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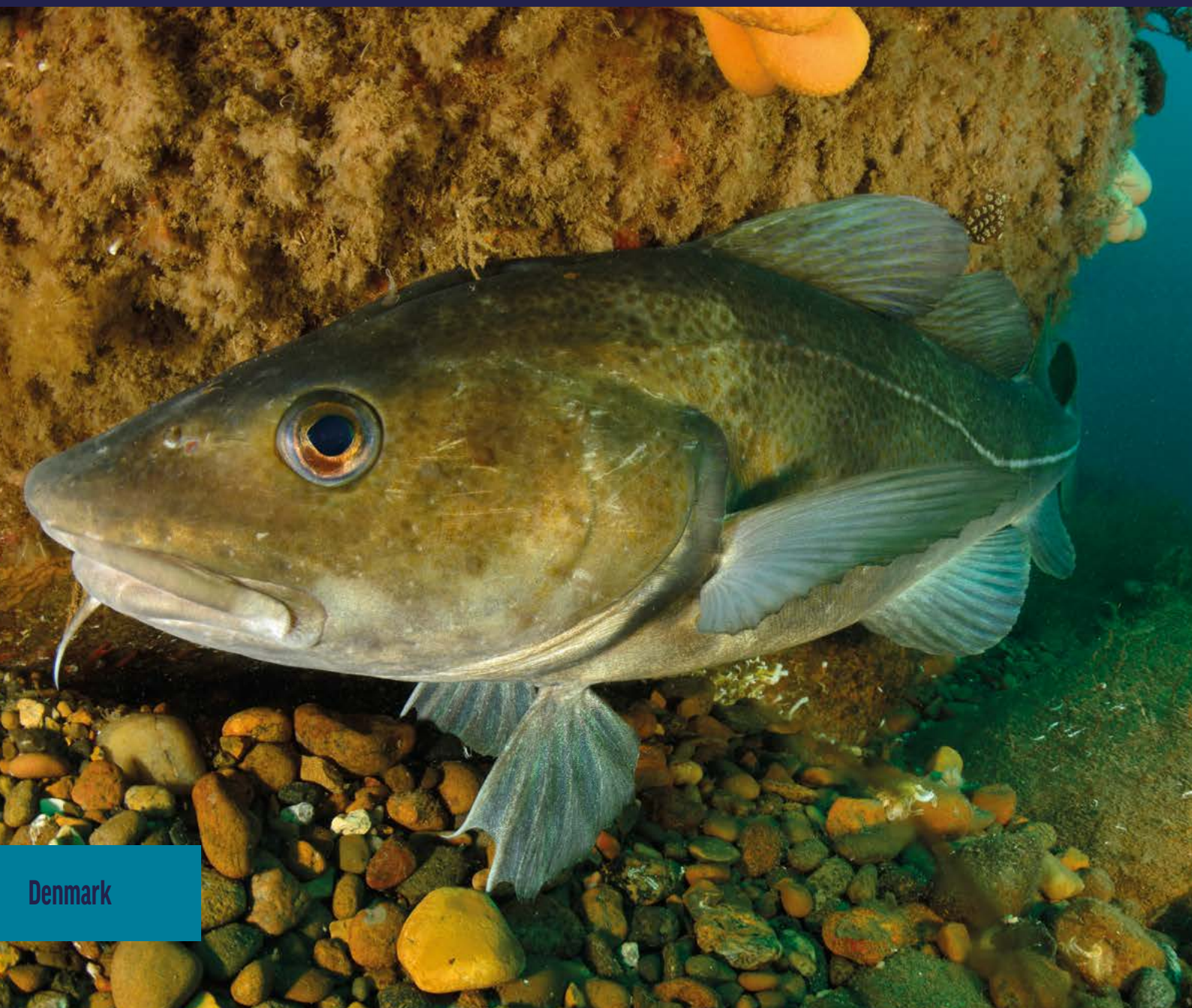
PROTECTING THE NORTH SEA: NORTHERN DANISH WATERS



Denmark

PROTECTING THE NORTH SEA: NORTHERN DANISH WATERS

Credits

Citation: García, S., Perry, A.L., Blanco, J., Álvarez, H., Petersen, H.C., Maaholm, D.J., Paulomäki, H. & Aguilar, R. 2019. Protecting the North Sea: Northern Danish waters. Oceana, Madrid. 106 p.

Cover image: Cod (*Gadus morhua*) in a rocky bottom area of Jutland Bank. © OCEANA/ Carlos Minguell

Acknowledgements: Oceana warmly thanks the crew of *MV Neptune* for their hard work and assistance during both the 2016 and 2017 expeditions. We are also grateful to Jan Nicolaisen and Mikkel Schmedes at Orbicon, and Jørgen Leth and Jørn Bo Jensen at the Geological Survey of Denmark and Greenland, for sharing their insights about important areas of benthic biodiversity in the Danish North Sea. Further thanks are due to Sarah Bedolfe, who carefully reviewed an earlier version of this report and provided valuable revisions and comments.

This project was made possible thanks to the generous support of the Dutch Postcode Lottery.

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The northern waters of the Danish North Sea encompass a wide range of depths, reaching down to 480 m in the region of the Skagerrak. The area is home to a rich diversity of seabed habitats and associated species, including those that are priorities for marine conservation at EU and international levels. As a result, eight marine protected areas (MPAs) have been designated with the aim of protecting habitats such as reefs, bubbling reefs, and sandbanks, as well as harbour porpoise. However, the poor condition of protected habitats within these areas indicates that current protection is insufficient, and recent assessments of the Danish MPA network have revealed key gaps in coverage in the North Sea that must be addressed, particularly in offshore areas.

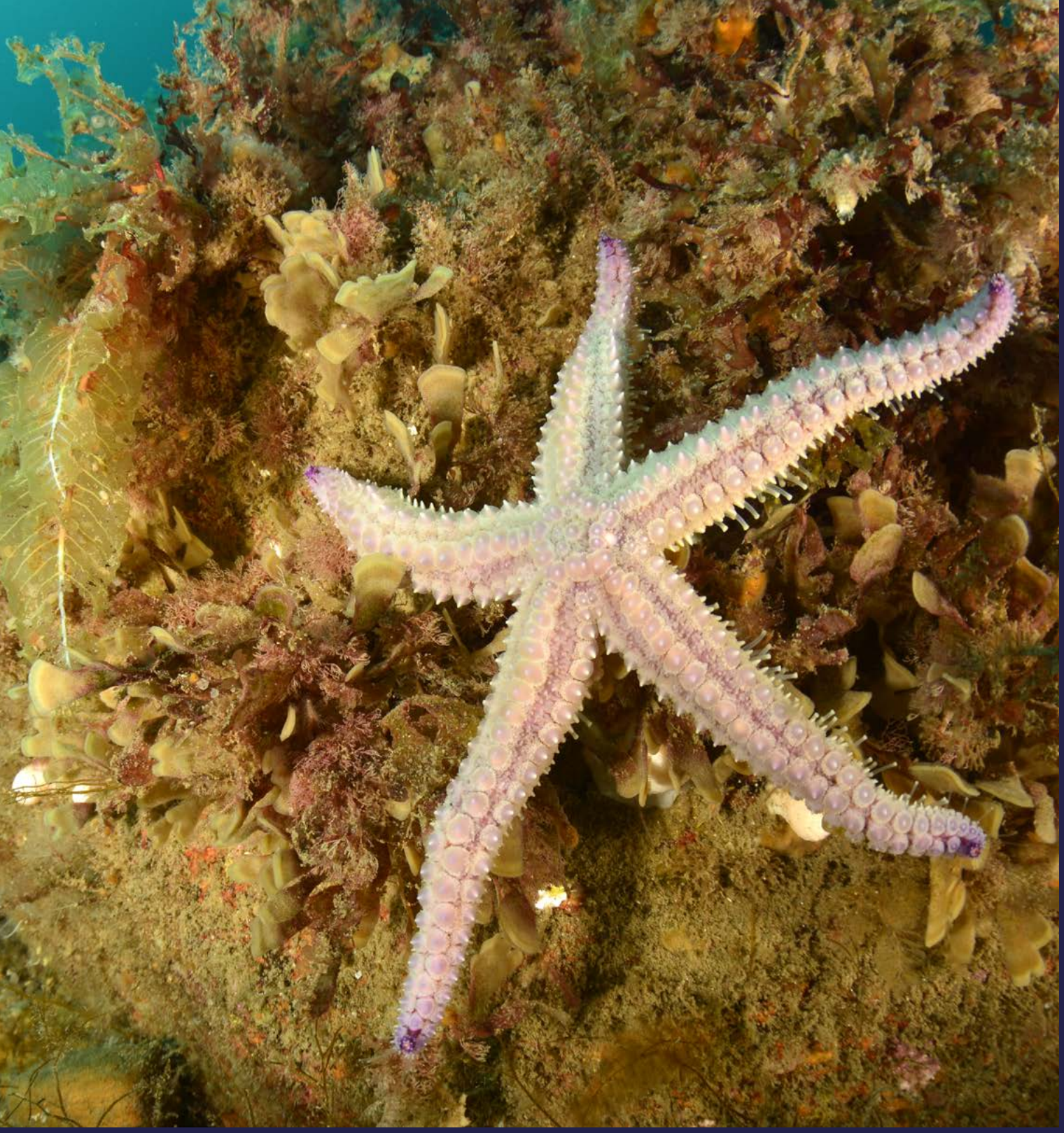
One of the challenges in strengthening the MPA network is a lack of data on benthic communities, particularly outside of existing protected sites. In order to help address this information gap, Oceana carried out two at-sea research expeditions in Denmark during 2016 and 2017, that aimed to gather data about 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 infauna, and seabed mapping with a multibeam echosounder. Both protected and unprotected locations were surveyed, across a broad area that extended from the northernmost waters of the Danish North Sea, westwards to Jutland Bank.

In total, Oceana documented 467 taxa (330 to the species level), in association with five benthic community types, on both hard and soft bottoms. Among the valuable marine features recorded were eight habitat types and six species that are considered priorities for conservation under EU or international frameworks. Key findings included a previously undocumented bubbling reef inside the *Store Rev* Natura 2000 MPA; and reefs, coral gardens, sea pen fields, and valuable areas of soft-bottom habitats in both protected and unprotected locations. On the basis of its findings, Oceana recommends the designation or enlargement of MPAs to safeguard these valuable features in specific areas, and the formal protection of priority features that occur within existing MPAs but which are not currently protected by those sites. Critically, given the intensity of human pressure in the Danish North Sea, designated MPAs must be effectively managed if they are to achieve their intended conservation aims.

Introduction

The northern waters of the Danish North Sea extend from the west coast of the northern part of the Jutland peninsula, northwards to the Skagerrak, and westwards to the north-western banks of Little Fisher Bank and Jutland Bank (*Lillefiskerbanke* and *Jyske Rev*, respectively, in Danish). These waters cover a wide range of depths and seabed types, and are characterised by higher biodiversity levels than many other parts of the North Sea, with a richness of benthic communities that comprise hundreds of species.

While some biodiversity hotspots, such as stone reefs and bubbling reefs, are known to occur within the Danish waters of the North Sea, relatively little is known about benthic assemblages across much of its offshore waters. To help fill this information gap, Oceana conducted two research expeditions, in 2016 and 2017, to gather information about marine life on the seabed. The findings of those surveys are presented in this report, in the broader context of the biodiversity of the area and the threats it faces, and the need for its protection.



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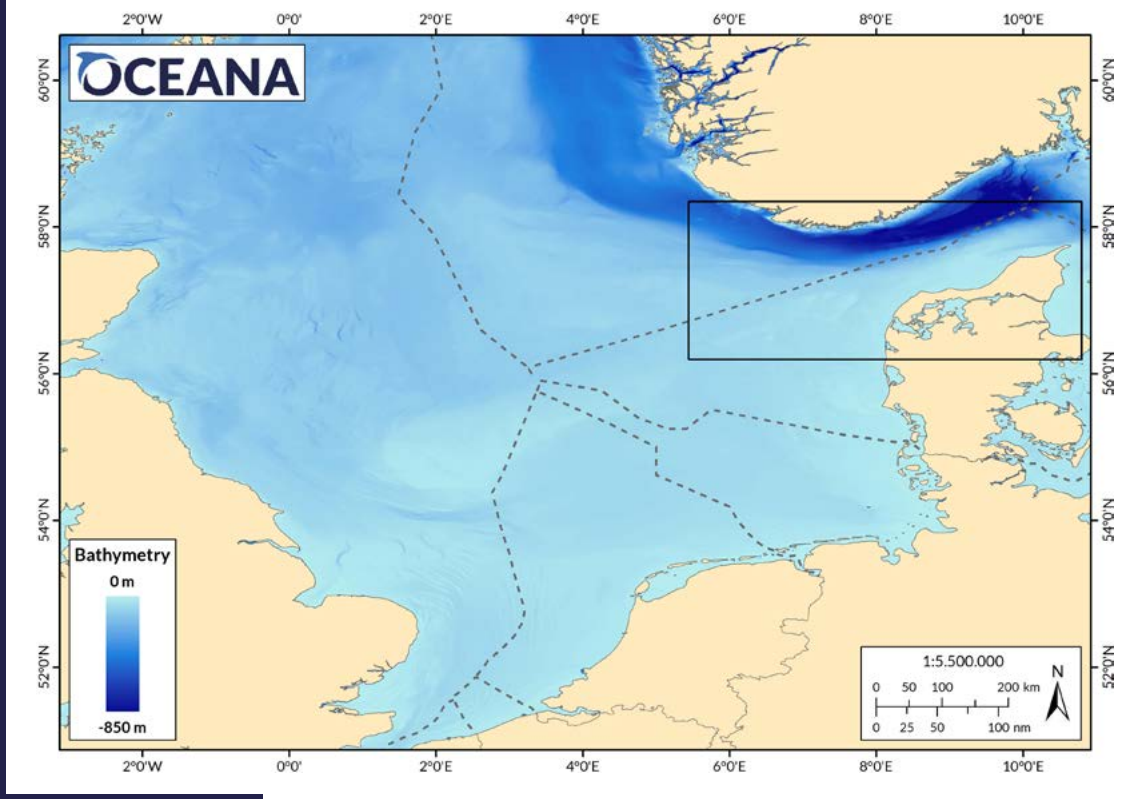
DESCRIPTION OF THE AREA

BATHYMETRY AND SUBSTRATE

The Oceana survey area covered the full bathymetric range of the Danish North Sea (Figure 1). Survey areas included waters ranging from shallow depths to the deepest waters in Denmark, which exceed 480 m depth and are found in the Skagerrak. Most of the area is shallower than 80-90 m, with Little Fisher Bank and Jutland Bank reaching depths of only 30-40 m.

a)



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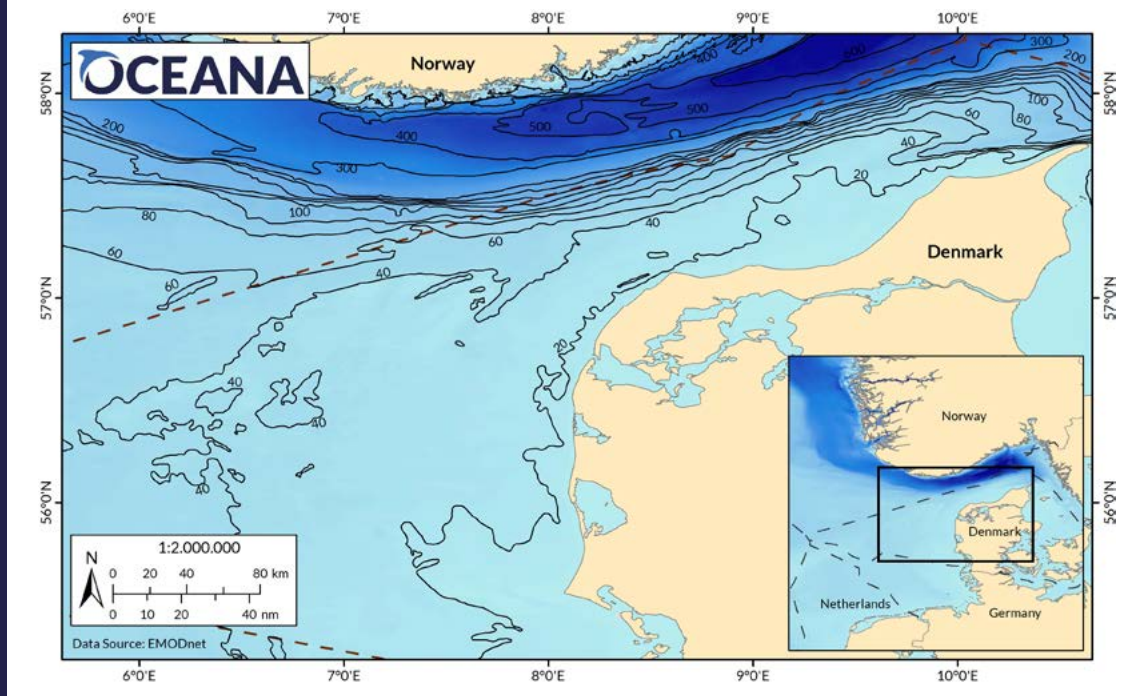

Figure 1. a) Location of Oceana survey area and b) detailed bathymetry of the area. Sources: EMODnet,[2] EEA. [5]

The seabed in the Danish North Sea consists mainly of sand, mud, and patches of till,[1] dominated by soft-bottom communities and reaching the deepest parts of the Skagerrak, to the north of Denmark. Within this region, the Oceana survey area is dominated by sandy bottom, muddy sand and, in the deepest areas to the North and West, sandy mud and mud (Figure 2).[2] The area also encompasses expanses of hard bottoms, including isolated areas with boulders, stones, gravel, and mixed sediments. In addition, locations with bubbling reefs have recently been discovered near the Skagerrak and Jutland Bank.[3,4]

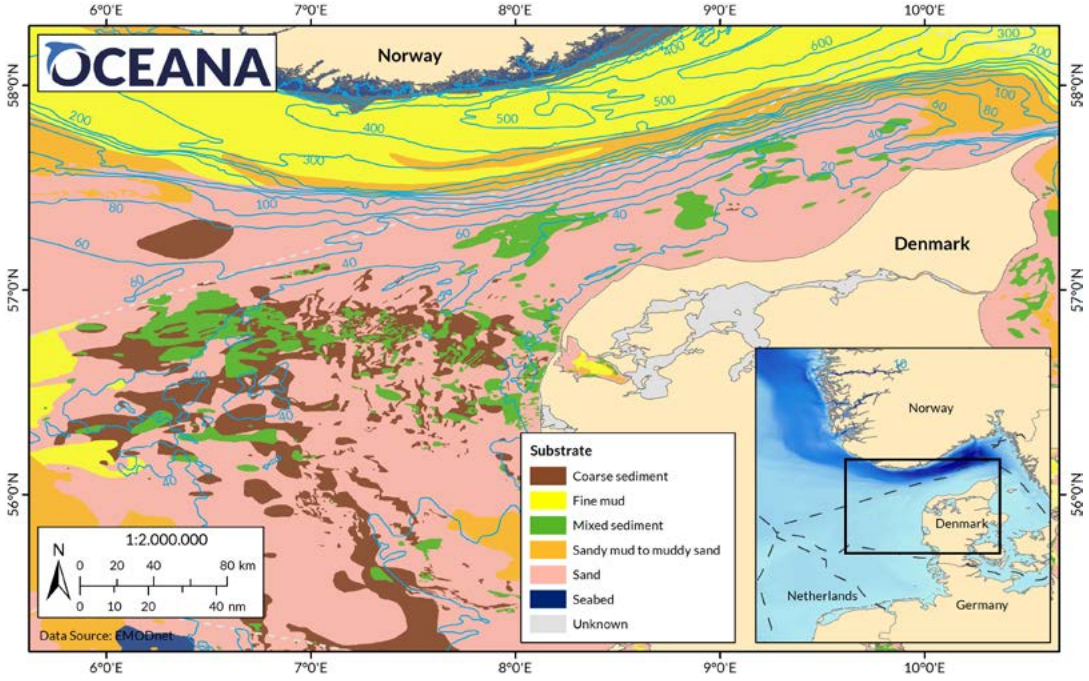

Figure 2. Substrate types and bathymetry of the Oceana survey area. Source: EMODnet,[2] EEA.[5]

THREATENED AND PROTECTED SPECIES

Ten species occur in Danish waters for which protected areas must be designated under the EU Habitats Directive.[4,6,] Specifically, these include four marine mammals (i.e., common bottlenose dolphin (*Tursiops truncatus*); harbour porpoise (*Phocoena phocoena*); grey seal (*Halichoerus grypus*); and harbour seal (*Phoca vitulina*)), and six fishes (i.e., sea lamprey (*Petromyzon marinus*); river lamprey (*Lampetra fluviatilis*); common sturgeon (*Acipenser sturio*); allis shad (*Alosa alosa*); twaite shad (*Alosa fallax*); and houting (*Coregonus oxyrhyncus*)). In addition, marine mammal species that require strict protection under the Habitats Directive are also present in Danish waters, such as white-beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Balaenoptera acutorostrata*).[4]

Within the Oceana survey area, some protection has been provided to one of these species through the establishment of three Natura 2000 sites (Figure 3). Specifically, *Gule Rev*, *Store Rev*, and *Skagens Gren og Skagerrak*[7] were designated in part because of their importance for harbour porpoise.[8]

The threatened ocean quahog (*Arctica islandica*), which is listed on the OSPAR List of Threatened and/or Declining Species and Habitats,[9] is known to live in sandy bottoms of the Natura 2000 sites *Store Rev* and *Gule Rev*, Jutland Bank, and close to Little Fisher Bank.[3,10] The North Sea population of this species has severely declined during the last century. A large, long-lived species with very slow growth rate, ocean quahog is highly sensitive to human impacts – especially the use of bottom fishing gears, which are intensively used in the North Sea and in the Oceana survey area.[9,11]

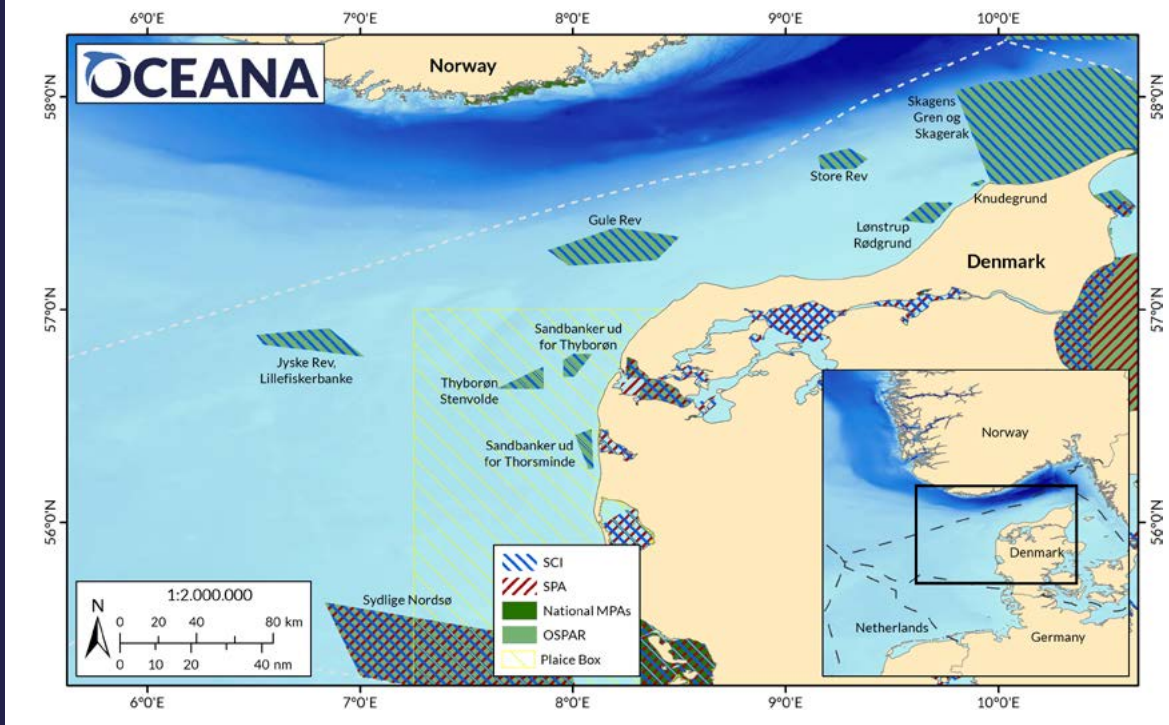

Figure 3. Natura 2000 sites in the northern Danish North Sea. Sources: EMODnet,[2] EEA,[5] OSPAR,[12] Pastoors *et al*., 2000[13]

Seabirds

The northern waters of the Danish North Sea are home to a diversity of seabirds, and the survey area coincides almost entirely with an Important Bird and Biodiversity Area (IBA), *Skagerrak-Southwest Norwegian trench*, which covers a total of 16 000 km^2.[14,15] This designation does not imply any legal protection, but underscores the importance of the area for species such as northern gannet (*Morus bassanus*), great skua (*Catharacta skua*), little auk (*Alle alle*), and species that are considered by IUCN to be Near Threatened in Europe,[16] such as European herring gull (*Larus argentatus*), razorbill (*Alca torda*) and common murre (*Uria aalge*).[14,15,17,18,19,20] Other seabird species of note reported from the area include common gull (*Larus canus*), which has high densities in Jutland Bank and some other areas, and northern fulmar (*Fulmarus glacialis*), for which the highest densities in the North Sea are found to the Northwest of Jutland Bank, especially in winter.[21]

Essential fish habitats

The northern waters of the Danish North Sea support a wide range of commercially fished species, some of which have spawning and/or nursery grounds in the area. Such species include sandeels (*Ammodytes* spp.), herring (*Clupea harengus*), lumpsucker (*Cyclopterus lumpus*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius merluccius*), lemon sole (*Microstomus kitt*), plaice (*Pleuronectes platessa*), whiting (*Merlangius merlangus*), and saithe (*Pollachius virens*).[22,23,24,25] The habitats that they rely upon for growth or spawning (along with other key habitats such as feeding grounds and migratory corridors) are known as essential fish habitats (EFH),[26] because of the critical role that they play during species' life cycles.

As one example, juveniles of cod (*G. morhua*) are known to concentrate in an area that extends from southern Norway to the Skagerrak and the northern part of Kattegat.[25,27] Cod is one of the most economically and historically important species in the North Sea, with records of cod fisheries in the region that go back for centuries.[28] Intensive overfishing of cod drove a steep decline in biomass from the 1970s until the mid-2000s,[29] which was later followed by a period of apparent increase, as a result of the application of stricter management measures. However, 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; it is below safe limits and remains subject to ongoing overfishing.[29] 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.

Other specific examples highlighted by researchers include the importance of the Skagerrak as a spawning area for mackerel (*Scomber scombrus*) and as an area where plaice (*P. platessa*) juveniles aggregate.[21,30] Both species support major fisheries, in terms of both volume and value, in the North Sea.[11]

Habitat types

The Danish benthos has been the subject of numerous research studies during recent decades (see Table 1 for examples). Depending on specific economic interests (e.g., fisheries, extraction of raw materials) and conservation interests, some areas of the seafloor have been intensively surveyed, such as in Kattegat, along the West coast of Denmark, and within Natura 2000 sites in the North Sea and Kattegat.[31] For other areas, especially in offshore North Sea waters, data remain patchy.[31]

Various public and private bodies, such as the Geological Survey of Denmark and Greenland (GEUS), the National Institute of Aquatic Resources at the Technical University of Denmark (DTU Aqua), and Orbicon (an environmental consultancy), have carried out research to map substrate types and seabed communities in the Danish North Sea. Some of these studies have been specifically commissioned by the Danish government. In particular, two large-scale government-funded projects have provided detailed data from within Natura 2000 MPAs in the Oceana survey area. The first of these focused primarily on two types of habitats that are listed under the Habitats Directive (reefs and submarine structures made by leaking gases – specifically, bubbling reefs) in six of the eight Natura 2000 sites in the Oceana survey area,[i] as well as two unprotected areas in which bubbling reefs were believed to occur.[3] A second follow-up project concentrated on a third Habitats Directive-listed feature: sandbanks. During this project, seabed and habitat mapping was carried out in Natura 2000 sites that had not been described by the first study, including the other two Natura 2000 sites[ii] inside the Oceana survey area.[31]

[i] *Lønstrup Rødgrund, Thyborøn Stenvolde, Jyske Rev/Lillefiskerbanke, Store Rev, Gule Rev* and *Knudegrund.*

[ii] *Skagens Gren og Skagerrak* and *Sandbanker ud for Thyborøn.*

Table 1. Major benthic biology and geological research studies carried out in the survey area. Areas indicated in italics refer to specific marine protected areas. Natura 2000 habitat types are indicated by their codes under the Habitats Directive (1110: Sandbanks which are slightly covered by sea water all the time; 1170: Reefs; and 1180: Submarine structures made by leaking gases).

INSTITUTE OR PROGRAMME	YEAR OF SURVEY	REFERENCE	SURVEY AREA	DESCRIPTION/AIMS
GEUS and Orbicon	2017-2018	Al-Hamdani *et al.* 2019[31]	*Skagens Gren og Skagerrak*, *Sandbanker ud for Thyborøn*, *Sandbanker ud for Thorsminde and Sydlige Nordsø*	Mapping of Natura 2000 habitat types 1110, 1170 and 1180
NOVANA Monitoring Programme	2010-2017	Hansen 2011;[32] Hansen 2012;[33] Hansen 2013;[34] Hansen 2015a;[35] Hansen 2015b;[36] Hansen 2016;[37] Hansen 2018;[38] Hansen 2019[39]	North Sea and Kattegat	Monitoring of macro-zoobenthos and macroalgae
GEUS and DCE	2006, 2007 and 2010	Al-Hamdani *et al.* 2015[3]	*Lønstrup Rødgrund*, *Thyborøn Stenvolde*, *Jyske Rev/Lillefisker-banke*, *Store Rev*, *Gule Rev*, *Knudegrund*, Boblerev 1 and Boblerev 2	Mapping of Natura 2000 habitat types 1110, 1170 and 1180
Orbicon	2013, 2014 and 2016	Orbicon 2013;[40] Orbicon 2014;[41] Orbicon 2018[42]	Jutland Bank region	Environmental Impact Assessments of sand extraction projects
GEUS	2011	Jensen *et al.* 2011[43]	Danish North Sea, with focus on Jutland and Little Fisher Banks	Mapping of potential raw materials and substrate types
Orbicon and GEUS	2010	Nicolaisen *et al.* 2010[10]	*Jyske Rev/Lillefisker-banke and Thyborøn Stenvolde* (Phase 1) and western part of Danish North Sea (Phase 2)	Mapping of raw materials and Natura 2000 habitat types 1110, 1170 and 1180
Orbicon	2006 and 2007	Orbicon 2007;[52] Orbicon 2008[53]	Jutland Bank region	Mapping of Natura 2000 habitat types 1110, 1170 and 1180 and visual survey of flora and fauna
GEUS	1991-2000 and 2005	Leth *et al.* 1998;[44] Leth *et al.* 2000;[45] Leth *et al.* 2003;[46] Leth *et al.* 2005[49]	Offshore Danish North Sea	Mapping Natura 2000 habitat types 1110, 1170 and 1180
GEUS	1991 and 1994	Leth 1996[47]	Jutland Bank	Seismic study
ICES-BEWG	1986 and 1989	Künitzer *et al.* 1992[48]	North Sea benthos	Benthic survey across the North Sea

Below is a summary of the distribution and extent of protection of those three habitat types in the northern waters of the Danish North Sea. The area of each habitat type protected inside Natura 2000 MPAs given in parentheses:

- *Sandbanks which are slightly covered by sea water all the time*. Sandy bottoms represent the most extensive substrate in the area, but this type of bottom does not always form banks. In the Oceana survey area, sandbanks are known to occur, and two of them have been protected within the *Skagens Gren og Skagerrak* (24000 ha) and *Sandbanker ud for Thyborøn* (1600 ha) Natura 2000 sites. Some offshore sandbanks remain outside of protected areas,[2,4,10] while others are located within MPA boundaries yet are not officially recognised as features of those sites, and therefore are not subject to measures of protection. One example is the case of sandbanks described during GEUS surveys in the *Jyske Rev/Lillefiskerbanke* MPA.[49]

- *Reefs*. Hard bottoms are common in the area, mainly in waters shallower than 90 m.[4] Six Natura 2000 sites have been designated that protect reefs (i.e., *Knudegrund* (650 ha); *Gule Rev* (25000 ha); *Lønstrup Rødgrund* (1300 ha); *Jyske Rev/Lillefiskerbanke* (13 500 ha); *Store Rev* (5500 ha); and *Thyborøn Stenvolde* (2800 ha)). However, other reefs remain outside of the protected areas, despite the fact that in some cases they are part of the same reef systems located inside the MPAs (i.e., *Thyborøn Stenvolde*, *Jyske Rev/Lillefiskerbanke*, *Gule Rev*, and *Store Rev*).[2,4,31] In *Skagens Gren og Skagerrak*, although hard bottoms have been documented, the Standard Data Form for the area (i.e., the official information about the area and its protected features) does not recognise that they are present. These reefs have been mapped in shallow waters[31] but detailed habitat mapping for the offshore areas is still pending.[4,31]

- *Submarine structures made by leaking gases*. This habitat type is extremely vulnerable to human impacts, as no recovery is possible once the structures have been destroyed. Therefore, protection of all Danish sites where the habitat is present has been recommended by the European Topic Centre on Biological Diversity and the European Environment Agency.[50] In the Danish North Sea, *Store Rev* is the only MPA that has been designated to date which includes submarine structures made by leaking gases among its protected features – specifically, bubbling reefs (100 ha).[8] In 2015, additional submarine structures made by leaking gases were discovered inside *Store Rev*, inside *Knudegrund*, and in two locations outside of any MPA.[3,4] An area was also documented inside the *Skagens Gren og Skagerrak* in which there are pockmarks (features that are formed by subjacent gas activity),[31] but no bubbling reefs or related structures have been found,[51] and so the presence of the protected habitat type has not been confirmed for this site.

Other types of sea bottom which are not listed under the Habitats Directive are also known to occur in offshore Danish waters. For example, muddy bottoms are common in Kattegat and also found in the Skagerrak. These bottoms are home to commercial and vulnerable species, such as Norway lobster (*Nephrops norvegicus*), cnidarians (e.g., dead man's fingers (*Alcyonium digitatum*) and sea pens, such as phosphorescent sea pen (*Pennatula phosphorea*) and slender sea pen (*Virgularia mirabilis*)).[31] In the Danish waters of the North Sea, slender sea pen (*Virgularia mirabilis*) and another unidentified sea pen species have been documented inside *Skagens Gren og Skagerrak*.[31]

Beyond habitat classifications, various types of benthic communities have also been described in Danish marine waters, with six indicated as being predominant in the Oceana survey area.[3] The two most common types appear to be *Epifaunal community dominated by* Alcyonium digitatum *and* Flustra foliacea, and *Sand/clay without epifauna*.[3,52,53] Another four community types appear to be present in two of the protected sites: *Lønstrup Rødgrund* is home to both *Communities of large red and brown algae*, including large kelps (*Laminaria digitata* and *L. hyberborea*) and *Communities of brown algae and red filamentous algae*; and *Gule Rev* hosts an *Epifaunal community dominated by hydroids and/or sponges*; and *Muddy bottom with starfishes/brittlestars*.[3]

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Threats

The North Sea is one of the most productive – yet also busiest – seas in the world. In addition to its biodiversity value, this sea is of significant socio-economic value due to its fisheries, oil and gas extraction, harbours, and other industry. Bordered by eight highly industrialised countries (Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden and the United Kingdom), and with an average of more than 500 people per km^2 inhabiting coastal areas,[54] the North Sea marine ecosystem is highly disturbed and altered by human intervention. Centuries of fishing activity have directly affected its marine biodiversity,[55,56,57] with losses in biomass, particularly of large fishes,[58] and resulting changes in ecosystem structure, as well as habitat damage caused by destructive fishing gear. Other anthropogenic activities place additional pressure on North Sea marine life, cause disturb and damage habitats, and overlap with areas that should potentially be protected for their biodiversity value. These threats include pollution, eutrophication, oil and gas platforms, wind energy parks, maritime shipping, the laying of cables and pipelines, coastal development, sand and gravel extraction, military training, and recreational activities.

In the Danish North Sea, many human activities on land and at sea impact and determine the status of the marine environment.[59] Below are highlighted those activities that are likely to have the greatest effect on species and habitats in the region: aggregate extraction, fishing, wind energy parks, oil and gas exploitation, and shipping (Figure 5).

Figure 4. Bottom trawler moored at Hirtshals port.
© OCEANA/ Juan Cuetos

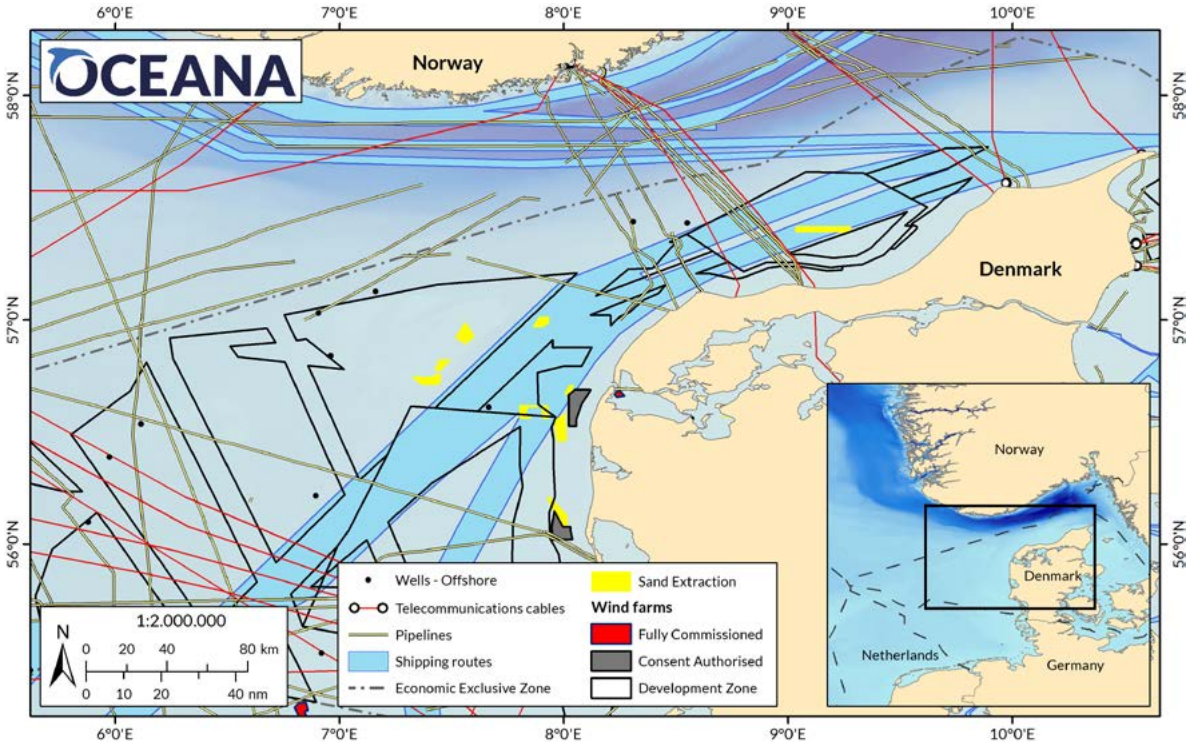


Figure 5. Shipping routes and other major offshore infrastructure in the Danish North Sea, including telecommunications cables, pipelines, gas and oil wells, sand extraction areas, and wind farms (both authorised and potential projects). Sources: EMODnet,[2] EEA,[5] GEUS,[60] TeleGeography,[61] ChartWorld,[62] University College London Energy Institute,[63] Danish Nature Agency, [64] and 4C Offshore.[65]

Aggregate extraction

The extraction of marine sand and gravel has been actively ongoing in the North Sea for decades. According to the International Council for the Exploration of the Sea (ICES), out of 12 countries for which data on aggregate extraction from Northeast Atlantic waters are available,[iii] the Netherlands, UK, and Denmark, respectively, account for the highest volumes of sediments extracted.[66] Denmark extracted more than 5 900 000 m^3 (13%) out of a total of approximately 45 800 000 m^3 of aggregate extracted in 2017.

Direct impacts of dredging for aggregates are many, and include: the removal of surface layers of seabed sediment, destroying benthic habitats and organisms; altered topography of the seabed; damaged seabed integrity; and increased turbidity resulting from the production of sediment plumes in the water column, with resulting impacts on both pelagic and benthic species.[40,67,68] High turbidity can hinder primary production, place filter feeders under added stress, and harm planktonic eggs and larvae[69] Sediment plumes later settle on the seabed, where they can effectively smother benthic organisms. Following dredging, benthic communities typically show a significant reduction in species number, and in particular, abundance and biomass. [68,69,70] These community changes can then have broader knock-on effects on marine ecosystems, for example, affecting food availability for birds, fish, and mammals,[68] adding to impacts on species

[iii] Belgium, Denmark, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.

that may have previously relied on dredged habitat for spawning or nursery areas. Even years later, full recovery may not occur, as some species may disappear forever or need centuries to be restored. Furthermore, synergistic effects with other human activities (e.g., fisheries, energy production, offshore infrastructure) must also be considered.

The northern waters of the Danish North Sea contain some areas that have been identified as potential sites for the extraction of raw materials, and there are active extraction areas close to Jutland Bank (Figure 5).[4,42,71] The implications of the damage and removal of the seabed there are of particular concern because Jutland Bank, in addition to being a location of aggregation extraction, is known to be a spawning area for sandeels (*Ammodytes* spp.), and is home to many other commercial and non-commercial fishes. These include sole (*Solea solea*), plaice (*Pleuronectes platessa*), turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*), dab (*Limanda limanda*), cod (*Gadus morhua*), hake (*Merluccius merluccius*), sprat (*Sprattus sprattus*), herring (*Clupea harengus*), greater weever (*Trachinus draco*), grey gurnard (*Eutrigla gurnardus*), sandeels (*Ammodytes tobianus* and *A. marinus*), greater sandeel (*Hyperoplus lanceolatus*), dragonet (*Callionymus lyra*), sand goby (*Pomatoschistus minutus*), crystal goby (*Crystallogobius linearis*) and transparent goby (*Aphia minuta*).[40,42]

Fishing

Fisheries in Denmark are of global and regional importance. Denmark accounts for nearly half (45%) of the total volume of North Sea fish catches, and is the fifth-largest exporter of fish and fish products in the world.[72]

The Danish fishing fleet comprised a total of 2135 vessels in 2018, of which almost 80% were under 10 metres in length.[73] Approximately 1400 of these vessels fish in the Greater North Sea region (i.e., the English Channel, North Sea, the Skagerrak, and Kattegat); 600 of these are engaged in demersal fishing with bottom trawl and seines, for species that include cod (*Gadus morhua*), plaice (*Pleuronectes platessa*), northern shrimp (*Pandalus borealis*), and Norway lobster (*Nephrops norvegicus*).[11] Meanwhile, pelagic fisheries target herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) for consumption, and species such as sandeel (*Ammodytes* spp.), sprat (*Sprattus sprattus*), and blue whiting (*Micromesistius poutassou*) for reduction to fish meal and oils.[74] The two most important ports of Denmark, in terms of economic value of landings, are Skagen (at the northern tip of Denmark, at the boundary of the Skagerrak and Kattegat) and Thyborøn (on the North Sea, in central Jutland).[75]

Danish waters of the North Sea and the Skagerrak are also exploited by other countries, such as Belgium, Germany, the Netherlands, Norway and Sweden.[75,76] Dutch and Belgian vessels have developed equipment that enables vessels to fish on rocky substrates without damaging the gear, but causing severe impacts to seabed habitats; protected areas such as *Store Rev* and *Gule Rev* are being fished in this way, with no measures in place to avoid the resulting damage.[76] The waters of the Skagerrak are also included in a trilateral fishing agreement between Norway, Sweden, and Denmark.[77] This agreement regulates access to fishing in the Skagerrak for vessels flagged by the three countries, for catch of various species, including cod (*G. morhua*), hake (*Merluccius merluccius*), pandalid shrimp (*Pandalus* spp.), herring (*C. harengus*), plaice (*P. platessa*), sprat (*Sprattus sprattus*), whiting (*Merlangius merlangus*), and others.

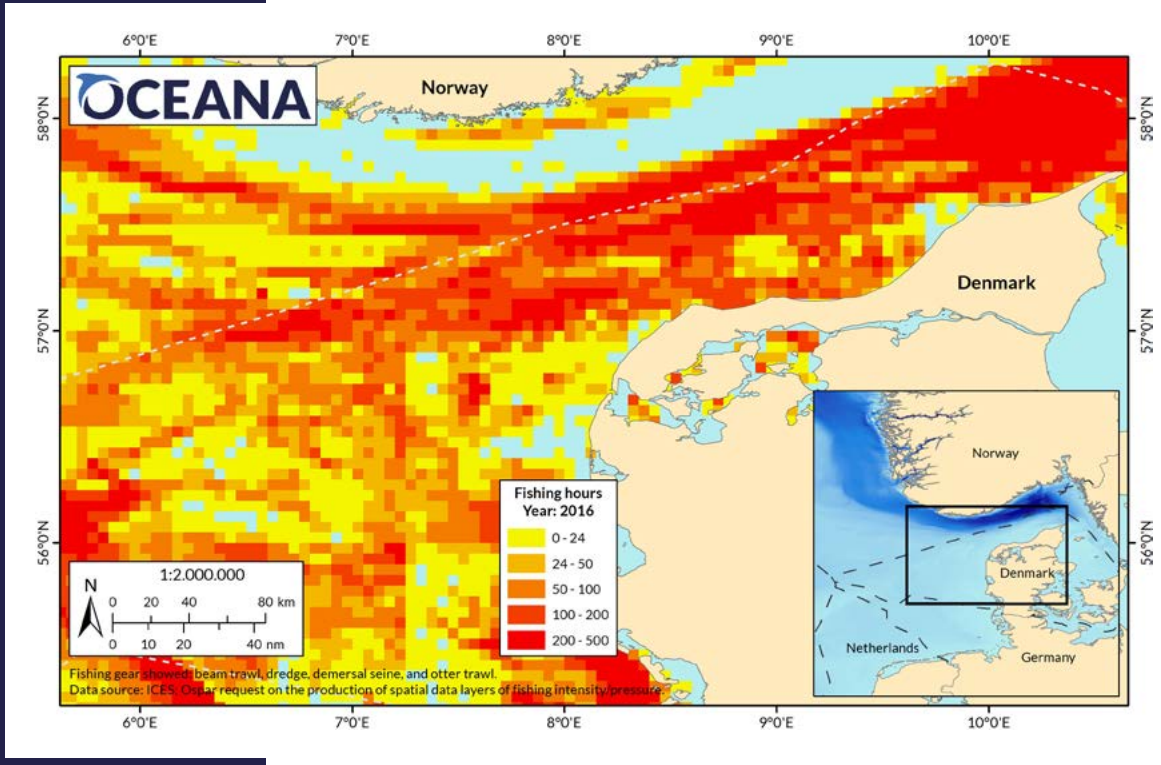
The main Danish fishing grounds lie to the north of Denmark, from the waters of the North Sea to the Baltic Sea (Figure 6), and support a high intensity of both pelagic and demersal fishing activities.[78] The most commonly fishing gear in the Greater North Sea, the otter trawl, is intensively used in this area.[11]

The Oceana survey area, especially around the Little Fisher and Jutland banks to the northwest part of the area, is characterised by high concentrations of zooplankton and sandeels (Ammodytidae), including larvae, and high zooplankton productivity.[79] Many commercial species are found in the survey area, such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), and Norway pout (*Trisopterus esmarkii*), with densities that are among the highest in anywhere in Danish waters.[25] The spawning biomasses of some of these fishes in the North Sea and the Skagerrak, such as cod, saithe and common sole (*Solea solea*), are below safe limits. Others, such as haddock, Norway pout, and herring (*Clupea harengus*), are considered to be in good status.[80]

The coastal waters from *Skagens Gren og Skagerrak* to Thyborøn are home to the highest abundance of lobster (*Homarus gammarus*) in Denmark, and so are highly important for pot fisheries.[81] Other crustaceans are also abundant in the deeper waters of the Skagerrak, such as Norway lobster (*Nephrops norvegicus*) and shrimps (Pandalidae).[25] According to Maar *et al.* (2016), the area of highest primary productivity in the Danish North Sea lies in front of Klitmøller/*Thy National Park*. [82] This site is located between *Gule Rev* and *Thyborøn Stenvolde* and is unprotected.

In some locations, benthic surveys have documented obvious impacts of trawlers on the seabed, in terms of grooves left by contact of fishing gears. Sites where trawl marks have been documented include the Jutland Bank region,[52] to the east of *Gule Rev*,[3] inside Natura 2000 sites such as *Store Rev* and *Skagens Gren og Skagerrak*.[3]

Figure 6. Fishing hours by bottom-contact gears in 2016. Sources: EMODnet,[2] EEA,[5] ICES.[83]



Wind energy development

Offshore wind energy capacity in Europe is growing exponentially every year; investments in new offshore wind have increased 37% from 2017.[84] The UK and Germany lead the list of EU Member States with the greatest offshore wind capacity, and with the most new wind energy developments in 2018 (85% of all new installations). Denmark is the third country on this list, with 7% of EU offshore installations in its waters, and connected 61 new offshore turbines to the grid in 2018, the first ones in the country since 2013.[84] Furthermore, Denmark is the country with the highest proportion of its total electricity demand covered by wind energy in Europe.[85]

The government of Denmark, as part of its 2018 Energy Agreement,[86] unanimously decided to procure three new offshore wind farms, to be fully operational in 2027 as a contribution to the green transition from oil and gas resources to clean and sustainable energies.[86,87] One of these wind farms, named *Thor*, will be located in the Danish North Sea, south of the Oceana survey area. It could become the largest offshore wind farm in Europe,[86] with a capacity between 800 MW and 1000 MW.[87] The other two projected wind farms could potentially be placed inside the survey area, as it includes one of the allocated Development Zones (Figure 5).

Figure 7. Offshore wind farm in Danish waters.
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Oil and gas exploitation

Denmark aims to focus on renewable energies and become a low-emission society under its 2018 Energy Agreement, as previously mentioned.[86] By 2020, Denmark intends to supply 30% of final energy consumption from renewable energies and to achieve 100% fossil fuel free energy production by 2050.[88]

At the same time, Denmark is currently the second-largest oil producer in the European Union, after the UK.[89] Since 1972, the source of Danish fuel production has been the oil and gas fields in the Danish North Sea.[90] The future of hydrocarbon extraction in the Danish North Sea is uncertain; the Danish government announced in October 2019 that it was assessing whether to proceed with a tender for new oil and gas exploration or to prohibit future exploration, in the interest of meeting climate change targets.[91]

To the west of *Jyske Rev/Lillefiskerbanke* is an area open for licensing for hydrocarbon exploration and exploitation.[92] Some isolated, dry oil wells are also located around the offshore banks and to the south of Thyborøn.[60]

Shipping

The North Sea is the most crowded sea in the world, after the South China Sea, in terms of maritime shipping, with the major seaports – Rotterdam, Amsterdam, Antwerp, Hamburg, Le Havre and London – located in the southern area.[93,94] Most of the fleet crossing North Sea waters is non-European flagged,[93] which represents one of the most significant environmental problems associated with this activity: the introduction of non-indigenous species through ballast water and fouling organisms. Other threats to North Sea ecosystems related to intensive shipping are the elevated concentration of contaminants from illegal or accidental waste discharge and the disposal of toxic and hazardous substances (such as oil spills and persistent organic pollutants); contaminants affect marine life, particularly top predators such as large pelagic fishes and marine mammals, and threaten human and environmental health. Shipping also contributes to littering (i.e., loss of cargo), and underwater noise, affecting animals further away, and collisions experienced by cetaceans and birds.[95,96]

Denmark is a key nation for the global shipping industry due to its strategic location linking the North Sea and the Baltic Sea. Denmark is the sixth-largest nation in terms of operating tonnage of shipping vessels, and the thirteenth in terms of owned tonnage.[97,98] The shipping industry is a top Danish export, providing almost 4% of total employment in Denmark.[99] Therefore, the Danish government has prioritised establishing a strong framework for shipping development, setting recommendations for maintaining and developing the Danish shipping industry under the umbrella of 'Blue Denmark' (Denmark's maritime cluster).[100,101]

The Oceana survey area is affected by the intense shipping activity in the Skagerrak, which represents one of the busiest shipping routes in the world (Figure 5). In recent years, more than 10 000 vessels visited the Skagerrak and Baltic area annually.[102] The impacts of this scale of maritime traffic are of concern with respect to marine ecosystems; together with fishing, shipping is one of the most intensive human activities in the eastern North Sea.[95] Shallow and coastal Danish waters are also heavily affected by both commercial and recreational shipping.[103]

Also troubling is the fact that shipping traffic passes through some Natura 2000 MPAs, such as *Skagens Gren og Skagerrak*, *Knudegrund*, *Store Rev*, and *Gule Rev*. The Jutland Bank region is also affected by shipping but at a lower intensity, while Little Fisher Bank sees limited shipping activity.[4]

Denmark is in the process of developing a Maritime Spatial Plan that is expected to enter into force in 2021,[104] to meet the 21 March 2021 deadline established under the EU Directive on Maritime Spatial Planning.[105] The plan will assign nationally

designated priority areas for shipping,[106] but these areas have not yet been published. Denmark is the only North Sea country for which data on priority shipping areas have not been made publicly available.

Current management measures

Denmark has protected 17% of its marine area,[107] having designated Natura 2000 MPAs for the protection of marine habitats and species listed under the Habitats Directive in both the North and Baltic Seas. By mandate of the Habitats Directive, all Natura 2000 sites, once designated as Special Areas of Conservation (SACs), require the establishment of conservation measures (typically through a management plan) to maintain or restore the favourable conservation status of the habitats and species for which the areas have been designated.

The current management plans (for the period 2016-2021) for the eight Natura 2000 MPAs inside the Oceana survey area[iv] (Figure 3) state the government's commitment to protect habitats and species, achieve favourable conservation status, and ensure ecological integrity of the marine ecosystems. However, these plans have yet to be completed and only provide for two measures for all sites: i) a shared guideline to be prepared for *Stone Rev* and *Gule Rev* for the protection of harbour porpoise (despite the fact that the species occurs in all eight sites); and ii) a second guideline common to the six sites with reefs, indicating that an assessment will be carried out on the need to regulate fisheries on and around the reefs. The plans for *Skagens Gren og Skagerrak* and *Sandbanker ud for Thyborøn*, which are areas with no reef habitat recognised inside their limits, do not contain any specific guidelines for the conservation of the areas' marine habitats and species.

The three habitat types that are listed under the Habitats Directive and are present in Danish offshore waters (i.e., *Reefs*, *Sandbanks which are slightly covered by sea water all the time*, and *Submarine structures made by leaking gases*) have been partially protected through the designation of Natura 2000 MPAs: 11 in the North Sea and 66 in the Baltic Sea.[4,108] At the Danish national level, these three habitat types are considered by the European Commission as being sufficiently protected in terms of coverage.[109] All of the Danish Natura 2000 sites within the OSPAR area have also become part of the OSPAR MPA Network. However, regardless of these designations, the conservation status of all three habitat types in Danish waters has been assessed as 'Unfavourable-Bad'.[110]

[iv] *Skagens Gren og Skagerrak*, *Knudegrund*, *Lønstrup Rødgrund*, *Store Rev*, *Gule Rev*, *Sandbanker ud for Thyborøn*, *Thyborøn Stenvolde* and *Jyske Rev/Lillefiskerbanke*.

Under the Habitats Directive, Member States are required to protect more than 20% of the population (and geographical area) of listed species and habitats, in each bioregion of their waters.[111,112] For example, recent calculations show that only 18.8% of reefs[4] are currently protected in Denmark: 19.4% of reefs in Atlantic waters (North Sea and Kattegat), and 18.2% in the Danish Baltic Sea.[113] Based on these data, current protection of Danish reefs in the Atlantic region falls below the 20% minimum,[111,112] indicating that the protection of more reefs should still be considered a priority for Denmark.

Focusing on the waters of the North Sea and the Skagerrak, a recent analysis estimated that Natura 2000 sites cover only 14% of sandbanks and 17% of reefs.[4] Most of the sites occur in waters shallower than 40 m; some deeper areas (with a maximum depth of approximately 210 m) are protected in the northernmost region, but protections do not cover the deepest Danish zones. Based on this analysis and applying the same European Commission criteria to this biogeographical region,[111] protection of these habitat types in the surveyed areas remains insufficient, below the minimum 20% recommended.

Under the Danish Programme of Measures of the EU Marine Strategy Framework Directive (MSFD), Denmark has committed to implement a series of measures for the protection and improved management of the marine environment, under Descriptors 1, 4 and 6 (Biodiversity, Food Webs, and Seafloor Integrity), including some spatial protection measures and new MPAs.[107] Examples of such measures related to the conservation of benthic biodiversity include: mapping of all stone reefs, sandbanks and bubbling reefs; defining and mapping of biogenic reefs; designating protected areas in Kattegat beyond Habitats Directive requirements; assessing the need for new MPAs in the North Sea and Baltic Sea; developing a benthic fauna index for physical disturbance; announcing new fisheries regulations for stone reefs and bubbling reefs in Natura 2000 sites in the North Sea; regulating fishing activities to avoid impacts on fish habitats, seabirds and mammals; protecting mapped reefs within Natura 2000 areas; restricting dredging in relevant areas, such as sandeel and horse mussel habitats; and developing regulations for offshore activities, with the exception of shipping.[107]

Fishing regulations for the protection of Danish reefs[114] were applied for the first time in 2013[115] in four Baltic Sea coastal Natura 2000 MPAs and extended in 2018[116] to 19 other MPAs in the Baltic Sea, including five bubbling reefs. Inside these Natura 2000 sites, bottom-towed gears are prohibited on reefs, and bubbling reefs are protected from all types of fishing.[117] Any other activity which could potentially damage the reefs may be assessed to avoid impacts on the habitat.[117]

Under the MSFD, new fisheries regulations are being developed for the protection of reefs and bubbling reefs inside Natura 2000 areas in the North Sea. The Danish Ministry of Foreign Affairs is preparing such regulations for five Natura 2000 MPAs, all located in the Oceana survey area: *Store Rev*, *Jyske Rev/Lillefiskerbanke*, *Gule Rev*, *Lønstrup Rødgrund* and *Thyborøn Stenvolde*.[118] These areas represent fishing grounds for both national and foreign fisheries,[119] and such measures must be developed jointly with EU Member States that fish within the areas.

Fishing regulations for the protection of harbour porpoises (including the use of acoustic deterrents to mitigate incidental catches, other technical measures, and surveillance such as on-board observers) are also expected to be in place by 2020 for the 16 Danish marine Natura 2000 MPAs that have been designated to protecting this species.[120] Three of these sites are in the Oceana survey area: *Skagens Gren og Skagerrak*, *Gule Rev* and *Store Rev*. Research is also being carried out on seabird bycatch in net fisheries and the effects of fishing gears on sandbanks, to determine whether additional new fishing regulations are needed.[121]

Since 2009, real-time temporary closures have been applied by the European Union in the North Sea and the Skagerrak for the protection of juveniles of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and saithe (*Pollachius virens*).[122] In Danish waters, real-time closures have only recently been put in place, with the closure of two areas inside the *Skagens Gren og Skagerrak* during inspections carried out in 2015.[123] The areas were closed for 21 days due to the presence of large quantities of juvenile fishes. No closures were applied after the inspections in 2016,[124] and at the time of writing this report, no closures were active in Danish waters.[125]

Additionally, the Oceana survey area partially overlaps with the transboundary fisheries management area known as the 'Plaice Box,'[126] which lies in the area of Jutland Bank (Figure 8). The Plaice Box is a Danish/Dutch/German coastal area in which reduced fishing effort has been in place since 1989 to recover plaice and sole stocks, by reducing discarding of undersized individuals. Its effectiveness has been questioned, as the spawning stock biomass of targeted species has not increased as expected, possibly due to the combined influence of certain fisheries which are still permitted in the area and changes in the environment (e.g., eutrophication and temperature).[13,127,128,129]

Previous conservation proposals

Various national and international NGOs and scientists have proposed the protection of new areas and the enlargement of existing ones within Danish waters, because of their importance for protected or threatened habitats and species.

A coalition of major Danish environmental organisations, the *Grønne Kontaktudvalg* (DGK, known in English as the Green Coalition Group of Danish NGOs), including Oceana, has pushed the Danish government to designate more MPAs, to meet its legal commitments under the Convention of Biological Diversity and European Directives. Among other initiatives for the protection of the Danish environment, the coalition proposed, based on the research, the enlargement of *Jyske Rev/Lillefiskerbanke*, *Store Rev*, *Sandbanker ud for Thyborøn* and *Thyborøn Stenvolde* to provide adequate protection for large reefs and bubbling reefs that were predicted to occur there (Figure 8).[130] The coalition emphasised the need for further surveys to better map the areas and establish adequate boundaries. These enlargements had been previously proposed by WWF Germany, as part of a proposal for a network of MPAs for the entire North Sea,[131] along with a set of large areas named Blue Belts (Figure 8), with integrated management across different MPAs to develop a coherent network.

A detailed analysis of the status of the MPA network in the Danish part of the North Sea and Skagerrak, and the Central Baltic Sea around Bornholm[4] was carried out to determine if Denmark fulfils MSFD requirements for a coherent and representative network of MPAs. The study, which was commissioned by the Danish government, found that large areas of reefs, sandbanks, and submarine structures made by leaking gases remained unprotected, or occurred inside MPAs but were not listed as protected features of the sites. The study also identified a lack of protection of other habitats of ecological relevance that are not listed under the Habitats Directive, such as deeper soft bottoms, which are essential for commercial and vulnerable species and strongly impacted by bottom fisheries.[4] Soft bottom areas occur inside Natura 2000 MPAs such as *Skagens Gren og Skagerrak*, but as these habitats are not covered by the Habitats Directive, they are not subject to any specific conservation or management measures. The analysis identified the protection of both hard and soft bottom areas as a key priority.[4] In order to improve the network of MPA, the authors further recommended increased research on soft bottom communities – and on benthos in general – in the North Sea and deeper parts of the Skagerrak, to fill critical gaps in knowledge.

As mentioned in *Threatened and protected species*, no seabird offshore protected areas have been declared in northern Danish waters of the North Sea. BirdLife International, with its Danish partner Dansk Ornitologisk Forening, identified an extensive area (16 000 km^2) as an Important Bird and Biodiversity Area[130,132] for the protection of seabirds. Thirty-three percent of the area, named *Skagerrak-Southwest Norwegian trench*, is in Danish waters[15] and overlaps with most of the Oceana survey area. BirdLife has advocated the designation of *Skagerrak-Southwest Norwegian trench* and other IBAs as Special Protected Areas under the Birds Directive.[132]

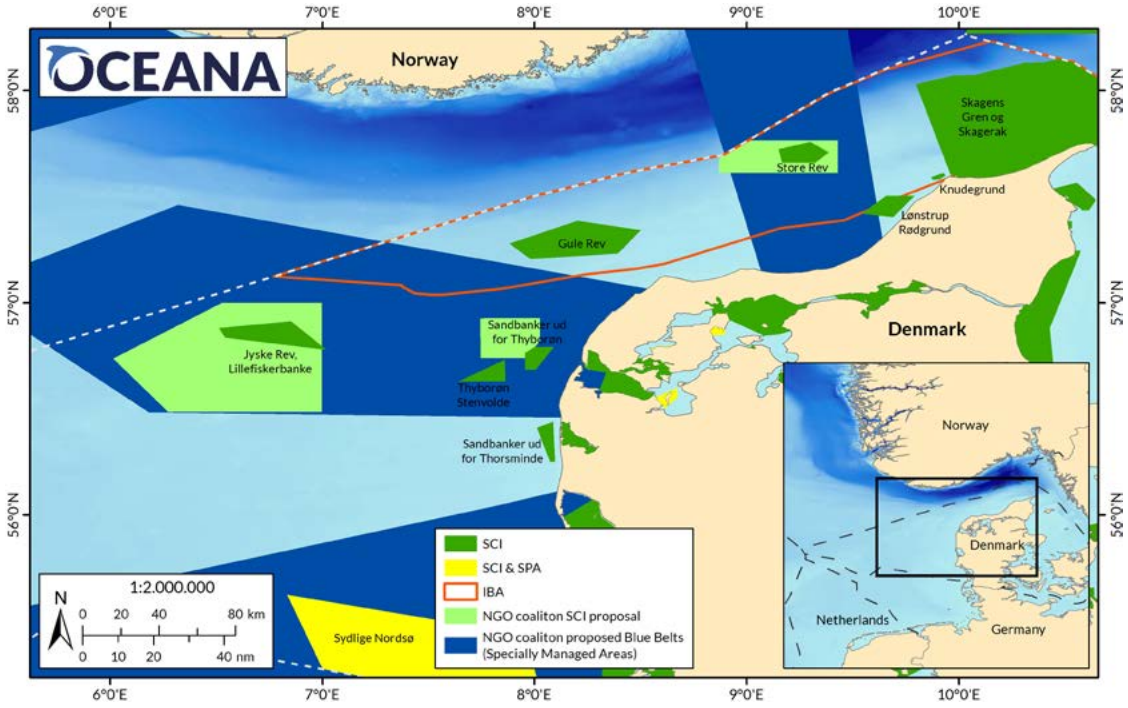


Figure 8. Current and proposed Natura 2000 MPAs under the Habitats and Birds Directives in the Oceana survey area. Sources: EMODnet,[2] EEA,[5] WWF,[131] Birdlife International,[132] and the Green Coalition of NGOs.[130]

OCEANA SURVEYS

Oceana surveyed Danish waters as part of two eight-week, at-sea research expeditions carried out across the North Sea in 2016 and 2017. These expeditions 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 areas 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.

Surveys of the northern waters of the Danish North Sea were conducted over a total of 10 days, in three regions (henceforth referred to as 'Little Fisher Bank', 'Jutland Bank', and 'North of Denmark'), as shown in Figure 9. On 11, 12, 17 and 18 August 2016, surveys were carried out in the areas of Jutland Bank and Little Fisher Bank; on 21-26 July 2017, surveys were done in the North of Denmark, extending from the northernmost waters of the Danish North Sea (near the maritime border with Norway), westwards to Jutland Bank (Figure 9).

Survey areas were selected on the basis of published and grey literature and spatial data on marine biodiversity, bathymetry, and substrate types, as well as through consultation with Danish scientific experts.

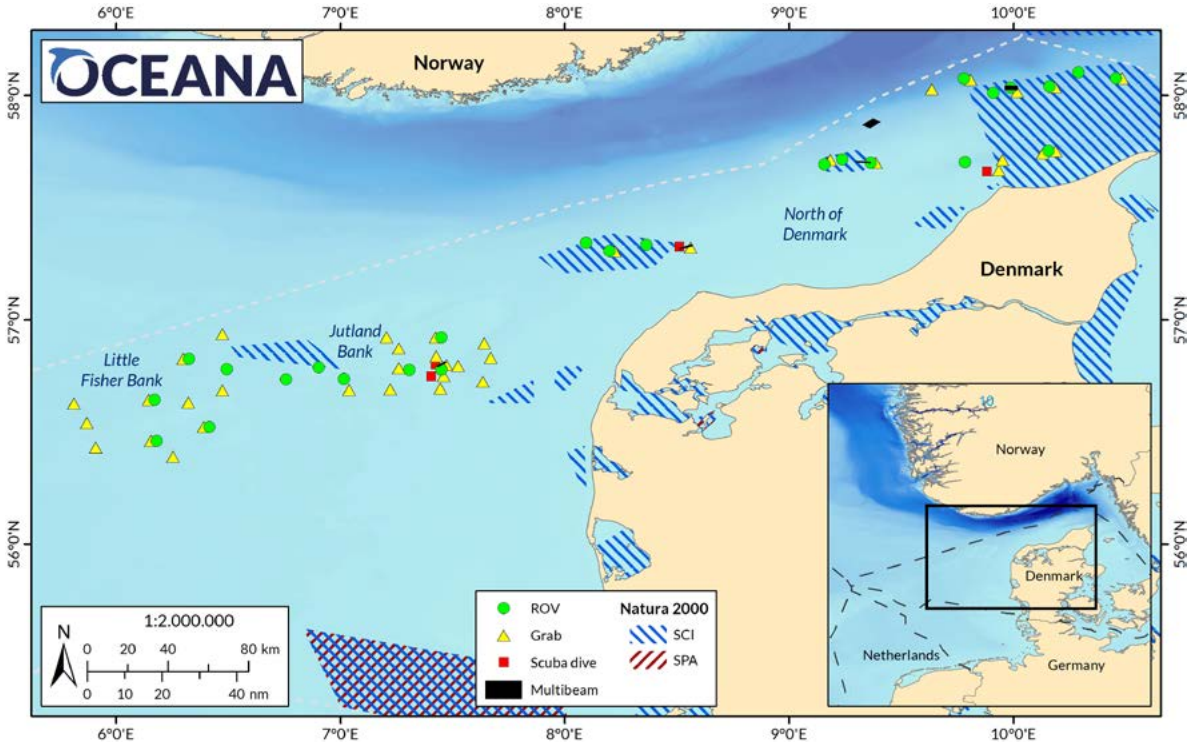


Figure 9. Survey points in the northern waters of the Danish North Sea, during the 2016 and 2017 Oceana North Sea expeditions. Points are shown according to sampling type (i.e., ROV, SCUBA dives, grab samples, and multibeam echosounder). Sources: EMODnet,[2] EEA.[5]

The seabed was explored mostly by low-impact visual means: filming with a remotely operated vehicle (ROV) and by professional SCUBA divers. Infaunal grab sampling was also carried out, as well as seabed mapping with a multibeam echosounder, and sampling of oceanographic parameters using a conductivity, temperature, and depth (CTD) device. Each of the survey methods are described in more detail below.

Figure 10. *MV Neptune* moored at Hirtshals port.
© OCEANA/ Carlos Minguell

ROV SURVEYS

For ROV image recording, a Saab Seaeye Falcon DR ROV was used, equipped with a high-definition video (HDV) camera of 1920 x 1080 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 resolution (for the total duration of the surveys), along with position, depth, course and time. Lasers on the ROV were used to estimate sizes and abundances. Considering the average speed and the wide angle of the camera (which could film transects of approximately 1.5 m width), the ROV allowed the observation of around 550-650 m^2 of seabed per hour.

A total of 25 ROV transects were carried out: four in Little Fisher Bank, seven in Jutland Bank, and 14 in North of Denmark. Surveyed sites ranged in depth from 27 m in Jutland Bank to 288 m in North of Denmark.

During and following the expedition, Oceana scientists analysed the ROV footage and identified all visible species to the finest taxonomic level possible.

Figure 11. ROV operator and deckhand launching the ROV into the water.
© OCEANA/ Juan Cuetos

Figure 12. Yellow hedgehog sponge (*Polymastia boletiformis*) surveyed by ROV in *Store Rev*, at 40 m depth.

Infaunal sampling

Benthic infaunal community composition was examined using a 12 L Van Veen grab sampler. A total of 38 grab samples were taken in the survey area: nine in Little Fisher Bank, 16 in Jutland Bank, and 13 in North of Denmark. Surveyed sites ranged from 20 m depth in Jutland Bank to 378 m depth in North of Denmark. More than 1300 biological specimens were collected from the 38 sampling points.

Oceana scientists analysed these specimens during and following the expeditions. Specimens retained on 0.5 mm, 1 mm, 3.15 mm, and 10 mm mesh sieves were kept and identified to the finest taxonomic resolution possible. Those samples that could not be identified definitively while on board were preserved and identified following the expeditions.

Figure 13. Van Veen grab sampler collecting a sample of coarse sand.
© OCEANA/ Carlos Minguell

Figure 14. Stones with attached hydrozoans, collected in a grab sample in Jutland Bank.
© OCEANA/ Juan Cuetos

SCUBA DIVES

Visual data were gathered by one team (2016 expedition) or two teams (2017 expedition) of professional SCUBA divers. Each team comprised a photographer, a videographer, and two safety divers. A total of four dives were carried out: two in Jutland Bank, and two in North of Denmark (Figure 9), with divers producing high-definition videos and still images. Surveyed sites ranged in depth from 21 m in Jutland Bank to 30.6 m in North of Denmark.

Figure 15. SCUBA divers at a survey point in the Danish North Sea, with the *MV Neptune* in the distance.
© OCEANA/ Juan Cuetos

Figure 16. Lion's mane jellyfish (*Cyanea capillata*) photographed by Oceana divers in the waters of Jutland Bank.
© OCEANA/ Juan Cuetos

In total, from both expeditions, Oceana documented 467 taxa in the surveyed areas, of which 330 were identified to the species level, and 137 to higher levels (see *Annex*). Among the recorded organisms were 369 taxa of invertebrates (with 260 identified to species level), 60 taxa of fishes (44 identified to species level, including one chondrichthyan, lesser-spotted dogfish (*Scyliorhinus canicula*)), and 13 taxa of tunicates (8 identified to species level). A single species of marine mammal, long-finned pilot whale (*Globicephala melas*) was also documented. Recorded species also included red macroalgae (15 taxa), brown macroalgae (9 taxa) and green macroalgae (1 taxon).

Both hard and soft bottoms were documented in the area, normally forming mixed bottoms and harbouring rich communities. A description of the main associated epibenthic communities found is given below, together with some annotations from infaunal records from grab surveys.

COMMUNITY TYPES

Surveys revealed a mosaic of ecosystems, in which hard and soft bottoms patches of different grain sizes coexist. Rocks and boulders were present among sand and gravel patches and surrounded by muddy bottom, harbouring diverse communities. Therefore, a description of the key community types documented is presented, based on their dominant features and with reference to substrata and communities with which they co-occurred. In total, a set of five community types is described, according to the three survey areas (North of Denmark, Jutland Bank and Little Fisher Bank), as listed below:

North of Denmark

- Stone reefs with *Alcyonium digitatum* and *Flustra foliacea*
- Sea pen fields in deep bathyal muds and muddy sand
- Mixed substrata of sandy bottoms with sparse rocks or gravel

Jutland Bank

- Stone reefs with *Alcyonium digitatum* and *Flustra foliacea*
- Mixed substrata of soft bottoms with boulders with *Alcyonium digitatum*, *Flustra foliacea* and faunal and/or algal turfs

Little Fisher Bank

- Mixed substrata of boulders, stones and gravel with *Alcyonium digitatum* and muddy sand

NORTH OF DENMARK

Stone reefs with *Alcyonium digitatum* and *Flustra foliacea*

Two species characterise stone reefs found in the North of Denmark: the cnidarian *Alcyonium digitatum* and the bryozoan *Flustra foliacea*. Surveys (carried out at depths ranging from 33.7-56.5 m) documented rocks on which both species coexisted, as well as rocks on which one or the other species was dominant. They were normally accompanied by a turf of other bryozoans (*Parasmittina trispinosa*, *Escharoides coccinea*, *Schizomavella linearis*, *Alcyionidium* sp., or *Cellepora pumicosa*) and many different hydrozoans (*Halecium halecinum*, *Abietinaria abietina*, and *Kirchenpaueria pinnata*, among others).

Many other species were also settled on this hard substratum, including anthozoans (*Epizoanthus* sp., *Metridium senile* and *Caryophyllia (Caryophyllia) smithii*); molluscs (*Anomia ephippium*); tunicates (*Ascidiella aspersa*, *Clavellina lepadiformis*, *Botrylloides leachii*, *Diplosoma spongiforme* and *Botryllus schlosseri*); polychaetes (*Filograna implexa* and *Spirobranchus triqueter*); a wide variety of sponges (*Polymastia boletiformis*, *Mycale (Carmia) micracanthoxea*, cf. *Protosuberites denhartogi*, *Leucosolenia complicata*); and algae (*Delesseria sanguinea* and *Phymatolithon lenormandii*). The refuges created by these rocky reefs and the abundance of faunal coverage allows the presence of a wide variety of other species. Examples documented by Oceana included crustaceans (*Cancer pagurus*, *Galathea dispersa*, *Hyperia galba*, *Inachus* spp.), echinoderms (*Asterias rubens*, *Marthasterias glacialis*, *Ophiothrix fragilis*, *Ophiocomina nigra*, *Echinus esculentus*) and molluscs *(Calliostoma zyziphinum*, *Acanthodoris pillosa*, *Eubranchus tricolor*, *Fjordia lineata*, *Polycera fareoensis).*

Among the stones, coarse sediments, and soft bottoms around the rocks, many other species were recorded, such as the tube anemone *Cerianthus lloydii*; the slender sea pen *Virgularia mirabilis*; the snails *Turritellinella tricarinata*, *Buccinum undatum*, *Colus* sp. and *Neptunea antiqua*; the anemones *Urticina felina* and *Actinia fragacea*; the hermit crab *Pagurus bernhardus*; the starfish *Luidia ciliaris*; and the annelid *Chaetopterus variopedatus*. Notably, surveys revealed an abundance of large mollusc shells, such as *Panomya norvegica*, *Modiolus modiolus* and *Arctica islandica*. Other important bivalve species seen in this area were *Pecten maximus*, *Aequipecten opercularis*, *Acanthocardia* sp., and *Dosinia exoleta*.

Some of the fishes that were observed in association with this mixed seabed were rock gunnel (*Pholis gunnellus*), sand goby (*Pomatoschistus minutus*), plaice (*Pleuronectes platessa*), flounder (cf. *Platichthys flesus*), reticulated dragonet (*Callionymus reticulatus*), white anglerfish (*Lophius piscatorius*), goldsinny (*Ctenolabrus rupestris*), poor cod (*Trisopterus minutus*), and cod (*Gadus morhua*). Juveniles of cod were commonly recorded from this habitat.

Figure 17. Edible crab (*Cancer pagurus*) under colonies of dead man's fingers (*Alcyonium digitatum*), in the North of Denmark survey area.
© OCEANA/ Carlos Minguell

Inside the *Store Rev* Natura 2000 MPA is a known bubbling reef area, in which bacterial mats are formed due to leaking gases. Oceana carried out visual surveys around one of the known bubbling reefs of this protected site, documenting bacterial mats surrounded by small concretions that had possibly been formed by the methane seepage. Bubbles were also documented. Inside this same protected site, a second bubbling reef was found in a location that has not been described in available literature.[3,4] In the area of this bubbling reef, no calcareous-like structures were found, but bacterial mats and gas seepage shimmers were documented.

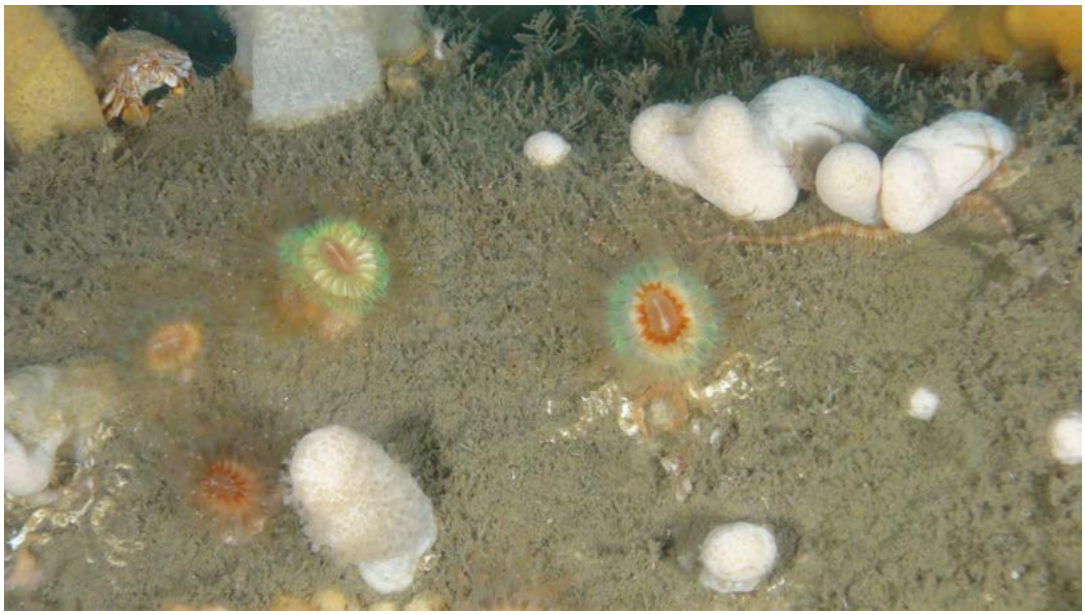


Figure 18. The stony coral *Caryophyllia (Caryophyllia) smithii* and soft coral *Alcyonium digitatum*, on rocky bottom in the North of Denmark survey area.

Sea pen fields in muddy sand and bathyal muds

Many parts of the North of Denmark area were characterised by muddy bottoms with sea pens, such as the habitat-building species *Virgularia mirabilis*, *Funiculina quadrangularis*, *Halipteris finmarchica*, and *Protoptilum carpenteri*. The latter species of sea pen was found in the deepest waters of the surveyed area, with only three individuals recorded at approximately 280 m depth, while the other species were recorded from depths of 62-142 m. The predominant bottom in these areas was mud, with almost no other substrata present. In some areas, bioturbations were observed, which were mainly created by burrowing crustaceans such as Norway lobster (*Nephrops norvegicus*).

In one of these fields, the bottom was densely covered by buried brittle stars (*Amphiura filiformis*) and some brittle worms (*Ophiodromus flexuosus*). In a different location, close to the area where *P. carpenteri* individuals were recorded, aggregations of anemones (approximately 300 individuals) of an unidentified species were documented (Figure 20).

On the Norwegian side of the Skagerrak, Oceana observed three species of sea pen during previous sections of the North Sea expeditions in 2016 and 2017: *Virgularia mirabilis*, *Pennatula phosphorea* and *Kophobelemnon stelliferum*.[133] Although these species were not observed during the surveys carried out in Denmark, their proximity to Danish waters and the similarity of the habitat type mean their existence in Danish waters cannot be ruled out.

Other cnidarians, such as North Sea tube anemone *Cerianthus lloydii* and deeplet sea anemone *Bolocera tuediae*, also play important roles in shaping seabed communities. *B. tuediae*, in particular, is often surrounded by various shrimps and prawns, to which it provides shelter and feeding opportunities.[134]

Other species associated with this community type included the sea stars *Astropecten irregularis*, *Asterias rubens* and *Marthasterias glacialis*. *A. rubens* was frequently found in nearly all of Oceana's ROV and SCUBA surveys across Denmark, while *A. irregularis* was only found on soft bottoms, and *M. glacialis* was found in scattered locations. Serpent's table brittlestar (*Ophiura albida*), serpent star (*O. ophiura*) and *O. robusta* were widely distributed on soft bottoms. Dense aggregations of white sea urchin (*Gracilechinus acutus*) were also observed. Other frequently recorded invertebrates included the polychaete *Aphrodita aculeata*, and various crustaceans, such as hermit crab (*Pagurus bernhardus*), sandy swimming crab (*Liocarcinus depurator*), northern shrimp (*Pandalus borealis*), friendly blade shrimp (*Spirontocaris liljeborgii*), squat lobster (*Munida rugosa*), lyre crab (*Hyas coarctatus*), and Norway lobster (*Nephrops norvegicus*). The latter species is a key habitat-structuring organism due to the bioturbations it creates with its burrows and galleries. Among the

molluscs, the gastropods *Neptunea antiqua* and *Buccinum undatum* and the bivalve *Aequipecten opercularis* were among the most abundant.

The most common fishes found in these habitats were gadoids (i.e., cod (*Gadus morhua*), saithe (*Pollachius virens*), blue whiting (*Micromesistius poutassou*), haddock (*Melanogrammus aeglefinus*) and Norway pout (*Trisopterus esmarkii*)); flatfish (i.e., Mediterranean scaldfish (*Arnoglossus laterna*), dab (*Limanda limanda*), American plaice (*Hippoglossoides platessoides*), plaice (*Pleuronectes platessa*) and witch (*Glyptocephalus cynoglossus*)); zoarcids of the genus *Lycodes*; greater silver smelt (*Argentina silus*); and hagfish (*Myxine glutinosa*).

Other species of ecological importance that were less frequently seen (in some cases due to the fact that they lived within the sediment) were the echinoids *Brissopsis lyrifera* and *Spatangus purpureus*, auger shell *Turritellinella tricarinata*, and the polychaetes *Oxydromus flexuosus*, *Lagis koreni* and *Sabella* sp. Some species characteristic of hard bottom were also found in the area, such as dead man's fingers (*Alcyonium digitatum*, which was found covering annelid tubes or fixed on snail shells) and hornwrack (*Flustra foliacea*, which had possibly been carried by current from shallower areas).

Samples of muddy bottoms were collected in eight of 13 grab samples taken from the North of Denmark area during the 2017 expedition, from depths of 69-381 m. Molluscs were the most abundant and diverse group of species collected, with bivalves belonging to the genus *Abra* present in all eight grab samples, in high numbers. The brittle star *Amphiura filiformis* was also abundant; it occurred in high numbers in four of the eight samples. No sea pens were found in these samples.

Figure 19. Slender sea pen (*Virgularia mirabilis*) surrounded by buried ophiuroids (*Amphiura filiformis*) in muddy bottom.

Figure 20. Unidentified species of anemone on muddy bottom.

Mixed substrata of sandy bottoms with sparse rocks or gravel

Sandy bottoms were also found in the North of Denmark survey area, and in some cases were characterised by the presence of sparse rocks.

The most commonly observed species in association with this habitat type were flatfishes such as plaice (*Pleuronectes platessa*), turbot (*Scophthalmus maximus*), Mediterranean scaldfish (*Arnoglossus laterna*), and dab (*Limanda limanda*). Other documented species included sand mason worm (*Lanice conchilega*), hermit crab (*Pagurus bernhardus*), sandy swimming crab (*Liocarcinus depurator*), and the common razor shell (*Ensis ensis*) and basket shell (*Corbula gibba*). The rocks were covered by tube worms and bryozoans (*Flustra foliacea*, *Securiflustra securifrons*), among other invertebrates, and dead man's fingers (*Alcyonium digitatum*).

During the 2017 expedition, samples of soft bottom with gravel were collected in five of the 13 grab samples taken, west of *Skagens Gren og Skagerrak*, inside and to the east of *Gule Rev*, and inside *Store Rev*, over a depth range of 21-48 m. Sediments in these samples included sand with and without gravel and stones, many individuals of pea urchin (*Echinocyamus pusillus*), and a high diversity and abundance of molluscs, including individuals of ocean quahog (*Arctica islandica*) and horse mussel (*Modiolus modiolus*).

A variety of gelatinous organisms were observed in the water column over this type of bottom. Species observed included the hydromedusa *Leuckartiara octona*, comb jellies (i.e., *Beroe cucumis* and *B. ovata*), and jellyfishes (i.e., *Cyanea lamarcki* and *C. capillata*). Some of the large jellyfishes had juvenile whiting *(Merlangius merlangus)* living within their tentacles.

Figure 21. *Alcyonium digitatum* garden, with brittle stars (*Ophiocomina nigra* and *Ophiothrix fragilis*) and common sea star (*Asterias rubens*), in *Store Rev*.

Figure 22. Plaice (*Pleuronectes platessa*) on mixed bottom, with dead man's fingers (*Alcyonium digitatum*) and mollusc shells, in *Store Rev.*

JUTLAND BANK

Stone reefs with *Alcyonium digitatum* and *Flustra foliacea*

As in the North of Denmark area, the most commonly found community on hard bottom in Jutland Bank was that characterised by *Alcyonium digitatum* and *Flustra foliacea*. The abundance of these and associated species differentiated such areas from surrounding bottoms. Associated invertebrates included hydrozoans (e.g., *Tubularia indivisa*, *Abietinaria abietina*) and the bryozoan *Escharoides coccinea*, together with numerous polychaetes (e.g., *Spirobranchus triqueter*) and various sponges, such as *Antho* sp., *Halichondria* sp., *Haliclona (Haliclona) oculata*, *Haliclona (Haliclona) urceolus*, *Leucosolenia* sp. and *Sycon ciliatum*. This area also hosted a high abundance and diversity of anemones (e.g., *Sagartia elegans*, *S. troglodytes*, *Sagartiogeton undatus)*, crustaceans (e.g., *Pagurus bernhardus*, *Anapagurus* sp., *Galathea* spp., *Pandalus montagui*, *Pisidia longicornis*, *Inachus* sp.) and molluscs (e.g., *Flabellina* sp., *Fjordia lineata*, *Simnia patula*, *Euspira nitida)*. Also recorded were echinoderms of different classes, like *Ophiothrix fragilis*, *Marthasteria glacilis* and *Echinus esculentus*.

The sandy bottoms around and among the reefs also supported the presence of some soft-bottom species and molluscs (e.g., *Dosinia exoleta*, *Ensis* sp., *Aequipecten opercularis* or *Aporrhais pespelecani*), crustaceans (e.g., *Liocarcinus marmoreus*, *Pagurus bernhardus*), bryozoans (*Alcyonidium diaphanum)*, echinoderms *(Asterias rubens*, *Luidia sarsi*, *Ophiura ophiura)* and fishes (e.g., *Callionymus maculatus*, *C. reticulatus*, *Chelidonochthys gurnardus*, *Pleuronectes platessa*, *Pomatoschistus minutus*). Cod (*Gadus morhua*) was recorded both in these sandy areas and on the reefs.

Figure 23. White and orange colonies of dead man's fingers (*Alcyonium digitatum*), and hornwrack (*Flustra foliacea*) covering a rock.

Figure 24. Erect sponge (*Haliclona (Haliclona) oculata)* and dead man's fingers (*Alcyonium digitatum*).

Mixed substrata of soft bottoms with boulders with *Alcyonium digitatum*, *Flustra foliacea* and faunal and/or algal turfs

Similar to the seabed in North of Denmark, described above, the boulders in Jutland Bank were colonised by many species of cnidarians and bryozoans. Under the Habitats Directive, such boulders qualify as reefs.

Together with dead man's fingers (*Alcyonium digitatum*) were dense turfs of tall tubularian (*Tubularia indivisa*) and plumed hydroid (*Kirchenpaueria pinnata*). In addition to hornwrack (*Flustra foliacea*), bryozoan species observed included *Cellepora pumicosa* and *Bugulina flabellata*. Other species associated with these communities included the polychaetes *Hydroides norvegica* and *Spirobranchus triqueter*; crabs (*Cancer pagurus*, *Anapagurus* sp., and *Inachus* sp.); and echinoderms such as spiny starfish (*Marthasterias glacialis*) and common sea star (*Asterias rubens*).

The area was surrounded by muddy bottoms, where sea stars (*A. rubens* and *Astropecten irregularis*) were the predominant fauna. Also abundant were molluscs, including ocean quahog (*Arctica islandica*; Figure 25), thorny cockle (*Acanthocardia echinata*), razor shell (*Ensis* sp.) and *Turritellinella tricarinata*, as well as hermit crab (*Pagurus bernhardus*) and the polychaete *Oxydromus flexuosus*. Among the fish recorded from this community type, the most common species found were plaice (*Pleuronectes platessa*), reticulated dragonet (*Callionymus reticulatus*), spotted dragonet (*Callionymus maculatus*) and cod (*Gadus morhua*).

Figure 25. Ocean quahog shells (*Arctica islandica*) on mixed bottom in Jutland Bank.

This mixed substratum in Jutland Bank was also documented in shallow water (21 m depth) during a SCUBA dive. In the sampled area the seabed was covered by hard bottom (i.e., rocks and boulders), with mixed sediments of sand and small stones/ gravel. The algal community was abundant, with tangle (*Laminaria hyperborea*) and various red algae (e.g., *Delesseria sanguinea*, *Desmarestia aculeata*, *Dilsea carnosa*, *Furcellaria lumbricalis*, *Gracilaria* sp., *Gracilariopsis longissima*, *Phymatolithon lenormandii*, *Polysiphonia fucoides*, *Rhodophyllis divaricata*) as the main habitat-building species. In some places with sand and small stones, the brown alga *Arthrocladia villosa* was also present. In some rocks, the communities formed by the above algal species coexisted with dead man's fingers (*Alcyonium digitatum*) and hornwrack (*Flustra foliacea*).

Among the associated species in this site were various crustaceans (e.g., *Cancer pagurus*, *Homarus gammarus*, *Galathea nexa* and Caprellidae), and sea stars (e.g., *Asterias rubens*, *Marthasterias glacialis* and *Astropecten irregularis*). Other invertebrate species present included bryozoans (e.g., *Scrupocellaria* cf. *scruposa*, *Crisia denticulata*, *Membranipora membranacea* and *Crisularia plumosa*), the knotted thread hydroid (*Obelia geniculata*), keelworm (*Spirobranchus triqueter*), molluscs (e.g., *Edmundsella pedata*, *Polycera quadrilineata* and *Euspira nitida*), and tunicates (e.g., *Synoicum incrustatum* and *Botryllus schlosseri*). Documented fish species were lesser-spotted dogfish (*Scyliorhinus canicula*), saithe (*Pollachius virens*), cod (*Gadus morhua*), goldsinny (*Ctenolabrus rupestris*) and topknot (*Zeugopterus punctatus*).

A sandy bottom area with no gravel or rocks was also studied during one of the Jutland Bank ROV surveys in 2016, at 26-27 m depth. There, Oceana found shells of threatened ocean quahog (*Arctica islandica*), among shells of other mollusc species.

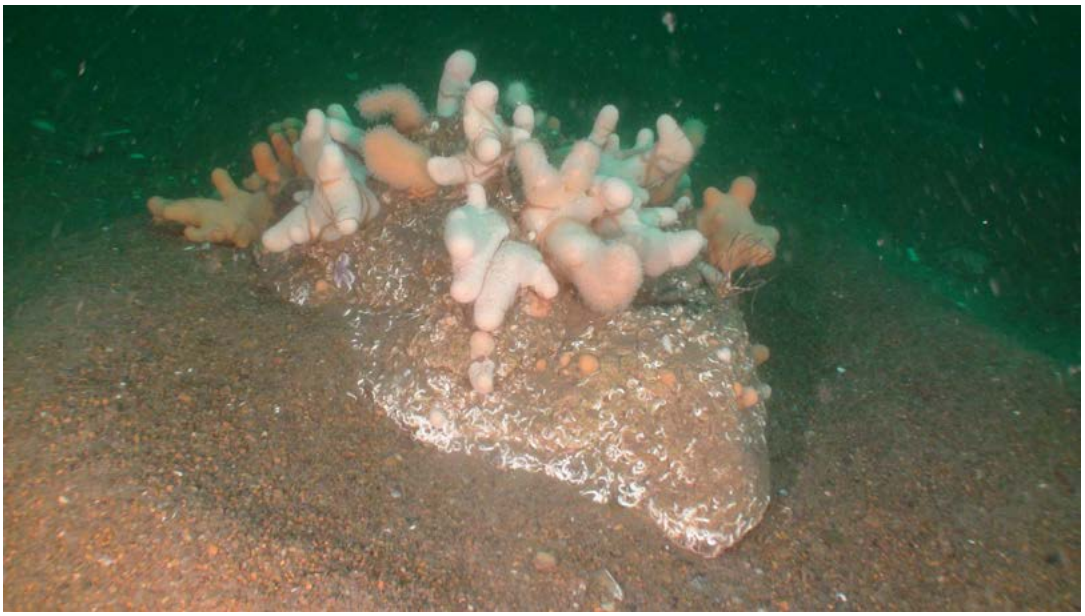


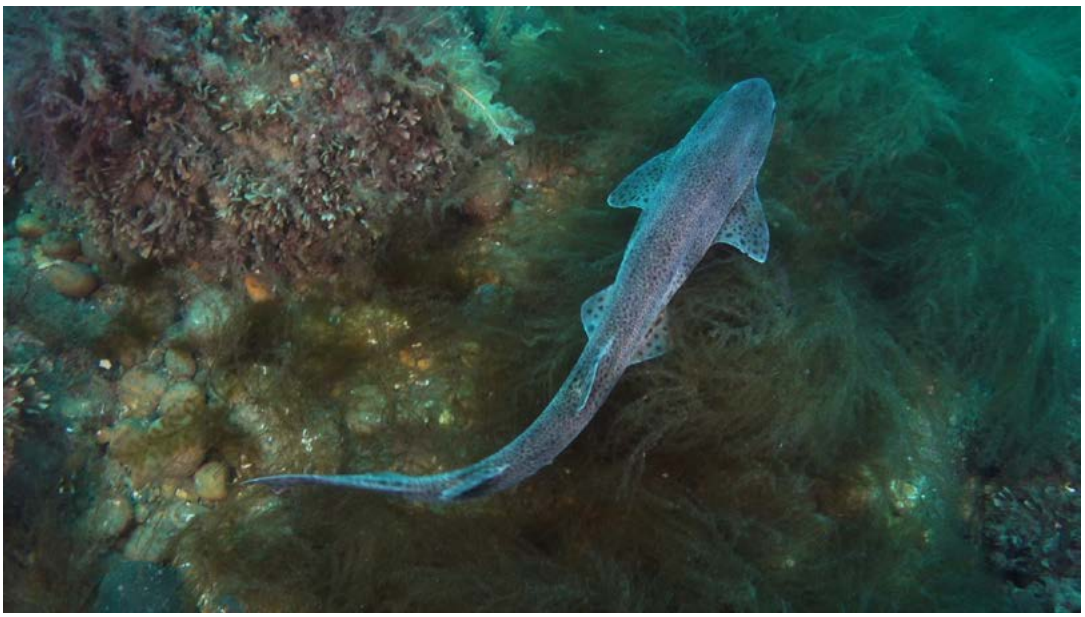
Figure 26. Soft corals (*Alcyonium digitatum*) on a boulder surrounded by soft sediment.

Also present were remains of *Laminaria* sp., *Alcyonium digitatum* and *Flustra foliacea*, which had possibly been carried by currents from nearby rocky-bottom areas.

A total of 14 grab surveys were carried out in Jutland Bank area, from points ranging in depth from 20-46.4 m. The substrate obtained from shallower surveyed points was sandy, with pebbles and cobbles (i.e., corresponding to mixed bottoms), while the seabed at the remainder of sampled points was rocky. Fauna within those samples comprised typical species of those types of bottoms, such as bivalves and echinoderms that live in soft sediment, and tunicates, bryozoans and hydrozoans attached to the small rocks.

In the water column, scyphozoans and ctenophores were also recorded, such as lion's mane jellyfish (*Cyanea capillata*), blue jellyfish (*C. lamarckii*), and comb jelly (*Beroe* sp.).

Figure 27. Lesser-spotted dogfish (*Scyliorhinus canicula*) in an area of mixed bottom covered by algae. © OCEANA/ Enrique Talledo



LITTLE FISHER BANK

Mixed substrata of boulders, stones and gravel with *Alcyonium digitatum* and muddy sand

The typical community composed of dead man's fingers (*Alcyonium digitatum*) and hornwrack (*Flustra foliacea*) was not found in Little Fisher Bank. The mixed sediment and smaller sized rocks observed may have prevented this type of community from developing.

Instead, at Little Fisher Bank, *A. digitatum* was still common, but the associated community of hydrozoans and bryozoans were less diverse, with sickle hydroid (*Hydrallmania falcata*) as the main representative. The mix of hard and soft bottoms of different grain sizes facilitated the occurrence of species from different environments. Associated invertebrates included anthozoans such as dahlia anemone (*Urticina felina*), sponges (e.g., *Suberites ficus*), echinoderms (e.g., *Asterias rubens*, *Opiothrix fragilis*, *Astropecten irregularis*, *Luidia sarsi*, and *Gracilechinus* sp.), crustaceans (e.g., *Galathea* sp., *Pagurus bernhardus*, *Corystes cassivellaunus* and *Balanus balanus*), annelids (*Spirobranchus triqueter* and *Oxynodromus flexuosus*), and molluscs (e.g., *Buccinum undatum*, *Cerastoderma glaucum*, *Neptunea antiqua* and *Arctica islandica*). Recorded fishes from this community type included cod (*Gadus morhua*), hake (*Merluccius merluccius*), plaice (*Pleuronectes platessa*), American plaice (*Hippoglossoides platessoides*) and lemon sole (*Microstomus kitt*).

In sites with soft bottoms without a hard component, commonly observed species included hermit crab (*Pagurus bernhardus*) and sea stars (*Asterias rubens* and *Astropecten irregularis*), and flatfishes (e.g., *Limanda limanda*). Isolated individuals of cod (*G. morhua*) and hake (*Merluccius merluccius)* were also documented.

A total of nine grab samples were collected from the soft bottoms of Little Fisher Bank area, at depths of 32.6-52.3 m. Among these samples were invertebrates that are typical of soft bottoms, such as bivalves, including one shell of *Artica islandica*, *Abra* spp., *Spisula eliptica* and *Venus casina*, among many other species, and sea urchins (e.g., *Echinocyamus pusillus*), brittle stars (e.g., *Amphiura filiformis*) and worms (species not identified). In one of the surveyed points, the sediment sample contained pebbles with attached worm tubes.

Figure 28. Boulder covered with dead man's fingers (*Alcyonium digitatum*).

Figure 29. Common sea star (*Asterias rubens*) and razor shell (*Ensis sp.*) on gravel sediment.

FEATURES OF CONSERVATION INTEREST

The two Oceana expeditions documented a variety of species and habitats in northern Danish waters that are considered priorities for conservation because these features are included within national, European, or regional frameworks that recognise their threatened status and/or establish requirements for their legal protection (Table 2). These include the IUCN Red List of Threatened Species[16] and the European Red List of Habitats,[135] the EU Habitats Directive and Marine Strategy Framework Directive, and the OSPAR List of Threatened and/or Declining Species & Habitats. As such, their occurrence deserves special consideration, with respect to the biodiversity value of the area and required management measures.

No marine species that are included on the Danish national Red List[136] were recorded during the surveys. However, it is worth noting that this list includes relatively few marine species and excludes some species that are recognised elsewhere as being threatened, such as kelps and various corals and sponges, among others.

THREATENED AND PROTECTED HABITATS

During the surveys in the northern waters of the Danish North Sea, eight habitats listed as threatened and/or protected were recorded (Table 2; Figure 30). Details are provided about each of those habitats below.

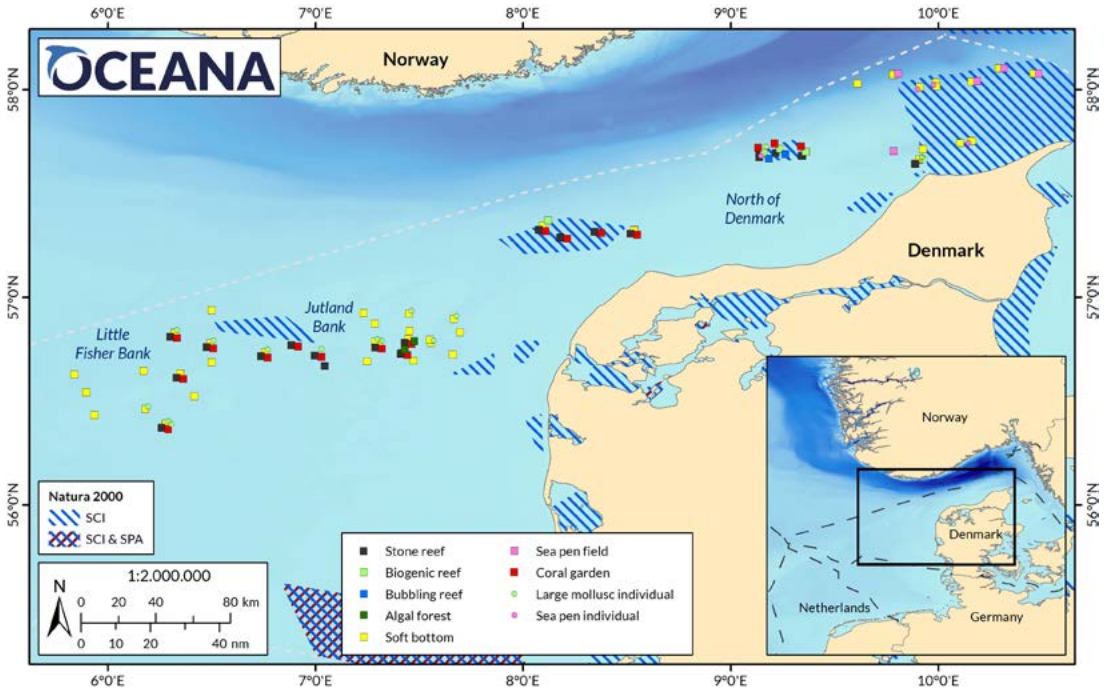


Figure 30. Protected and threatened habitats observed in northern Danish North Sea during the 2016 and 2017 Oceana expeditions. Sources: EMODnet,[2] EEA.[5] 'Stone reef' corresponds to those bottoms with rocks > 64 mm; 'Biogenic reef' corresponds to aggregations of shells (3 or more) of any of the relevant species (*Arctica islandica*, *Modiolus modiolus*, with occasional presence of *Mytilus edulis* and *Panomya norvegica*); 'Bubbling reef' corresponds to areas of bubbles and/or gas seepage shimmer; 'Algal forest' corresponds to living *Laminaria* spp. and *Delesseria sanguinea* forests; 'Soft bottom' corresponds to sandy and muddy bottoms without sea pens or rocks; 'Coral garden' corresponds to *Alcyonium digitatum* aggregations; 'Sea pen fields' are not included under coral gardens, to avoid duplicating the occurrence of the habitat; 'Sea pen individual' corresponds to solitary sea pens, rather than aggregations; 'Large mollusc individual' corresponds to isolated individuals of relevant species (*Arctica islandica*, *Modiolus modiolus*, *Mytilus edulis*, *Panomya norvegica*), while molluscs of these species were mapped as biogenic reef where there were aggregations of 3 or more shells.

Stone reefs

Stone reefs are included in the Habitats Directive under the broader category of reefs. According to the most recent official assessment of the conservation status of Danish habitats and species listed under the Habitats Directive, although the status of stone reefs in Denmark is improving, they remain in 'Unfavourable-Bad' condition,[110] suggesting that current protection measures are insufficient. Stone reefs are among the 21 Danish coastal habitats – including both marine and terrestrial – which have been assessed as being in unfavourable condition; all six marine habitats are categorised as being in 'Unfavourable-Bad' condition.[110]

Reefs are important features on the seabed, which provide surfaces and structure that allow other species to settle and find shelter; they are therefore associated with high levels of biodiversity. Various species lay their eggs in the epibenthic fauna and flora of reefs,[137,138] and juveniles of different commercial species are also common in these features.[139,140,141] In Denmark, reefs are still poorly represented in Danish MPAs in the North Sea and the Skagerrak, with only 17% of reefs inside Natura 2000 MPAs.[4] Other reefs have been recently mapped inside the protected area *Skagens Gren og Skagerrak*,[31] but have not been officially recognised as a protected feature within that site.

During the surveys, stone reef areas (i.e., with boulders and cobbles > 64 mm, in accordance with the Habitats Directive definition)[31,142] were documented in 25 locations: 12 in North of Denmark, of which nine were inside Natura 2000 MPAs (*Store Rev* and *Gule Rev*) and three were outside; and ten in Jutland Bank and three in Little Fisher Bank, all outside of currently protected areas (Figure 30).

Many of the reefs documented by Oceana did not harbour epifauna, but others were covered by algae (see *Algal forests*) or by the typical association of dead man's fingers (*Alcyonium digitatum*) and hornwrack (*Flustra foliacea*). Aggregations of dead man's fingers (*A. digitatum*) were documented both inside and outside of existing protected areas during Oceana surveys (see *Coral gardens*). Another habitat of conservation interest, biogenic reefs (see *Biogenic reefs*) were often found nearby to areas in which stone reefs were present. Stones qualifying as reefs (i.e., larger than 64 mm)[142] collected in grab samples were usually covered by invertebrates, such as worms, hydrozoans, bryozoans, or even small colonies of dead man's fingers.

Figure 31. Cod (*Gadus morhua*) sheltering in a rock in Jutland Bank. © OCEANA/ Juan Cuetos

Figure 32. Edible crabs (*Cancer pagurus*) sheltered in a rocky outcrop surrounded by muddy bottom in *Skagens Gren og Skagerrak*. © OCEANA/ Carlos Minguell

Biogenic reefs (formed by large molluscs)

Living and dead large molluscs, such as the observed ocean quahog (*Arctica islandica*), horse mussel (*Modiolus modiolus*) and Arctic roughmya (*Panomya norvegica*), can structure the seabed by providing hard substrata upon which species may settle, and for larvae and juveniles to find shelter. Some of these habitats are listed by OSPAR as Threatened and/or Declining Habitats (i.e., beds of *Mytilus edulis*, *Modiolus modiolus*, or *Ostrea edulis*). Mollusc beds are also considered as a type of reef under the Habitats Directive, as they fall within the definition of biogenic concretions: 'bivalve mussel beds originating from dead or living animals'.[142] Denmark is also preparing its own definition of biogenic reefs, as one of the measures included within the country's Programme of Measures (PoM) under the MSFD.[107]

The presence of mollusc beds is considered a good indicator for declaring the areas where they occur as MPAs, in order to allow the restoration of large mollusc beds in the North Sea.[143] Such biogenic reefs have almost disappeared in the region, due to overfishing and the use of destructive fishing gears.[144]

During the Oceana expeditions, aggregations of *A. islandica* and *M. modiolus*, together with some individuals of *P. norvegica*, were mainly found close to stone reefs in the North of Denmark survey area (Figure 30 and Figure 47) These mollusc aggregations were found at a depth range of approximately 30-60 m, in mixed bottoms (i.e., with hard and soft components). They were especially abundant inside the bubbling reef area of *Store Rev* (Figure 33 and Figure 34), while a smaller aggregation of ocean quahog and horse mussel shells was also documented in *Gule Rev*.

Figure 33. Aggregation of mollusc shells of various species, in *Store Rev.*

Figure 34. Shells of horse mussel (*Modiolus modiolus*) and other large molluscs, with cod (*Gadus morhua*) and dead man's fingers (*Alcyonium digitatum*), in *Store Rev.*

Bubbling reefs

Bubbling reefs are protected under the Habitats Directive, as 'Submarine structures made by leaking gases'. This habitat type has attracted the attention of both scientists and the general public, due to the spectacular landscape they create and the high biodiversity that lives within them.[145] Bubbling reefs represent an important hotspot for both benthic and pelagic species.[4,142]

To date, the best-known bubbling reefs in Denmark are found in Kattegat, where many are listed features inside Natura 2000 MPAs, and some sites have management measures in place to protect both reefs and bubbling reefs against damage from fishing gears (see *Current management measures*). In the Danish North Sea, the few known bubbling reef areas were recently mapped[3] (i.e., six inside the only Danish North Sea Natura 2000 site (*Store Rev*) declared to protect this habitat (together with reefs and harbour porpoises), one inside Natura 2000 site *Knudegrund* (but not officially listed as a protected feature of the site), and two unprotected bubbling reef areas east of *Gule Rev* and north of *Knudegrund*). Bubbling reefs in *Store Rev* are not currently subject to any fisheries management measures to protect them from damage, and bubbling reefs in both unprotected areas and inside *Knudegrund* remain essentially unprotected (see *Known ecological features of interest*).

According to the most recent official report on the conservation status of habitats and species listed under the Habitats Directive, the quality of these habitats in Denmark is 'Unfavourable-Bad',[50] suggesting that current protection measures are insufficient. Bubbling reefs are among the 21 Danish coastal habitats (both marine and terrestrial) that have been assessed as being in

unfavourable condition; all marine habitats, from a total of six, have been assessed as 'Unfavourable-Bad'.[50]

As mentioned before, bubbling reefs were previously known to occur in the Oceana survey area, both inside and outside protected areas. Oceana's research has revealed the presence of a previously undescribed bubbling reef inside the boundaries of *Store Rev* (Figure 30). Is it probable that more bubbling reefs could be found in Danish waters, together with other structures related to leaking gases. For example, one potential area lies in deep Danish waters close to a methane seep area on the Norwegian side of the Skagerrak,[146] where abundant populations of annelids and molluscs have been found settled on symbiotic bacteria.

Pockmarks, which are also related to gas activity below the surface of the seabed, are known to occur in the MPA *Skagens Gren og Skagerrak*.[31] Not all pockmarks are protected under the Habitats Directive as 'submarine structures made by leaking gases', as not all these features contain submarine structures. In *Skagens Gren og Skagerrak*, no bubbling reefs or any other type of related submarine structure have been documented to date, including during Oceana's surveys in this protected area.

Bacterial mats are another type of marine feature related to sites of leaking gases.[147,148] Leaking gas activity and associated bacterial mats were documented by Oceana in the North of Denmark survey area, inside *Store Rev* (Figure 35 and Figure 36). These mats were surrounded by small concretions, and bubbles and gas seepage shimmer were apparent in two locations. Although no large hard structures were documented, they could potentially form in these locations in the future, and they may host symbiotic organisms that are rare in other places. Bacterial mats have also been documented elsewhere in the Danish North Sea by Oceana, during ROV surveys in Vesterhavet in 2016 (unpublished data).

Figure 35. Leaking gas activity and bacterial mats in *Store Rev*, with nudibranch *Onchidoris muricata* and hermit crab (*Pagurus* sp.).

Figure 36. Leaking gas activity in *Store Rev.*

Algal forests

The Habitats Directive description of various types of reefs includes red, brown and green macroalgae among the characteristic species of reef vegetation.[142] Large laminarians or kelps such as *Laminaria hyperborea* and *L. digitata* can create large and dense forests, together with foliose Rhodophyta (red algae). These species can provide a large 'canopy' and surface to which other species may attach.

Given their importance, Denmark has established specific targets and measures to specifically protect macroalgal species under its MSFD Programme of Measures (PoM).[117] For example, macroalgal density and species composition are to be maintained or improved in selected areas of Kattegat, the Danish Straits and Bornholm; and damage to macroalgal species by some types of fishing activities is to be prevented.[107]

During the Oceana expeditions, algal communities were observed on rocky reefs in the three surveyed areas (Figure 30), including large laminarians (*L. hyperborea*) that formed forests (Figure 37 and Figure 38). These forests were observed in two locations outside of the *Jyske Rev/ Lillefiskerbanke* MPA, to the west of the area.

Figure 37. Red algae *Dilsea carnosa* among other algal species in Jutland Bank waters.
© OCEANA/ Carlos Minguell

Figure 38. Kelp forest (*Laminaria hyperborea*) in Jutland Bank.
© OCEANA/ Carlos Minguell

Sandbanks

The conservation of sandbanks is a priority, because of the range of ecosystem goods and services that these systems provide. They support diverse communities of epifauna and infauna (particularly in areas between banks), they serve as feeding and nursery grounds for certain commercial fishes, and they act to dissipate wave energy, thereby reducing coastal erosion. Sandbanks are considered threatened in Europe, and are categorised as Endangered on the European Red List of habitats.[135]

The Habitats Directive prioritises the protection of 'sandbanks which are slightly covered by water all the time'. This category is relatively broad, comprising systems with a variety of substrate characteristics and depths; according to the definition, the water above a sandbank is not typically more than 20 m deep, while the sides of sandbanks can extend below this depth.[142]

These elevations of soft bottom can be found both in shallow and deeper waters, close to the coast or in offshore areas. Sandbanks do not always harbour epifaunal communities, but normally support important infaunal communities of molluscs, worms, crustaceans, and other invertebrates. These habitats represent important feeding grounds for marine mammals and birds, and for commercial species.[151] Invertebrates such as starfishes, brittle stars, snails, sea urchins, and hermit crabs can be very abundant on sandbanks.

Sandbanks have been one area of focus for marine research in Danish waters in recent decades (see *Habitat types*), for example through efforts to map benthic habitats inside Natura 2000 MPAs. The mapping of sandbank within these areas was included in the Danish MSFD PoM, with the longer-term objective of implementing appropriate management measures for these habitats.[107] Outside protected areas, sandbanks are targeted by one of the main human activities exploiting marine resources in these waters, marine aggregate extraction.

According to the most recent assessment of the conservation status of features listed under the Habitats Directive, while the status of sandbanks in Denmark is improving, they remain assessed as 'Unfavourable-Bad'.[50] This suggests that current measures of protection are failing to safeguard this habitat type in Danish waters.

In the Oceana survey area, sandbanks were previously known to occur inside Natura 2000 MPAs (as protected features within two sites) and in unprotected areas (see *Habitat types*). Oceana surveyed the biodiversity living on and within sandy bottoms, from shallow to deeper waters (Figure 30). Sandy bottoms without hard components were documented throughout the three surveyed areas – Jutland Bank, Little Fisher Bank and North of Denmark (Figure 39 and Figure 40), outside currently protected areas.

Figure 39. Plaice (*Pleuronectes platessa*) on sandy bottoms of Jutland Bank.

Figure 40. Turbot (*Scophthalmus maxima*) camouflaged on sand, east of *Store Rev.*
© OCEANA/ Carlos Minguell

Soft bottoms

In the northern waters of the Danish North Sea, soft bottoms are threatened by a range of human activities, including the use of bottom-contact fishing gears, aggregate extraction and dumping, and marine litter. Protection of these habitats under the Habitats Directive is limited, however, as it lists only a few types of soft-bottom marine habitats (e.g., sandbanks and mudflats). Partly as a result of that gap in protection, soft bottom conservation is one of the areas of focus of the MSFD. Within that directive, soft bottom habitats are included under the two broad categories of habitats that should be protected by EU Member States to achieve a representative and coherent network of MPAs: 'predominant habitats' and 'special habitats'.[152,153]

Under the MSFD, predominant soft bottoms include coarse, sandy, muddy, and mixed sediments, at all depths (i.e., littoral, sublittoral, bathyal and abyssal). Special soft bottoms are all those listed under legislation or regional conventions for protection, such as sandbanks (which are listed under the Habitats Directive) and sea pen fields (which are listed as threatened and/or declining by OSPAR).[9] Therefore, the Danish PoM highlights the need to protect soft bottoms other than those included in Annex I of the Habitats Directive. New measures are being developed towards this purpose, such as restrictions on offshore activities (i.e., dredging, wind farms and others) in certain soft bottom habitats, and the designation of new MPAs to protect vulnerable soft bottom species, such as haploops and sea pens in Kattegat (see *Current management measures*).

In the Oceana survey area, soft bottoms were documented in many locations, from North of Denmark to the western banks (Figure 30). They were characterised by various types of sediment (from sand to mud, both with and without gravel), and hosted a variety of types of biological communities, with and without epifauna, shell remains, and burrows (see *Community types*). In some cases, these bottoms were close to or surrounded by rocky areas, for example in Jutland Bank (16 locations) and Little Fisher Bank (13 locations), all in locations outside of MPAs. Soft bottoms were also documented both inside and outside of Natura 2000 MPAs in the North of Denmark survey area. In the surveyed soft bottom areas, community types observed included sea pen fields (see *Sea pen fields*), fields of an unidentified species of anemone, a dense field of an unidentified species of worm, and muddy bottoms with Norway lobster (*Nephrops norvegicus*) burrows, among many others *(see Community types)*. Oceana's surveys documented a wide array of species associated with these habitats, particularly molluscs, crustaceans, echinoderms and fishes, including both adults and juveniles of commercial species (Figure 41 and Figure 42).

Figure 41. Hake (*Merluccius merluccius*) in a sandy mud area of Little Fisher Bank.

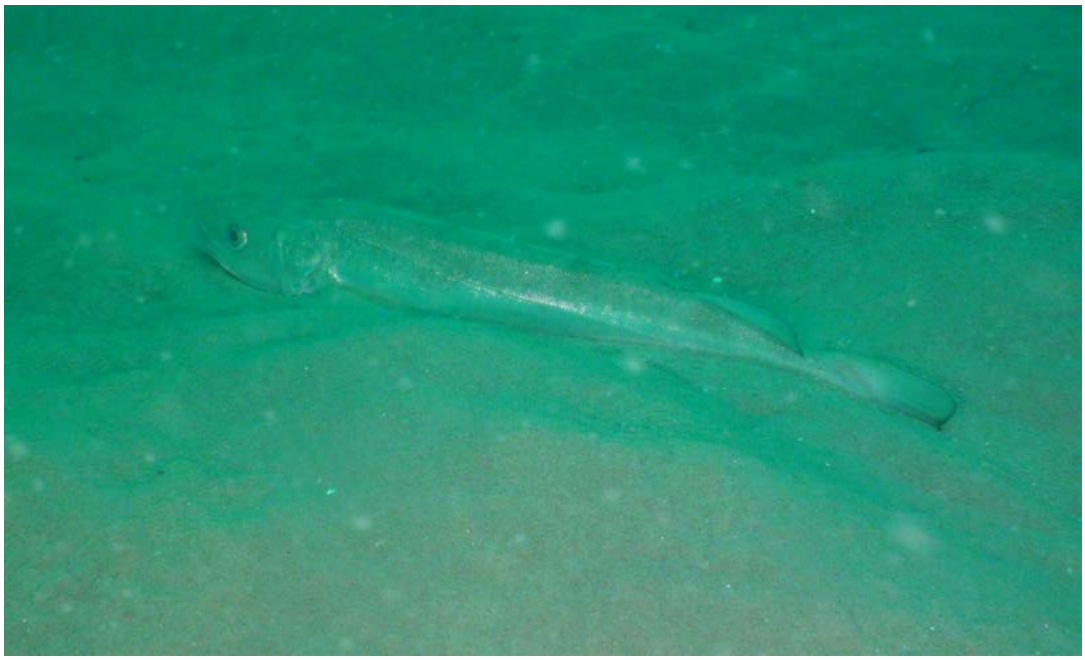


Figure 42. Aggregated deeplet sea anemones (*Bolocera tuediae*) and associated northern shrimp (*Pandalus borealis*) on a burrowed muddy bottom, north of *Skagens Gren og Skagerrak*.

Sea pen fields

The OSPAR List of Threatened and/or Declining Habitats includes the habitat type *Sea-pens and burrowing megafauna communities*, on the basis of both its decline and sensitivity to threats. This habitat type 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.[154]

This habitat has been reported to OSPAR as being present in Danish waters, but no data have been supplied. Soft bottoms, where sea pens are found, are frequently affected by bioturbations, but sea pens do not necessarily coexist with burrowing megafauna. In muddy bottoms, sea pens can be associated with Norway lobster (*Nephrops norvegicus*), while in sandy and sandy-muddy bottoms, other crustaceans or fishes can build burrows and galleries.

The most noteworthy sea pen fields documented by Oceana were found in the deeper parts (100-280 m) of the North of Denmark survey area. These communities comprised tall sea pen (*Funiculina quadrangularis*; 100-140 m depth), slender sea pen (*Virgularia mirabilis*; 62-142 m depth) and hammer-tipped sea pen (*Halipteris finmarchica*; 137-141 m depth). Three individuals of Carpenter's sea pen (*Protoptilum carpenteri*) were found in deeper waters than the other three species (279-280 m), during one of the ROV surveys in North of Denmark. Oceana's findings complement the results of surveys carried out within *Skagens Gren og Skagerrak*, also within 2017, which recorded sea pens (*V. mirabilis* and other unidentified specimens) in some locations.[31]

Parts of these vulnerable communities were found outside of existing protected areas. For example, a field of slender sea pen (*V. mirabilis*) was documented to the southeast of *Skagens Gren og Skagerrak*, and individuals of the rare Carpenter's sea pen (*P. carpenteri*) were found together with a field of an unidentified anemone species, to the north of this same protected area (Figure 44).

Figure 43. Hammer-tipped sea pen (*Halipteris finmarchica*) in *Skagens Gren og Skagerrak*.

Figure 44. The rare Carpenter's sea pen (*Protoptilum carpenteri*), lying on the seabed in an area of burrowed mud, inside *Skagens Gren og Skagerrak*.

Coral gardens

Coral gardens can occur over a wide range of depths, from shallow to deeper waters, and on both soft and hard bottoms. Sea pens, leather corals, scleractinians, bamboo corals, and black corals are some examples of these habitat-forming species.[155,156] In this type of habitat, biodiversity is commonly high, as the habitat-forming species provide substrate and shelter for many associated species.[155]

It should be noted that in addition to being considered separately, as a specific habitat type of conservation interest, sea pen fields are also considered by OSPAR as a type of coral garden.[155,156] At the same time, however, some types of coral gardens are not included under the official OSPAR definition of this habitat type. For example, dense aggregations of vulnerable dead man's fingers (*A. digitatum*), such as those documented by Oceana on hard bottoms in Jutland and Little Fisher banks, are not currently considered coral gardens by OSPAR. The extension of the OSPAR definition to include many other coral garden-forming species, such as *Alcyonium* spp. and *Madrepora oculata*, has previously been recommended by Oceana.[157] In the case of *M. oculata*, this species was later added to the definition,[158] while *Alcyonium* spp. remain outside it.

The potential presence of other types of coral gardens in the survey area cannot be ruled out. For example, gardens of bamboo coral (*Isidella lofotensis*), and of other sea pen species are found in the neighbouring Norwegian waters of the Skagerrak, and the full extent of their distributions is not well known.[159,133]

Figure 45. Edible sea urchin (*Echinus esculentus*) on a rock covered by dead man's fingers (*Alcyonium digitatum*) and polychaetes.

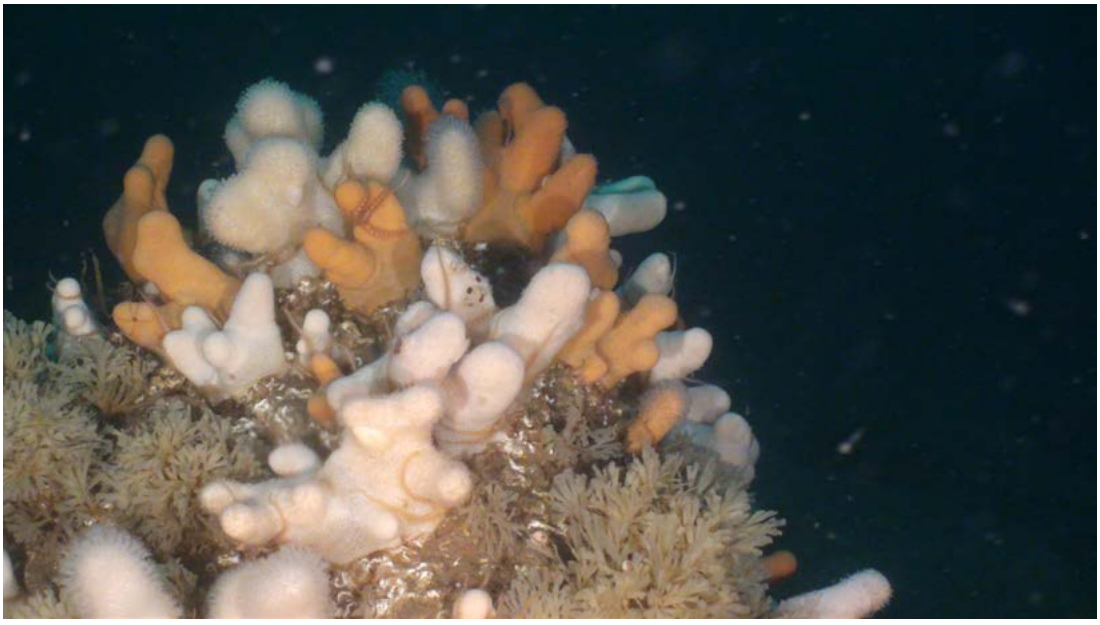


Figure 46. Coral garden formed by dead man's fingers (*Alcyonium digitatum*) and associated species, such as hornwrack (*Flustra foliacea*) and ophiuroids.

THREATENED AND PROTECTED SPECIES

During the surveys in the northern waters of the Danish North Sea, six species listed as threatened and/or protected were recorded (Figure 47 and Table 2). Details are provided about each of those species below.

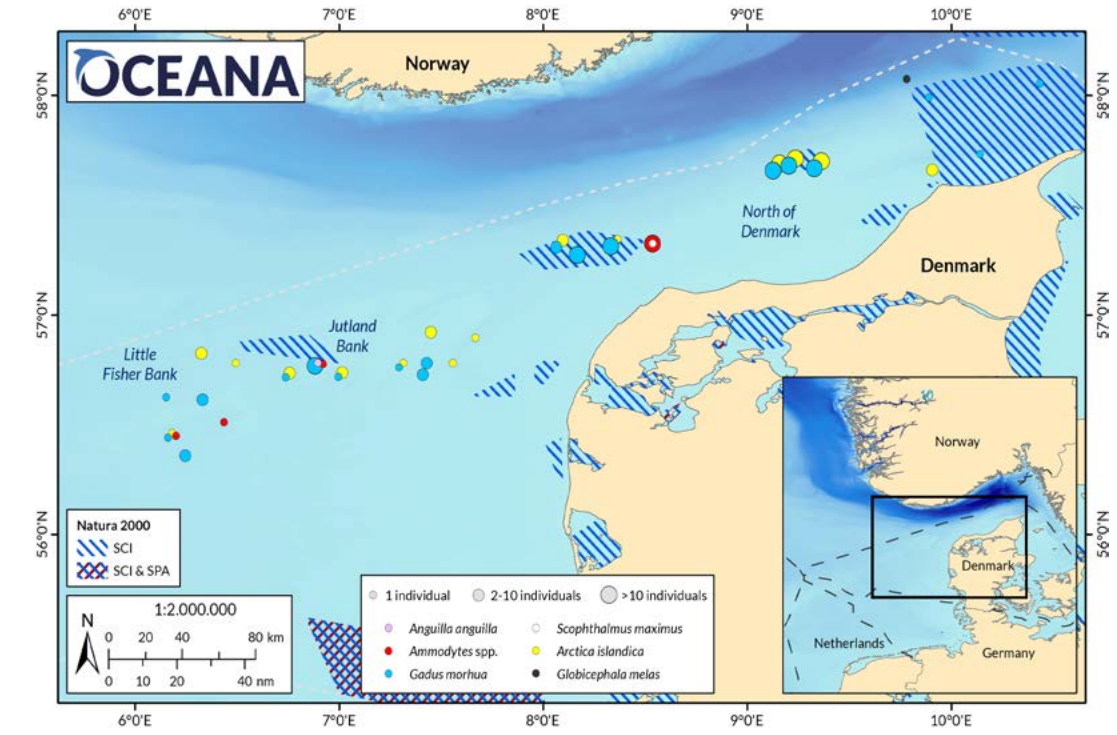


Figure 47. Protected and threatened species observed in northern waters of the Danish North Sea during the 2016 and 2017 Oceana expeditions. Sources: EMODnet,[2] EEA.[5]

Fishes

Some fish species recorded during the Oceana expeditions are listed as threatened under the IUCN Red List of Threatened Species, are on the OSPAR List of Threatened and/or Declining Species and Habitats, and/or are included in the MSFD PoM, as key species to manage and conserve in order to achieve Good Environmental Status (GES) of Danish waters by 2020.[v]

European eel (*Anguilla anguilla*) is a globally threatened species[160] that is considered Critically Endangered in Europe.[161] The most recent stock assessment for the Northeast Atlantic indicated its status as being critical.[162] It is protected under OSPAR in the Greater North Sea and other Northeast Atlantic regions. The species has declined due to commercial and recreational fishing, as well as human activities such as pollution and hydropower development.[162] ICES has recommended that all types of human activities, apart from fisheries, be reduced or eliminated if possible in 2019,

[v] The main goal of the Marine Strategy Framework Directive is to achieve Good Environmental Status of EU marine waters by 2020. The Directive defines Good Environmental Status (GES) as: "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive" https://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm

in order to avoid any further impacts on the stock.[162] Recommended measures under OSPAR include implementation of management plans, control of fisheries and illegal trade, population monitoring, and creation of MPAs, among others. During Oceana's surveys, one juvenile eel was recorded south of *Jyske Rev/Lillefiskerbanke*, above a mixed bottom of sand, gravel and stones, at 36 m depth.

Sandeel (*Ammodytes* spp.) is an important part of the food base for many fishes, marine mammals, and seabirds in the North Sea.[117] The stock in the Skagerrak and northern and central North Sea is currently in good condition.[163] Sandeel habitat (i.e., sandy bottoms) are vulnerable to damage from aggregate extraction, and under the MSFD PoM, Denmark will require environmental impact assessments of new activities in areas of importance to the species before granting new licenses.[107] Together with cod (*Gadus morhua*), herring (*Clupea harengus*), and plaice (*Pleuronectes platessa*), sandeel is considered an indicator species under the PoM, for assessing the management of commercially exploited stocks according to maximum sustainable yield (MSY). According to ICES, plaice and autumn-spawning herring in the North Sea and Skagerrak are currently within safe biological limits.[164,165] The Western Baltic spring-spawning herring stock (which extends into Kattegat and the Skagerrak) is considered overfished.[166]

Cod (*G. morhua*) is considered to be overexploited in the North Sea, and the spawning stock biomass is below safe biological limits (see *Known ecological features of interest*).[29] The species is also listed as threatened and/or declining under OSPAR.[9] During the Oceana surveys, cod individuals were recorded multiple times in all of the areas, especially in North of Denmark. Cod were mainly documented in association with mixed bottoms of sand and stones, but with some occasional sightings in deeper muddy areas (88-140 m depth). Most of the recorded observations of cod in hard bottom areas were of juveniles. Under the Danish PoM, the lengths of cod and saithe (*Pollachius virens*) are used as indicators to assess the status of the food web. According to ICES, the saithe stock in the North Sea and Skagerrak is currently within safe biological limits.[167] Turbot (*Scophthalmus maximus)* is Red Listed as Vulnerable in European waters, on the basis of population declines driven by over-exploitation;[168] it is considered a valuable bycatch species. The North Sea stock is currently considered to be within safe biological limits and fished sustainably, but the status of the stock in the Skagerrak and Kattegat is unknown.[169,170] There is no official minimum landing size for the species, but Denmark has adopted a minimum landing size of 30 cm. ICES has noted that catches of turbot in the North Sea fishery predominantly comprise juveniles, and has recommended reducing fishing pressure on these younger age classes.[170]

Figure 48. Cod (*Gadus morhua*) in a coarse sand area of Jutland Bank.
© OCEANA/ Carlos Minguell

Figure 49. Juvenile whiting (*Merlangius merlangus*) among the tentacles of a lion's mane jellyfish (*Cyanea capillata*).
© OCEANA/ Juan Cuetos

Large molluscs

Ocean quahog (*Arctica islandica*) is a very vulnerable species due to its long lifespan (which can exceed 500 years),[171] size (which can reach 100 mm in length)[156] 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. At the national level, Denmark lists the presence of large, fragile, long-lived species such as ocean quahog as indicators of the status of the seabed, under the MSFD.

No living individuals were found during any of the Oceana surveys, although remains of *A. islandica* were found during ROV surveys in all surveyed areas, over a depth range of 27 to 53 m. These remains were especially abundant in North of Denmark, where hundreds of *A. islandica* shells were documented, both in aggregations and as isolated (see *Biogenic reefs*). In this area, the species was also documented during a SCUBA dive, and five individuals were collected in a grab sample.

Figure 50. Shells from a grab sample, including ocean quahog (*Arctica islandica*) and horse mussel (*Modiolus modiolus*).
© OCEANA/ Juan Cuetos

Figure 51. Mollusc shells and dead crab on soft bottoms in *Store Rev*.

Cetaceans

Surveys in North of Denmark recorded a group of at least four long-finned pilot whales (*Globicephala melas*). This species is strictly protected in European waters, under Annex IV of the Habitats Directive. In the last European Red List assessment of the species – in 2007 – the European population was listed as Data Deficient,[172] and more research is needed to determine its conservation status in these waters.

Table 2. Features of conservation interest documented in northern waters of the Danish North Sea during the 2016 and 2017 Oceana expeditions, and the international frameworks under which they are recognised as threatened, protected, and/or priorities for conservation. The Marine Strategy Framework Directive (MSFD) Programme of Measures (PoM) column includes only targets and measures directly focused on features listed in the table column; other MSFD targets and measures, established to improve the status of the marine ecosystem, habitats, species and seabed, that have an indirect effect have not been included.

FEATURES		INTERNATIONAL FRAMEWORKS				OCEANA SURVEYS
		Habitats Directive	MSFD PoM[107]	OSPAR List of Threatened and/or Declining Species and Habitats	European Red List of Habitats[135] & IUCN Red List of Threatened Species[16]	Survey area
Habitats	Stone reefs	Annex II: 1170 Reefs	• Mapping, fisheries regulation and protection in Natura 2000 sites (1) • Stone reef macroalgal coverage maintained or improved (2)		Vulnerable	All
	Biogenic reefs	Annex II: 1170 Reefs	• Mapping, fisheries regulation and protection in Natura 2000 sites (1) • Definition and mapping of biogenic reefs (3) • Dredging restrictions (4)	*Modiolus modiolus* beds		North of Denmark
	Bubbling reefs	Annex II: 1180 Submarine structures made by leaking gases	• Mapping, fisheries regulation and protection in Natura 2000 sites (1)			North of Denmark
	Algal forests	Annex II: 1170 Reefs	• Mapping, fisheries regulation and protection in Natura 2000 sites (1) • Stone reef macroalgae coverage maintained or improved (2) • Control of macroalgal density (5)			Jutland Bank
	Soft bottoms	Annex II: 1170 Reefs	• Improvement of bottom fauna diversity, density and distribution, and presence of vulnerable species (6) • Development of benthic faunal index (7) • MPAs in Kattegat (8)		Endangered	All
	Sea pen fields		• Improvement of bottom fauna diversity, density and distribution, and presence of vulnerable species (6) • Development of benthic faunal index (7) • MPAs in Kattegat (8) • Protection of sea pen community in Kattegat (9)	• Sea-pen and burrowing megafauna communities • Coral gardens	Endangered	North of Denmark
	Coral gardens	Annex II: 1170 Reefs	• Mapping, fisheries regulation and protection in Natura 2000 sites (1)	vi		All

FEATURES		INTERNATIONAL FRAMEWORKS				OCEANA SURVEYS
		Habitats Directive	MSFD PoM[107]	OSPAR List of Threatened and/or Declining Species and Habitats	European Red List of Habitats[135] & IUCN Red List of Threatened Species[16]	Survey area
Species	European eel (*Anguilla anguilla*)			*Anguilla anguilla*	Critically Endangered	Jutland Bank
	Sandeel (*Ammodytes* spp.)		• Commercially exploited species stocks fished below MSY and within safe biological limits (10) • Protection of sandeel habitat (11) • Dredging restrictions (4)			All
	Cod (*Gadus morhua*)		• Commercially exploited species stocks fished below MSY and within safe biological limits (10) • Length of fish is stable (12)	*Gadus morhua*		All
	Turbot (*Scophthalmus maximus*)				Vulnerable	North of Denmark
	Ocean quahog (*Arctica islandica*)		• Improvement of bottom fauna diversity, density and distribution, and presence of vulnerable species (6)	*Arctica islandica*		All (especially North of Denmark)
	Long-finned pilot whale (*Globicephala melas*)	Annex IV: all Cetacean species				North of Denmark

[vi] Coral gardens documented by Oceana, which were characterised by aggregations of *Alcyonium digitatum*, do not fall within the OSPAR definition of 'Coral gardens'.

(1) Habitats inside Natura 2000 - Measures M001, M010, M026 on mapping, fisheries regulations and protection of reefs, sandbanks and bubbling reefs in Natura 2000 areas.
(2) Macroalgae on reefs - Targets 4 and 11 (Kattegat and the Danish Straits) on macroalgal coverage on stone reefs.
(3) Biogenic reefs - Target 9 (Kattegat and the Danish Straits) on the protection of horse mussel beds; Target 48 (North Sea) on mapping of horse mussel beds, and defining and mapping of biogenic reefs (M002); declaration of MPAs in Kattegat (M003), and implementation of dredging restrictions (M025, M038).
(4) Biogenic reefs - Measures M0025 and M038 on dredging restrictions to avoid physical damage to the habitat.
(5) Macroalgae - Targets 20 and 22 on macroalgal density in open marine waters.
(6) Soft bottom fauna - Targets 10, 24 and 25 on the conservation of soft-bottom species.
(7) Benthic fauna - Target 26 and M009 on developing a benthic vulnerable species index.
(8) Soft bottom MPAs - M003 on the designation of MPAs in Kattegat to protect deep sediment seabed habitats.
(9) Sea pen community - Target 51 on the protection of selected sea pen communities in Kattegat.
(10) Commercially exploited species - Target 14 on the management of commercial species under MSY, focusing on spawning stock biomass of cod, herring, sandeel, and European plaice.
(11) Sandeel - Targets 47 and 50 on the protection of important areas for sandeel.
(12) Food-web - Target 17 on stabilisation or improvement of cod and saithe lengths.

COMMERCIAL SPECIES

Species of major commercial importance were documented by Oceana in all of the surveyed areas. Among these commercially exploited organisms were many species of fishes, arthropods, molluscs, and echinoderms (Table 3).

In reefs and areas of coarse and mixed bottoms (i.e., Jutland and Little Fisher Banks), observed fishes included European eel (*Anguilla anguilla*), hake (*Merluccius merluccius*), plaice (*Pleuronectes platessa*), white anglerfish (*Lophius piscatorius*), and cod (*Gadus morhua*). In muddy bottom areas (i.e., North of Denmark), recorded fishes ranged from hagfish (*Myxine glutinosa*) to American plaice (*Hippoglossoides platessoides*), dab (*Limanda limanda*), Norway pout (*Trisopterus esmarkii)* and saithe (*Pollachius virens*).

Juveniles of cod (*Gadus morhua*) were documented in areas of rocky reefs and gravel bottoms, especially in North of Denmark and Jutland Bank, suggesting the potential importance of these areas as essential habitats for this species. North Sea cod, as previously indicated, was recently assessed by ICES as being overfished, contrary to what had previously been believed about the stock having nearly recovered from earlier severe declines.[29] Poor recruitment has been identified as a critical factor in the lack of recovery, highlighting the importance of measures to protect nursery areas. Oceana's observations of juvenile whiting (*M. merlangus*) in the same areas further indicates that North of Denmark and Jutland Bank may play an important role as nursery habitats for gadoids. These observations support other research that has shown the broader importance of the northern Danish North Sea as nursery areas for these species.[25]

Important commercial species of crustaceans were also documented, including edible crab (*Cancer pagurus*) in rocky areas of North of Denmark; *Nephrops norvegicus* and *Pandalus* spp., together with mollusc species such as whelk (*Buccinum undatum*) in muds of North of Denmark; and blue mussel (*Mytilus edulis*) and scallop (*Pecten maximus*) in mixed bottoms of North of Denmark.

Figure 52. Remains of plaice (*Pleuronectes platessa*) abandoned on a beach close to Hirtshals port.
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Figure 53. Common razor shell (*Ensis ensis*) in sandy bottom east of *Store Rev*.
© OCEANA/ Juan Cuetos

Species	Common name	North of Denmark	Jutland Bank	Little Fisher Bank
RHODOPHYTA				
Delesseria sanguinea	Sea beech	x	x	
Dilsea carnosa	Dulse		x	
Furcellaria lumbricalis	Clawed Fork Weed		x	
OCHROPHYTA				
Fucus sp.	Wrack	x		
Laminaria hyperborea	Kelp, oarweed		x	
Laminaria sp.	Tangle	x		
ARTHROPODA				
Cancer pagurus	Edible crab	x	x	x
Crangon crangon	Common shrimp		x	
Geryon trispinosus	Three-spined geryon	x		
Liocarcinus depurator	Sandy swimming crab	x		
Meganyctiphanes norvegica	Norwegian krill	x		
Nephrops norvegicus	Norway lobster	x		
Palaemon elegans	Rockpool prawn	x		
Palaemon sp.	Palaemonid shrimp	x		
Pandalina brevirostris	Pandalid shrimp		x	
Pandalina sp.	Pandalid shrimp		x	
Pandalus borealis	Northern shrimp	x	x	
Pandalus montagui	Pink shrimp	x	x	
Pandalus sp.	Pandalid shrimp	x		
CHORDATA				
Ammodytes spp.	Sandeel	x	x	
Ammodytes tobianus	Small sandeel		x	
*Anguilla anguilla**	European eel		x	
Argentina silus	Greater silver smelt	x		
Arnoglossus laterna	Mediterranean scaldfish	x		
Buglossidium luteum	Solenette	x		
Callionymus lyra	Dragonet		x	
Chelidonichthys lucerna	Red gurnard	x		
Ctenolabrus rupestris	Goldsinny	x	x	
Eutrigla gurnardus	Grey gurnard		x	
*Gadus morhua**	Cod	x	x	x
Glyptocephalus cynoglossus	Witch	x		
*Hippoglossoides platessoides**	Sand dab	x		x
Lycodes vahlii	Vahl's eelpout	x		
Limanda limanda	Dab	x	x	x
Lophius piscatorius	White anglerfish	x		
Melanogrammus aeglefinus	Haddock	x		
*Merlangius merlangus**	Whiting	x	x	
Merluccius merluccius	Hake			x
Micromesistius poutassou	Blue whiting	x		
Microstomus kitt	Lemon sole	x		x
Molva molva	Ling		x	
Myxine glutinosa	Hagfish	x		
Pleuronectes platessa	Plaice	x	x	x
Pollachius pollachius	Pollack	x		
Pollachius virens	Saithe	x		
Scophthalmus maximus	Turbot	x		
Scyliorhinus canicula	Lesser-spotted dogfish		x	
Sprattus sprattus	Sprat	x		
Trisopterus esmarkii	Norway pout	x		
Trisopterus minutus	Poor cod	x		
Zeugopterus punctatus	Topknot		x	
ECHINODERMATA				
Asterias rubens	Common starfish	x	x	x
Echinus esculentus	Edible sea urchin	x	x	x
MOLLUSCA				
Arctica islandica	Ocean quahog	x	x	x
Acanthocardia echinata	Thorny cockle	x	x	
Buccinum undatum	Whelk	x	x	x
Cerastoderma edule	Edible cockle	x		
Cerastoderma glaucum	Lagoon cockle		x	x
Dosinia	Rayed dosinia	x	x	
Ensis ensis	Common razor shell	x	x	
Laevicardium crassum	Norwegian cockle			x
Mytilus edulis	Blue mussel	x		
Pecten maximus	Scallop	x		
Solen capensis	Pencil bait	x		
Spisula sp.	Surf clam	x		
Tellina sp.	Tellin	x		

Table 3. Commercial species observed during Oceana surveys. Species were identified as commercially fished based on reported catches from the central North Sea (FAO Division 27.4.b) and the Skagerrak (FAO Division 27.3.a.20), according to Eurostat records from 2008-2017.[173] Commercial species for which juveniles were also recorded are marked with an asterisk.

ANTHROPOGENIC IMPACTS

Several types of human impacts were documented in North of Denmark. Assorted pieces of plastic were found on the seabed, as well as lost or abandoned fishing gear (Figure 54 and Figure 55), such as nets, ropes, and lines. Plastic litter was present inside the Natura 2000 MPA *Store Rev*.

Multiple signs of bottom-contact fishing activities were recorded, including large trawling scars in the seabed. These marks were especially common in the northern part of North of Denmark survey area, at a depth range of 120-280 m. Clear impacts of bottom fishing were also seen inside Natura 2000 MPAs in North of Denmark. At least two trawl scars were documented in the muddy bottoms of *Skagens Gren og Skagerrak*, and fishing gears or parts thereof were documented in *Store Rev* and *Gule Rev*.

In contrast to the surveys in North of Denmark, Oceana did not document any physical signs of anthropogenic effects in Jutland Bank or Little Fisher Bank. These areas may be benefit from some degree of natural protection from human impacts, because the higher coverage of rocky bottoms attracts less bottom-contact fishing than does North of Denmark (Figure 6).

Figure 54. Entangled fishing net on rocks in *Gule Rev*.

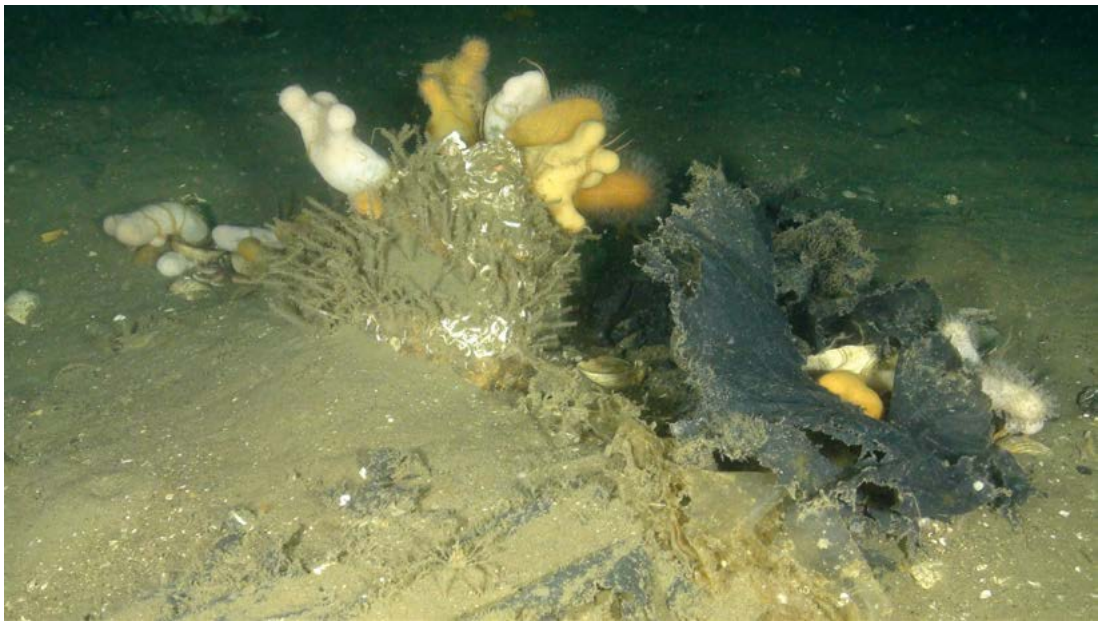

Figure 55. Plastic litter on the sea bottom in *Store Rev.*

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CONCLUSIONS AND PROPOSAL FOR PROTECTION

The northern waters of the Danish North Sea are home to a diversity of marine ecosystems of high natural value, encompassing features that are prioritised for protection under frameworks such as the Habitats Directive (e.g., reefs and harbour porpoise) and OSPAR (e.g., sea pen fields and ocean quahog). While the presence of these habitats and species has led to the designation of eight Natura 2000/OSPAR MPAs in the area, the status of protected seabed habitats such as stone reefs, bubbling reefs, and sandbanks within MPAs is 'Unfavourable-Bad' in Danish waters (see *Features of conservation interest*). Their poor condition indicates that current protection is clearly insufficient in the face of intense human activity – such as fisheries, aggregate extraction – that directly impacts the seabed.

Scientists and NGOs have long called for more extensive and stronger spatial protection in the waters of the Danish North Sea (see *Previous conservation proposals*). More recently, a government-commissioned assessment of the status of the Danish MPA network in the North Sea and Central Baltic Sea provided detailed analyses and scientific evidence supporting the need for expanding and strengthening the network (see *Previous conservation proposals*). The study concluded that more research and additional MPAs are needed in the North Sea and highlighted specific priorities for protection, such as offshore areas, hard bottom areas that lie outside of existing MPAs, and soft bottoms other than sandbanks, which require protection beyond the scope of the Habitats Directive. Following that assessment, in 2019 the Danish government initiated a process to identify potential new areas for protection in the country's North Sea waters.

One of the identified challenges in advancing marine protection in the region is a lack of data on benthic communities, particularly outside the boundaries of currently protected areas.[4] In recent years, detailed benthic habitat mapping has been carried out inside Danish Natura 2000 MPAs in the North Sea, focused mainly on reefs and sandbanks;[3,31] surveys of the benthos outside these areas have been relatively limited, especially in offshore deeper waters.

Oceana, through its 2016 and 2017 research expeditions in Danish North Sea waters, sought to help fill these key information gaps. The two Oceana expeditions aimed to provide more detailed information about the benthic biodiversity of Danish North Sea (including the Skagerrak), both inside and outside of existing MPAs. Oceana focused, in particular, on areas that are currently unprotected and on deeper offshore areas that have been less well studied, for which a lack of knowledge impedes their conservation.

In total, Oceana's surveys documented 467 taxa (see *Annex*), in association with five community types. Recorded features included six species and eight habitat types that are conservation priorities, because they are recognised as threatened and/or protected under various frameworks (see *Features of conservation interest*). On the basis of these findings, Oceana recommends a series of measures to safeguard benthic biodiversity in the northern part of the Danish North Sea, as described below.

Designation of new areas to protect features of importance

Oceana proposes the expansion of the current network of MPAs that extends across the Danish North Sea, through designating new MPAs and/or enlarging existing ones to safeguard newly discovered locations with features of high ecological value that lie outside MPAs (Figure 30 and Figure 47). These specific features include:

- stone reefs: a feature for protection under the Habitats Directive (under *Reefs*). Stone reefs were found outside *Skagens Grens og Skagerrak*, as well as in many locations outside protected areas in Jutland and Little Fisher Bank.
- algal forests: a feature for protection under the Habitats Directive (under *Reefs*). Forests formed by kelps and other large macroalgal species were found to the east of *Jyske Rev/ Lillefiskerbanke*.
- sea pen fields: a protected habitat type under OSPAR (under *Sea pen fields* and *Coral gardens*). Fields of sea pens such as tall sea pen (*Funiculina quadrangularis*) and slender sea pen (*Virgularia mirabilis*) were found to the north and west of the boundaries of *Skagens Gren og Skagerrak*.
- coral gardens: a feature for protection under the Habitats Directive (under *Reefs*) and protected under OSPAR (under *Coral gardens*, although the OSPAR definition does not include coral gardens characterised by the soft coral dead man's fingers (*Alcyonium digitatum*). Oceana found coral gardens outside protected sites in many locations in Jutland Bank and Little Fisher Bank, as well as outside the boundaries of *Store Rev* and *Gule Rev*.
- soft bottom habitats: a priority for protection under the MSFD. Oceana documented soft-bottom areas in unprotected locations across Little Fisher Bank, Jutland Bank, and outside of *Skagens Gren og Skagerrak*.
- ocean quahog (*Arctica islandica*), a protected species under OSPAR. Remains of ocean quahog were documented in unprotected locations in Little Fisher Bank, Jutland Bank, and aggregations of shells were found in North of Denmark.

In accordance with the OSPAR Recommendation for this species, Denmark should assess whether any of these sites justify selection as MPAs for the recovery of ocean quahog.[174]

- other species of conservation interest documented outside MPAs (Figure 47) included European eel (*Anguilla anguilla*) to the south of Jutland Bank, and sandeel (*Ammodytes* spp.) to the east of *Gule Rev*. Further research should be carried out to determine the importance of those areas for the two species.

Figure 56. Juvenile European eel (*Anguilla anguilla*) among rocks covered by soft corals (*Alcyonium digitatum*) and bryozoans (*Flustra foliacea*) in Jutland Bank survey area.

All of the habitat types above have been highlighted as important for protection, in order to fill gaps in the current network of Danish MPAs in the North Sea.[4] Due to their biodiversity value, all types of reefs are considered a conservation priority, including within the Danish PoM, which has established a set of conservation measures that include reef mapping and restrictions on specific type of anthropogenic activities that threaten them.

Soft bottoms have also been long recognised as poorly protected in the Danish North Sea, particularly given that they are heavily impacted by bottom fisheries. These habitats are home to communities that include threatened and vulnerable species (e.g., sea pens, large molluscs) and adults and juveniles of commercial species. Soft bottom areas are predominant in the North Sea, and were found across the Oceana survey area, both inside and outside protected sites. Associated species on soft bottoms included key habitat-forming species (e.g., sea pens, anemones, burrowing fauna, and worms) and rich infaunal communities. Under the MSFD, Denmark has committed to assess the need for protection of soft bottom areas in the North Sea and the Skagerrak. Such

habitats are not currently represented in the MPA network, other than sandbanks (which are covered by the Habitats Directive); other soft bottoms, are not protected. Given the vulnerability of these areas to impacts and the array of threatened and sensitive species and community types they support, the designation and management of MPAs to conserve soft-bottom areas of the North Sea – in Denmark and beyond – should be carried out without delay.

Protection of priority features within MPAs sites

Oceana's research revealed the presence of priority habitats and species within the boundaries of existing Natura 2000 MPAs (Figure 30 and Figure 47), but which remained essentially unprotected in those locations, because they are not officially listed among the protected features of the sites. Oceana proposes that appropriate designations be put in place to safeguard these features, to ensure that the maximal benefits are attained from the MPAs with respect to the full range of vulnerable and threatened marine life within their boundaries. This may be done either by adding the Habitats Directive-listed features to the official information for the site (i.e., the Standard Data Form) or by developing complementary, spatially overlapping designations that allow for the protection of features that are not covered by the Habitats Directive.

The specific features of high ecological value that were documented inside MPAs yet do not benefit from protection include:

- biogenic reefs formed by large molluscs: a feature for protection under the Habitats Directive (under *Reefs*). Such reefs were found inside *Gule Rev* and *Store Rev*, and included horse mussel (*Modiolus modiolus*) beds, which are protected under OSPAR.
- bubbling reefs: a feature for protection under the Habitats Directive (under *Submarine structures made by leaking gases*). The extreme vulnerability of these features to human activities underlies the advice from the European Topic Centre on Biological Diversity and the European Environment Agency that all known locations with bubbling reefs should be protected.[50] Oceana documented a new, previously unknown bubbling reef in *Store Rev*, which should be added to the Standard Data Form for this site (as should the previously documented bubbling reef inside *Knudegrund*, be added to the Standard Data Form for that MPA).[3]
- coral gardens: a feature for protection under the Habitats Directive and protected under OSPAR (see above). During Oceana's surveys, coral gardens were found inside *Gule Rev* and *Store Rev.* The locations of these gardens should be officially updated, to ensure that they are properly managed within the MPAs.

- sea pen fields: a protected habitat type under OSPAR (see above). Oceana documented fields of sea pens inside *Skagens Gren og Skagerrak*. Measures should be taken to ensure that these areas are protected, and to develop appropriate management measures to ensure their conservation.
- soft bottom habitats: a priority for protection under the MSFD. As with sea pen fields, soft-bottom areas were documented across *Skagens Gren og Skagerrak*, particularly across the deeper, northern part of this Natura 2000 MPA. These habitats should be officially reviewed and considered for protection, as an area of importance for soft-bottom habitats in northern Danish waters.
- ocean quahog (*Arctica islandica*): a protected species under OSPAR (see above). Oceana found aggregations of ocean quahog inside *Store Rev* and, to a lesser extent, in *Gule Rev*. Measures should be taken to protect these sites, and to determine the full extent of these aggregations.

MPA management and additional measures

In addition to the protection of further areas of the Danish seabed, and the formal inclusion of new protected features within existing MPAs, Oceana's findings point to a series of complementary measures that are needed to strengthen marine protection in the Danish North Sea.

Critically, it is clear that there is a need for the development of robust and targeted management measures to protect the priority features present within Denmark´s North Sea MPAs. Habitat types that are meant to be protected within Natura 2000 MPAs are considered to be in poor condition,[110] and the current management plans for sites state that they are aimed at restoring protected habitats to favourable condition. However, they are markedly lacking in specific measures to achieve this objective. As just one example, *Store Rev* is intended to protect bubbling reefs, reefs, and harbour porpoise (*Phocoena phocoena*). However, the two detailed measures laid out in the management plan for this site are vague; the Danish Environmental Protection Agency will prepare a strategy for the protection of harbour porpoise in Danish waters, and will assess the need for and initiate the regulation of fishing on and around bubbling reefs and reefs. No deadlines are indicated by which these measures should be in place, nor are there any precautionary management measures outlined that should be followed in the interim, before the harbour porpoise protection strategy and fisheries regulation assessment are completed.

At the broader scale, the Danish government should undertake a thorough assessment of the sufficiency of management measures currently in place to reduce and minimise anthropogenic impacts

on priority species and habitats within its North Sea waters. This assessment should include features listed as conservation priorities under the Habitats Directive, the MSFD, and OSPAR, to ensure that effective management measures are in place, and at appropriate scales. Given the intensity of bottom-fishing in the northern waters of the Danish North Sea, the threat posed by demersal fisheries should be given particular and urgent attention. While the Danish government plans to develop fisheries management measures for North Sea MPAs with reefs and bubbling reefs, no precautionary measures are in place until such time as the measures are finalised. Moreover, the need for such measures must be considered for a broader suite of features, on both hard and soft bottoms. Attention should also be paid to the establishment of adequate buffer zones around features, to ensure that impacts are effectively minimised.

Oceana's findings further highlight areas where additional research is warranted to determine the distribution and importance of benthic habitats in Danish North Sea waters. For example, Oceana and others have documented previously unknown bubbling reefs and sea pen fields[3,31] in northern Denmark. It is highly probable that these habitats are found in additional locations to the ones surveyed (e.g., there may be other bubbling reefs in the pockmark area in *Skagens Gren og Skagerrak)*, but further research would be needed to confirm their occurrence (see *Known ecological features of interest*).

With respect to commercial fishes, Oceana recorded the presence of juveniles of species such as herring (*Clupea harengus*), cod (*Gadus morhua*), and plaice (*Pleuronectes plastessa*), on a variety of substrates and in the water column. The waters of the Oceana survey area are known to coincide with essential fish habitat (EFH) for these and many other commercial species (see *Known ecological features of interest*), yet protection of EFH in the area is relatively limited. Further research should be carried out to identify specific sites of EFH that should be considered for protection – particularly for stocks that are currently overfished – as a management tool to complement science-based catch limits and appropriate technical measures.

The research of Oceana and others (see Table 1) in recent years have added significantly to knowledge about benthic biodiversity in the Danish North Sea. These studies have yielded extensive data, in particular, about the distribution of key habitat features (e.g., reefs (stone reefs, biogenic reefs, algal forests, and coral gardens) and bubbling reefs) in Danish North Sea waters. In light of this new information, Oceana urges the Danish government and the European Commission to reassess the sufficiency of the current Natura 2000 network with respect to these habitat types. Coverage of Natura 2000 MPAs for reefs in the North Sea and Skagerrak was estimated at 17% in 2017,[4] which was already

below the minimum threshold of 20%, prior to the collection of more recent data. For bubbling reefs, the recommendation of the European Topic Centre on Biological Diversity and the European Environment Agency is that all known locations should be protected, indicating that the Danish government is obliged to protect bubbling reefs that have been documented inside and outside of existing MPAs.

Oceana welcomes the recent efforts of the Danish government to assess its network of MPAs in the North Sea and Skagerrak[4] and, in 2019, to identify new areas that should be designated for protection. Given the biodiversity importance of the northern Danish North Sea, the poor conservation status of certain habitats and species, recognised gaps in protection, and the intensity of human pressure on the Danish marine environment, the designation (and effective management) of such areas is critical if Denmark is to safeguard its benthic biodiversity and restore its waters to Good Environmental Status.

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ANNEX: RECORDED TAXA

Species	North of Denmark	Jutland Bank	Little Fisher Bank
CHLOROPHYTA			
Chlorophyceae		X	
OCHROPHYTA			
Arthrocladia villosa		X	
Desmarestia aculeata		X	
Fucus sp.	X		
Halidrys siliquosa		X	
Laminaria hyperborea		X	
Laminaria sp. (remains)		X	
Phaeophyceae	X	X	
Saccharina latissima		X	
Sporochnus pedunculatus		X	
RHODOPHYTA			
Bonnemaisonia asparagoides	X	X	
Callithamnion cf. *tetragonum*		X	
Coccotylus truncatus		X	
Delesseria sanguinea	X	X	
Dilsea carnosa		X	
Furcellaria lumbricalis		X	
Gracilaria sp.		X	
Gracilariopsis longissima		X	
Hildenbrandia rubra		X	
Lithothamnion sp.		X	
Phycodrys rubens	X		
Phymatolithon lenormandii	X	X	
Rhodophyllis divaricata		X	
Rhodophyta	X	X	
Vertebrata fucoides	X	X	
ANNELIDA			
Annelida	X	X	X
Aphrodita aculeata	X		
Chaetopterus variopedatus	X		
Filograna implexa	X		
Hydroides norvegica		X	
Hydroides sp.		X	
Lagis koreni	X		
Lanice conchilega	X		
Oxydromus flexuosus	X	X	X
Pectinariidae	X		
Polychaeta	X	X	X
Polydora ciliata	X		
Sabella cf. *discifera*		X	
Sabella sp.	X		
Sabellidae		X	
Serpulidae		X	X
Spirobranchus triqueter	X	X	X
Terebellidae	X		
SIPUNCULA			
Golfingia (Golfingia) vulgaris vulgaris	X		
ARTHOPODA			
Amphipoda	X	X	X
Anapagurus chiroacanthus		X	
Anomura		X	
Aora gracilis		X	

Table A. Taxa documented in the survey area during the Oceana North Sea research expeditions in 2016 and 2017. Taxa are listed according to the survey areas where they were recorded.

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Astacilla longicornis	X	X	
Balanus balanus	X		X
Balanus crenatus	X	X	
Balanus sp.			X
Brachyura			X
Caligidae		X	
Cancer pagurus	X	X	X
Caprella linearis		X	
Caprella sp.	X	X	
Caridea	X	X	
Corystes cassivelaunus			X
Crangon crangon		X	
Crustacea	X		X
Diastylis bradyi	X		
Diastylis cf. *cornuta*	X		
Diastylis rathkei	X		
Diastylis rugosa	X		
Diogenes pugilator			X
Eualus sp.	X		
Eusergestes arcticus	X		
Galathea dispersa	X		
Galathea intermedia	X	X	
Galathea nexa	X		
Galathea sp.	X	X	X
Galathea strigosa		X	X
Galatheidae		X	
Geryon trispinosus	X		
Hyas coarctatus	X		
Hyperia galba	X		
Inachus phalangium	X		
Inachus sp.	X	X	
Liocarcinus depurator	X		
Liocarcinus holsatus	X	X	
Liocarcinus marmoreus	X	X	
Liocarcinus sp.	X	X	X
Macropodia rostrata	X	X	
Meganyctiphanes norvegica	X		
Munida rugosa	X		
Munida sp.		X	
Mysida	X		
Nephrops norvegicus	X		
Novocrania anomala		X	X
Pagurus bernhardus	X	X	X
Pagurus pubescens	X		
Pagurus sp.	X	X	X
Palaemon elegans	X		
Palaemon sp.	X		
Pandalidae		X	X
Pandalina brevirostris		X	
Pandalina sp.		X	
Pandalus borealis	X	X	
Pandalus montagui	X	X	
Pandalus sp.	X		
Phtisica marina		X	

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Pisidia longicornis		X	
Sessilia sp.		X	
Spirontocaris liljeborgii	X		
Terebratulina retusa		X	
Upogebia deltaura			X
Xantho pilipes	X		
BRYOZOA			
Alcyonidium diaphanum	X	X	
Alcyonidium hirsutum	X		
Bryozoa		X	
Bugula neritina	X		
Bugula sp.		X	
Bugulina flabellata		X	
Calpensia cf. *nobilis*	X		
Carbasea carbasea		X	
Cellaria fistulosa	X		
Cellepora pumicosa	X	X	
Celleporella hyalina	X		
cf. Chartella papyracea		X	
Cheilostomatida		X	
Conopeum reticulum		X	
Cradoscrupocellaria reptans	X		
Crisia denticulata	X	X	
Crisia eburnea		X	
Crisidia cornuta		X	
Crisularia plumosa	X	X	
Cryptosula pallasiana	X	X	
Electra pilosa		X	
Escharoides coccinea	X	X	X
Flustra foliacea	X	X	
Membranipora membranacea		X	
Omalosecosa ramulosa	X		
Palmiskenea skenei	X		X
Parasmittina trispinosa	X	X	
Porella sp.	X		
Schizomavella (Schizomavella) linearis	X		
Schizoporella sp.	X		
Schizoporella unicornis	X		
Scrupocellaria cf. *scruposa*		X	
Scrupocellaria sp.	X		
Securiflustra securifrons	X	X	
Vesicularia spinosa		X	
CHORDATA			
Actinopterygii	X	X	X
Ammodytes sp.	X	X	
Ammodytes tobianus		X	
Ammodytidae			X
Anguilla anguilla		X	
cf. *Aphia minuta*		X	
Aplidium turbinatum		X	
Argentina silus	X		
Arnoglossus laterna	X		
Ascidiacea		X	X
Ascidiella aspersa	X		

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Blennioidei	X		
Botrylloides leachii	X		
Botryllus schlosseri	X	X	
Branchiostoma lanceolatum	X	X	
Buglossidium luteum	X		
Callionymus lyra		X	
Callionymus maculatus		X	
Callionymus reticulatus	X	X	
Callionymus sp.	X	X	
Chelidonichthys lucerna	X		
Clavelina lepadiformis	X	X	
Cottidae		X	
Crystallogobius linearis	X		
Ctenolabrus rupestris	X	X	
Cystodytes sp.	X		
Didemnum albidum	X		
Didemnum sp.		X	
Diplosoma sp.	X		
Diplosoma spongiforme	X		
Eutrigla gurnardus		X	
Gadidae	X		
Gadus morhua	X	X	X
Globicephala melas	X		
Glyptocephalus cynoglossus	X		
Gobiidae	X	X	
Halichoerus grypus		X	
Hippoglossoides platessoides	X		X
Limanda limanda	X	X	X
Lophius piscatorius	X		
Lycodes gracilis	X		
Lycodes pallidus	X		
Lycodes sp.	X		
Lycodes vahlii	X		
Melanogrammus aeglefinus	X		
Merlangius merlangus	X	X	
Merluccius merluccius			X
Micromesistius poutassou	X		
Microstomus kitt	X		X
Molva molva		X	
Myxine glutinosa	X		
Pholis gunnellus	X		
cf. *Platichthys flesus*	X		
Pleuronectes platessa	X	X	X
Pleuronectidae		X	X
Pleuronectiformes	X	X	X
Pollachius pollachius	X		
Pollachius sp.	X	X	
Pollachius virens	X		
Pomatoschistus microps	X	X	
Pomatoschistus minutus	X	X	
Pomatoschistus pictus	X	X	
Pomatoschistus sp.	X		
Scophthalmus maximus	X		
Scyliorhinus canicula		X	

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Sprattus sprattus	X		
Styelidae	X		
Synoicum incrustatum		X	
Trachinidae			X
Trisopterus esmarkii	X		
Trisopterus minutus	X		
Trisopterus sp.	X		
Zeugopterus punctatus		X	
CNIDARIA			
Abietinaria abietina	X	X	
Actinia fragacea	X		
Actiniaria	X	X	X
cf. *Actinostola callosa*	X		
Aglaophenia pluma	X		
Alcyonium digitatum	X	X	X
Aurelia aurita		X	X
Bolocera tuediae	X		
Caryophyllia (Caryophyllia) smithii	X		
Cerianthus lloydii	X		
Cerianthus membranaceus	X		
Corymorpha nutans		X	
Corymorpha sp.		X	
Cyanea capillata	X	X	X
Cyanea lamarckii	X	X	X
Diphasia margareta	X		
Epizoanthus sp.	X		
Eudendrium rameum		X	
Eudendrium sp.		X	
Funiculina quadrangularis	X		
Halecium beanii	X		
Halecium halecinum	X		
Halecium muricatum	X		
Halecium plumosum	X		
Halecium sp.	X	X	
Halipteris finmarchica	X		
Hydractinia echinata	X	X	X
Hydrallmania falcata	X		X
Hydroidolina	X	X	
Hydrozoa	X	X	X
Kirchenpaueria pinnata	X	X	
Laomedea flexuosa	X		
Leptothecata sp.		X	X
Leuckartiara octona	X		
Metridium senile	X		
Nemertesia antennina	X	X	
Nemertesia ramosa	X		
Obelia geniculata		X	
Plumularia setacea	X	X	
Plumulariidae		X	
Protoptilum carpenteri	X		
Sagartia elegans		X	
Sagartia sp.		X	
Sagartia troglodytes		X	
Sagartiogeton sp.		X	

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Sagartiogeton undatus		X	
Scyphozoa	X	X	
Sertularella gayi	X		
Sertularella sp.		X	
Sertularia argentea	X		
Sertularia cupressina	X		
Sertulariidae			X
Thuiaria thuja	X		
Tubularia indivisa	X	X	
Tubulariidae		X	
Urticina eques	X		
Urticina felina	X	X	X
Urticina sp.	X		
Virgularia mirabilis	X		
CTENOPHORA			
Beroe cucumis	X	X	
Beroe ovata	X		
Beroe sp.		X	
Bolinopsis infundibulum	X		
Ctenophora	X		
Pleurobrachia pileus	X		
ECHINODERMATA			
Amphiura chiajei	X		
Amphiura filiformis	X		X
Asterias rubens	X	X	X
Asteroidea	X		
Astropecten irregularis	X	X	X
Brissopsis lyrifera	X		X
Echinocardium cordatum	X	X	
Echinocyamus pusillus	X	X	X
Echinoidea	X		X
Echinus esculentus	X	X	X
Gracilechinus acutus	X		X
Gracilechinus cf. *elegans*			X
Henricia sp.	X		
Leptasterias (Leptasterias) muelleri	X	X	
Luidia ciliaris	X		
Luidia sarsii		X	X
Marthasterias glacialis	X	X	
Ophiocomina nigra	X		
Ophiothrix fragilis	X	X	X
Ophiopholis aculeata		X	
Ophiura albida	X		
Ophiura ophiura	X	X	
Ophiura robusta	X		
Ophiura sp.	X	X	X
Psilaster andromeda	X		
Spatangoida	X		
Spatangus purpureus	X		
MOLLUSCA			
Abra alba	X		X
Abra longicallus	X		X
Abra nitida	X		
Abra prismatica	X		X

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Abra sp.	X	X	
Acanthocardia echinata	X	X	
Acanthodoris pilosa	X		
Acteon tornatilis	X		
Cladobranchia		X	
Aequipecten opercularis	X	X	X
Anomia ephippium	X	X	X
Aporrhais pespelecani	X	X	
Arcopagia crassa	X		
Arctica islandica	X	X	X
Astarte elliptica		X	X
Astarte montagui	X	X	
Astarte sp.	X	X	X
Astarte sulcata	X		
Bivalvia	X	X	X
Boreotrophon truncatus	X	X	
Buccinum undatum	X	X	X
Calliostoma zizyphinum	X		
Cardiidae	X	X	X
Carronella pellucida	X	cf.	
Cerastoderma edule	X		
Cerastoderma glaucum		X	X
Cerastoderma sp.	X		
Chamelea striatula	X	X	X
Clausinella fasciata	X		
Cochlodesma praetenue			X
Colus gracilis	X		
Corbula gibba	X	X	X
Cuspidaria obesa	X		
Diaphorodoris papillata		X	
Doris pseudoargus		X	
Dosinia exoleta	X	X	
Dosinia lupinus	X	X	
Dosinia sp.		X	
Doto sp.	X		
Edmundsella pedata		X	
Ennucula tenuis	X		
Ensis ensis	X	X	
Ensis sp.	X	X	X
Epitonium clathrus	X	X	
Eubranchus tricolor	X		
Euspira catena	X	X	X
Euspira nitida	X	X	
Euspira sp.	X	X	X
Fabulina fabula		X	
Facelina auriculata	X		
Favorinus blianus	X		
Fjordia lineata	X	X	
Flabellina cf. *pellucida*		X	
Gari depressa	X		
Gari fervensis			X
Gastropoda	X		
Gibbula cineraria		X	
Gibbula tumida	X	X	

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Gouldia minima	X	X	
Hermania scabra			X
Heteranomia squamula	X		
Hiatella arctica	X		
Hiatella rugosa	X		
Iothia fulva		X	
Janolus cristatus	X	X	
Laevicardium crassum			X
Leptochiton cancellatus	X		
Littorina obtusata	X		
Lucinoma borealis	X		
Lucinoma sp.	X		
Lutraria lutraria	X		
Mactra sp.	X	X	
Mactra stultorum	X	X	X
Mactridae	X	X	
Mangelia attenuata	X		
Mangeliidae	X		
Mimachlamys varia	X	X	X
Mimachlamys varia nivea	X		
Modiolula phaseolina		X	
Modiolus modiolus	X	X	
Mya sp.	X		
Mya truncata	X		
Mysia undata	X		
Mytilus edulis	X		
Neptunea antiqua	X		X
Neptunea sp.	X		
Nucula hanleyi		X	X
Nucula nitidosa	X		
Nucula nucleus	X		
Nucula sp.	X		
Nuculana minuta	X		
Nuculidae	X		
Nudibranchia	X	X	
Onchidoris muricata	X		
Panomya norvegica	X		
Parathyasira equalis	X		
Parvicardium exiguum		X	
Parvicardium minimum	X		
Parvicardium pinnulatum	X	X	
Parvicardium scabrum	X		
Parvicardium sp.	X		
Patellogastropoda	X		
Pecten maximus	X		
Pectinidae	X		
Phaxas pellucidus		X	
Philine sp.	X		
Pododesmus patelliformis			X
Pododesmus sp.	X		
Pododesmus squama	X		
Polycera faeroensis	X		
Polycera quadrilineata		X	
Propebela cf. exarata		X	

Species	North of Denmark	Jutland Bank	Little Fisher Bank
Propebela turricula	X	cf.	
Pseudamussium peslutrae	X		
Raphitoma sp.	X		
Semelidae	X		
Sepiola sp.		X	
Simnia patula		X	
Solen capensis	X		
Spisula elliptica	X	X	X
Spisula sp.	X		
Steromphala cineraria	X	X	
Tellimya ferruginosa	X		
Tellina sp.		X	
Tellinidae	X		
Thracia phaseolina	X		
Thracia sp.			X
Thracia villosiuscula	X	X	
Thyasira flexuosa	X		
Thyasira sarsii	X		
Thyasira sp.	X	X	
Timoclea ovata	X	X	X
Tritia incrassata	X		
Tritia pygmaea	X		
Trochidae sp.		X	X
Turritellinella tricarinata	X	X	X
Urosalpinx cinerea	X		
Veneridae	X		
Venus casina		X	X
Yoldiella philippiana	X		
NEMERTEA			
Lineus ruber	X		
PORIFERA			
Antho sp.	X		
Aplysilla sulfurea	X		
Demospongiae		X	
Halichondria (Halichondria) panicea	X		
Halichondria sp.		X	X
Haliclona (Haliclona) oculata		X	
Haliclona (Haliclona) urceolus		X	
Hymedesmia (Stylopus) coriacea	X		
Leucosolenia complicata	X		
Leucosolenia sp.		X	
Leucosolenia variabilis	X		
Mycale (Carmia) micracanthoxea	X		
Polymastia boletiformis	X		
Polymasti a penicillus	X		
Porifera	X	X	X
cf. *Protosuberites denhartogi*	X		
Suberites ficus	X		X
Sycon ciliatum		X	

Denmark

PROTECTING THE NORTH SEA: NORTHERN DANISH WATERS

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