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RECOVERING NORTH SEA FISH STOCKS THROUGH MARINE HABITAT PROTECTION

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Credits

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The North Sea is one of the most heavily impacted water bodies in the world. Centuries of human activities have placed its marine ecosystems under heavy pressure, resulting in extensive and significant changes in ecosystem structure and function. Intensive fishing activity – particularly bottom-trawling – has driven the near disappearance of certain species and habitats, and pushed some commercial stocks to the brink of collapse.

Despite these impacts, the North Sea is still the most productive sea in Europe, with current commercial catches of approximately two million tons per year. Improvements in fisheries control and management in recent years have allowed some stocks to rebuild, but biomass remains far below potential levels. Modelling estimates suggest that, if managed properly, North Sea fish stocks could recover to much higher levels of abundance and provide catches 70% greater than at present.

One clear means of rebuilding both the biodiversity and productivity of the North Sea is through an ecosystem-based approach to fisheries management. Such an approach takes into account not only target species, but also their inter-relationships, and their interactions with the abiotic environment. A critical element of ecosystem-based management is the protection of 'essential fish habitats' (EFHs), those areas that are important for events in the life cycles of commercial species, such as breeding, spawning, nursery, and feeding areas. In the context of benthic ecosystems, the protection of EFH is especially relevant. To date, however, protection of EFH in North Sea waters has been relatively limited, and the identification of areas of EFH has not been a priority for many countries. As a result, knowledge about these key zones is incomplete and patchy for many areas and species.

Pollack (*Pollachius pollachius*)
in the Norwegian Trench
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Norway haddock (*Sebastes viviparus*) in *Polycarpa pomaria* field. Karmøy, Norway. © OCEANA

In 2016 and 2017, Oceana carried out two research expeditions in the North Sea, which aimed to help fill gaps in knowledge about benthic species and habitats in the region. Data were gathered from 25 areas across the North Sea, and included records of more than 13 000 individuals of commercial species and observations of areas of potential importance for them. This report presents those findings, in the context of broader information about the state of North Sea benthic ecosystems, areas of known importance as EFH of exploited species, and specific habitat types that are a priority for protection, because they both serve as EFH and are vital for biodiversity. This information can contribute to the identification of key areas and habitats for conservation and management measures, in support of stronger, ecosystem-based management of the broader North Sea.

The North Sea it is not a pristine sea – it is just the opposite. Its waters have been under heavy pressure for centuries due to human activities such as fisheries, marine war activities and confrontations, and coastal development.[1,2] Other activities, like oil and gas exploitation, coastal modification, sand extraction, dredging, toxic dumping, land run-off, offshore renewable energy development, and maritime traffic have also played important roles.[3] In the southern North Sea, pronounced morphological changes due to diking have drastically altered river mouths and estuaries, and also waves and tidal energy, thereby changing sediment processes and modifying the whole ecosystem.[4] Meanwhile, the impacts of large-scale threats such as climate change are becoming more and more evident each year (see *A changing and changed ecosystem*).

Therefore, changes in the functionality of the North Sea have been occurring for a long time, and ecosystem services have been modified. Anthropogenic impacts have led to widespread and significant ecosystem changes, including the loss of key habitats and structurally complex seabed features.[4,5] Once abundant ecosystems such as saltmarshes, seagrass meadows, and oyster reefs have vanished,[3,6] and many habitats are considered to be threatened and/or declining in the North Sea,[7] such as coral gardens, mussel beds, seagrass meadows, and worm reefs.

Despite all these impacts, the North Sea remains the most productive sea in Europe, providing roughly two million tons of food each year,[8] and with a potential sustainable productivity of approximately 3.4 million tons of catches per year.[8] During the 1970s, catches even reached a peak of four million tons.[9] Currently, more than 6600 boats from more than ten countries are fishing roughly 100 different stocks of commercial species in the North Sea; of these, the most important fleets are those belonging to the Denmark, France, the Netherlands, Norway, and the UK.[8]

There are more than 200 species of fishes in the North Sea,[10,11,12] but not all of them are caught commercially. Only ten species (i.e., *Ammodytes tobianus*, *Clupea harengus*, *Gadus morhua*, *Melanogrammus aeglefinus*, *Merlangius merlangus*, *Pleuronectes platessa*, *Pollachius virens*, *Scomber scombrus*, *Sprattus sprattus*, and *Trisopterus esmarkii*) account for up to 90% of the catches in the North Sea.[11] The total biomass of commercial fish species in the North Sea has been estimated at between 10 and 19 million tons.[8,13,14] In the 1980s-1990s, it was estimated that North Sea fisheries removed roughly 25-40% of the biomass of exploited fish each year;[15] a better current estimate could be closer to 10-20%.

Despite reductions in fishing effort and the improved status of certain North Sea stocks,[16] 37% of fish stocks in the North Sea are still fished unsustainably.[17] According to the European Environment Agency, only 30% of fish stocks in the North Sea meet the criteria for 'Good Environmental Status' (GES) as described in the Marine Strategy Framework Directive (MSFD).[18] The case of North Sea cod is a striking example of poor fisheries management; after a period of apparent recovery from earlier declines, the stock is once again overfished and ICES advised a catch reduction of at least 61% for 2020.[19]

The Common Fisheries Policy aims to establish a holistic approach to fisheries management that takes into account the interrelationships among species, and between species and the broader ecosystem.[20] This means that the exploitation of commercial species must also take into account what their removal means for other species, both commercial and non-commercial, and for the entire ecosystem, while also considering the impacts of fishing gear on the marine environment.

As was defined in the 1997 Assessment Report of the Intermediate Ministerial Meeting of the North Sea Conference:

> "An ecosystem approach involves considering all the physical, chemical and biological variables within an ecosystem. In the management of living resources this means that decisions are based on the best available scientific knowledge of the functions of the ecosystem, including the interdependence of species and the interaction between species (food chains) and the abiotic environment, as well as knowledge of the temporal development of the ecosystem. It could therefore imply a widening of the multispecies approach, currently used in fisheries, to encompass not only fish but also other organisms which directly or indirectly depend on fish or on which fish depend, as well as other significant biotic and abiotic environmental factors."[21]

The 'Ecosystem Approach to Fisheries' (EAF) was later adopted and updated by FAO,[22] and has been similarly incorporated as the primary framework for action under the Convention on Biological Diversity.[23] One of the critical elements of such an approach to fisheries management is the identification and protection of key habitats, both for maintaining biodiversity and productivity; doing so will prevent the ecosystem from collapsing,[24,25] will improve the general GES of the sea, and will maintain ecosystem services, including the provision of food and jobs. It will also increase the resilience of ecosystems in the face of both old and new threats. Even the loss or removal of weak interactions can provoke damaging effects on ecosystem productivity and resilience.[26]

Many habitats under threat are key for the survival of commercial species. They are used during important events in the life cycle of fishes, molluscs, and crustaceans such as for spawning, feeding, as nurseries, and migratory corridors. Such sites are considered essential fish habitats (EFH)[27] and are critical for both improving fisheries management and for marine conservation in general.

Of central importance is the healthy status of the seabed for the development of habitats suitable for the survival of marine species, including commercial ones. One of the key descriptors of GES under the Marine Strategy Framework Directive is the maintenance of sea-floor integrity (Descriptor 6). The target for this descriptor is characterised as being “at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.”[28]

Ensuring healthy functioning benthic ecosystems in the North Sea depends on knowledge about the habitats, species, and communities that comprise them. Despite the fact that the North Sea is one of the most studied seas on the planet, knowledge regarding its benthic ecosystems is patchy, which represents an obstacle for both fisheries management and conservation. To help fill gaps in knowledge about benthic species and habitats in the North Sea, Oceana carried out two research expeditions in 2016 and 2017. The main objectives of this research were to: gather first-hand information from areas of known or potential ecological importance, but from which benthic biological data were lacking; provide decision-makers with better data about North Sea benthic biodiversity for conservation and management; and to help strengthen the network of marine protected areas in the North Sea. Among the information gathered were data on apparent areas of importance for commercial species. These findings are presented here, in the context of broader information about the state of North Sea benthic ecosystems and areas of known importance for exploited species. Together, this information can help to provide new insights for improving North Sea fisheries and habitat management, as part of an ecosystem-based approach.

School of saithe (*Pollachius virens*) in Newcastle, United Kingdom.
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A CHANGING AND CHANGED ECOSYSTEM

The North Sea has gone through centuries of human impacts and activities that have changed the dynamics of its marine ecosystems. Against this backdrop of significant historical change, more recent global impacts – such as those related to climate change – represent additional and worrying threats for marine ecosystems.

Climate change impacts on the North Sea are extensive, and include changes in water circulation, pH, temperature, and dissolved oxygen, altering the distribution, abundance, and phenology of species and driving changes in their habitats.[29,30,31] There are worrying signs that primary production in the North Sea may be declining due to climate change, the loss of riverine inputs,[32] and a decrease in water clarity.[33]

In the North Sea, primary production is also related to external factors like the North Atlantic Oscillation, the English Channel Nutrient Flow, and riverine run-off,[34] as well as the flux of organic matter, carbon, and nitrogen from the water surface to the bottom.

Anthropogenic impacts, like those resulting from oil and gas exploitation, wind farms, sand extraction, coastal destruction, and pollution cannot be ignored, as these impacts can be cumulative and work in synergy, producing wider effects.[35,36,37]

Although climate changes, eutrophication, oil exploration and other human impacts have played significant roles in the disturbance of the North Sea marine ecosystem, fishing activities appear to be the main factor responsible for changes in epibenthic communities during the last century.[38] These activities have wide-ranging effects on marine ecosystems. They result in the extraction of large amounts of biomass, altering the interrelations among marine species, and also causing interspecific changes, due to the removal of the largest animals. Other species and sizes are also affected due to the impacts of fishing gears on the seabed, bycatch, and discards. Moreover, the discarding and loss of many tons of fishing gear produces significant quantities of pollution in the sea.[39,40]

Trawling as a driving force that changes the marine environment

Fishing activities can have substantial impacts on the characteristics of the marine environment, changing its physical, chemical, and biological structure. On the seabed, the impacts of such activities – especially trawling – are a major driver of change, disturbing habitats and modifying the structure of benthic communities,[41] changing nutrient and carbon cycles,[42] and altering interrelationships in the food chain between predators and prey.[43,44]

The repeated and cumulative impacts of trawlers fishing over decades in the same areas of seabed are likely to affect most of the North Sea.[45] For example, one of the most damaging types of trawling, beam trawling, causes dramatic reductions and losses in infaunal and epifaunal biomass, with especially adverse effects on biogenic reefs.[46,47,48] Species with slow growth, longer lifespans, and lower recruitment are more vulnerable to benthic disturbance, and therefore may disappear in favour of other species with faster growth, higher reproductive rates, and lower sensitivity to fishing impacts.[49]

Trawler in the Skagerrak, Norway.
© OCEANA/ Juan Cuetos

Data collected by ICES on benthic fishing intensity and pressure show the extensive distribution of this impact across the whole North Sea.[50,51] Less than 7% of the seabed in the North Sea is untrawled, while the estimated area swept by trawlers annually is close to 120% of the entire area of the North Sea.[52] Some areas are trawled more than 400 times per year.[53]

Scientific studies have estimated the rate of direct mortality related to fishing activities in various North Sea species. Considering all types of fishing activities, mortality rates can be between 7-45% of all the individuals[54] for benthic invertebrates in general. In the case of beam trawling specifically, estimated mortality ranges from 10-40% in gastropods, starfish, crustaceans and annelids; 10-50% in sea urchins; and 30-80% in bivalves.[55]

Changes in species composition

Intensive fishing activities in the North Sea have led to significant ecosystem changes. Both bottom-up and top-down effects can have long-term impacts,[56] on the whole ecosystem, altering productivity and species composition.

Such changes in composition have been documented in recent decades in both pelagic and benthic ecosystems.[12,57,58,59] Changes in pelagic species composition have also led, in turn, to changes in plankton composition, and vice versa.[56,60,61] Fish species that have been overexploited in the pelagic realm have been replaced by other fishes, but in benthic ecosystems, the niche occupied by demersal fish species has been partially filled by invertebrates. This has led to increases in the populations of some crustaceans, as well as a shift in some fisheries towards targeting them. However, this displacement of fishing effort has not resulted in fish stock recovery.[61]

Changes in species composition also result from the combined effects of fishing activities with other anthropogenic and natural drivers. For example, the reduction in North Sea cod recruitment during the 1980s was attributed to synergistic effects of fishing and climate change. This reduction caused a cascade effect, which had the greatest impacts on the most commercially valuable species (stocks of which were already in poor condition, and with lowered resilience due to overfishing), and promoted non-commercial ones, including gelatinous and opportunistic species.[62]

Discards also play an important role in the dynamism and distribution of benthic species. Significant levels of mortality are experienced by some target fish species that are caught and discarded by fisheries targeting benthic invertebrates. For example, Frid *et al.*[63,64] suggest that, on average, 26% of fisheries catches (by weight) are discarded, but that discards can represent as much as 84% of the catch in shrimp/prawn fisheries.

Figure 1. Dead fish on the North Sea seabed.

In 1996, Garthe *et al.*[65] estimated the total amount of fishery discards in the North Sea to be 262 200 onnes of roundfish and 299 300 tonnes of flatfish. Later estimates have placed the total level of discards for the North Sea at between 570 000-950 000 tons per year,[42,65,66,67] an amount close to around 30-40% of total landings.[66,68] Discards within North Sea fisheries are estimated to account for 13% of total global discards.[67]

The rate of discards varies among fisheries and species, as well as seasonally, although it is also known that data on discards are not completely reliable due to the limited coverage of observers in fisheries fleets.[69,70] Pelagic fisheries are typically estimated to have a low discard rate, but due to the high volume of catches the total amount of discards can reach high levels at certain moments. Demersal and benthic fisheries are those with the worst records in general for discard rates in the North Sea.

For example, roundish trawl fisheries (for cod, haddock, etc.) can discard between 20-50% of catches by weight;[71,72] brown shrimp fisheries can have a strong impact on other species, discarding up to one billion juvenile fish per year.[73,74] Within the dab fishery, close to 90% of the fish caught can be discarded.[66]

The rate of discards appears to have been decreasing during recent years, partly as a result of the discard plans adopted under the revised CFP.[20] Discards are estimated to be very low in pelagic fisheries, between 7% and 20% for benthic species, and close to 25% for demersal ones.[8] While these rates are still high, they nevertheless appear to be improving.

The discard plans agreed by the EU for the North Sea include both pelagic and demersal species.[75,76] They have the aim of progressively eliminating the waste of fisheries resources and introducing a landing obligation for all species that are subject to catch limits. These plans apply to all of the most important fishing gears and North Sea fished species, such as herring, mackerel, horse mackerel, sprat, blue whiting, sole, haddock, whiting, cod, saithe, plaice, Norway pout, greater silver smelt and Norway lobster. These plans also include some "de minimis" exemptions for specific fishing gears and species, and other exemptions allowing for the live release of some species that can have high rates of survivability if returned to the water.

Various studies have analysed how discards and species damaged by trawling gears affect populations of scavengers and change species composition – not only in benthic ecosystems but also other communities, including seabirds.[77,78,79,80] These studies have shown that the species that benefit most from discards and damaged animals are crustaceans like *Pagurus bernhardus*, *Carcinus maenas*, *Cancer pagurus*, *Liocarcinus depurator*, and various amphipods; echinoderms like *Asterias rubens* and various ophiuroids; molluscs like *Neptunea antiqua* and *Buccinum undatum;* and fishes like *Myxine glutinosa* and some commercial species, like juvenile gadoids, some flatfishes, and others.

Large vs. small, long-lived vs. short-lived

Jennings and Blanchard[81] evaluated the size composition of fishes in the North Sea based on their sizes and weights. The results indicated that the biomass of large fishes in the North Sea (in size categories of 4-16 kg and 16-66 kg) at that time was 97.4% and 99.2% lower, respectively, than if no fishing had occurred. In other words, there were found to be only 0.6-2.6% of large fishes left in this sea.

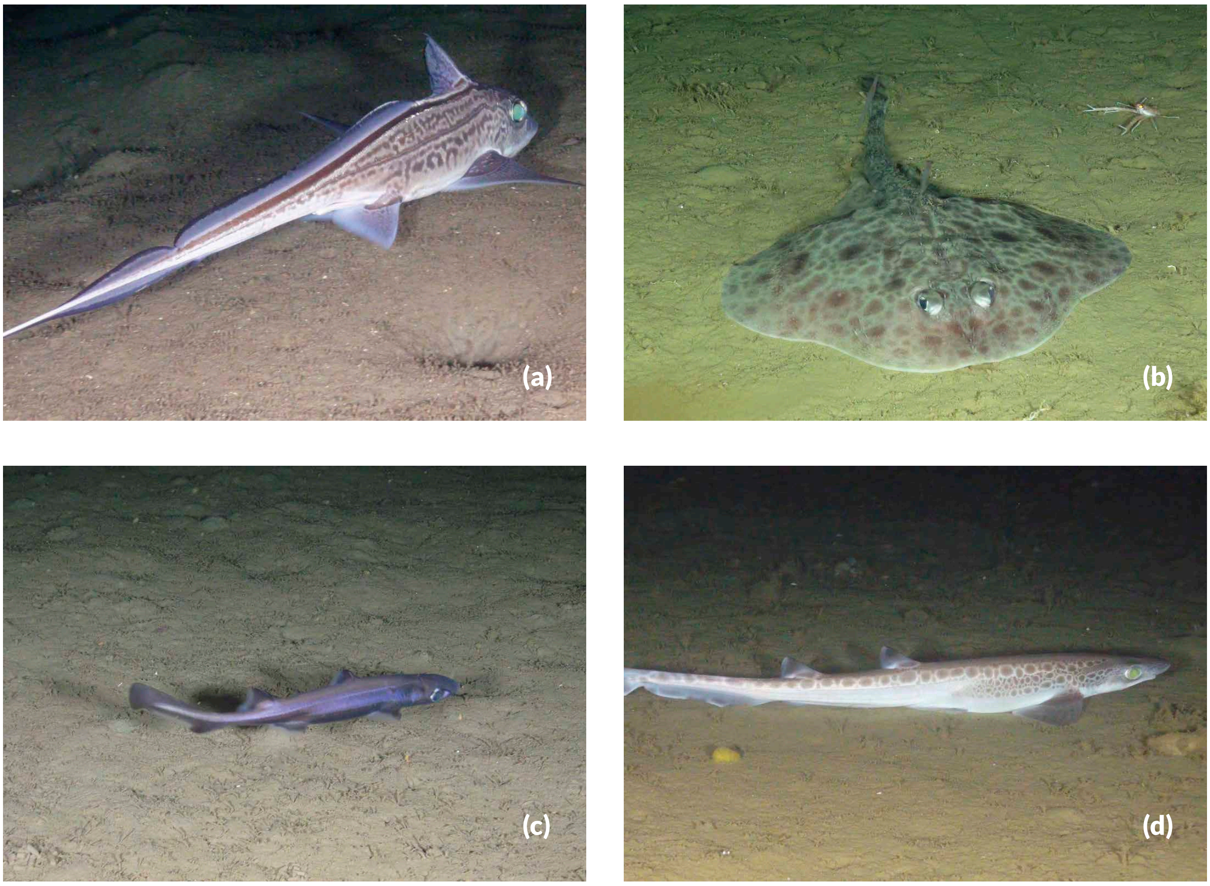
Other studies of large fishes in the North Atlantic have used different methodologies but reached similar conclusions. Christensen *et al.*,[82] Myers and Worm[83] and Thurstan *et al.*[84] estimated that the biomass of large predatory fishes had declined by 90-94% since 1900. As noted in the latter study, "this implies an extraordinary decline in the availability of bottom-living fish and a profound reorganization of seabed ecosystems since the nineteenth century industrialization of fishing."[84]

While the biomass of large fishes appears to have increased during recent years, rising from 2% of total biomass in 2001 to up to 12% in 2017,[85] this percentage is still far below the Ecological quality Objective (EcoQO) established by OSPAR.[86] Moreover, it remains extremely impoverished in comparison with biomass levels as they would once have been, in the North Sea's original, unfished state.

Various studies have shown shifts that have been produced in the benthos, from species with long lifespans and low levels of productivity to others with shorter lifespans and higher rates of reproduction, as a result of the impacts of trawling and other human activities.[21,87,88] The disturbance to the seabed and the increased abundance of dead and damaged organisms has benefited opportunistic species, like scavengers.[89,90,91,92]

The high intensity of fisheries has led to the removal of large individuals in the entire North Sea, sometimes promoting the expansion of smaller ones.[93] Such effects are particularly striking among chondricthyans; large skates, rays, and sharks have almost disappeared from the North Sea. The Greater North Sea and Celtic Sea region is considered to host 75% of the North Atlantic population of common skate (*Dipturus batis*).[94] However, this species, which is Red Listed globally as Critically Endangered, has nearly vanished from vast parts of its range.[95] Catches of *D. batis* in North Sea fisheries have fallen from nearly 40% in some skate fisheries to zero within one century.[94]

Figure 2: (a) *Chimaera monstrosa*, (b) *Rajella fyllae*, (c) *Etmopterus spinax* and (d) *Galeus melastomus*, four of the few chondrichthyan species that are still abundant in certain areas in the North Sea.



In addition to impacts on chondrichthyans, some bony fishes and invertebrates have severely declined or even disappeared in different areas of the North Sea due to fisheries by-catch.[96] This trend seems to have accelerated since the introduction of beam trawling in 1960s.

Recent ICES evaluations of the state of the North Sea ecoregion stated that "fishing has reduced the number of large fish in the North Sea ecosystem (mostly cod *Gadus morhua*, saithe *Pollachius virens*, ling *Molva molva*, sturgeon *Acipenser sturio*, and some elasmobranchs). In historical times, the large whale populations of the North Sea were depleted or extirpated by hunting. Whilst the impact of these removals on the ecosystem functioning is not clearly understood, it should be assumed that the North Sea ecosystem is currently in a perturbed state. Several of these elasmobranch species are now considered threatened or endangered by OSPAR and IUCN and are still caught as bycatch in fisheries."[3]

The impacts of changes and pressures in the North Sea have not been limited to larger fishes. In the last 40 years, forage fish have been reduced in length (by 5%), weight (by 13%) and recruitment (by 28%). These reductions could be related to changes in ocean circulation due to climate change and the changes in plankton production.[97] In many cases, however, fishing impacts and climate change have had synergistic effects on North Sea ecosystems, including benthic ecology,[98] contributing to the extirpation of some fragile species and vulnerable habitats.

Fishes have not been the only species affected by these general shifts in community composition, from larger to smaller organisms. Molluscs and crustaceans, for example, are other good examples of the changes that the North Sea ecosystem has experienced. The ocean quahog (*Arctica islandica*) population in the North Sea has suffered large declines since the beginning of the twentieth century.[99,100,101] This species is especially vulnerable to beam trawling, which causes shell damage and direct mortality;[102,103] the rate of mortality of individuals caught in this gear type has been estimated at 74-90%.[104] This is especially worrying for a species with a long lifespan, with individuals growing to ages estimated at up to 500 years.[105,106] In the case of crustaceans, observed changes in species composition include examples such as short-lived species (such as hermit crabs) being favoured over larger and longer-lived species (such as European lobster),[107] thereby also hindering their recovery.

Figure 3. Remains of ocean quahog (*Arctica islandica*) in the North Sea.

Disappearance of key habitats

Biogenic reefs and seagrass meadows were once common and important habitats in the North Sea but have now almost completely disappeared.[6] For example, since the seventeenth century, banks formed by European flat oyster (*Ostrea edulis*) have declined due to overfishing and the use of increasingly damaging fishing techniques, together with climatic episodes and increased damage by boring sponges.[108] By the first half of the twentieth century, these oyster beds were almost completely extirpated and no economically viable fishery could develop.[109]

Similarly, horse mussel (*Modiolus modiolus*) — another reef-forming species — has also declined in the North Sea.[110] There remain only very few and isolated spots where horse mussel beds occur.[111]

The reduction of biogenic reefs has led to associated changes in benthic species composition. For example, shellfish communities in Helgoland shifted from oyster grounds to beds dominated by small clams such as *Nucula nucleus*.[112]

Fishing impacts extend far beyond species-specific impacts,[113,114,115] inducing changes that include altered sediment composition, biogeochemistry, and functionality of species and habitats. Some physical impacts include alterations in chemical flux rates, modifications in microbial activity, resuspension of sediments and pollutants, changes in granulometry and nutrient supplies, and modifications to the absorption and cycles of nitrogen/ammonia and silicate.[113,114,115,116,117,118,119,120,121]

Some of these impacts can lead to functional extinctions,[115] threatening the biodiversity and resilience of the entire ecosystem. For example, resuspension of sediments by trawling and dredging, and changes in granulometry due to the resuspension and the erosion created by the continuous passes of trawling gear on the seabed, can lead to drastic changes in benthic fauna, particularly through the smothering of suspension feeders.[122,123,124]

IMPACTS ON THE WATER COLUMN RESULTING FROM BOTTOM CHANGES

There are many important connections between the water column and the seabed, also known as pelagic-benthic coupling, in which physio-chemical and biological processes in one influence the other.[125,126] In relation to this coupling, changes in benthic communities can also influence life in the water column. For example, an increase in the abundance of benthic echinoderm larvae may influence the availability of phytoplankton via competition with zooplankton.[127] Similarly, a decline in filter-feeding species, like sponges, clams, and oysters, can affect water turbidity[128] and reduce the penetration of light; diminished light, in turn, reduces the growth and extent of algae and plants on the sea bottom, and promotes eutrophication processes.

School of pouting (*Trisopterus luscus*) in Borkum Stones, the Netherlands. © OCEANA/ Carlos Minguell

© OCEANA/ Carlos Minguell

ESSENTIAL FISH HABITAT: KEY AREAS FOR PROTECTION

In addition to directly reducing the impacts of human activities on North Sea ecosystems, there is one key ecosystem-level tool that will help to recover and restore their abundance and functionality: increasing the coverage of marine protected areas (MPAs). According to the OSPAR definition, MPAs are recognised as areas "for which protective, conservation, restorative or precautionary measures have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment".[129]

Among the many types of MPAs, one type of protection that has been relatively underutilised is the designation of sites that specifically protect areas of essential fish habitat (EFH). EFHs are those areas that are critical for the life cycles of commercially exploited fishes, crustaceans, molluscs and others. Examples of EFH include spawning grounds, mating sites, feeding or foraging grounds, nursery grounds, and migratory corridors. Such areas may require special protection to improve stock status and long-term sustainability.[130]

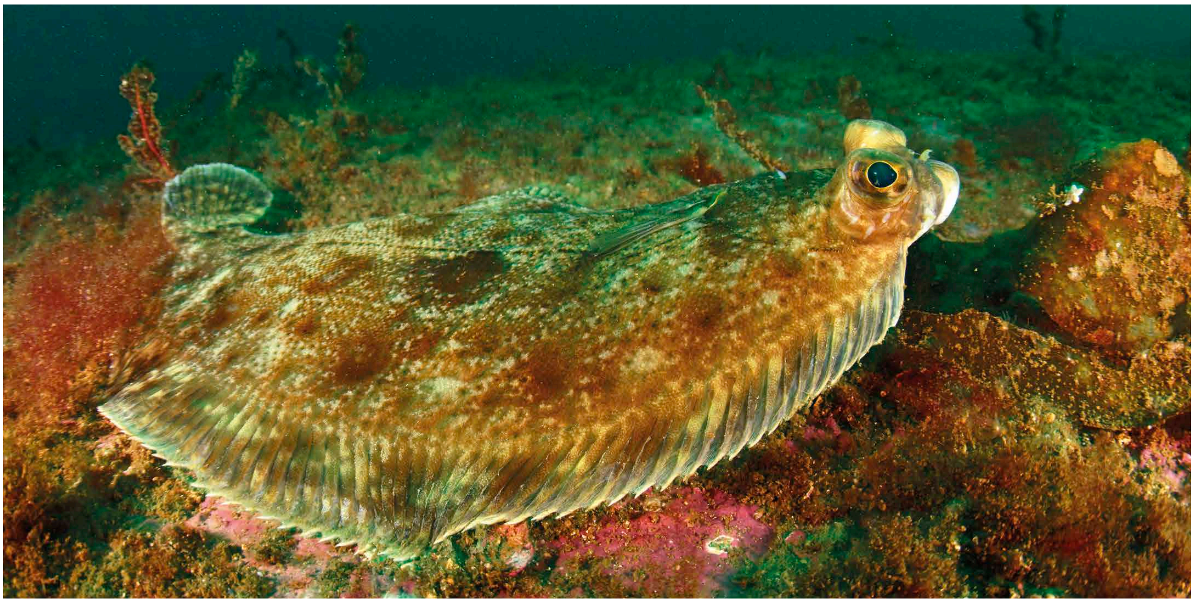
In many cases, EFH may coincide with sensitive habitats or vulnerable marine ecosystems (VMEs). Although the term VME is typically used for deep-sea ecosystems, habitats and communities,[131] such features can also be found in shallower waters, especially in places where oceanographic conditions (e.g., cold waters and turbidity or lack of light) can resemble those in deep waters. Therefore, the establishment of protected areas for rebuilding fisheries stocks can, in some cases, also benefit the protection of vulnerable and sensitive habitats.

In the North Sea, some areas have been temporarily or permanently protected, with the aim of recovering fish stocks (see *Spatial planning and existing closed areas*). In general, however, protection of EFH in North Sea waters is relatively limited.

Major spawning grounds and nursery areas for commercial species in the North Sea

Various countries worldwide (e.g., Australia, Canada, and the US,), the EU, and international conventions (e.g., GFCM, NEAFC) have legislation for declaring protected areas in locations where EFH are identified. In some regions, such as the Baltic Sea, workshops have been held with the specific aim of developing strategies for protecting these key zones.[132]

Under the 2013 Common Fisheries Policy, the European Union established the term 'fish stock recovery areas' (FSRAs) to describe biologically sensitive areas, including spawning grounds and apparent nursery areas, and includes their protection among the set of tools for improving fisheries management and



Lemon sole (*Microstomus kitt*) in the Norwegian Trench.
© OCEANA/ Carlos Minguell

conservation. [21] Member States are meant to identify suitable areas of FSRA that can form part of a coherent network, with the aim of covering between 10-20% of EU waters under FSRAs to improve the status of the commercial stocks and increase the productivity of fisheries.[133]

Unfortunately, European countries have paid little attention to EFH or FSRAs[134] despite information on spawning grounds and nursery areas having been collected for decades. While there are still gaps in information about the role that different habitats play as EFH and about the exact location of some of these areas — especially nursery areas — the information available is already more than sufficient to use as the basis for starting to take decisions.

Unfortunately, and despite the fundamental importance of EFH for fisheries activities and management, identifying the location of EFHs has not been a priority for many countries. As a result, knowledge about these key areas is neither comprehensive nor equally distributed among regions and species. In the North Sea, only a few countries have provided partial information on nursery and spawning areas, and it is believed that the maps available underestimate nursery habitats, while confidence levels regarding spawning and feeding grounds are low.[135]

Long-term studies on the biology and catches of commercial species in the North Sea can provide good indications as to where some EFHs are located. Some of the most important studies of EFH in the North Sea have focused on two important phases of the life cycle: reproduction (spawning grounds) and juvenile aggregations (nursery areas). This approach has allowed for the identification of specific areas of importance. Tables 1-2 and Figures 4-7, below, provide examples of documented spawning and nursery areas, respectively, for key North Sea species of commercial importance.

Table 1. Documented spawning grounds of North Sea commercial species.

Anglerfish ***(Lophius piscatorius)***	There are no data on spawning grounds in the North Sea,[136,140] although old records of show anglerfish eggs in the northwestern North Sea[137] It has been suggested that the northern North Sea and Norwegian Trench could be plausible spawning grounds for the species.[138,141]
Cod ***(Gadus morhua)***	Cod spawns in similar areas to dab, including western Denmark, the Netherlands (Oyster Grounds), the UK (Flamborough Head-Holderness and the Moray Firth), north of Dogger Bank and in offshore waters close to the Norwegian Trench.[143,148]
Dab ***(Limanda limanda)***	The most important spawning areas are in the southeastern North Sea, between the Netherlands and Denmark, with some sites around the Dogger Bank and in UK waters (off Flamborough Head).[148]
Haddock ***(Melanogrammus aeglefinus)***	Spawning grounds of haddock are widely distributed: from Dogger bank to Newcastle and the Firth of Forth, Devils Hole/Long Forties, around Shetland and Orkney to the transboundary area with Norway, and the Danish Great and Lesser Fisher Banks.[139]
Hake ***(Merluccius merluccius)***	The species is not known to spawn in the North Sea.[140,141]
Herring ***(Clupea harengus)***	Herring eggs have been documented from around Orkney, to the north and south of the Firth of Forth, north of Flamborough Head, around Newcastle, Dogger Bank, and from the English Channel to Brown Bank.[140]
Horse mackerel ***(Trachurus trachurus)***	This species mainly spawns in the English Channel.[140,141]
Ling ***(Molva molva)***	Most spawning grounds for ling lie outside the North Sea. There are a few documented spawning sites between Devil's Hole and the border with Norway, and in the English Channel.[140,141]
Mackerel ***(Scomber scombrus)***	This species primarily spawns outside the North Sea. There are some spawning grounds in the English Channel, which sometimes extend into the southern and eastern North Sea.[140,141,146]
Plaice ***(Pleuronectes platessa)***	The species spawns in shallow waters. The main spawning areas are found in the southern North Sea (e.g., Oyster Grounds and around Dogger Bank), and in UK coastal waters, like Scottish bays, the Moray Firth, and Flamborough Head in the north of England.[141,142,143]
Sandeel **(Ammodytidae)**	This group of fishes spawns in the north of Scotland, the Firth of Forth and Moray Firth, Flamborough-Holderness, Dogger Bank, the English Channel to Brown Bank, Norfolk Banks, and in the Great and Lesser Fisher Banks.[140,141,144,145]
Sole ***(Solea solea)***	Sole spawns in the area between the English Channel and the southern part of the North Sea till the Dogger Bank,[140,145,146,147] and potentially in the Danish Fisher Banks.[141]
Whiting ***(Merlangius merlangus)***	It reproduces in deeper waters, mainly from the north of England to south of Shetland. Spawning grounds are also found in Cleaver Bank, North Dogger Bank, close to the English Channel to the Norfolk Banks, and off of Belgium and the Netherlands.[143,148]
Other demersal species	The most suitable areas for other demersal species to spawn are in the north of Dogger Bank, Cleaver Bank, the Firth of Forth, and off of Vesterhavet and Holderness.[148]

Table 2. Documented nursery areas of commercial species in the North Sea.

Anglerfish (*Lophius piscatorius*)	Some nursery areas have been documented in northern Scotland. [136,140]
Blue whiting (*Micromesistius poutassou*)	Although there are some nursery areas in the northern North Sea (from around Shetland to Norway Bank),[140] juveniles mainly aggregate outside the North Sea.[149]
Cod (*Gadus morhua*)	Juveniles aggregate in Moray Firth, the Firth of Forth, the area from Holderness to Newcastle, and from northwest Dogger Bank to the Great and Lesser Fisher banks.[140,146]
Hake (*Merluccius merluccius*)	Nursery areas for hake are widely distributed (with the highest density of juveniles in the Moray Firth).[140]
Herring (*Clupea harengus*)	Juvenile aggregations have been reported from the Firth of Forth, Moray Firth, and waters from the eastern Dogger Bank to the Fisher Banks.[140,145]
Horse mackerel (*Trachurus trachurus*)	Nurseries of horse mackerel are widely distributed in the North Sea.[140,141,150]
Ling (*Molva molva*)	Juveniles of this species are found in the Firth of Forth, Moray Firth and south of Shetland.[140]
Mackerel (*Scomber scombrus*)	The main nursery areas for mackerel are outside the North Sea, to the north of Ireland and Scotland.[140] Juveniles have also been documented across the northwestern part of the North Sea, extending to waters of the Netherlands (e.g., Oyster Grounds) and western Denmark (e.g., the Great and Lesser Fisher Banks).
Plaice (*Pleuronectes platessa*)	Juvenile plaice are found in the southern coastal areas of the North Sea, from Newcastle to the Netherlands,[140,151,152] with additional locations in coastal Scottish waters.[140,153]
Sandeel (Ammodytidae)	Nursery areas for these species are similar to their spawning grounds. [140,144,145]
Sole (*Solea solea*)	The North Sea nursery area of this flatfish lies in the area from the English Channel to the southern North Sea and Dogger Bank.[140,147]
Whiting (*Merlangius merlangus*)	Nursery areas have been found in Moray Firth, the Firth of Forth, waters north of Flamborough and Dogger Bank.[140]

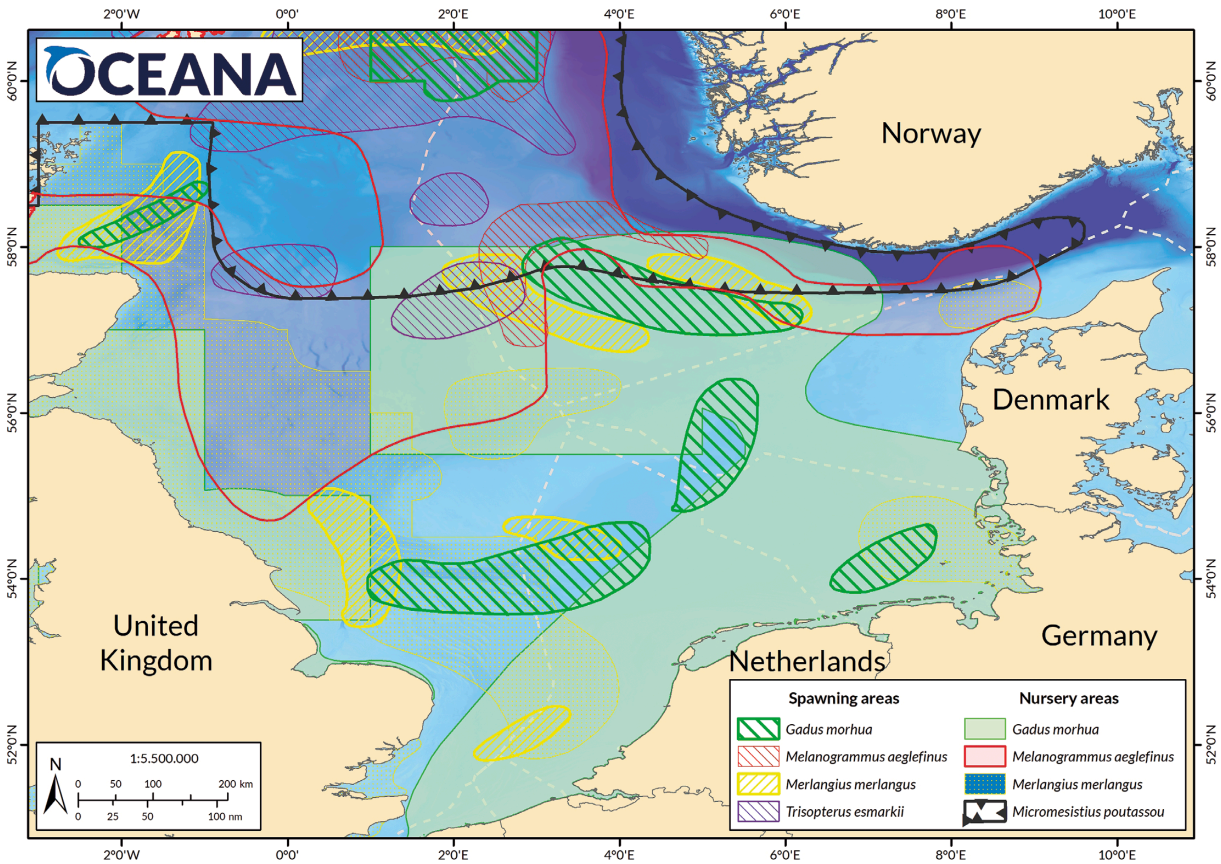
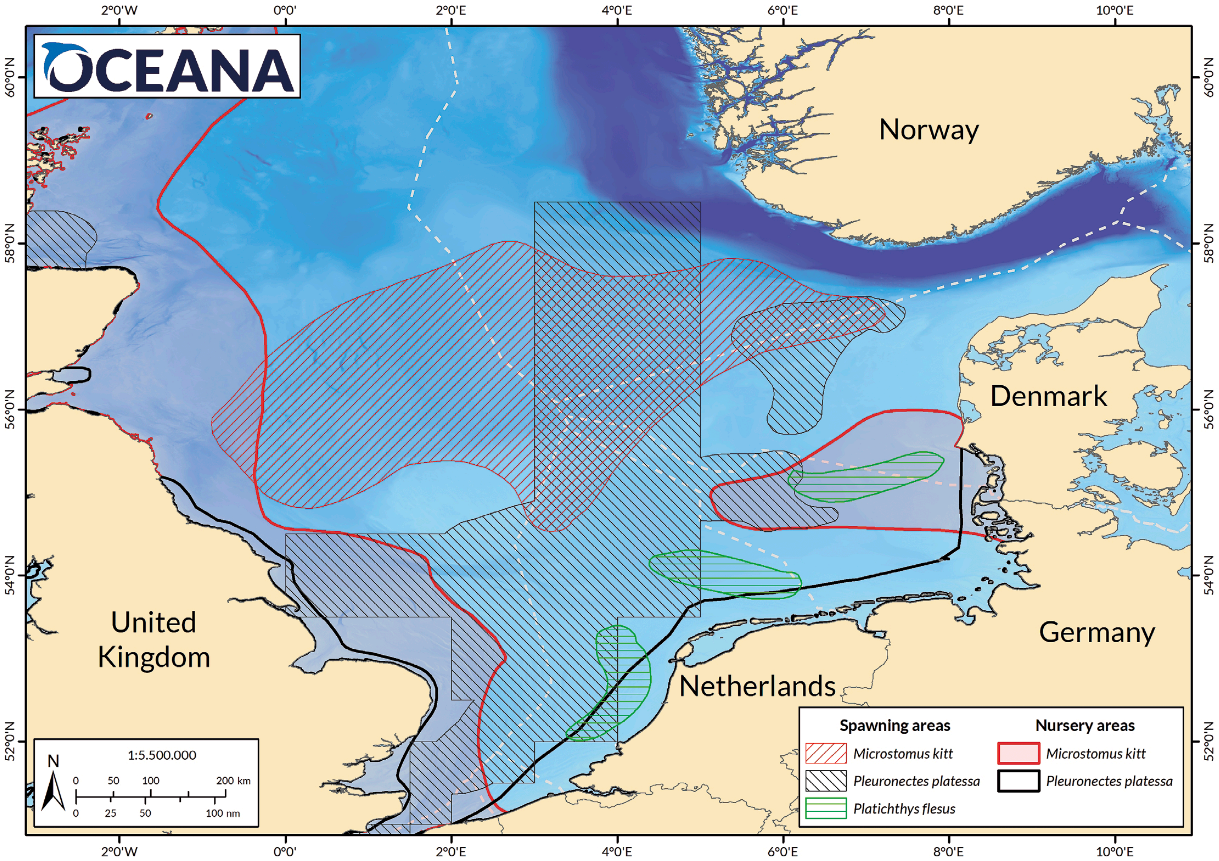


Figure 4. Key known spawning and nursery areas for gadoids in the North Sea.[140,141,154,155,156,157]

Haddock (*Melanogrammus aeglefinus*) in the Norwegian Trench © OCEANA

Ballan wrasse (*Labrus bergylta*)
in the Norwegian Trench.

Figure 5. Key known spawning and nursery areas for flatfishes in the North Sea.[140,141,154,155,156,157]



Common dab (*Limanda limanda*) in Vesterhavet, Denmark. © OCEANA/ Juan Cuetos

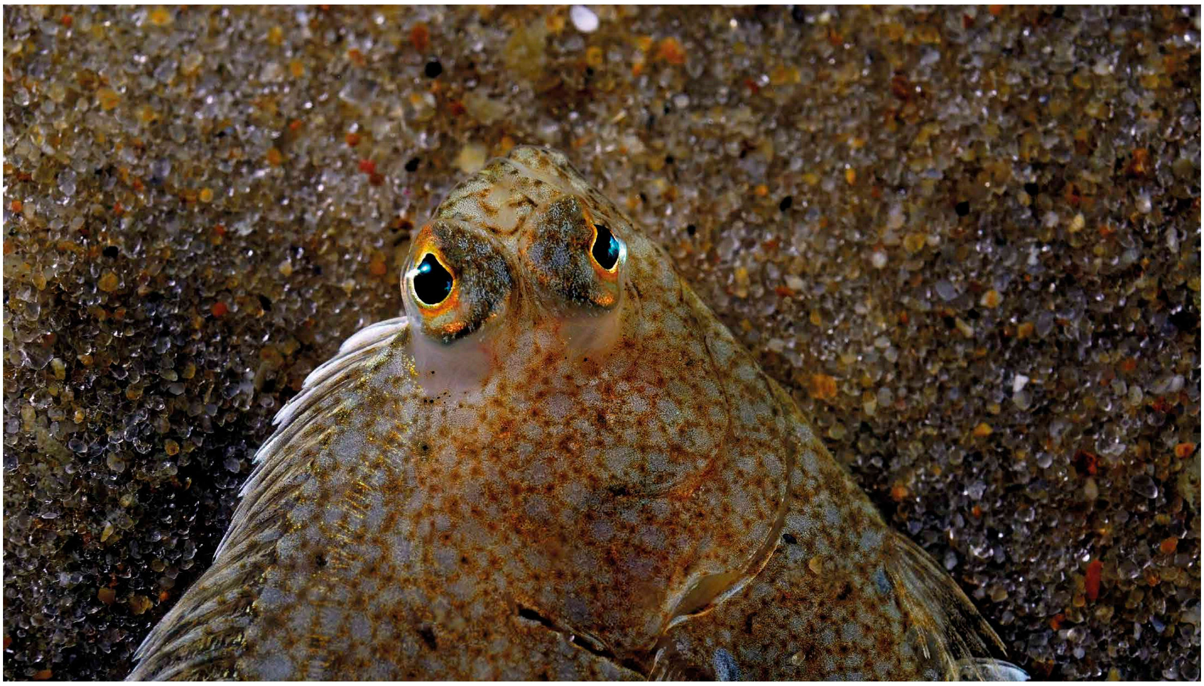
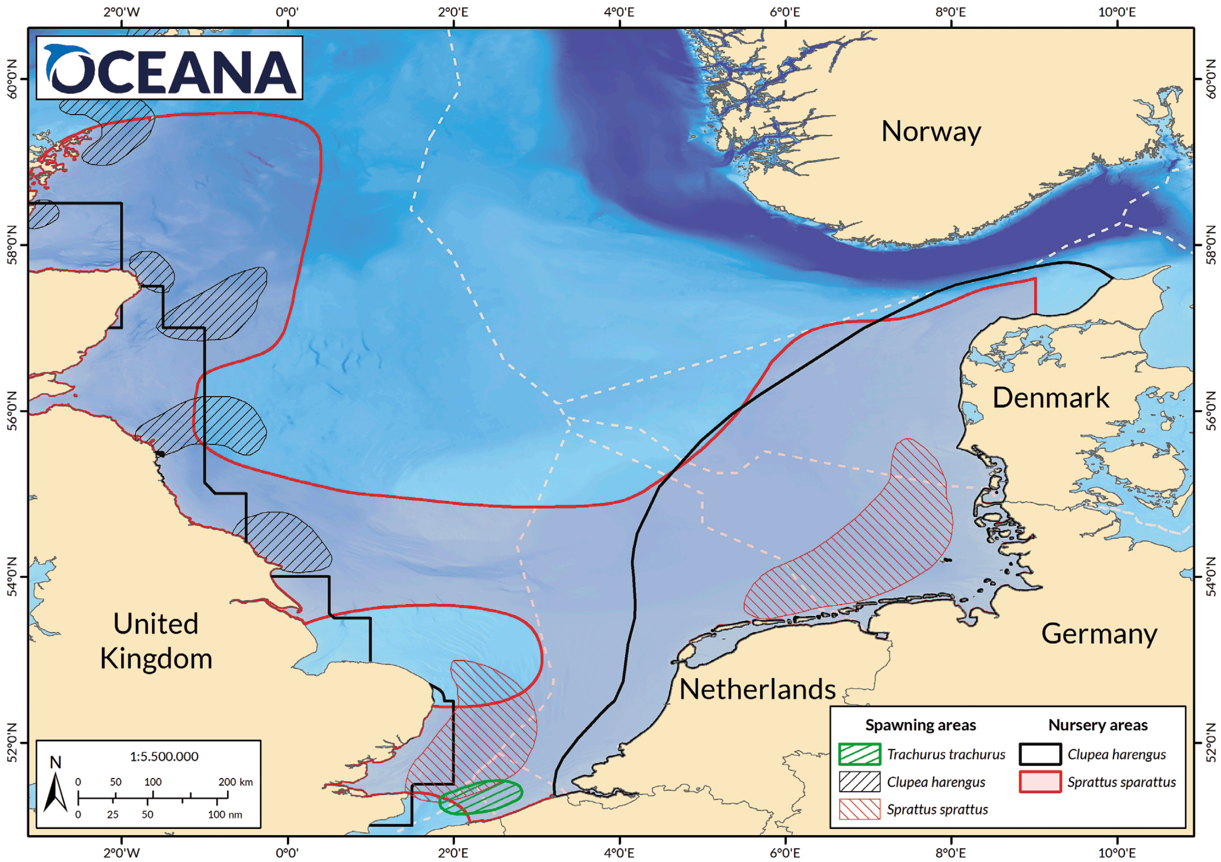


Figure 6. Key known spawning and nursery areas for small pelagic fishes in the North Sea.[140,141,154,155,156,157]



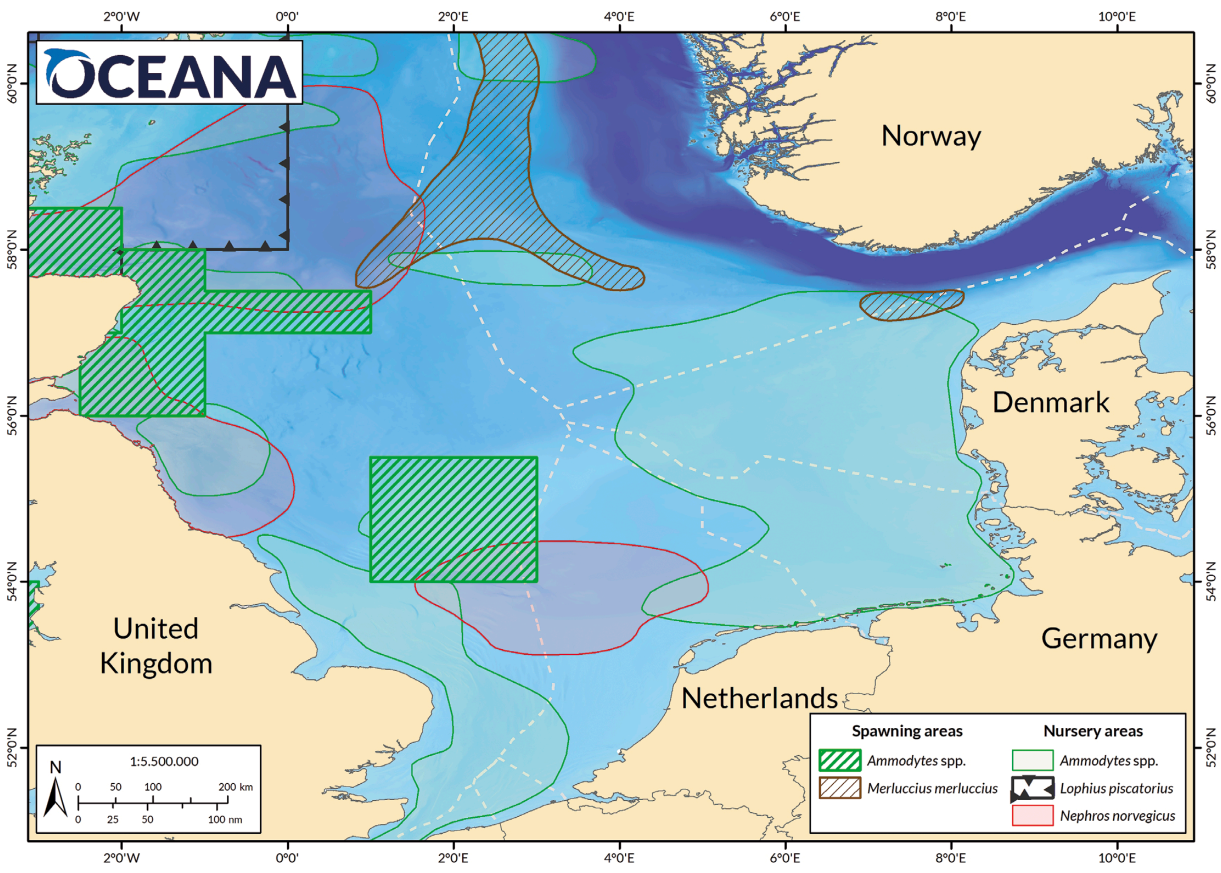


Figure 7. Key known spawning and nursery areas for other demersal species in the North Sea.[140,141,154,155,156,157]

Oceana has compiled the available spatial data on spawning and nursery grounds of commercial species in the North Sea. An interactive map of these areas can be viewed at: http://arcg.is/0O8qSK

Distribution of commercial species observations

During 2016 and 2017, Oceana carried out two eight-week research expeditions in the North Sea. The main objective was to collect data about seafloor habitats and species in areas of potential ecological importance, in the interest of strengthening the network of MPAs in the North Sea. Surveys were carried out in the waters of five European countries: Denmark, Germany, the Netherlands, Norway, and the United Kingdom, using visual methods (i.e., filming with a remotely operated vehicle (ROV) and by a team of professional SCUBA divers) and infaunal grab sampling. In total, Oceana surveyed 25 areas covering approximately 111 000 km^2 (see below). The ROV completed over 100 km of seabed surveys and filmed an area of close to 190 000 m^2. Data collected included information about the distributions of commercial species, including eggs and juveniles.

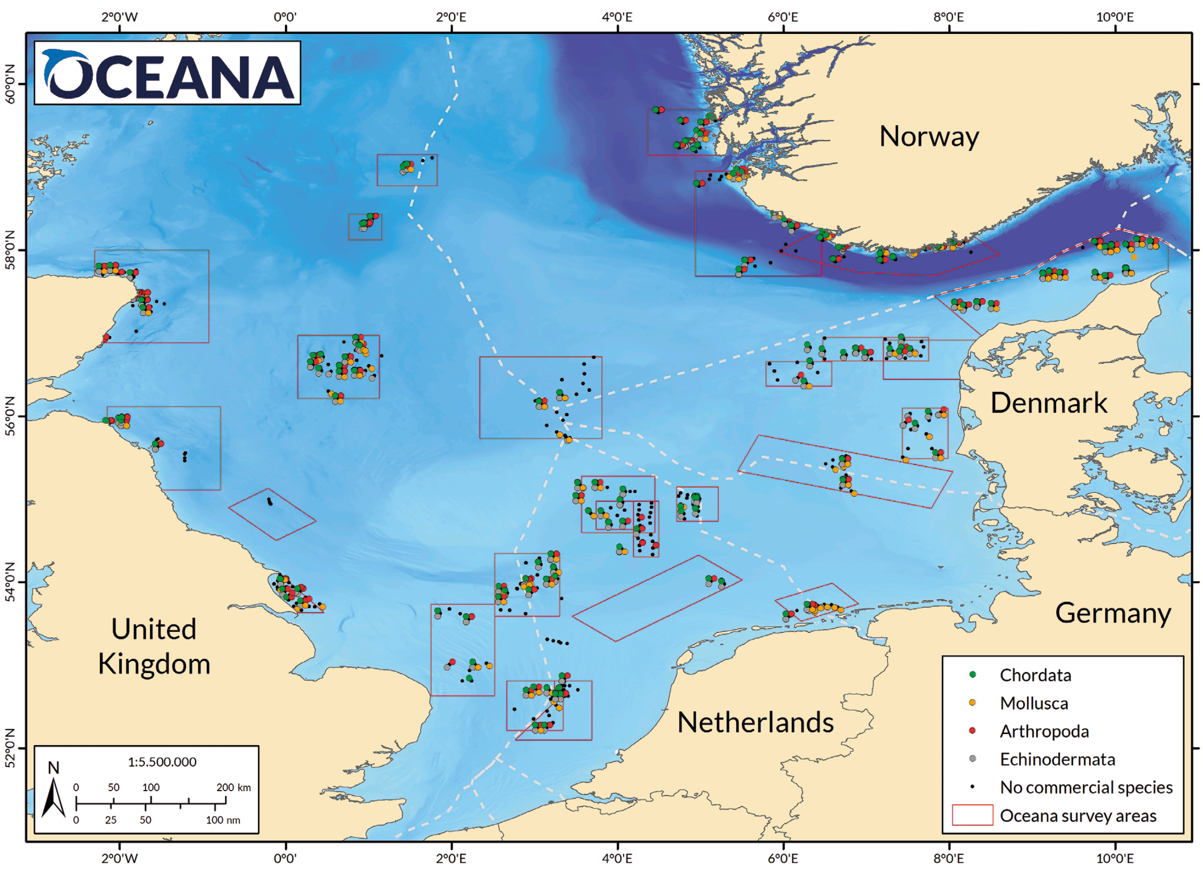
Both expeditions were carried out in summer (between July-August 2016 and 2017) and, therefore did not coincide with the peak abundance of juveniles for various species.[140,141] Nevertheless, the data collected provide information about the presence, habitat preferences and behaviour of commercial species, which can help to increase our knowledge about their biology.

Although the information collected is not enough by itself to allow for the identification of EFHs, the direct observation of those individuals and species can allow us to identify patterns that are important for their presence.

In total, more than 13 000 commercial individuals were recorded. The highest number and diversity of commercial species observed was in Norway, accounting for 23% of all sightings (Figure 8). Other important areas were Cleaver Bank, Brown Bank, the area between Jutland Bank and Lesser Fisher Bank, the deep Danish waters of the Skagerrak, Devil's Hole, Holderness, and Aberdeenshire.

Most of the commercial species documented are managed with Total Allowable Catches (TACs) in the European Union, as shown in Figure 9.

Figure 8. Distribution of observations of commercial species during the 2016 and 2017 Oceana North Sea expeditions.[155,156,157]



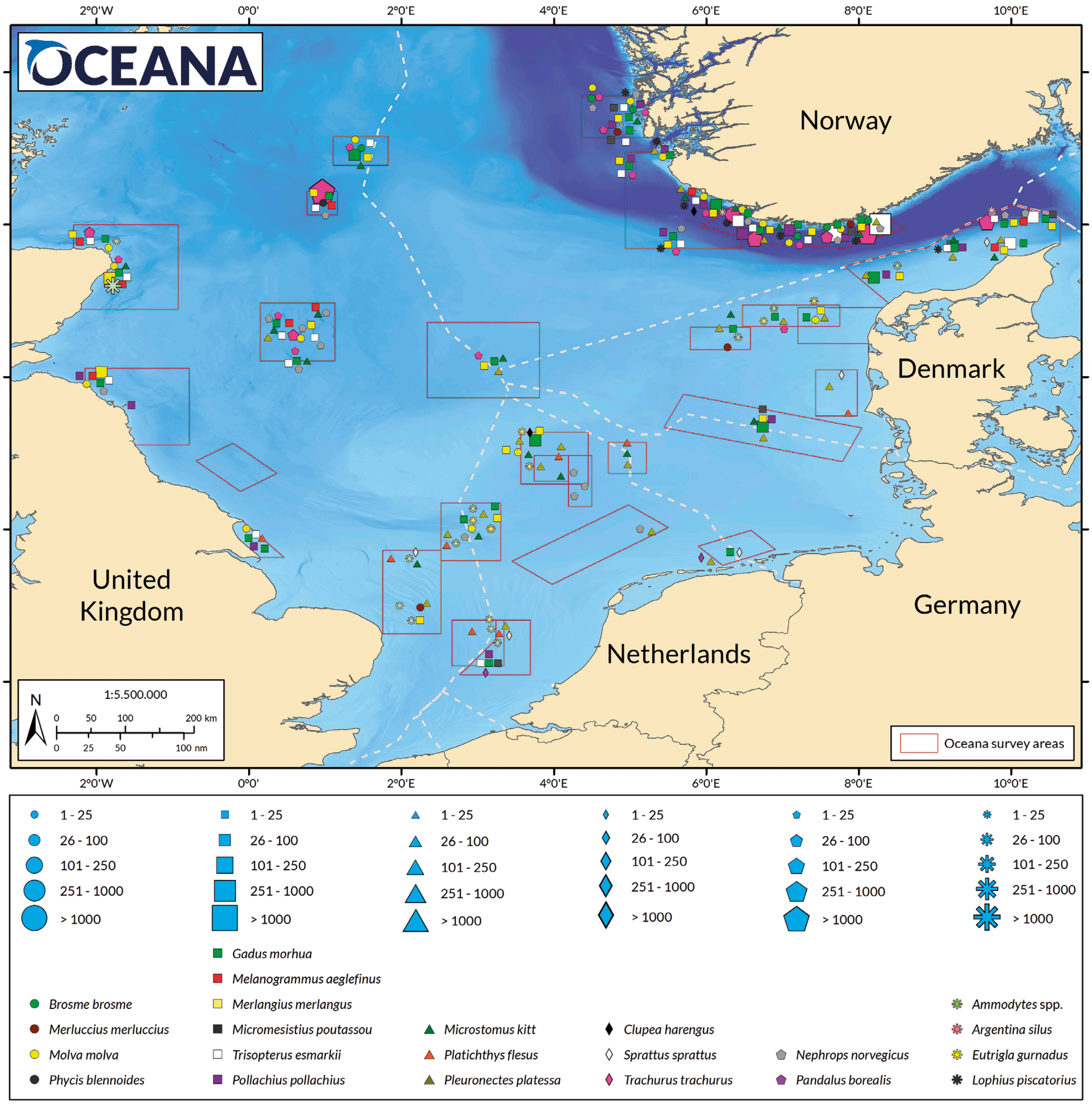


Figure 9. Distribution of observations of those commercial species managed under TACs, during the 2016 and 2017 Oceana North Sea expeditions.[155,156,157]

Juveniles of commercial species were mainly concentrated in the Skagerrak and the northern North Sea, with the highest abundance by far in Norway (76%), followed by the deep Danish waters of the Skagerrak, Devil's Hole, Jutland Bank, Lesser Fisher Bank, Holderness and Aberdeenshire (Figure 10).

Juveniles of gadoids such as cod, haddock or whiting were especially abundant in the south of Norway and to the north of Denmark, although they were also found in Scotland and Holderness, with isolated sightings in the Netherlands. Juvenile flatfishes, such as dab, American plaice and lemon sole were common in Scottish offshore waters, like Braemar Pockmarks, Scanner Pockmark, and Devil's Hole.

Poor cod (*Trisopterus minutus*) in the Norwegian Trench.
© OCEANA/ Carlos Minguell

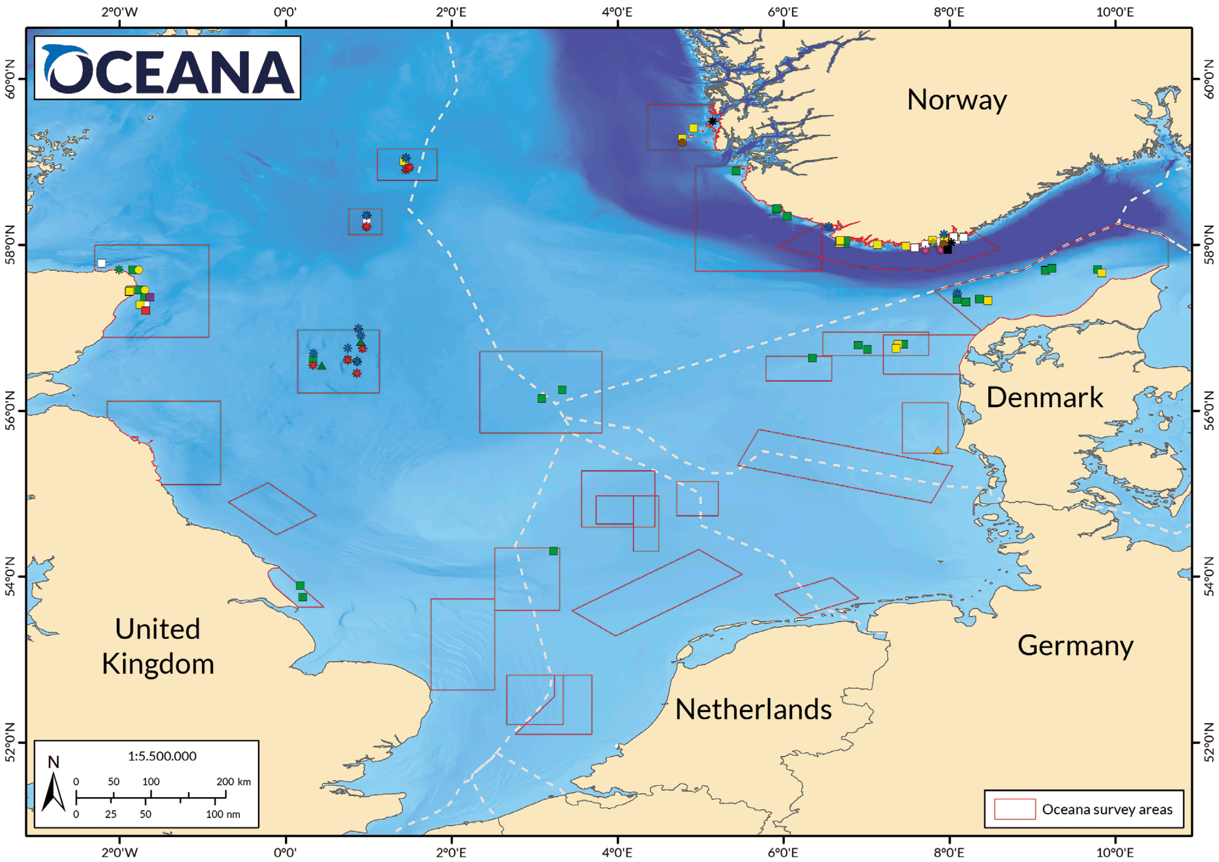


Figure 10. Distribution of juvenile fishes recorded during the 2016 and 2017 Oceana North Sea expeditions.[155,156,157]

It is interesting to note that most sightings of juveniles were in areas with rocky or coarse sediment bottoms, with the exception of Devil's Hole (Figure 11). This was the case for cod in particular, as is described below.

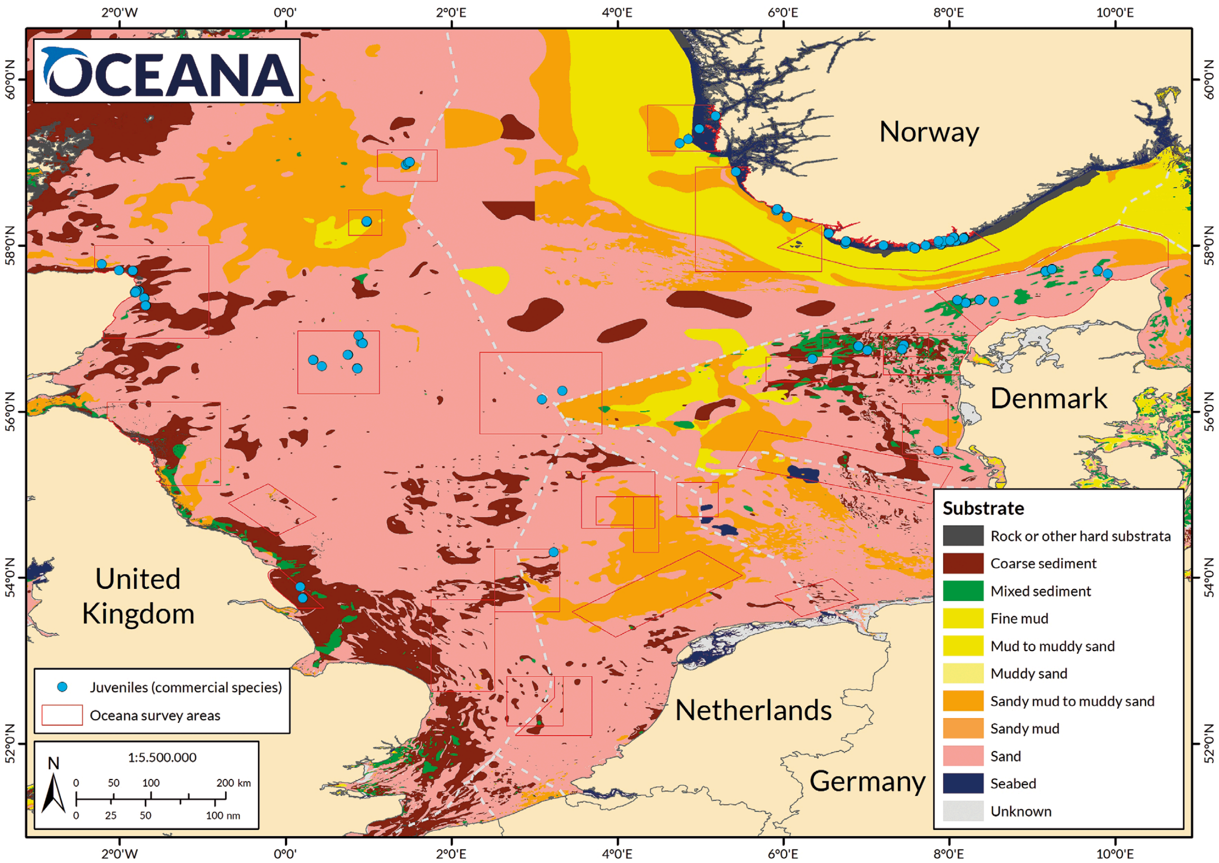


Figure 11. Records of juvenile commercial species from the 2016 and 2017 Oceana North Sea expeditions, in relation to seabed substrate.[155,156,157]

Edible crab (*Cancer pagurus*) on a fish pot in the Norwegian Trench. © OCEANA/ Juan Cuetos

Juvenile cod on rocky bottoms

Small gadoids, mainly cod, were found in rocky and mixed sediment bottoms. These juveniles find shelter and food among rocks and stones that normally coincide with coastal areas and frontal areas where copepods, cladocerans and mysidaceans are abundant.[158,159,160]

This behaviour has also been observed in relation to artificial hard substrata like offshore wind farms,[161] which may be related to food availability as well as serving as shelter against currents and predators.

Juvenile cod appear to attain higher densities, survival, and growth rates in more structured habitats, like reefs and seagrass meadows of *Zostera marina*,[162] which is considered a nursery habitat for this species.[163] Unfortunately, since 1930 the distribution of this aquatic plant has declined by 90% in the North Atlantic[164] and its coverage is continuing to decrease.[165] Eelgrasses have declined across all the North Sea and they are considered threatened.[166]

In Atlantic offshore areas with no rocky structures, gravel habitats support higher densities of juveniles than do soft bottoms.[167,168] More complex areas with the densest epifauna on cobbles have been found to serve much better as refuges for juvenile cod, reducing mortality by predation.[169]

During Oceana's surveys in 2016 and 2017, juvenile cod were mainly recorded among rocks, cobbles and mixed sediments, like in the coastal zone of Norway and Holderness, and the offshore reefs of Denmark (Figure 12). The only exceptions were in Devil's Hole and the transboundary area at the centre of the North Sea. Juvenile gadoids were also recorded in these offshore areas, despite the fact that there were almost no rocks or coarse sediments present (Figure 13).

Figure 12. Juvenile cod
(*G. morhua*) among cobbles
in Norway and Scotland.

Figure 13. Juvenile cod
(*G. morhua*) on muddy bottom in
the transboundary area in
the centre of the North Sea.

The seabed in the North Sea is predominantly composed of sandy and muddy bottoms,[155,170,171,172] while rocky bottoms and coarse sediments are scarce and only located in a few places. Due to the lack of these hard substrata and coarse sediments, and the disappearance of other key habitats, like reefs and seagrass meadows in the North Sea, there must be a special plan for the protection of the remaining habitats with rocks, reefs and coarse sediments. Such habitats appear to be important not only for biodiversity in general, but also specifically for juvenile gadoids.

Edible crab in Norway

The mating and spawning seasons are the two most vulnerable periods for edible crab (*Cancer pagurus*), because they aggregate in large numbers.

The mating behaviour of *C. pagurus* has been studied for many years. Males usually attend females prior to moulting their shells,[173] which is the time when copulation can occur. During spring and summer, they aggregate for mating[174] which makes them more susceptible to capture.

Males and females stay close to shore for feeding and mating, but the berried females migrate to offshore areas for spawning,[175] normally in fall-winter.[176] This represents another risky moment for the species, because aggregations of egg-carrying females are also more vulnerable to overfishing.[177]

To avoid overfishing of edible crab, scientists have proposed management measures that include closed seasons in different parts of the Atlantic, minimum landing sizes by gender, and a prohibition on catching moulting females.[178,179]

Figure 14. Edible crab (*C. pagurus*) aggregation in southern Norway.

Edible crabs appear to exhibit gender-specific habitat preferences, with males on rocky bottoms and females in sandy beds, as well as age-dependent preferences. For example, juvenile edible crabs are mostly found in the intertidal zone.[177,180]

In most of the areas surveyed by Oceana in the North Sea, edible crabs were hidden under rocks and appeared to avoid being too openly exposed. However, in nearshore rocky bottom areas in Norway, large aggregations of edible crabs were observed on top of rocks. Such aggregations could relate to mating behaviour, in which males compete and fight for females.[177]

During the mating season, both males and females meet in rocky areas, and they are especially vulnerable to fishing. Such coarse bottoms seem to play an important role for edible crab, similar to the case described above for cod juveniles. As such, these areas merit special consideration for protection, as a tool to support fisheries conservation and management of the species.

Edible crab in the EU is not subject to catch limits, nor is there a management plan for the species, despite the EU requirement under the CFP that all commercial stocks must be managed to ensure their long-term sustainability. The UK evaluation of the status of this stock concluded that the exploitation rate in the southern North Sea is high, and that fishing levels in the Central North Sea are above levels that could support the maximum sustainable yield. In both cases, spawning stock biomass is lower than recommended.[181]

Norway lobster

The distribution of Norway lobster (*Nephrops norvegicus*) is known to be constrained to specific muddy areas where the granulometry and level of compact mud is suitable for individuals to create their burrows.[182]

There is still a lack of information on the pelagic dispersal and settlement of Norway lobster larvae and on the biology of juveniles. Due to predation, advection and turbulent diffusion, not all of the larvae manage to settle in suitable areas (muddy beds). Even if they do reach these habitats, levels of larval and juvenile mortality can be high.[182]

Those juveniles that do survive to attach their burrows to those of adults, forming some complex underground structures.[183] Juveniles may be less vulnerable to fishing catches than adults, due to lower activity outside the burrow.[184,185]

EFH for larval and juvenile lobsters are the same that those for adults. Therefore, the protection of Norway lobster EFH implies a potential conflict, in that the EFH overlaps with Norway lobster fishing grounds. It is also important to understand that for this species, maintaining the integrity of the seabed is the best strategy for protecting juvenile EFH.

During the 2016 Oceana North Sea expedition, in one location in the Dutch waters of the Oyster Grounds, close to 50% of the sightings of *N. norvegicus* were of juveniles. This observation could indicate that while previous studies have pointed out that juveniles live together with adults, the density of juveniles may be higher in some patches, or in specific areas within patches.

Figure 15. Juvenile Norway lobster (*N. norvegicus*) in Oyster Grounds, the Netherlands.

Although the status of several stocks of *N. norvegicus* in the North Sea are above MSY, according to ICES,[186] the status of this southern stock is unknown, and reference points have not been defined. Data on discards are only partially available for the last three years, and represent, on average, more than one-third of the total catches. Since 2015, catches of Norway lobster in the southern North Sea have been 130% higher than those recommended by scientists.

Catches of Norway lobster must clearly be reduced to those levels recommended by ICES and technical measures should be approved to reduce the bycatch of juveniles. A more detailed study of the stage-specific habitat preferences of this species would contribute to improving its management, by identifying the most vulnerable areas and informing management measures to protect juveniles from habitat damage and bycatch.

Spatial planning and existing closed areas

Various areas of the North Sea have already been fully or partially closed to some fisheries, in order to protect nursery areas, avoid high rates of bycatch, protect 'forage fish', avoid catches of specific species, or achieve a balance between industrial and coastal fishing fleets.[187,188] In addition, there are many other local-scale zones that are closed seasonally. Many of these closures can be considered as FSRAs, so long as adequate management measures are in place and enforced.

Some of the most important such closures are listed in Table 3.

Table 3. Main spatial closures for fisheries in the North Sea.

Fisheries closure	Reasons
Sandeel fisheries in Scotland	Closed for recovering stocks of sandeel (Ammodytidae) from severe declines, which in turn affect all those organisms that feed on these species (such as seabirds, cod, etc.).
Sprat fisheries off eastern Scotland	To protect juvenile herring that are often caught as bycatch.
Sprat and herring fisheries off Jutland	To protect juvenile herring and to improve herring fisheries management.
Norway pout, to the northeast of Scotland	To protect other roundfishes that are normally caught as bycatch.
Shetland Box	To protect stocks that are important for local fisheries and to reduce the number of large demersal fishing vessels.
Plaice Box	In coastal waters of Denmark, Germany, and the Netherlands, to reduce discards of undersized *Pleuronectes platessa* by large vessels.

There are many other seasonal closures or areas where specific fishing gears are not allowed, which can also be considered as management tools to improve fisheries and protect EFH.

Protect biodiversity, enhance resilience and recover productivity

EFH can occur in areas where oceanographic processes, fronts, primary productivity, sediment granulometry or other physio-chemical parameters provide suitable and appropriate conditions for the development of larvae and juveniles. In some cases, these areas do not comprise visible structures, but in many others, they coincide with habitats that are not only vital for commercial species, but for biodiversity in general.

In the North Sea, an array of habitats that are threatened, in decline, or that play a vital ecological role, can also represent EFH.[189,190] and should therefore be prioritised for protection. Examples of such habitat types are described below and shown in Figure 17.

Worm reefs and aggregations

Some of the most important worm aggregations in the North Sea are those formed by the colonial polychaete worms *Sabellaria* spp. Reefs formed by ross worm (*S. spinulosa*) are included in the list of Threatened and/or Declining Species and Habitats of OSPAR,[7] but their protection is still is far from being effective.

One of the main reasons underlying this weak protection is that there are still areas where worm aggregations are yet to be discovered, as highlighted by Oceana's discovery of a *S. spinulosa* reef in the Dutch waters of Brown Bank during its 2017 North Sea expedition.[191] At the same time, governments tend only to protect worm reefs if they cover a wide area and have a high density. This political behaviour ignores the fact that the patchy distribution of reefs is due to the same threats that have led to the inclusion of these bioconstructions in the OSPAR List. Protecting only the densest and most extensive reefs does not permit more damaged reefs to recover by eliminating the threats that have destroyed them.

Sabellaria reefs serve as a feeding ground for commercial juvenile flatfishes like Dover sole, dab and plaice,[192] as well as for shore crab (*Carcinus maenas*),[193] common starfish (*Asterias rubens*) and pink shrimp (*Pandalus montagui*). The loss of *Sabellaria* reefs could help to drive further changes in the surrounding substratum, adversely affecting herring spawning grounds.[194]

Other important habitats are those formed by sand mason worm (*Lanice conchilega*) and other tube annelids like *Polydora ciliata*. It has been argued that sand mason aggregations must also be considered as reefs, due to their ecological role in the benthic ecosystem.[195]

Mollusc reefs

Unfortunately, both oyster reefs and horse mussel beds have nearly disappeared from the North Sea.[111,196] During Oceana's surveys, various individuals of these species were observed, but only in isolation or in small groups.

Flat oyster (*Ostrea edulis*) was found in the areas of Oyster Grounds, Brown Bank, Cleaver Bank, and Norfolk Banks, while horse mussel (*Modiolus modiolus*) was found in nine of the 25 areas surveyed, including Northern Denmark/

Skagerrak, Jutland Bank, the transboundary area in the middle of the North Sea, around the Tess Estuary, Holderness, Aberdeenshire, close to the Firth of Forth, and Brown Bank. In addition to some locations between the Shetland and Moray Firth, the waters around Holderness are one of the sites in the North Sea where horse mussels have been found more recently.[196]

Horse mussel beds are considered important for commercial species like whelk (*Buccinum undatum*), queen scallop (*Aequipecten opercularis*), and Atlantic spider crab (*Maja brachydactyla*).[197,198] Oyster reefs, and even their remains, can be used as nursery habitats by other mollusc species, like mussels or cuttlefish.[190,199]

Coral reefs and gorgonian forests

Coral gardens are another habitat included in the OSPAR List that also represent important spawning and nursery areas, for species like *Phycis blennoides*, *Gadus morhua*, *Melanogrammus aeglefinus*, *Lophius piscatorius*, *Sebastes* spp., and *Microstomus kitt*.[200,201,202]

During Oceana's North Sea expeditions, several areas were found with coral gardens formed by gorgonians like *Paramuricea placomus*, *Swiftia dubia*, and *S. osea*, all of which were documented from rocky bottoms in Norwegian waters. On muddy bottoms, bamboo corals (*Isidella lofotensis)* and sea pens (i.e., *Funiculina quadrangularis*, *Kophobelemnon stelliferum*, *Pennatula rubra*, *Halipteris finmarchica*, *Virgularia mirabilis*, *V. tuberculata, and Protoptilum carpenteri*) were found in Norwegian, Danish, and UK waters. They were most abundant in the Norwegian Trench and the Skagerrak, but were also observed in Devil's Hole.

In addition to the species highlighted, cold-water coral reefs formed by *Lophelia pertusa* and *Madrepora oculata* are also found in the North Sea. They occur primarily in the northern North Sea and in the Norwegian fjords, with some additional locations in Skagerrak.[203] Apart from their importance as biodiversity hotspots,[204] they are considered to play an important role as habitats for fish species.[205,206]

Sponge aggregations

Large sponge aggregations, like those of habitats dominated by *Geodia* spp., occur in Norwegian waters. These aggregations also comprise many other sponge species, like *Mycale lingua*, *Phakellia* spp., *Stryphnus* sp., *Oceanapia robusta*, and *Craniella* spp. They can also be mixed with other important habitats, like coral gardens.

The role of such aggregations for enhancing biodiversity and acting as nursery areas for commercial has previously been recognised.[207,208,209] During the Oceana North Sea expeditions, many species of fishes and crustaceans were recorded among these sponges, including juveniles of commercial species, such as cod, redfish, Norway pout and edible crab.

Figure 16. Norway haddock (*Sebastes viviparus*) on cup sponge.

Macroalgal communities

Communities of large algae, like kelp forests, create high-value habitats in wave-exposed rocky bottoms, from the coast down to nearly 80 m depth.[210] In the North Sea, such communities are more abundant in the northern part, from Scotland to Norway, and are mainly found in coastal waters.

Kelp forests represent one of the most productive marine habitats in the world.[211] In the North Sea specifically, kelp forests represent a very important habitat, comprising species that include *Alaria esculenta*, *Laminaria digitata*, *L. hyperborea*, *L. ochroleuca* and *Saccharina latissima*. They play a significant role as nursery habitat for many organisms, including fish like *Labrus bergylta*, *Gadus morhua* and *Myoxocephalus scorpius*.[212,213,214]

Unfortunately, kelp forests globally – and in Europe – are in decline.[210,215] As a result of this worrying trend, kelp forests in the North Sea are in the process of being listed as threatened and/or declining by OSPAR. Some species have decreased in specific areas of the North Sea, like *Saccharina latissima* in Skagerrak[216] and *L. hyperborea* in UK waters,[217] while others such as *L. digitata* have shown a more general decline.[210] Meanwhile, warmer-water species like *L. ochroleuca* are spreading northwards, and shifting kelp forest composition.[214]

Seagrass meadows

Eelgrass (*Zostera marina*) meadows were once common in the North Sea, but after die-offs in the first decades of the twentieth century, followed by further declines, they have almost disappeared from this sea.[166] Only a few locations with eelgrass meadows remain, such as in the Wadden Sea, but their abundance is very far below historical levels.[218,219]

This habitat is known to be important for many species, because it acts as feeding and nursery grounds for commercial species,[213,220,221] including cod.[222]

Eelgrass (*Zostera marina*) meadow in the Norwegian Trench. © OCEANA/ Carlos Minguell

Other key habitats

Various other habitats must also be considered for their potential importance as EFH. For example, geogenic habitats (e.g., rocks, boulders, stones, cobbles and gravel beds, pockmarks) can play a significant role, such as those described in the case of cod (above).

Some sessile and mobile species, when in large aggregations, can also structure the seabed by creating habitats or 'microhabitats' that are used by many organisms. This is the case for some tunicates (e.g., *Polycarpa* sp., *Molgula manhattensis*), echinoderms (e.g., *Gracilechinus acutus*, *Conocrinus lofotensis*, and various brittle stars), stalked bryozoans (e.g., *Kynetoskias* sp.), giant foraminifera (e.g., *Pelosina arborescens*), and brachiopods (e.g., *Novocrania anomala*, *Terebratulina retusa*).[223,224,225,226]

Aggregations of echinoderms, brachiopods, tunicates, bryozoans and other benthic invertebrates are known to provide feeding, spawning and/or nursery areas for commercial species worldwide.[130,227,228,229] As such, they have been recognised not only as EFH , but also as vulnerable marine ecosystems (VMEs).

Artificial reefs as 'oases'

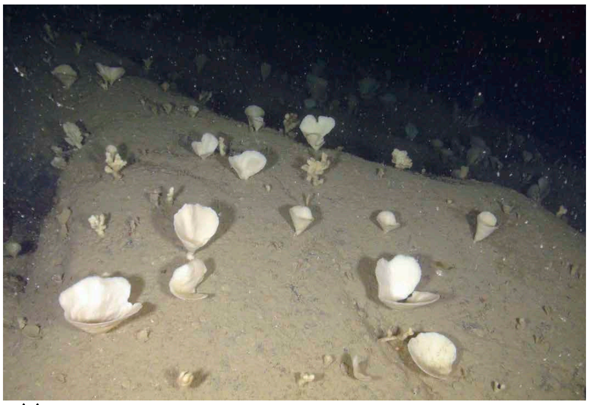
Recent years have seen an increase in the addition of new artificial hard substrates to the North Sea, in the form of platforms, wind turbines, and rocks. These additions have altered the biodiversity and productivity in local areas,[3] and in some cases have enabled threatened and protected species to colonise or recolonise areas.[230]

Although they cannot be considered 'the solution' for recovering North Sea biodiversity, these artificial structures can play an important role, in the context of a lack of natural reefs, in some cases due to destruction by human activities. They provide new substrata and shelter for species that have disappeared from other places in the North Sea, and they serve as features where large individuals of commercial species congregate.

For decades, wrecks have played the role of artificial reefs in the North Sea,[231,232] enhancing biodiversity and providing shelter and substrata for many different organisms. Although they can act as complementary tools for managing the already altered marine environment, they must never replace protection and restoration of natural geological and biological reefs.

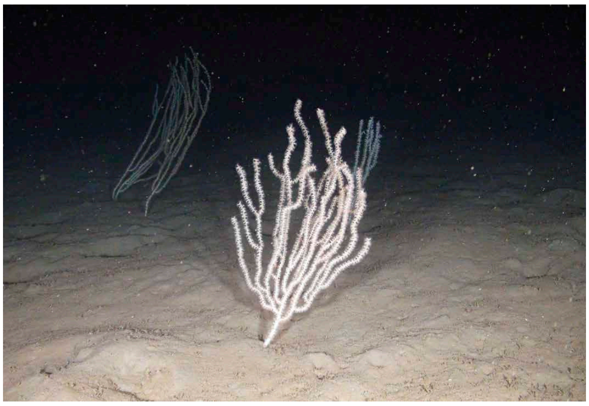
(a) Gorgonians (*Paramuricea placomus*)

(b) Large sponges (*Geodia* sp.)

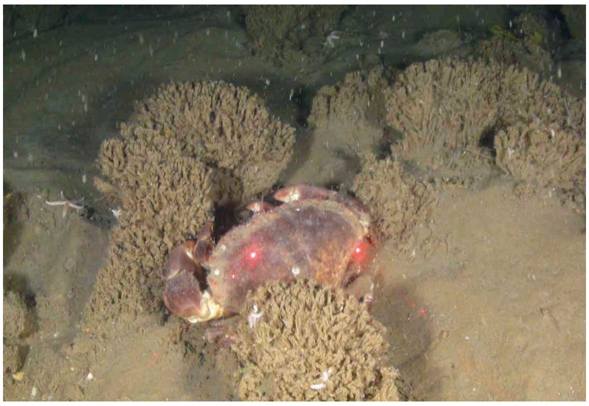


(c) Cup sponges (*Phakellia ventilabrum*)

(d) Sea pens (*Pennatula phosphorea*)

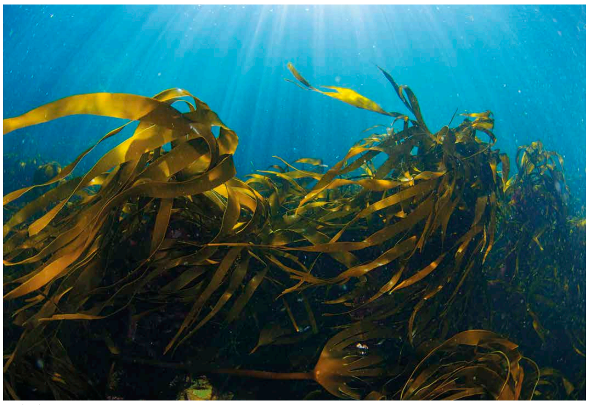


(e) Bamboo coral (*Isidella lofotensis*)



(f) Ross worm reef (*Sabellaria spinulosa*)

(g) Sea squirt bed (*Polycarpa* sp.)



(h) Kelp forest (*Laminaria digitata*)

Figure 17. Key habitats in the North Sea.
(h): © OCEANA/ Juan Cuetos

CONCLUSIONS

It has been estimated that the maximum sustainable yield (MSY) of fisheries in the North Sea, if all stocks were exploited at sustainable levels, could reach some 3.4 million tons – more than double the amount of current catches.[10] The increase in biomass at sea that would underlie this increase in catches would be significant: up to 11 million tons.

Unfortunately, under the current situation, many stocks remain subject to unsustainable exploitation.[17] There is clearly substantial room for improvement in North Sea fisheries, if all stocks are to be managed in line with scientific recommendations. In order to achieve proper, science-based management, the governments of all countries whose fleets fish in the North Sea must commit to fisheries management measures and limits that will recover stocks to levels which can produce MSY.

One key tool for achieving this goal is by managing commercial species in accordance with broader ecosystem needs and dynamics, under an ecosystem approach to fisheries management (EAFM), also known as ecosystem-based fisheries management (EBFM). As Zhou *et al.* explain:

> *"This concept (EBFM) may require reducing exploitation rates on certain target species or groups to protect vulnerable components of the ecosystem. Benefits to society could be maintained or even increased because a greater proportion of the entire suite of harvested species is used."* [233]

As these concepts clearly state, fisheries cannot be managed without considering the environment in which the activity is going on; therefore, fisheries management must also address the inter-relations among species, and between species and their habitats.

Under an ecosystem-based approach, one critical element for managing fisheries is the protection of EFH, to allow stocks to recover. Despite the fact that the CFP emphasises the importance of FSRAs, none have yet been specifically identified or designated as protected under that framework. To reach the estimated 10-20% of coverage that experts have recommended,[133] European countries must begin immediately.

These FSRAs must be added to the European network of marine protected areas (MPAs). The protection of some key habitats, like worm reefs, sponge aggregations, and corals gardens, can serve both to enhance biodiversity and safeguard important nursery and/or spawning grounds. These habitats, once protected, can therefore be used as indicators and stepping stones towards achieving more profitable, and socioeconomically and ecologically sound fisheries.

Areas of EFH in the North Sea that have already been identified can be easily used in combination with known distributions of key habitats, to identify locations spots that meet the requirements for EFH protection. Many of these key habitats are part of the benthic ecosystem, and their protection can contribute to the target of recovering fish stocks, and more broadly, to achieving 'good environmental status' in the North Sea.

There is hope for recovering seabed ecosystems. An analysis by Allen and Clark[113] estimated that with the complete cessation of demersal trawling, the benthic system could recover and go back to the original state within only five years. Obviously, as the authors mentioned, this would not be the situation in cases "where the deposit or filter feeder function is effectively removed, when a permanent change in the function of the benthic ecosystem may result." Similarly, the potential for recovery is much more limited in cases where human activities had damaged or removed habitats built by long-lived species.

Unfortunately, recovery has not happened in all the places where damaging fishing techniques has been banned or when protection and/or recovery plans have been approved.[234,235,236,237] By itself, protection is not enough to rebuild benthic ecosystems. Many species need to expand and recolonise to make up habitats that have declined during the past decades. MPAs are normally designated in those few areas where habitats and species remain in good condition, but the role of these protected areas must also be to replenish lost habitats, where possible.

If spatial protection efforts are to be successful, they should target not only those areas that have been relatively well preserved, but also those with a high potential for recovery. The presence, even in small densities, of habitat-forming species must be used to inform the selection of such areas. Such species include tube worms, large molluscs, corals, and sponges, as well as epibenthic fauna that create three-dimensional habitats in soft-bottom areas. These organisms, such as sea pens, bamboo corals, stalked bryozoans and crinoids, sea squirts, and brachiopods, play a significant role in structuring the seabed, yet tend to be less well protected.

A special plan must also be put in place to protect and recover reefs and reefs-like seabeds, like rocky and coarse sediment bottoms. These substrates are relatively scarce in the North Sea, yet play a critical role for supporting biodiversity, including key commercial species such as cod. While reefs are one of the features designated as protected in many North Sea MPAs, their status is poor in many areas, indicating that current measures of protection are insufficient. Expanding and strengthening the protection of these – and other critical – habitats in the North Sea will bring benefits both for biodiversity and for recovering the productivity of North Sea fisheries.

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