* SPA, (D) offshore from Peterhead.

Community types and species

Oceana documented a total of 351 species, 76 genera and 54 higher-level taxa in the Aberdeenshire survey area (see Annex), in association with 14 habitat types (Figure 9). Our findings are presented by community types categorised to the finest degree of classification according to the EUNIS habitat type hierarchy.[105] All of the communities identified fall under the broad EUNIS habitat classification of Sublittoral sediment (A5). Sublittoral sediment habitats extend from the sublittoral zone to the edge of the bathyal zone (200 m) and encompass a range of sediment types, from mud to boulders.[105] Details of the habitat types and sub-types found are provided below.

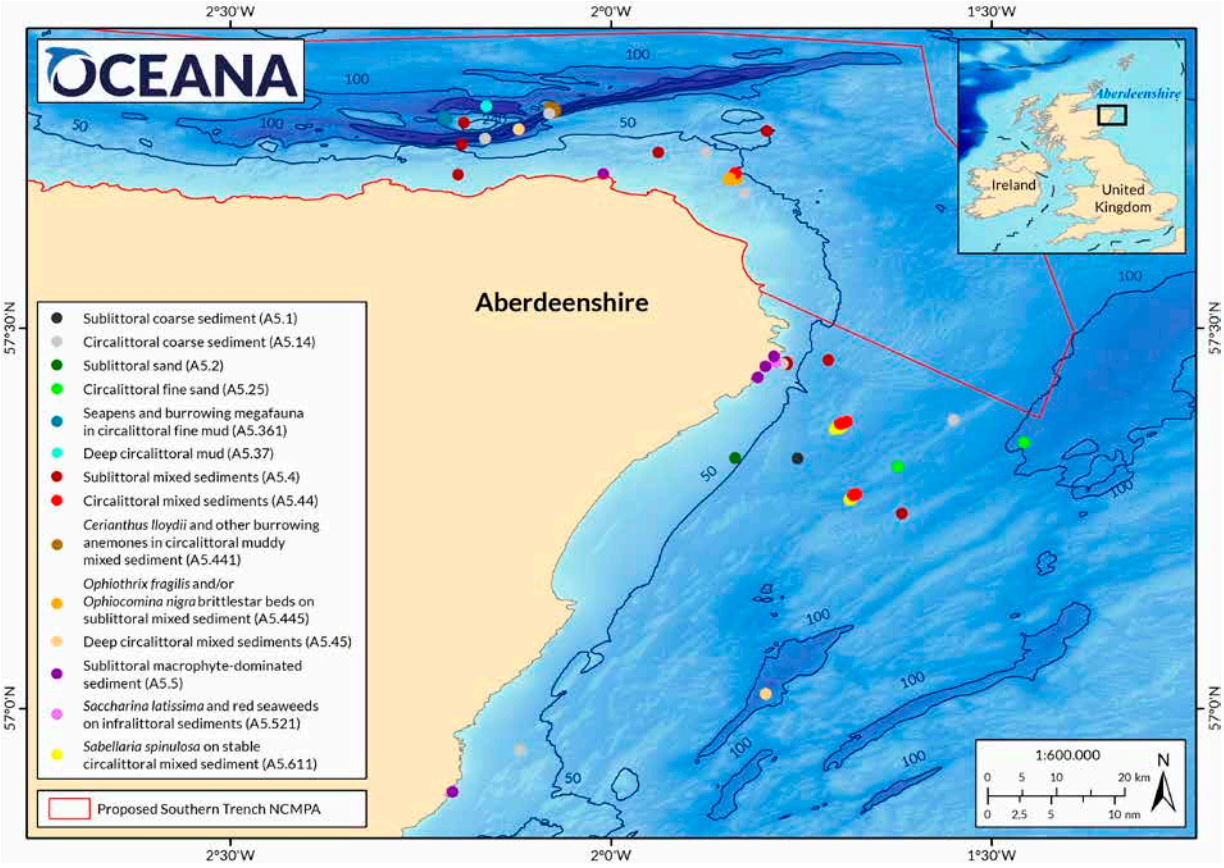


Figure 9. Distribution of 14 habitat types documented in the Aberdeenshire survey site during the 2017 Oceana expedition, classified according to the EUNIS habitat hierarchy. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] SNH.[92]

Sublittoral coarse sediment (A5.1)

Sublittoral coarse sediment includes coarse sand, gravel, pebbles, shingle and cobbles.[105] The typical associated species are bivalves, particularly those belonging to the Veneridae family. During the Oceana expedition, this habitat biotype was found offshore from Aberdeen, in an area of coarse sand at 64 m depth. Here, a grab sample revealed a total of 22 species of bivalves, including a specimen of *Arctica islandica* and of some species of Veneridae, such as *Venus cassina*. Other bivalves found include *Timoclea ovata*, *Parvicardium pinnatulum*, *Astarte* spp. and *Nucula* spp. Several echinoderms were included in the grab sample, including *Echinocyamus pusillus* and *Amphiura filiformis*. Tubes of *Sabellaria spinulosa* were also found attached to bivalve shells and cobbles.

Circalittoral coarse sediment (A5.14)

A sub-category of Sublittoral coarse sediment, circalittoral coarse sediment is defined by coarse sands, gravel and shingle in depths over 15-20 m.[105] These habitats are characterised by infaunal polychaetes, mobile crustaceans and bivalves. This habitat type was found in multiple locations including offshore from Aberdeen, within the Southern Trench area, within *Buchan Ness to Collieston Coast* SPA and outside *Fowlsheugh* SPA. Offshore from Aberdeen was home to mobile crustaceans, including *Cancer pagurus*, *Galathea* sp., *Munida sarsi* and *Pandalus montagui*, and bivalves such as *Abra prismatica*, *Mimachlamys varia*, *Tellina* spp. and *Timoclea ovata*. Within the Southern Trench area, four grab samples were characteristic of this habitat. All four grabs contained mobile crustaceans such as amphipods, *Eualus cranchii*, and *Strobopagurus gracilipes*, and polychaetes. Tubes of *S. spinulosa* were found attached to shells, and densely covered collected cobbles and pebbles, at some of the grab survey samples collected. Bivalves were also found in these grabs with the most diverse and abundant sample comprising; a total of 23 species and 86 individuals. A grab sample from *Buchan Ness to Collieston Coast* SPA contained a diverse array of polychaetes, including *Amphectine auricoma*, *Lagis koreni*, *Owenia fusiformis* and *S. spinulosa* as well as the sponge *Leucosolenia* sp., bivalves and crustaceans. Similarly, a grab sample from outside of *Fowlsheugh* SPA had a comparable composition, with three species of polychaetes identified alongside bivalves and amphipods.

Sublittoral sand (A5.2)

Sublittoral sands are defined as 'clean medium to fine sands or non-cohesive slightly muddy sands on open coasts, offshore or in estuaries and marine inlets'.[105] The typical associated taxa include polychaetes, bivalves and amphipods. This habitat type and the associated community were found offshore from Aberdeen in a grab sample. An array of bivalves was found (12 species), including *Abra alba*, *Chamelea striatula*, *Nuculua nucleus*, *Tellina* spp. and *Venus cassina*. The substrate type was slightly muddy sand at a depth of 41 m.

Circalittoral fine sand (A5.25)

This habitat types consists of fine sands in deeper water (>15-20 m) and is characterised by echinoderms, including pea urchin (*Echinocyamus pusillus*), polychaetes and bivalves. Circalittoral fine sand was found in the furthest sampling site from the shore, off the east coast of Aberdeen. The depth ranged from 70-100 m with fine sand and muddy sand. Among the sampled fauna, *E. pusillus* was abundant, with a total of 56 individuals recorded from the grab samples. Other echinoderms documented included *Amphiura filiformis* and *Echinocardium flavescens*. A diverse range of bivalves were found, including *Abra prismatica*, *Arctica islandica*, *Astarte montagui*, the habitat-forming species *Modiolus modiolus*, *Tellina pygmaea* and *Timoclea ovata*. Polychaetes found included *Hyalinoecia tubicola* and *Sabellaria spinulosa*, of which two small aggregations of tubes were collected in one grab.

Sublittoral mud (A5.3): Seapens and burrowing megafauna in circalittoral fine mud (A5.361)

This habitat type is characterised by mud at depths greater than 15 m, supporting populations of *P. phosphorea* and *V. mirabilis*. The mud may contain burrows due to the presence of burrowing megafauna such as Norway lobster (*Nephrops norvegicus*). This habitat type was recorded by the ROV within the Southern Trench at depths ranging from 163-244 m. During this survey, 104 individuals of *Pennatula phosphorea* were found in burrowed mud sites. *Cerianthus lloydii* was also recorded, as well as *Liocarcinus depurator* and *Pagurus bernhardus*, and brittlestars (*Ophiura albida* and *Ophiothrix fragilis*). Burrowed mud was observed in this site, although *N. norvegicus* was not encountered.

Figure 10. *Astrorhiza limicola* and *Pennatula phosphorea.*

Sublittoral mud (A5.3): Deep circalittoral mud (A5.37)

Typically below 50-70 m, this habitat type is characterised by muddy sediment and dominated by polychaetes and high numbers of bivalves, echinoderms and foraminifera. This habitat type was found in a grab sample taken in the Southern Trench at a depth of 200 m. Within this sample there were echinoderms *Amphiura chiajei* and *Echinocyamus pusillus*, bivalves Semelidae and *Nucula* sp., and also polychaetes.

Sublittoral mixed sediments (A5.4)

This habitat type consists of heterogeneous sediments (including muddy gravelly sand and cobbles and pebbles) that can support a wide range of infauna and epibiota including polychaetes, bivalves, echinoderms, sponges, anemones, hydroids and bryozoans. It was documented in *Buchan Ness to Collieston Coast* SPA during an ROV survey, and hosted seven species of cnidaria including hydroids (*Kirchenpaueria pinnata*, *Nemertesia antennina*, and *Tubularia indivisa*) and anemones (*Urticina eques* and *Cerianthus lloydii*). Over 400 individuals of *Asterias rubens* were documented along this transect. Bryozoans present included *Flustra foliacea*, *Membranipora membranacea* and *Parasmittina trispinosa*, while sponges documented included *Grantia compresa*, the habitat-forming species *Stelligera stuposa* and *Sycon ciliatum*. Macroalgae such as *Delesseria sanguina*, *Heterosiphonia plumosa* and *Desmarestia aculeata* were also documented in low numbers.

Five grab samples taken within the Southern Trench area also fell under this habitat type. These samples contained anthozoans such as *Caryophyllia smithii* and *Stomphia coccinea*, hydrozoans such as *Lafoea dumosa* and *Tubularia indivisa*, and various echinoderms and bryozoans. Other grab samples representing this habitat type were taken offshore from the east coast of Aberdeen, and included habitat-forming species, such as *Tellina* spp. and remains of *Arctica islandica*. Tubes of *Sabellaria spinulosa* were found densely covering some shells and rocks collected in one grab sample in that area.

Circalittoral mixed sediments (A5.44)

This biotype is also characterised by mixed sediments that host a variety of communities, particularly hydroids (*Nemertesia* spp. and *Hydrallmania falcata*). Circalittoral mixed sediment areas were recorded in the majority of ROV surveys both within the Southern Trench area and also in waters offshore from Aberdeen. The ROV survey within the Southern Trench recorded more than 120 individuals of sickle hydroid (*H. falcata*) and more than 490 individuals of *Nemertesia* spp. Offshore from Aberdeen, three ROV surveys documented more than 181 individuals of *H. falcata* and over 233 of *Nemertesia* spp. Some sponges were also present, including the habitat-forming species *Polymastia boletiformis*, *Halicolona urceolus*, and *Suberites* sp.

Figure 11. *Nemertesia antennina*.

Cerianthus lloydii and other burrowing anemones in circalittoral muddy mixed sediment (A5.441)

This habitat type is characterised by sandy muddy gravel that hosts burrowing anemones such as North Sea tube anemone (*Cerianthus lloydii*). An ROV survey site in the Southern Trench comprised this biotype due to the muddy sandy sediment present and the presence of *C. lloydii* and *Cerianthus membranaceus*. Hermit crab (*Pagurus bernhardus*) was also present, along with common sea star (*Asterias rubens*). Other species within this community included scallop (*Pecten maximus*), sand mason worm (*Lanice conchilega*) and sponges such as *Antho (Antho) dichotoma*, *Haliclona urceolus* and *Suberites* spp.

Figure 12. *Cerianthus lloydii*.

Ophiothrix fragilis and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment (A5.445)

The sediment in this habitat biotype is dominated by brittle stars *Ophiothrix fragilis* and *Ophiocomina nigra*, which form dense beds. An example of this community was observed in the north of Fraserburgh in the Southern Trench area, where more than 1081 individuals of *O. nigra* and more than 1281 individuals of *O. fragilis* were found on rocky sandy sediments. The soft coral dead man's fingers (*Alcyonium digitatum*) was frequently encountered, as well as hydroids (*Nemertesia* spp.) and anemones (*Urticina* spp). Various species of crustacean were also documented, including *Cancer pagurus*, *Galathea* sp., *Inachus dorsettensis*, *Munida* spp. and *Necora puber*. Some sponges were also observed, including *Antho* sp., *Halichondria (Halichondria) panicea* and *Hymedesmia* sp. These communities inhabited areas of rocks and sand in depths of around 45 m.

Figure 13. Brittlestars covering the seafloor.

Deep circalittoral mixed sediments (A5.45)

This habitat type comprises substrates of slightly muddy mixed gravelly sand and stones or shell. Associated species typically include a diversity of polychaetes and bivalves, and some areas may support horse mussel (*Modiolus modiolus*). Grab samples in two locations revealed the presence of the habitat type: one in the Southern Trench, and one offshore from Aberdeen. The samples indicated that polychaetes were present in both sites, while six species of bivalves were recorded in the Southern Trench (including the habitat-forming species *Tellina pygmaea*) and 12 species of bivalves in the offshore Aberdeen grab (including remains of *Arctica islandica*).

Sublittoral macrophyte-dominated sediment (A5.5)

This habitat type includes maërl beds, macroalgae on mixed sediment, seagrass beds and lagoonal angiosperm communities. All of the SCUBA dive surveys documented this habitat biotype, and showcased high diversity and abundance of macroalgae, particularly of tangle (*Laminaria hyperborea*), the red alga *Phycodrys rubens*, and encrusting red alga *Phymatolithon lenormandii*. The first dive was conducted within *Fowlsheugh* SPA, and documented more than 78 individuals of *L. hyperborea* and over 61 specimens of *P. rubens*. A dive conducted on the north coast of Aberdeenshire recorded nine species of macroalgae, including more than 573 individuals of *L. hyperborea*. This kelp forest supported populations of echinoderms such as *Echinus esculentus*, *Henricia* sp. and *Marthasterias glacialis*, as well as seven species of crustaceans, and more than 361 individuals of dead man's fingers (*Alcyonium digitatum*). Three dives were conducted within the *Buchan Ness to Collieston Coast* SPA, where more than 668 individuals of *L. hyperborea* were documented, alongside other macroalgae species including *Alaria esculenta*, *Desmarestia* spp. and *Saccharina latissima*. These sites hosted over 16 species of crustaceans, nine species of tunicates, and nine species of bryozoans. Grey seals (*Halichoerus grypus*) were documented during four of these SCUBA surveys, both from the surface and inside submerged caves (with one individual found in one cave, and a group of nine individuals in a second cave).

Figure 14. *Laminaria hyperborea* forest. © OCEANA/ Carlos Minguell

Saccharina latissima and red seaweeds on infralittoral sediments (A5.521)

This biotype comprises infralittoral mixed muddy substrata communities characterised by sugar kelp (*Saccharina latissima*), with mixed filamentous and foliose red macroalgae. This habitat type was found during a SCUBA dive inside the *Buchan Ness*

to Collieston Coast SPA. During this dive, over 60 individuals of *S. latissima* were documented alongside an abundance of red macroalgae. Other brown macroalgae documented in this habitat included *Alaria esculenta*, *Fucus serratus* and *Laminaria hyperborea*.

Figure 15. *Saccharina latissima*.
© OCEANA/ Carlos Minguell

Sublittoral biogenic reefs (A5.6): Sabellaria spinulosa on stable circalittoral mixed sediment (A5.611)

This habitat includes the reef-forming polychaete known as ross worm (*Sabellaria spinulosa*) in high abundances on mixed sediment. Such concentrations of *S. spinulosa* were documented in three ROV surveys conducted off the coast of Aberdeen, which revealed a total of 36 aggregations of *S. spinulosa* amongst rocks and sand. The size of these aggregations ranged in size from 10 cm to more than 80 cm width. The ross worm aggregations provided a hard substrate for species to colonise in otherwise sandy habitat. Species found living on and amongst the *S. spinulosa* included hydroids such as *Tubularia indivisa*, *Nemertesia* spp., and *Hydrallmania falcata*; dead man's fingers (*Alcyonium digitatum*); and anemone *Urticina* sp.

Consolidation of sediment by *S. spinulosa* tubes was also documented in six grab samples from depths of 30 m to 250 m in sand, coarse sediment, and mixed sediment sites (see corresponding habitat type sections, above) in the same offshore Aberdeen area where reefs were observed via ROV, and in other locations. Although the extent of coverage or size of aggregations cannot be determined from grab samples, they nevertheless confirmed the presence of *S. spinulosa* aggregations in locations that had not previously been documented (Figure 16).

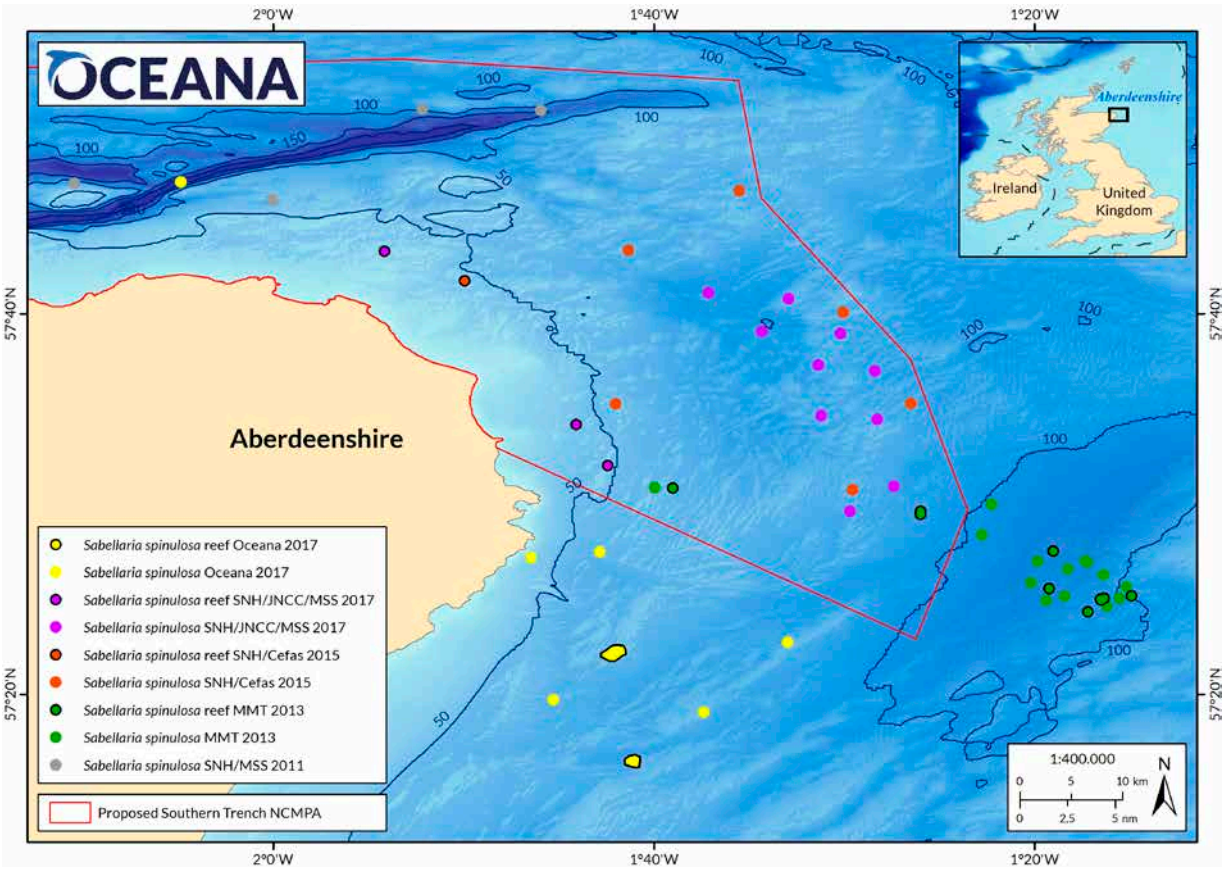


Figure 16. Overview of known ross worm (*Sabellaria spinulosa*) aggregations and reefs in the Aberdeenshire area. Points are located where reefs have been documented. Research organisations and survey years are detailed in the legend. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] Oceana (present study), SNH/JNCC/MSS,[18] SNH/Cefas,[17] SNH/MSS,[21] MMT,[22] and SNH.[92]

Figure 17. *Sabellaria spinulosa* reef with laser points (10 cm apart) for size reference.

Features of conservation interest

The Oceana expedition documented 16 species and seven habitat types in the waters of Aberdeenshire that are considered priorities for conservation because these features are included within international or Scottish frameworks that recognise their threatened status and/or establish requirements for their legal protection (Table 4). These include: the OSPAR List of Threatened and/or Declining Species and Habitats;[106] the EU Habitats Directive;[107] the list of Vulnerable Marine Ecosystem (VME) habitats and indicator taxa from the International Council for the Exploration of the Sea (ICES);[108] the Scottish Biodiversity List;[109] and the list of Priority Marine Features (PMFs), which are recognised priorities for marine conservation in Scottish waters.[24] Of the 14 PMFs recorded, six are further considered to be MPA search features,[97,110] which are used to guide the development of the Scottish MPA network. The occurrence of features listed in Table 4 deserves special consideration with respect to the biodiversity value of the area and required management measures. These features are discussed in more detail below.

Threatened and protected species

Most of the 16 species of conservation interest found in the survey area (Figure 18) were fishes, including sandeels (*Ammodytes* spp.) and gadids such as cod (e.g., *Gadus morhua*) and whiting (*Merlangius merlangus*). Also documented were six species that are listed by ICES as indicators of North Atlantic deep-water VMEs: ecosystems that are especially vulnerable to impacts from fishing activities. These species included cnidarians (*Caryophyllia smithii*, *Cerianthus lloydii*, *C. membranaceus*, *Pachycerianthus multiplicatus*, and *Pennatula phosporea*) and one species of sponge (*Polymastia boletiformis*); they are considered representative of four specific VME habitat types.[108]

Surveys also recorded the remains of seven specimens of ocean quahog (*Arctica islandica*), in four grab samples taken at depths between 64 m and 127 m. This mollusc is very vulnerable due to its long lifespan (which can exceed 500 years),[111] size (which can reach 100 mm in length),[112] and preferences for soft sandy bottoms, where it suffers from many anthropogenic impacts. The protection of the species is a priority under OSPAR for the Greater North Sea, where it is under threat and/or decline. In Scotland, ocean quahog is a PMF and an MPA search feature, and there remains a noted lack of data on its abundance in the areas where it is known to occur.[99]

Reefs and other aggregations formed by ross worm (*Sabellaria spinulosa*) were one of the features of greatest conservation interest that was observed during Oceana's surveys in Aberdeenshire waters (Figure 19). The importance of reefs formed by these tube-building polychaetes has been well recognised, as they increase the habitat complexity of soft bottoms and have been defined as biodiversity hotspots due to their associated species richness.[113,114] The conservation value of *S. spinulosa* reef habitats is highest where they occur in areas of sediment or mixed sediment bottoms, such as off Aberdeenshire; they provide a biogenic habitat that rises above the seabed, thereby permitting the settlement of epibenthic and infaunal species not found in adjacent habitats.[6,115]

Given their ecological importance, the protection of ross worm reefs is included under two major international conservation frameworks that are relevant for North Sea waters. The EU Habitats Directive covers biogenic concretions under the '*Reefs*' habitat type of community interest, and specifically mentions *S. spinulosa* as a reef-forming species in the North Sea.[116] OSPAR also includes *S. spinulosa* reefs on its List of Threatened and/or Declining Species and Habitats, and establishes recommended measures for their protection, such as limiting certain fisheries and aggregate extraction practices.[117]

In the waters of Aberdeenshire, several surveys during the past decade had documented the presence of *S. spinulosa* aggregations (Figure 16), including locations with extensive reefs that hosted high levels of biodiversity.[22] In 2017, both Oceana's research and SNH surveys[18] revealed the occurrence of ross worm aggregations and reefs in additional sites off the coast of

Grey seals (*Halichoerus grypus*).
© OCEANA/ Juan Cuetos

Aberdeen, Peterhead, and in the Southern Trench (at a depth of 250 m) (Figure 16). This suggests that *S. spinulosa* may be much more widespread in this area, and that there is the potential for additional reefs to be discovered.

A second key habitat type of importance documented Oceana's surveys in Aberdeenshire waters is burrowed mud, a recognised conservation priority both internationally and within Scotland. '*Sea pen and burrowing megafauna communities*' are included on the OSPAR List of Threatened and/or Declining Habitats,[106] on the basis of both documented declines and sensitivity to threats. Sea pen fields are also considered a VME habitat type,[108] which is threatened by activities that cause physical disturbance to the seabed, primarily demersal fisheries (in particular, trawl fisheries) that directly damage fragile invertebrate such as sea pens, cause changes in benthic community structure and function, and resuspend fine particles of sediment.[118] Within Scotland, the habitat type 'Mud habitats in deep water' is considered a conservation priority;[109] burrowed mud is both a PMF and an MPA search feature[24,97] and is one of the four biodiversity features that would be protected if the *Southern Trench* proposed NCMPA were designated.[102] Moreover, a network-level assessment carried out in 2015 by JNCC, SNH, and Marine Scotland concluded that without the protection of the *Southern Trench*, this habitat type would not be adequately protected in Scottish waters.[99]

Also worthy of note were rich habitats comprised by macroalgae. Large laminarians or kelps can create large and dense forests, together with foliose Rhodophyta (red algae). These species can provide an extensive 'canopy' under which many other species live, and a surface to which other organisms may attach. These habitats are of recognised importance at both the European and national level. The Habitats Directive descriptions of various types of reefs include red, brown and green macroalgae among the characteristic species of reef vegetation,[116] and different types of kelp and macroalgal communities are considered both PMFs and MPA search features in Scotland.[24,97] Furthermore, kelp forests in the North Sea are currently in the process of being listed as a threatened and/or declining habitat by OSPAR. During Oceana's surveys, kelp forests were documented on the northern and eastern coasts of Aberdeenshire, including areas inside the *Fowlsheugh* and *Buchan Ness to Collieston Coast* SPAs. Key species that comprised these habitats were tangle (*Laminaria hyperborea*) and sugar kelp (*Saccharina latissima*), mixed with a variety of red macroalgae and other brown macroalgal species. Associated fauna included other habitat-forming species such as the soft coral *Alcyonium digitatum*, as well as ascidians, bryozoans, hydrozoans, sponges, anemones, echinoderms, and molluscs.

Submerged caves represented another important habitat type found during Oceana's surveys. Caves are listed under Annex I of the EU Habitats Directive[107] and based on the conclusions

of the last biogeographical seminar to assess the status of the marine Natura 2000 Network, the UK has not yet sufficiently protected this habitat type in Scotland. During this seminar, it was highlighted that such caves provide important habitat for grey seal (*Halichoerus grypus*), and the UK government representative noted the difficulty of identifying cave areas. During Oceana's surveys, four submerged caves were documented inside *Buchan Ness to Collieston Coast* SPA, and grey seals and a school of sandeels were found inside them.

In addition to these habitat types, aggregations of burrowing anemones (*Cerianthus* spp.) and phosphorescent sea pen (*Pennatula phosphorea*) were also recorded, which are considered VME habitat types by ICES (see *Threatened and Protected Species*).[108]

Table 4. Benthic features of conservation interests documented in Aberdeenshire during the 2017 Oceana expedition, and the international and national frameworks under which they are recognised as threatened, protected, and/or priorities for conservation. HD: EU Habitats Directive; VME: Vulnerable Marine Ecosystem (both habitats and indicator species); PMF: Priority Marine Feature.

	Features	International Frameworks			National Frameworks		
		OSPAR[106]	HD[107]	VME[108]	Scottish Biodiversity List[109]	PMF[24]	MPA search feature[110]
Species	*Ammodytes marinus*				X	X	
	Ammodytes tobianus				X	X	X
	Arctica islandica	X				X	X
	Caryophyllia smithii			X			
	Cerianthus lloydii			X			
	Cerianthus membranaceus			X			
	Gadus morhua	X			X	X	
	Merlangius merlangus				X	X	
	Molva molva				X	X	
	Pachycerianthus multiplicatus			X	X	X[a]	
	Pennatula phosphorea			X			
	Pollachius virens					X	
	Polymastia boletiformis			X			
	Polyplumaria flabellata				X		
	Simnia patula				X		
	Trisopterus esmarkii				X	X	

Habitats	Burrowed mud				X	X	X
	Burrowing anemone aggregations			X		X	
	Kelp and macroalgal communities		Annex I: 1170 *Reefs*			X	X
	Sabellaria spinulosa reefs	X	Annex I: 1170 *Reefs*				
	Sea pens and burrowing megafauna communities	X		X	X	X	X
	Submerged caves		Annex I: 8330 *Submerged or partially submerged sea caves*				
	Subtidal sands and gravels				X	X	X

a. *P. multiplicatus* is a component species under the PMF '*Burrowed mud*'.

Beyond the documented PMFs that comprise habitat types, Oceana also found species that are considered indicators of three additional PMFs, both inside and outside the proposed *Southern Trench* NCMPA. Further research would therefore be needed to confirm whether the following three PMFs are also present in the area:

- *'Northern sea fan and sponge communities – Deep sponge communities (circalittoral)'*. The indicator species *Stelligera stuposa* (an erect branching sponge) was found outside the proposed MPA, together with other sponge species (e.g., *Sycon ciliatum* and *Grantia compressa*). Inside the *Southern Trench* area, a variety of sponge species growing on boulders were recorded, including *Antho* spp., *Haliclona urceolus*, *Suberites carnosus*, and *Suberites* spp. on deep bottom, and erect sponge species (i.e., *Antho* sp., *Halichondria panicea* and *Hymedesmia* sp.) in a shallower area. In both locations, other typical associated species for this biotope complex were also recorded.
- *'Horse mussel beds – Modiolus modiolus beds with Chlamys varia, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata'*. Shells of both *M. modiolus* and *Mimachlamys varia* (the accepted name for *Chlamys varia*) were collected together in a grab sample at 70 m depth, outside the proposed NCMPA.

- *'Inshore deep mud with burrowing heart urchins – Brissopsis lyrifera and Amphiura chiajei in circalittoral mud'*. Individuals of heart urchin (*B. lyrifera*) were collected in a grab sample from a location close to a second sampling site where individuals of brittlestar (*A. chiajei*) were also collected in two grab surveys. Both points were located inside the proposed NCMPA.

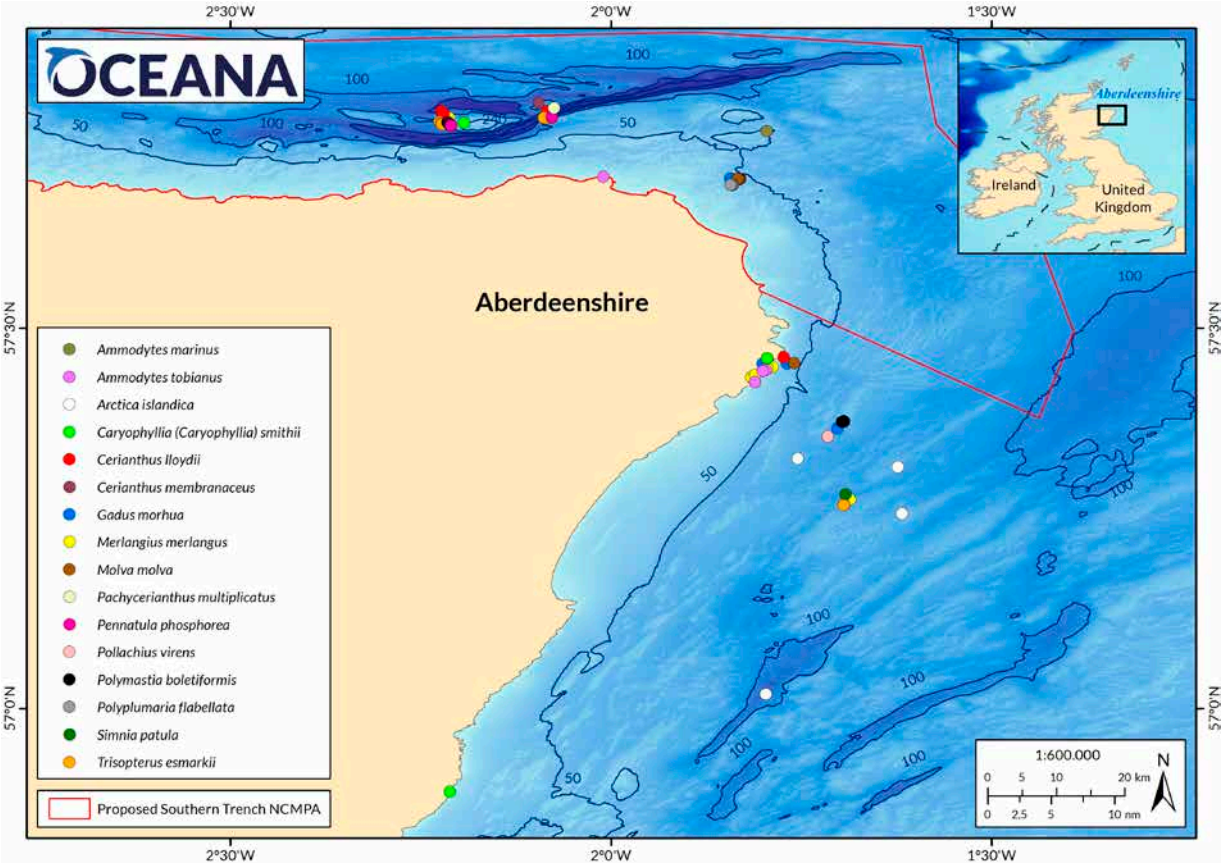
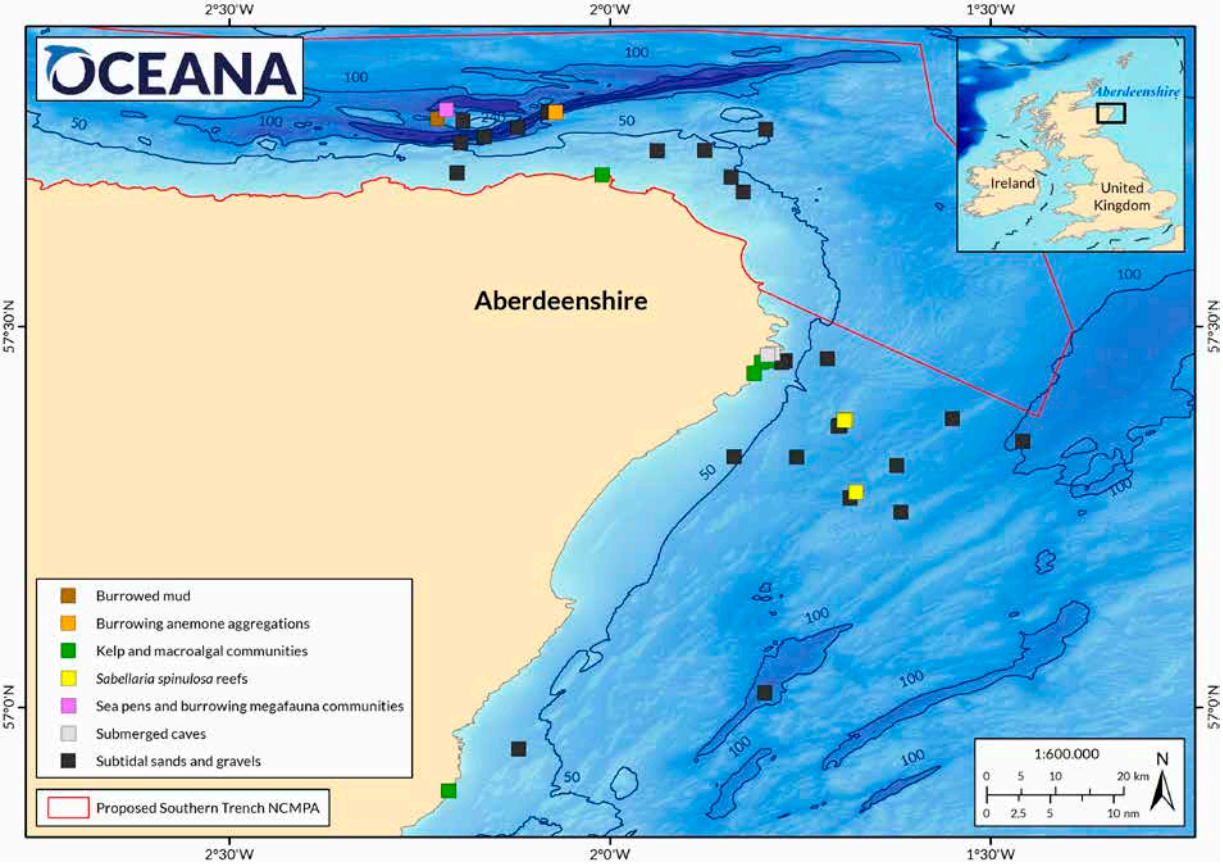


Figure 18. Species of conservation interest documented in Aberdeenshire during the 2017 Oceana expedition. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] SNH.[92]

Blue mussels (*Mytilus edulis*) and barnacles. © OCEANA/ Carlos Minguell

Figure 19. Habitats of conservation interest documented in Aberdeenshire during the 2017 Oceana expedition. Sources: EMODnet,[7] EEA,[8] Flanders Marine Institute,[9] SNH.[92]



Species of commercial interest and essential fish habitat

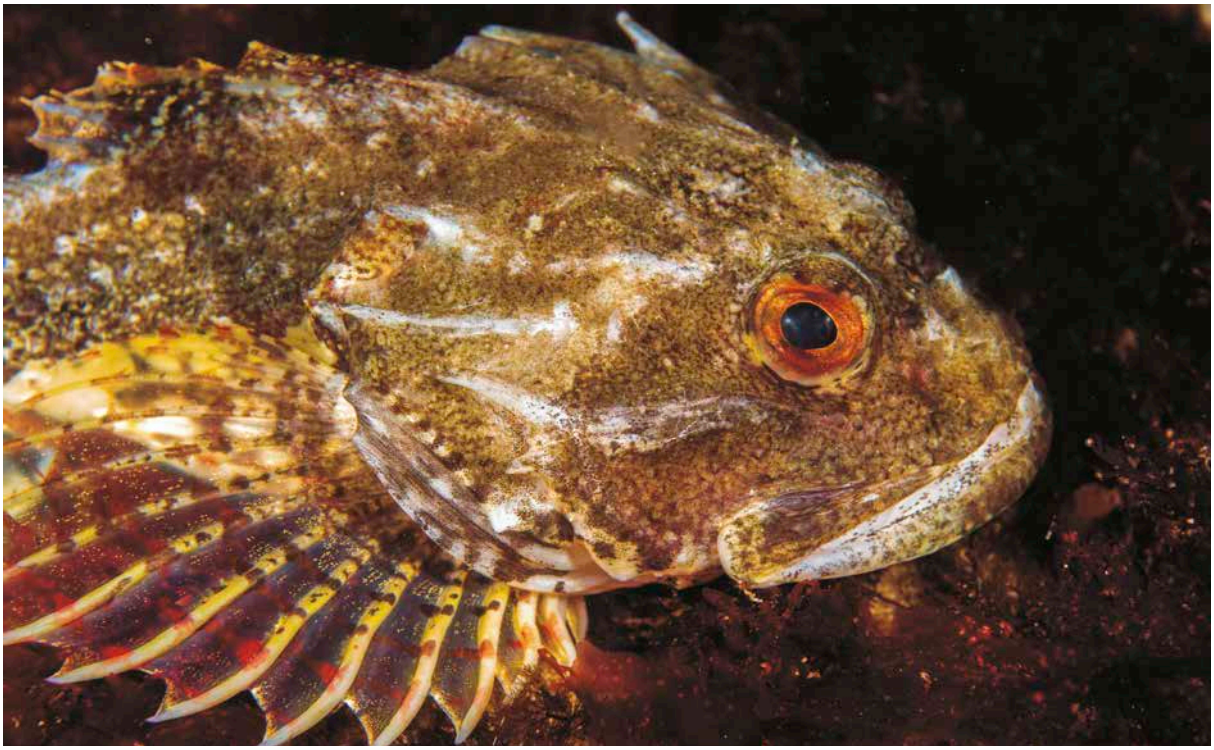
A total of 26 species of fishes were identified in the survey area (see Annex), many of which are commercially exploited (see Table 2). Of these species, the highest documented abundance of adult fishes was for dab (*Limanda limanda*), followed by sandeels (*Ammodytes* spp.). Records of juvenile fishes were dominated by gadids, such as whiting (*Merlangius merlangus*), cod (*Gadus morhua*), and poor cod (*Trisopterus minutus*).

The commercial species documented by Oceana included various fishes for which the waters of Aberdeenshire represent essential fish habitat (EFH): habitats that play a critical role during species' life cycles, such as spawning, nursery, or feeding grounds.[39] Specifically, spawning grounds have been

documented for at least eight species (of which Oceana recorded five), while nursery grounds have been identified in the area for at least 20 species (of which Oceana recorded eight) (Table 5).

For instance, Aberdeenshire waters encompass spawning and nursery grounds for sandeels (Ammodytidae).[37,38,119] During the Oceana surveys, sandeels were observed off both the north and east coasts of Aberdeenshire, including within the *Buchan Ness to Collieston* SPA. Shoals of *Ammodytes* spp. were recorded during surveys close to the east coast, near Fraserburgh and Peterhead. The local prevalence of sandeels in the area was unsurprising, given that the area is closed to sandeel fishing[89] on the basis of its known importance for these fishes.

The area also provides EFH for an array of gadids, including six species that were observed by Oceana (Table 5). For example, juveniles of cod (*G. morhua*), haddock (*M. aeglefinus*), and whiting (*M. merlangus*) were found in areas of mixed sediment and in shallow areas dominated by macroalgae on the east coast of Aberdeenshire. For all three species, safeguarding EFH is especially important, given the current status of the stocks. Although cod appeared to have been recovering from steep biomass declines during the 1970s until the mid-2000s, the most recent assessment of the population in the North Sea, eastern English Channel, and the Skagerrak indicates that cod in these areas has once again been declining.[120] It is currently considered to be below safe limits and remains subject to ongoing overfishing. One of the critical aspects highlighted in the assessment is the fact that recruitment has been poor since 1998 – which points even more strongly to the need to protect cod spawning and nursery grounds, to facilitate stock recovery.



Shorthorn sculpin (*Myoxocephalus scorpius*). © OCEANA/ Juan Cuetos

While the status of haddock (*M. aeglefinus*) in the area is considered to be better than that of cod, the most recent stock assessment for haddock in the North Sea, West of Scotland, and the Skagerrak also raises concerns about stock recruitment. It notes that recruitment has been low since the year 2000, with only occasional larger year classes, which have been decreasing in size over time.[121] The stock remains subject to unsustainable levels of fishing pressure.

Similarly, the 2019 assessment for whiting (*M. merlangus*) indicated that the stock in the North Sea and eastern English Channel is below safe biological limits, and that fishing pressure has been above sustainable levels for the past forty years (with the exception of the year 2005).[122] Recruitment in the last two years has been below average, again suggesting that measures to protect juvenile fishes may be especially important.

It should be noted that in addition to fishes, the waters of Aberdeenshire represent important spawning and nursery grounds for Norway lobster (*Nephrops norvegicus*),[123] although no individuals were observed during Oceana's surveys.

Table 5. Fish species with known essential fish habitat (EFH), specifically spawning and nursery grounds, in Aberdeenshire waters,[37,38,123,124] along with the abundances of fish species recorded during the Oceana 2017 expedition. Species for which no abundance is indicated were not observed during the expedition.

Species	Known EFH		Oceana observations	
	Spawning area	Nursery ground	Juveniles	Adults
Agonus cataphractus			-	23
Ammodytidae	X	X	-	>143
Aphia minuta			-	>21
Arnoglossus laterna			-	2
Callionymus maculatus			-	8
Callionymus sp.			-	1
Chelidonichthys cuculus			-	4
Chirolophis ascanii			-	1
Clupea harengus	X	X	-	-
Cottidae			-	1
Dipturus batis		X	-	-
Gadidae			>32	-

Gadus morhua	X	X	8	-
Galeorhinus galeus		X	-	-
Hyperoplus lanceolatus			-	2
Labrus mixtus			-	3
Limanda limanda			-	>299
Liparis liparis			-	2
Lophius piscatorius		X	-	-
Melanogrammus aeglefinus		X	3	4
Merlangius merlangus	X	X	26	1
Merluccius merluccius		X	-	-
Micromesistius poutassou		X	-	-
Microstomus kitt	X	X	1	2
Molva molva		X	2	4
Myoxocephalus scorpius			-	5
Myxine glutinosa			-	4
Pholis gunnellus			-	8
Phrynorhombus norvegicus			-	1
Pleuronectiformes			-	1
Pleuronectes platessa	X	X	-	-
Pollachius virens		X	2	-
Raja clavata		X	-	-
Raja montagui		X	-	-
Scomber scombrus		X	-	-
Sprattus sprattus	X	X	-	-
Squalus acanthias		X	-	-
Taurulus bubalis			-	7
Triglops murrayi			-	3
Trisopterus esmarkii	X	X	4	7
Trisopterus minutus			8	4

Considering the high level of demersal fishing activity in the area present in the area (see *Threats*), it was expected that surveys would find evidence of trawling activity and creel fisheries in the survey area. While no trawl marks were observed, some evidence of fishing activity was observed, as three pots were found in the survey area during SCUBA dives within *Buchan Ness to Collieston Coast* SPA. Two of these traps were in use, while one had been discarded.

The area's close proximity to the coast and busy shipping routes led to the expectation that there may have been considerable amounts of marine debris in the survey site. Nevertheless, only two pieces of litter were observed during two ROV surveys: glass at 45 m depth in the Southern Trench and a plastic pipe at 44 m depth within *Buchan Ness to Collieston Coast* SPA. However, microplastics (which cannot be observed in ROV and SCUBA footage) were collected in ten out of 21 grab samples. Microplastic obtained in these grabs were found at depths ranging from 30 m to 250 m. Five of these grabs were concentrated within the Southern Trench, and the rest were located along and offshore of the eastern coast of Aberdeenshire.

Figure 20. Fishing trap.
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PROPOSAL FOR PROTECTION

The sea surrounding Aberdeenshire is characterised by a rich diversity of benthic ecosystems, ranging from kelp forests along the coast to burrowed mud within the deep waters of the Southern Trench. These ecosystems encompass an array of features that are recognised priorities for conservation, at both the Scottish and international level. These features include species such as sandeels (*Ammodytes* spp.) and fireworks anemone (*Pachycerianthus multiplicatus*), and habitats such as ross worm (*Sabellaria spinulosa*) reefs and sea pen and burrowing megafauna communities.

Despite the high biodiversity value of benthic ecosystems in the Oceana survey area, protection of the benthos has been limited to date. Currently, the only measures of benthic protection in place within the area are restrictions on specific fisheries (i.e., Norway pout and sandeels); the only three MPAs that lie within the survey area are designated for the protection of birds (see *Current management measures*) and therefore do not grant any legal protection to the seabed. However, this situation may soon change. The Scottish government has formally recognised the value of benthic biodiversity in nearshore Aberdeenshire waters with its proposal to designate a large area (2536 km^2) of the Southern Trench as an NCMPA, to protect burrowed mud habitats and shelf deeps (as well as fronts, minke whale, and geodiversity features).[102] The *Southern Trench* site has been proposed as one of four new NCMPAs that would help to complete the Scottish network of MPAs. At the time of writing, a decision had not yet been announced on its designation.

The Oceana expedition in 2017 added further to knowledge about the rich diversity of benthic life in Aberdeenshire waters. During the expedition, 14 habitat types were recorded in the area, including sea pens and burrowing megafauna, brittle star beds, macroalgal communities and ross worm reefs. These habitat types were associated with high levels of biodiversity, with a total of 351 species, 76 genera and 54 higher-level taxa identified. Among the features documented were 23 features of conservation interest, including species and habitats that are priorities for protection in Scotland and/or internationally.

The Southern Trench clearly represents a biodiversity hotspot, and Oceana strongly supports the designation of the *Southern Trench* NCMPA to protect the rich biological communities found there. The protection of *Southern Trench* would represent a significant step to improve the conservation of the area itself, and to strengthen the network of Scottish MPAs in general. The Marine (Scotland) Act 2010 requires that Scottish Ministers designate NCMPAs as a contribution to a UK-wide network, and that the features protected by Scottish MPAs be representative of UK waters.[94] In this respect, the protection of burrowed

mud areas in *Southern Trench* is particularly important; Marine Scotland concluded in its 2015 assessment of the sufficiency of the Scottish MPA network that the protection of this feature would be insufficient in Scottish waters if the *Southern Trench* were not designated.[99]

Beyond the four biodiversity features that are proposed for protection in *Southern Trench*, Oceana's surveys indicated the presence of other features of conservation importance within the boundaries of the proposed site and therefore merit further consideration for protection. These features included additional PMFs: kelp forest (composed of *Laminaria hyperborea* and other macroalgae), sandeels (*Ammodytes* spp.), cod (*Gadus morhua*), ling (*Molva molva*), and whiting (*Merlangius merlangus*). Observations also indicated the potential occurrence of three other PMFs (see *Features of conservation interest*), for which further investigation would be needed to confirm their presence and determine their extent.

In addition to PMFs, Oceana's research highlighted the occurrence of another major feature of importance within the *Southern Trench* area that should be prioritised for protection: aggregations of ross worm (*S. spinulosa*). Oceana's findings supported observations from previous surveys that had also found dense encrustations of *S. spinulosa* within the proposed NCMPA (Figure 16). In fact, on the basis of earlier surveys, SNH noted that "*Sabellaria*-dominated habitats probably cover an extensive area in the eastern region of the proposed MPA."[17]

Given the decline of *S. spinulosa* reefs in European waters, their listing by OSPAR as a threatened and/or declining habitat in the Greater North Sea, and the fact that these reefs are currently not protected in waters off the east coast of Scotland, further investigation of *S. spinulosa* within the proposed *Southern Trench* site should be prioritised. Depending on the nature and extent of the aggregations, the Scottish government should consider granting them formal protection within the MPA, as well as considering more broadly whether such aggregations should also be added to the list of Scottish PMFs.

Furthermore, Oceana's research showed that the distribution of *S. spinulosa* aggregations outside the *Southern Trench* area is more extensive than was previously known. In particular, Oceana discovered ross worm reefs and aggregations off the east coast of Aberdeenshire, spread across the area immediately to the south of the proposed NCMPA (Figure 16). Based on the extent and distribution of *S. spinulosa* documented, Oceana urges the Scottish authorities to extend the southern boundary of the proposed *Southern Trench* area further to the south, to encompass these vulnerable habitats.

Oceana's findings of *S. spinulosa* aggregations in Aberdeenshire waters add to a growing body of records from both government and industry surveys that emphasise the potential importance of the area for the development of ross worm reefs (see *Known*

ecological features of interest), and therefore the need to identify appropriate measures of protection. One encouraging development in this respect is a project currently being carried out by Marine Scotland, which aims to categorise *S. spinulosa* reefs in the Moray Firth area, assess the applicability of current criteria for protection to those reefs, and to consider options for their conservation. Alongside those efforts, Oceana encourages the Scottish government to conduct comprehensive benthic habitat mapping in the Aberdeenshire area, to identify the presence of any additional *S. spinulosa* reefs and to assess their condition and extent. Many of the known *S. spinulosa* aggregations off Aberdeenshire have been discovered during exploratory ROV surveys in specific areas, rather than broader efforts to map benthic communities and habitats more systematically. It is therefore likely that additional ross worm reefs and aggregations exist in the area. Conducting such research falls within the obligations of the UK as a Contracting Party to the OSPAR Convention, under which seabed habitat surveys and monitoring are among the programmes and measures identified as priority actions for the conservation of *S. spinulosa* reefs.[125]

In addition to *S. spinulosa* aggregations, Oceana documented the presence of other priority features for conservation that lie outside the southern boundary of the proposed *Southern Trench* NCMPA. These features included nine biodiversity PMFs: two habitats and seven species. Specifically, Oceana found kelp beds comprising dense forests of tangle (*L. hyperborea*) and of sugar kelp (*S. latissima*), tide-swept algal communities formed by dense aggregations of toothed wrack (*Fucus serratus*), one low-mobility species (*A. islandica*), and six mobile species (*Ammodytes tobianus*, *G. morhua*, *Halichoerus grypus*, *M. merlangus*, *M. molva*, and *Pollachius virens*). Further research would be needed to confirm whether two additional PMFs occur in the same area (see *Features of conservation interest*). Finally, Oceana's observations of submerged caves within *Buchan Ness to Collieston Coast* SPA further highlight the rich variety of ecosystems that are currently unprotected in the area to the south of *Southern Trench*. Overall, these findings indicate that the *Southern Trench* area does not sufficiently encompass the habitats and species of conservation importance in the vicinity, and that either the boundaries of the proposed site should be extended, or that complementary measures of spatial protection should be developed.

Critically, it is essential that the protection of the *Southern Trench* and other areas of benthic biodiversity in Aberdeenshire waters be effective. According to the proposal for the designation of *Southern Trench* as a NCMPA, the conservation objective of the site is to "conserve" protected features.[102] This choice of objective assumes that the biodiversity features proposed for protection are all considered to be in favourable condition at present. However, it is unclear what the basis is for this assessment. For example, burrowed mud is listed as threatened and/or declining under OSPAR (i.e., 'seapen and burrowing

megafauna communities') in the Greater North Sea, as a result of declines in habitat quality due to demersal fisheries.[118] More broadly, the last EU-level assessment of MPAs showed that the conservation status of 71% of protected seabed habitats in the North-East Atlantic region was unfavourable, while the status of the remainder was unknown. Given the intensity of human activities in the region, a more ambitious and appropriate objective for *Southern Trench* would include the recovery of burrowed mud communities, with management measures in line with that aim. In particular, measures to limit the impact of demersal fisheries in Aberdeenshire waters would benefit not only burrowed mud communities, but also other fragile benthic features, such as *S. spinulosa* reefs and aggregations.

Such ambitious efforts are required if Scotland is to achieve the second part of its stated conservation objective for the proposed *Southern Trench* NCMPA: to "make a long-lasting contribution to the MPA network."[102] With over 60% of the UK's seas under its jurisdiction, Scotland is a key contributor to the development of ecologically coherent networks of MPAs – within Scotland, the UK, and the broader North Sea. Safeguarding the biodiversity richness of Aberdeenshire's waters is an integral part of that process.

Juvenile of Atlantic cod (*Gadus morhua*).
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ANNEX: RECORDED TAXA

Table A. Taxa documented in Aberdeenshire during the Oceana North Sea expedition in 2017.

Species
Chlorophyta
Cladophora rupestris
Cladophora sp.
Ulva lactuca
Ulva sp.
Rhodophyta
Calliblepharis ciliata
Ceramium virgatum
Cystoclonium purpureum
Delesseria sanguinea
Dilsea carnosa
Heterosiphonia plumosa
Jania rubens
Palmaria palmata
Phycodrys rubens
Phymatolithon lenormandii
Plocamium cartilagineum
Polysiphonia sp.
Porphyra sp.
Rhodophyta indet.
Ochrophyta
Alaria esculenta
Desmarestia aculeata
Desmarestia ligulata
Desmarestia viridis
Dictyota dichotoma
Fucus serratus
Fucus sp.
Laminaria hyperborea
Laminaria sp.
Leathesia marina

Ochrophyta indet.
Saccharina latissima
Undaria pinnatifida
Annelida
Amphictene auricoma
cf. *Amphilectene auricoma*
Annelida indet.
Arenicola marina
Bonellia viridis
Chaetopterus sp.
Chone fauveli
Filograna implexa
Hediste diversicolor
Hyalinoecia tubicola
Hydroides norvegica
Lagis cf. *koreni*
Lagis koreni
Lanice conchilega
Mysta picta
Nephthys sp.
Ophelia limacina
Owenia fusiformis
Polychaeta indet.
Pomatoceros sp.
Pomatoceros triqueter
Pyllodoce maculata
Sabella pavonina
Sabella sp.
Sabellaria spinulosa
Serpulidae indet.
Spirorbis sp.
Spirobranchus triqueter

Arthropoda
Achaeus cranchi
Ampelisca spinipes
Amphipoda indet.
Anomura indet.
Astacilla longicornis
Atelecyclus rotundatus
Balanus balanus
Balanus crenatus
Balanus sp.
Bathyporeia sp.
Bodotria scorpioides
Cancer pagurus
Carcinus maenas
Caridea indet.
Corystes casivelaunus
Crangon crangon
Decapoda indet.
Ebalia sp.
Eualus cranchii
Eualus gaimardii
Eualus pusiolus
Eualus sp.
Euphasiacea indet.
Galathea intermedia
Galathea nexa
Galathea sp.
Galathea squamifera
Galathea strigosa
Homarus gammarus
Hyas araneus
Hyas coarctatus

Hyas sp.
Idotea sp.
Inachus dorsettensis
Inachus sp.
Iphimedia obesus
Lebbeus polaris
Liocarcinus depurator
Liocarcinus marmoratus
Liocarcinus pusillus
Liocarcinus sp.
Lithodes maja
Macropodia rostrata
Macropodia sp.
Munida rugosa
Munida sarsi
Munida sp.
Necora puber
cf. *Owenia fusiformis*
Pagurus bernhardus
Pagurus prideaux
Pagurus pubescens
Pagurus sp.
Pandalina brevirostris
Pandalus borealis
Pandalus montagui
Pandalus sp.
Pariambus typicus
Pisa tetraodon
Pisidia longicornis
Polybius henslowi
Scalpellum scalpellum
Semibalanus balanoides

Spirontocaris liljeborgii
Stenopleustes latipes
Strobopagurus gracilipes
Bryozoa
Alcyonidium diaphanum
Alcyonidium hirsutum
Alcyonidium sp.
Bryozoa indet.
Bugula flabellata
Caberea ellisii
Caberea sp.
Cellaria sinuosa
Cellaria sp.
Conopeum reticulum
Crisia cf. *eburnean*
Crisia sp.
Electra monotaschys
Electra pilosa
Escharella variolosa
Escharina johnstoni
Escharoides coccinea
Exidmonea atlantica
Flustra foliacea
Membranipora membranacea
Omalosecosa ramulosa
Parasmittina sp.
Parasmittina trispinosa
Plagioecia patina
Porella sp.
Reteporella beaniana
Schizobrachiella sanguinea
Schizomavella cf. *auriculata*

Schizomavella linearis
Schizomavella sp.
Securiflustra securifrons
Smittoidea prolifica
Tubulipora liliacea
Turbicellepora avicularis
Turbicellepora magnicostata
Chaetognatha
Parasagitta elegans
Chordata – Aves
Alca torda
Fratercula arctica
Phalacrocorax aristotelis
Phalacrocorax sp.
Uria aalge
Chordata – Mammalia
Halichoerus grypus
Phoca sp. (skull)
Chordata – Pisces
Agonus cataphractus
Ammodytes marinus
Ammodytes sp.
Ammodytes tobianus
Aphia minuta
Arnoglossus laterna
Callionymus maculatus
Callionymus sp.
Chelidonichthys cuculus
Chirolophis ascanii
Cottidae indet.
Gadidae indet.
Gadus morhua

Hyperoplus lanceolatus
Labrus mixtus
Limanda limanda
Liparis liparis
Melanogrammus aeglefinus
Merlangius merlangus
Microstomus kitt
Molva molva
Myoxocephalus scorpius
Myxine glutinosa
Pholis gunnellus
Phrynorhombus norvegicus
Pisces indet.
Pleuronectiformes indet.
Pollachius virens
Taurulus bubalis
Triglops murrayi
Trisopterus esmarkii
Trisopterus minutus
Chordata - Tunicata
Aplidium punctum
Aplidium sp.
Ascidia conchilega
Ascidia mentula
Ascidia sp.
Ascidia virginea
Ascidiacea indet.
Ascidiella aspersa
Ascidiella scabra
Botrylloides leachii
Botrylloides sp.
Botryllus schlosseri

Botryllus sp.
Ciona intestinalis
Clavelina lepadiformis
Clavelina sp.
Corella parallelogramma
Dendrodoa grossularia
Didemnum sp.
Molgula manhattensis
Polycarpa pomaria
Cnidaria
Abietinaria abietina
Adamsi palliata
Aglaophenia pluma
Alcyonium digitatum
Caryophyllia smithii
Cerianthus lloydii
Cerianthus membranaceus
Cerianthus sp.
Clytia linearis
Cyanea capillata
Cyanea lamarckii
Diphasia rosacea
cf. *Diphasia rosea*
Dynamena pusilla
Ectopleura larynx
Eudendrium capillare
Eudendrium rameum
Eudendrium sp.
Halecium halecinum
Halecium plumosum
Halecium sp.
Hydrallmania falcata

Hydrozoa indet.
Kirchenpaueria pinnata
Lafoea dumosa
Litocarpia myriophyllum
Metridium senile
Nemertesia antennina
Nemertesia ramosa
Obelia cf. *bidentata*
Obelia geniculata
Pachycerianthus multiplicatus
Pennatula phosphorea
Polyplumaria flabellata
Rhizocaulus verticillatus
Sagartia elegans
Schizotricha frutescens
Sertularella gayi
Sertularia argentea
Stomphia coccinea
Thuiaria thuja
Tubularia indivisa
Urticina eques
Urticina felina
Urticina sp.
Ctenophora
Beroe cucumis
Bolinopsis infundibulum
Echinodermata
Amphiura chiajei
Amphiura filiformis
Antedon bifida
Asterias rubens
Asteroidea indet.

Astropecten irregularis
Brissopsis lyrifera
Crossaster papposus
Echinocardium chordatum
Echinocardium flavescens
Echinus esculentus
Echinocyamus pusillus
cf. *Halipteris* sp.
Henricia sp.
Hippasteria phrygiana
Luida ciliaris
Luida sarsi
Marthasterias glacialis
Ophiactis balli
cf. *Ophiactis* sp.
Ophiocomina nigra
Ophiothrix fragilis
Ophiura albida
Ophiura ophiura
Ophiuroidea indet.
Stichastrella rosea
cf. *Stomphia coccinea*
Strongylocentrotus droebachiensis
Foraminifera
Astrorhiza limicola
Foraminifera indet.
Mollusca
Abra alba
Abra prismatica
Abra tenuis
Acanthocardia echinata
Acanthodoris pilosa

Acteon tornatilis
Aeolidia papillosa
Aequipecten opercularis
Anomia ephippium
Anomiidae indet.
Antalis entalis
Antalis vulgaris
Aplysia punctata
Aplysia sp.
Aporrhais pespelecani
Arca tetragona
Archidoris sp.
Arcopagia crassa
Arctica islandica
Astarte cf. *elliptica*
Astarte elliptica
Astarte montagui
Astarte sp.
Astarte sulcata
Bivalvia indet.
Boreotrophon cf. *truncatus*
Boreotrophon truncatus
Caenogastropoda indet.
Calliostoma sp.
Calliostoma zizyphinum
Cardiidae indet.
Cephalopoda indet. (eggs)
Chamelea striatula
Chlamys islandica
Clausinella fasciata
Clelandella miliaris
Colus gracilis

Corbula gibba
Coryphella sp.
Ctena decussata
Cylichna cylindracea
Dendronotus cf. *frondosus*
Dentalium dentalis
Doris pseudoargus
Dosinia exoleta
Dosinia lupinus
Eledone cirrhosa
Emarginula fissura
Ennucula tenuis
Eubranchus farrani
Eubranchus pallidus
Eubranchus tricolor
Eulimella ataktos
Euspira catena
Euspira nitida
Euspira sp.
Facelina auriculata
Facelina bostoniensis
Favorinus branchialis
Gastropoda indet.
Gari costulata
Gari fervensis
Gari tellinella
Gibbula cineraria
Gibbula sp.
Gibbula tumida
Gibbula umbilicalis
Glossus humanus
Glycimeris glycimeris

Gouldia minima
cf. *Gouldia minima*
Heteranomia squamula
Hiatella arctica
Janolus cristatus
Jorunna tomentosa
Lacuna sp.
Leptochiton asellus
Limaria loscombi
Limatula gwyni
Lucinoma borealis
cf. *Lucinoma borealis*
Macoma moesta
Mactra stultorum
cf. *Mactra stultorum*
Mactridae indet.
Mimachlamys varia
Modiolula phaseolina
Modiolus modiolus
Muricidae indet.
Mya arenaria
Nassarius pygmaeus
Nassarius reticulatus
Nassarius sp.
cf. *Neilonella latior*
Nucula cf. *nucleus*
Nucula nitidosa
Nucula nucleus
Nucula sp.
Nuculana minuta
Nuculana pernula
Nudibranchia indet.

Nudibranchia indet. (eggs)
Oenopota assimilis
Oenopota cf. *assimilis*
Oenopota cf. *turricula*
Oenopota turricula
Onchidoris bilamellata
Onchidoris luteocincta
Ostreidae indet.
Palliolium incomparabile
Palliolum striatum
Panomya norvegica
Parvicardium cf. *pinnulatum*
Parvicardium pinnatulum
Parvicardium scabrum
Patella pellucida
Patella sp.
Pecten maximus
Patellogastropoda indet.
Pectinidae indet.
Phaxas pellucidus
Pododesmus patelliformis
Pododesmus striata
Polycera faeroensis
Polycera quadrilineata
Propebela turricola
Pseudamussium peslutrae
Pyrgiscus crenatus
Raphitoma aequalis
Raphitoma sp.
Rissoa parva
Rissoa sp.
Scaphopoda indet.

Semelidae indet.
Similipecten similis
Simnia patula
Spisula elliptica
Spisula sp.
Spisula subtruncata
Tapes corrugata
Tapes philippinarum
Tectura virginea
Tellimya ferruginosa
Tellina cf. *pygmaea*
Tellina fabula
Tellina pygmaea
Tellina tenuis
cf. *Tellimya tenella*
Thracia phaseolina
Thracia sp.
Thracia villosiuscula
Thyasira flexuosa
Thyasira sarsi
Timoclea ovata
Tonicella marmorea
Tonicella rubra
Tritia incrassata
Tritia reticulatus
Tritonia hombergii
Trivia arctica
Trivia monacha
Turbonilla rufa
Turritella communis
Raphistomidae indet.
Veneridae indet.

Venus cassina
Venus verrucosa
Platyhelminthes
Platyhelminthes indet.
Porifera
Antho (Antho) dichotoma
Antho sp.
Demospongiae indet.
Dysidea fragilis
Grantia compressa
Halichondria panicea
Haliclona urceolus
Hymedesmia sp.
Leucosolenia sp.
Polymastia boletiformis
Suberites carnosus
Suberites ficus
Suberities sp.
Sycon ciliatum

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