7.1 Celtic Seas ecoregion – Ecosystem Overview

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Key signals

Human activities and their pressures

- Fishing continues to be the main threat to ecosystem health. This is despite a decrease in fishing pressure since its peak in the late 1990s, as can be observed from two of its main pressures, i.e. a 35% reduction in physical seabed disturbance from 2003 to 2014 and species extraction. A further reduction in fishing pressure is likely to improve the status of the majority of ecosystem components.
- Land-based industry and wastewater continue to be important causes of pressures like marine litter, nutrient enrichment, and the introduction of contaminants from riverine run-off.
- Tourism and recreation were also found to contribute to marine litter.

State of the ecosystem

- Changes to the composition and distribution of plankton species in inshore areas have been observed. This may have implications for the frequency and intensity of harmful algal bloom events (HABs), which have caused widespread closures of shellfish farming areas and occasional mortalities of benthic organisms as well as farmed and wild fish.
- Fishing-induced physical disturbance is estimated to have resulted in an overall decrease of invertebrate benthic biomass of between 59% in offshore mud and 5% in sandy habitats compared to an unfished state. This impact is patchy and may be over 80% in the most heavily fished areas.
- The stock sizes of most groups of commercial species are now overall above levels that can provide the maximum sustainable yield (MSY); however, some individual species within these groups may still be below MSY levels.
- The numbers of many seabird species breeding in the ecoregion have been declining in the past decade. Widespread seabird breeding failures are frequent in the Celtic Seas and have been documented at 25% or greater since 2010. Declines may be related to prey availability and contaminant loads.
- The abundance of grey seals in the ecoregion is stable; there is little information on the overall trends of harbour seals and cetaceans.

Climate change

- Climate change is causing changes in water masses. Freshening of western subpolar north Atlantic waters is observed in deeper areas of the ecoregion. In addition, the warming of surface water temperature in shallow shelf regions has become increasingly seasonally stratified and nutrient-limited in some areas. This has already changed the spatial distribution of several plankton and fish species within the ecoregion and is likely to continue to do so.
- Climate change induced cascading effects are likely to occur throughout the ecosystem with consequences for the spatial distribution of fisheries. This should be considered in the marine spatial planning of infrastructure such as wind farms and the implementation of marine protected areas (MPAs).

Environmental and socio-economic context

- The current trend of increased fuel prices and resulting decrease of fishing with bottom-towed gears is likely to result in a further reduction of the extraction of demersal fish and disturbance of seabed habitats. If this also results in a shift toward less fuel-intensive fisheries such as gillnets, it is likely to result in increased bycatch risk of seabirds and marine mammals, including the longer-term effects from lost and abandoned fishing gear. Considering the ongoing downward trend in seabird numbers, such increased pressures on seabird populations should be avoided.

- Small-scale coastal fisheries contribute less than 10% of total fish landings but attract 22% of full-time equivalent (FTE) employment in the sector and 14% of total fisheries revenue. Coastal fisheries can therefore have a higher local social and economic importance than that expected by landings volume alone.

Ecoregion description

The Celtic Seas ecoregion covers the northwestern European continental shelf and seas, from western Brittany in the south to north of Shetland. The oceanography and climate of the region is strongly influenced by conditions in the adjacent Atlantic Ocean, particularly along the continental shelf edge where where water exchange occurs between the ocean and shallow shelf seas (< 200m depth). Ocean currents support strong linkages between the Celtic Seas ecoregion and its neighbouring ecoregions. The Rockall Trough is an important pathway for the transport of warmer and more saline water from the Northeast Atlantic to more northerly ecoregions. Water transport on the shelf is primarily from south to north, and prevailing southwesterly winds from the west and south.

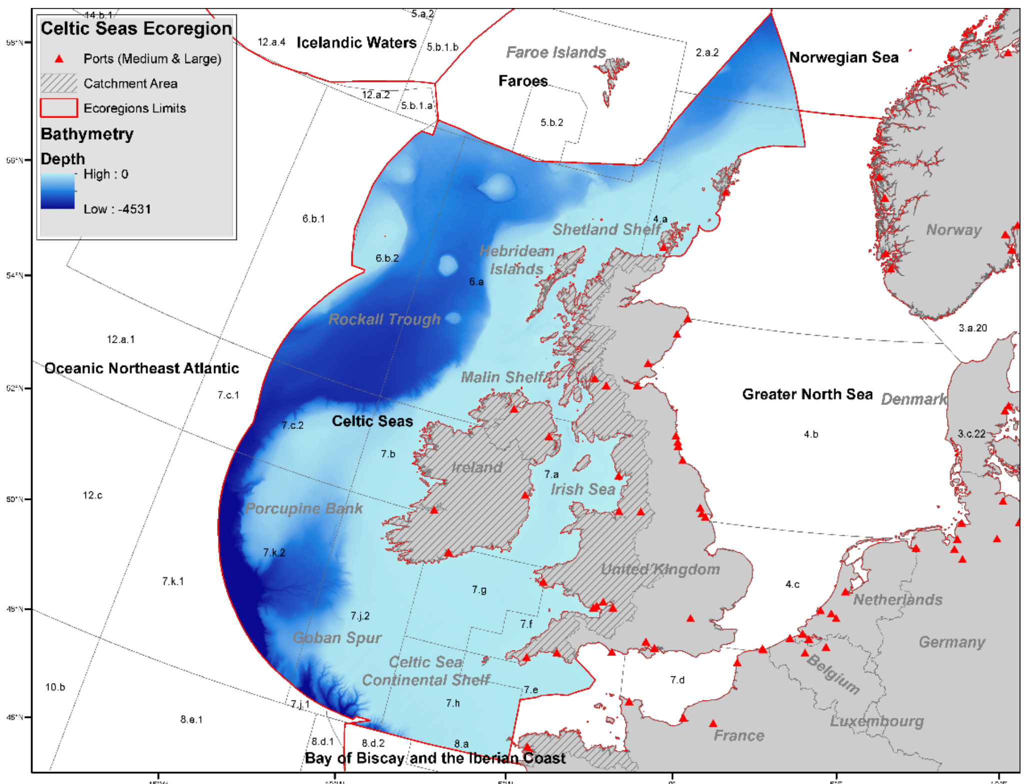

Figure 1 The Celtic Seas ecoregion, showing countries, catchment area, bathymetry, subregions described in the text (grey text), neighbouring eocregions (black text, red lines), medium and large ports (red triangles), and ICES areas (grey lines).

Four key areas constitute this ecoregion:

- The west of Scotland region consists of shallow shelf regions of the Shetland Shelf, Malin Shelf, Hebridean islands, and the coastal area between the Scottish mainland and the islands (including the Minch), and the adjacent deep-sea region of the Faroe-Shetland Channel.
- The Celtic Sea continental shelf (< 200 m), with southern and western boundaries delimited by sharp changes in bathymetry at the shelf edge.
- The continental shelf ecoregion to the west of Ireland, which is limited westward by the Rockall Trough, with the Goban Spur and Porcupine Bank forming long extensions of the coastal continental shelf.
- The relatively shallow, semi-enclosed Irish Sea. A higher density of large cities in this region leads to a concentration of human pressures.

The Celtic Seas ecoregion is characterized by a diversity of habitats, such as an extensive slope, canyons, ridges, and seamounts that support vulnerable marine ecosystems (VMEs) concentrated within northwest Scotland, west of Ireland, and the Celtic Sea areas.

Management

The Celtic Seas ecoregion includes all or parts of the Exclusive Economic Zones (EEZs) of two EU Member States (Ireland and France), the Isle of Man, and the United Kingdom, and it strongly overlaps with the North Western Waters Advisory Council administrative region and OSPAR Region III.

The Celtic Seas ecoregion is characterized by an intricate policy-scape and institutional framework that implies different governance structures at multiple scales. An analysis of marine legislation identified over 200 international, regional, EU, and national instruments that applied to marine environmental planning and management in the United Kingdom prior to Brexit. Despite increasing sustainability challenges stemming from cumulative impacts of multiple activities and pressures in the context of climate change, maritime affairs have historically been dealt with by independent sectoral policies and entities, leading to a strong land-sea divide while legislative integration is still a pressing challenge.

Environmental policy is managed by national governments and agencies via the EU Marine Strategy Framework Directive (MSFD), the Birds and Habitat Directives, and UK Marine Strategy. As a part of the overarching Integrated Maritime Policy of the EU, the Marine Spatial Planning Directive (MSP) sets the process by which Member States organize human activities in marine areas. Other relevant policies and legislative drivers in the EU include the Blue Growth Strategy, Integrated Maritime Policy, and the Green Deal Strategy. Advice on the marine environment in the EU is provided by national agencies, the European Environment Agency (EEA), OSPAR, and the International Council for the Exploration of the Sea (ICES). Additionally, a range of specific policies exist for addressing individual impacts (e.g. Registration, Evaluation, Authorisation and Restriction of Chemicals [REACH] regulation, the EU Urban Waste Water Treatment Directive, UK urban waste water treatment regulations, the EU Water Framework Directive (WFD), UK water environment regulations, and the OSPAR Coordinated Environmental Monitoring Programme).

Fisheries in the Celtic Seas are managed through national administrations via the EU Common Fisheries Policy (CFP; update expected in 2022) and through bilateral negotiations with UK (EU-UK Trade and Cooperation Agreement), with fisheries of some stocks managed by the North-East Atlantic Fisheries Commission (NEAFC) and by coastal state agreements. Non-quota managed species are generally managed through national regulations. The EU Deep Sea Access Regulation manages access to deep-sea stocks, prohibiting bottom trawling below 800 m and placing restrictions on fishing activity from 400–800 m to protect VMEs. Responsibility for salmon fisheries is taken by the North Atlantic Salmon Conservation Organization (NASCO) and for large pelagic fish by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Collective fisheries advice is provided by ICES, the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF), and the North Western Waters and Pelagic Advisory Councils. Stakeholders are involved in the process via engagement with the relevant advisory councils. Fishing activity is also influenced by market conditions and market relevant policies such as the regulation on the Common Organisation of the Markets of Fishery and Aquaculture Products (1379/2013).

International shipping is regulated under the International Maritime Organization (IMO; e.g., the International Convention for the Prevention of Pollution from Ships (MARPOL), the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), and the International Convention for the Control and Management of Ships' Ballast Water and Sediments).

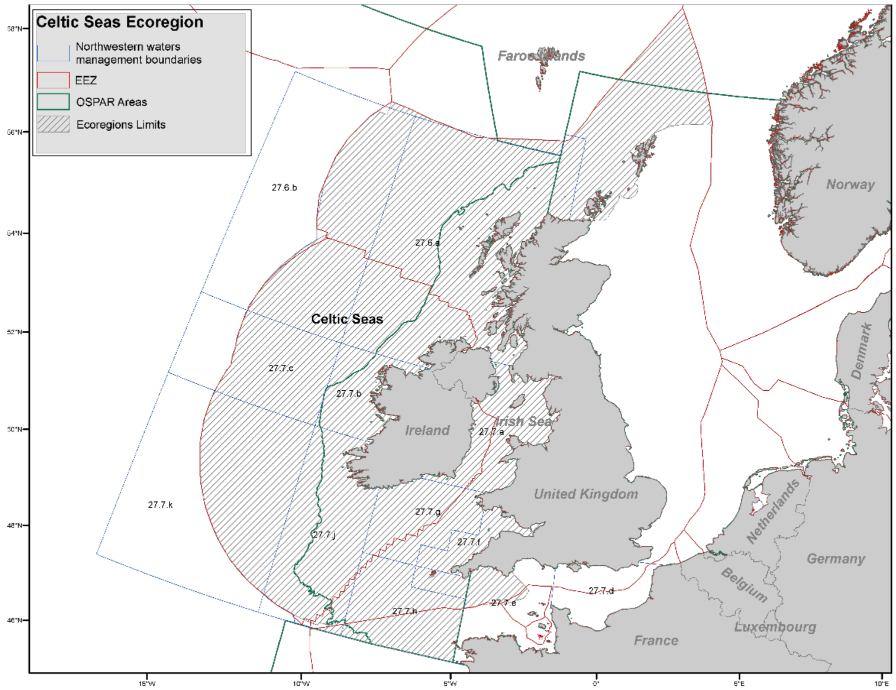

Figure 2 The Celtic Seas ecoregion showing limits (grey lines), countries and Exclusive Economic Zones (EEZs; red lines), the North Western Waters Advisory Council and Pelagic Advisory Council boundaries (blue lines), and OSPAR areas (green lines).

Pressures

ICES has evaluated 17 human activities and 17 pressures relevant to the Celtic Seas ecoregion.The five most important pressures are: selective extraction of species, marine litter, contaminants, nutrient and organic enrichment and physical seabed disturbance. These pressures are linked mainly to the following human activities: fishing, land-based industry, wastewater, tourism/recreation, and shipping.

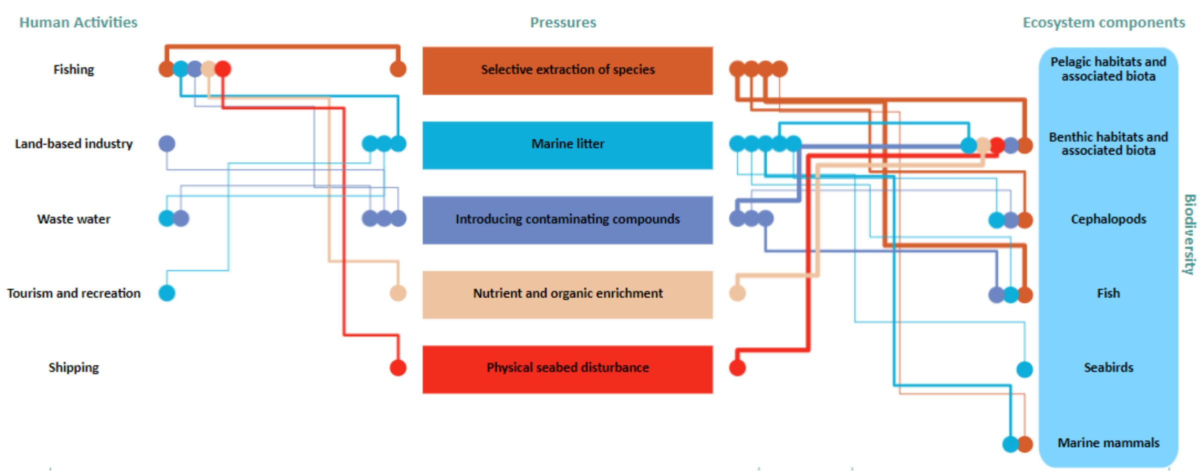

Figure 3 Celtic Seas ecoregion overview with the major regional pressures, human activities, and ecosystem state components. The top linkage chains (those that contribute > 1% to the risk score; 23 linkages/5% of those assessed) are responsible for 66% of the overall risk score and are illustrated in solid lines (line thickness is an indication of the magnitude of the illustrated elements). Each human activity and pressure is listed in decreasing order of their relative contribution to the total risk score. The absence of a line does not necessarily imply a total absence of any link; only the main links are shown. Shipping and pelagic habitats were assessed but do not contribute to the top impact chains. For methodology and definitions, see [ICES ecosystem overviews Technical Guidelines](#).

The illustrated activities account for 93% of the risk arising from the investigated activities, and the illustrated pressures account for 86% of the risk relating to pressures. Potential emerging pressures of concern relate to substrate loss (sealing), and underwater noise. Other human activities of concern include aquaculture, coastal infrastructure, agriculture, and non-renewable resource extraction (e.g. oil and gas). Details of each of the top five pressures follow below.

Selective extraction of species

Selective extraction of species (including bycatch) is primarily attributable to commercial fisheries. Research cruises and recreational fisheries also operate in the region.

Effects on commercial stocks

Overall fishing mortality (F) for shellfish, demersal, and pelagic fish stocks has reduced since the late 1990s (Figure 5), although the pelagic stocks are now above the reference point. Mean F is now closer to the level that produces maximum sustainable yield (MSY). The fishing mortality on 43 stocks has been evaluated (Figure 5) against MSY reference points; of these, 33 stocks are now fished at or below F_{MSY}.

The Celtic Seas is the third most important area after the English Channel and North Sea for landings of loliginids (mainly the long-finned squid [*Loligo forbesii*]). There was a substantial increase in landings of loliginids from the Celtic Seas in 2019. Cuttlefish (*Sepia officinalis*) are not as important in the Celtic Seas, but landings were up in 2019 on the previous year and approached levels last seen in 2015 (the second highest year in a series since 1992).

Detailed information on Celtic Seas fisheries is provided in ICES Celtic Seas ecoregion Fisheries Overview.

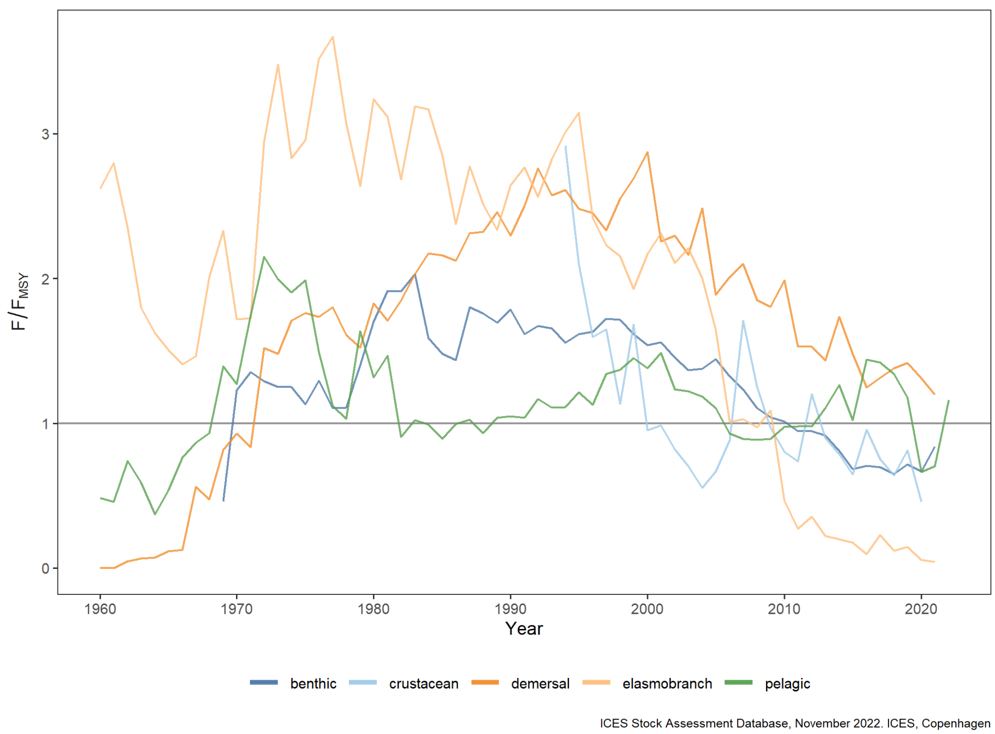

Figure 5 Time-series of annual relative fishing mortality (F to F_{MSY} ratio) by fisheries guild for benthic, crustacean, demersal, and pelagic stocks. Table A1 in Annex 1 details which species belong to each fish category.

European eel migrates throughout the Celtic Seas ecoregion as a larval recruit and maturing adult, and its status remains critical. ICES has advised that there should be zero catches of eels in all habitats, including in recreational and commercial fisheries, and catches of glass eels for restocking and aquaculture. In addition, all non-fisheries related anthropogenic mortalities of eel should be zero, and the quantity and quality of eel habitats should be restored.

Effects on non-target species

Several species have been depleted by fishing in the past and are now on the OSPAR list of threatened and declining species (see full in Table A2.1), including spurdog *(Squalus acanthias*), the common skate complex (*Dipturus* spp*.),* angel shark (*Squatina squatina)*, porbeagle (*Lamna nasus)*, and some deep-water sharks. High bycatch rates have recently been observed for some elasmobranch species which are of conservation concern in the Celtic Sea, particularly in trawl gears and nets. Although there are zero TACs, spatial restrictions, and prohibited listings for these species, several of them remain vulnerable to existing fisheries. Spurdog, thorny skate (*Amblyraja radiata)*, thornback ray (*Raja clavata)* and the common skate complex currently experience high bycatch in mixed demersal trawl fisheries and gill and setnet fisheries, porbeagles and angel shark (less frequently) are taken as bycatch in some setnet fisheries, and deep-water sharks are caught in the mixed deep-water trawl fishery.
Longline fisheries pose the greatest risk of bycatch to seabirds in offshore waters, while inshore net fisheries are known to catch diving bird species. Large-scale bycatch of great shearwaters (*Puffinus gravis*) has been reported from the hake (*Merluccius merluccius*) longline fishery on the Grand Sole fishing bank, and longline fisheries in waters north and west of Scotland appear to catch mainly northern fulmars (*Fulmarus glacialis*) and some other species at lower rates. Relatively high rates of common guillemot (*Uria aalge*) bycatch have also been observed in inshore net fisheries. Fisheries with risk of marine mammal bycatch in the Celtic Sea are bottom setnets (bycatch of harbour porpoises [*Phocoena phocoena*], grey seal [*Halichoerus grypus*], and several dolphin species but at lower rates) and pelagic trawls, particularly those for hake and previously seabass (*Dicentrarchus labrax*), (bycatch of common dolphin *Delphis delphinus*). The mean annual bycatch of the common dolphin in 2016–2018 across all métiers ranged from 278–1345 individuals, with bottom otter trawls and gillnets targeting demersal fish accounting for the largest share. Modelling indicates that it is likely that the bycatch of harbour porpoises in gillnets on the Celtic Shelf has affected population abundance at least in some past periods. Calculations of potential biological removals (PBR) indicate that this bycatch may be unsustainable in this region. Recent estimates of grey seal bycatch in the region showed that percentage mortality of the grey seal population in the ecoregion was 1.5–2.8%. Given that the grey seal population in the area is steadily increasing, such bycatch rates are unlikely to have detrimental effects on the population. Bycatch in both fisheries may have been reduced in recent years due to lower fishing activity and the use of acoustic alarms attached to fishing gear as a mitigation technique in some parts of the fleet.

Ship strike has also been identified by the International Whaling Commission (IWC) as an issue for marine mammals. The Atlantic has been indicated as a potential hotspot for collisions, and incidents have increased in recent decades. However this may represent a reporting bias, and more data is required before drawing conclusions.

Discarding by commercial fisheries

Total discard tonnage of pelagic species in the ecoregion is estimated to be very low. Discards of demersal, crustacean, and benthic species are estimated to be around 10%. Discard rates for some species are very high, for example plaice (*Pleuronectes platessa* [around 60% of tonnage]) and whiting (*Merlangius merlangus* [17–99% of tonnage]). The EU's landing obligation for demersal stocks came partially into force for its Member States in 2016 and has been in full force since 2019.

Recreational fishing

Recreational fishing is an important activity in the Celtic Sea with a diverse range of species exploited from a variety of platforms (e.g. shore, boat) using many gears (e.g. rod and line, speargun, nets, pots, traps), along with hand collecting/harvesting from the shoreline. The main countries with recreational fisheries in the English Channel are UK, France, and Ireland, with methods varying between countries. In UK and France, no licence is required. In UK angling from shore and boat is the most popular method, with a number of charter boats offering trips. Angling, nets, and spearfishing are popular gears in France. Catches can be significant, representing around 5%, 27%, and 42% of total stock removals of cod (*Gadus morhua*), seabass, and pollack (*Pollachius pollachius*) respectively. The main targets include: saithe (*Pollachius virens*), cod, dogfish (Scyliorhinidae), flatfish (plaice, common dab [*Limanda limanda*], flounder [*Platichthys flesus*], and sole [*Solea solea*]), mackerel, pollack, sea bass, sea bream (*Sparus aurata*), wrasse (*Labrus* spp.), and whiting. There are also catches of sharks, skates, and rays. In addition, shellfish, crustaceans, and cephalopods are exploited.

Marine litter

Litter is pervasive; it is produced by all sectors and presents risk to all habitats and species, which leads to its high risk score. The majority of marine litter originates from land-based activities and uses. All five top pressures in the Celtic Sea contribute to litter, with primary inputs from fishing, waste water, and tourism and recreation.

Plastic fragments, food and drink packaging, fishing-related litter, cotton buds, cigarette butts, rubber balloons, and shotgun cartridges are among the top beach litter items recorded in the Celtic Seas. Seabed macrolitter in the Celtic Seas (2012–2014) was composed of 58% plastic, with the highest amounts of litter in the southern Celtic Sea. Amounts of microplastics in Celtic Sea surface waters appear to be relatively low compared to regions such as the Pacific gyre, with higher concentrations near the coast and river estuaries.

In 2011 the mean number of macrolitter items in the Celtic Sea was found to be 21.6 km^{-2} offshore, and 24.3 km^{-2} inshore, consisting of 94% and 77% plastic respectively. While higher than the neighbouring North Sea, it would appear to represent a relatively low value compared to global studies which have indicated average seabed litter concentrations of 723 plastic items km^{-2}, Data from the Irish Groundfish Survey
2010–2014 indicate that litter is present in 57% of offshore sites sampled, with plastic making up 84% of the litter encountered, 51% of which could be directly linked to fishing activity (e.g. nets, rope, fishing line, gloves, buoys, pots. A recent study in Scottish waters found microplastics in 65% of sampled sites, with fragmented plastics accounting for 70% of sea surface microplastics.

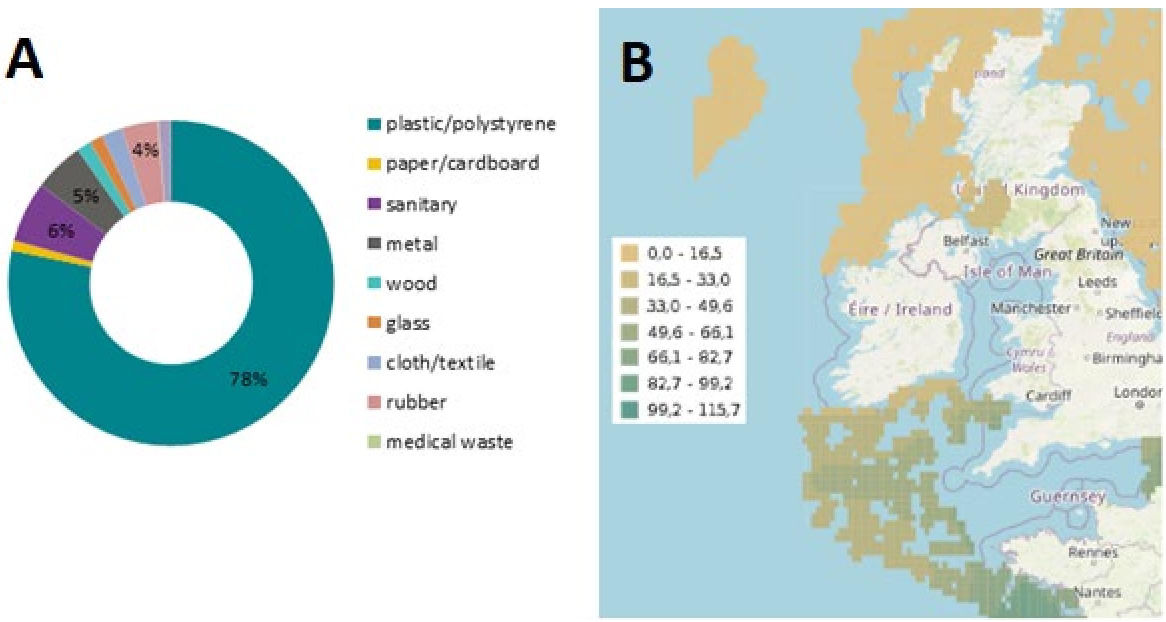

Figure 6 Panel A (left). Composition of beach litter according to material/use categories for the period 2014–2015 in the Celtic Seas ecoregion; Panel B (right). Relative number of litter items per km^2 seabed based on the number of items taken as bycatch in fisheries trawls.

Effects

Marine litter impacts organisms and habitats through entanglement and ingestion; through chemical and microbial transfer; by acting as a vector for transport of non-indigenous species, and through indirect foodweb effects. Marine litter further negatively impacts vital economic sectors such as tourism, fisheries, and aquaculture resulting in economic losses to enterprises and communities.

In the Celtic Seas, recent research demonstrated the presence of microplastic in 35 demersal fish and invertebrate species on the west coast of Ireland (0.11–4.67 particles per individual), in 16 species of seabird and in apex predators such as porbeagel sharks, probably as a result of trophic transfer, and in cetaceans. The biological impacts of these microplastics are not fully known, but can include reduction in feeding, as well as negative effects on growth, reproduction, and even survival.

Evidence for cetacean entanglement in fishing gear has been provided through stranding records. Rates of gear loss (and thus ghost fishing mortaility) are generally unknown and difficult to quantify.

Contaminating compounds (synthetic and non-synthetic)

Contamination in the Celtic Seas is derived from industrial, urban (coastal and wastewater), and agricultural run-off as well as atmospheric deposition, shipping, fisheries, tourism and recreation, oil and gas extraction, aquaculture, and renewable energy installments. Contamination appears high on the list of pressures in the Celtic Sea as a result of its high prevalence – many sectors introduce various synthetic and non-synthetic compounds into the marine environment. As many of the contaminating compounds are long lasting, nearly all habitats are affected to some degree. Inputs of the majority of contaminant sources are regulated, monitored, and managed within the ecoregion but remain high risk due to the numerous sources.

Contamination in the Celtic Seas is typically below adverse effects levels; however, 78.6% of areas assessed throughout the Northeast Atlantic were classified as 'problem areas' by the European Environment Agency. Levels of most contaminants are declining or stable, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and polychlorinated biphenyls (PCBs) but in general remain higher in the somewhat enclosed Irish Sea than in the rest of the ecoregion. The most toxic PCB congener (CB118) is an exception with levels above the OSPAR environmental assessment criteria (EAC), meaning it may have adverse effects on marine organisms in the Irish Sea.

Lead and cadmium concentrations in sediment were observed above effects range low (ERL) assessment criteria (AC) in the most recent UK Marine Strategy assessment at two stations in the Celtic Seas. Furthermore, sediment PAH concentrations in the UK Western Channel and Celtic Seas region were above ERL AC according to this UK Marine Strategy.

Effects

Acute impacts include toxicity to marine organisms and foodwebs (including to humans). Additionally, bioaccumulation in higher trophic levels and the interacting effects of multiple contaminants remain difficult to assess. For example, marine mammals may experience a depression in their immune or reproductive systems via bioaccumulation of contaminants in their food sources.

Since a ban on TBT (in 2008) there has been a marked improvement in the levels of imposex in marine gastropods (2010–2015), with levels along the Irish and Scottish west coast and in the Irish Sea being significantly below the OSPAR EAC. Levels within the Celtic Sea are highest in the ecoregion but remain close to the EAC.

The most recent UK Marine Strategy assessment report on trends in biological effects of contaminants for the common dab indicates a significant downward or stable (no trend) in EROD enzyme (7-ethoxy-resorufin-O-deethylase, an indicator of PAHs and PCBs) activity, as well as a stable trend for bile metabolite (indicator of PAH exposure) in the UK Celtic Seas region.

Liver neoplasms in the common dab are reducing in the English and Welsh region of the Celtic Seas ecoregion, but are still considered significant compared to other UK marine ecoregions. The assessment status for the Scotland regions of the Celtic Seas is considered to be 'background', although no trend data is currently available.

Nutrient and organic enrichment

The urbanization of coastal areas is associated with nutrient releases and related pressures on the marine environment. The most important nutrient sources contributing to eutrophication in the Celtic Seas ecoregion are shipping, urban wastewater, aquaculture, agriculture, land-based industry, and atmospheric deposition. The major sources of nitrogen and phosphorous input in the environment are diffuse losses (agriculture and atmospheric deposition) and sewage treatment works.

Atmospheric deposition of nitrogen is estimated to provide about one-third of all inputs of nitrogen. A major contribution to atmospheric deposition, and therefore to the overall input of nitrogen to the environment, is emissions from shipping.

Total inputs of nitrogen and phosphorous to the Celtic Seas area showed significant reductions between 1990 and 2014. Management measures have been most successful in reducing phosphorous, with inputs roughly halving during this period. The greater success in reducing phosphorous relative to nitrogen has resulted in an increase in the N:P ratio in freshwater inputs.

The primary contribution of organic matter is via discarding of unwanted catch and offal from fisheries. Additional sources of organic input include those from fisheries, through emissions, effluent discharge, and discarding of biological material.

Effects

In the Celtic Seas ecoregion, eutrophication exist but is primarily site-restricted to inlets, estuaries, and harbours, based on elevated chlorophyll-a and low dissolved oxygen. Within the OSPAR Celtic Sea region, 28 problem areas and 22 potential problem areas were identified with respect to eutrophication. These areas are associated with higher population densities and intensive agricultural activities and are unlikely to extend to offshore waters.

Physical seabed disturbance

Physical seabed disturbance can occur via abrasion (the scraping of the substrate), resuspension of the substrate (siltation), removal of the substrate, and deposition (smothering). The impacts associated with such disturbances include the biotic impacts linked to the physical action and include additional mortality through, for example, collisions with bottom-contacting mobile and set fishing activities. Other activities such as aquaculture, tourism/recreation, coastal infrastructure, hydrodynamic dredging, shipping (anchoring), and cable burial may also contribute.

Effects on benthic habitats and associated biota

Physical disturbance of benthic habitats by bottom trawl fishing gear is described by vessel monitoring system (VMS) and logbook data. Fishing is mainly concentrated along the shelf edge, i.e. around the southern shelf regions and on fishing grounds in the Irish Sea and to the west of Scotland. The extent, magnitude, and impact of mobile bottom-contacting fishing gear on the seabed and benthic habitats varies geographically across the Celtic Seas (Figure 7).

Using VMS and logbook data, ICES estimates that mobile bottom trawls used by commercial fisheries in the 12 m+ vessel category have been deployed over approximately 480 700 km^2 of the ecoregion in 2018-2021; this corresponds to ca. 52% of the ecoregion's spatial extent (Figure 7). The fishing effort of bottom mobile gears in the Celtic Seas ecoregion decreased by 35% from 2003 to 2014. This has reduced the spatial fishing footprint and the average number of times the seabed is trawled per year.

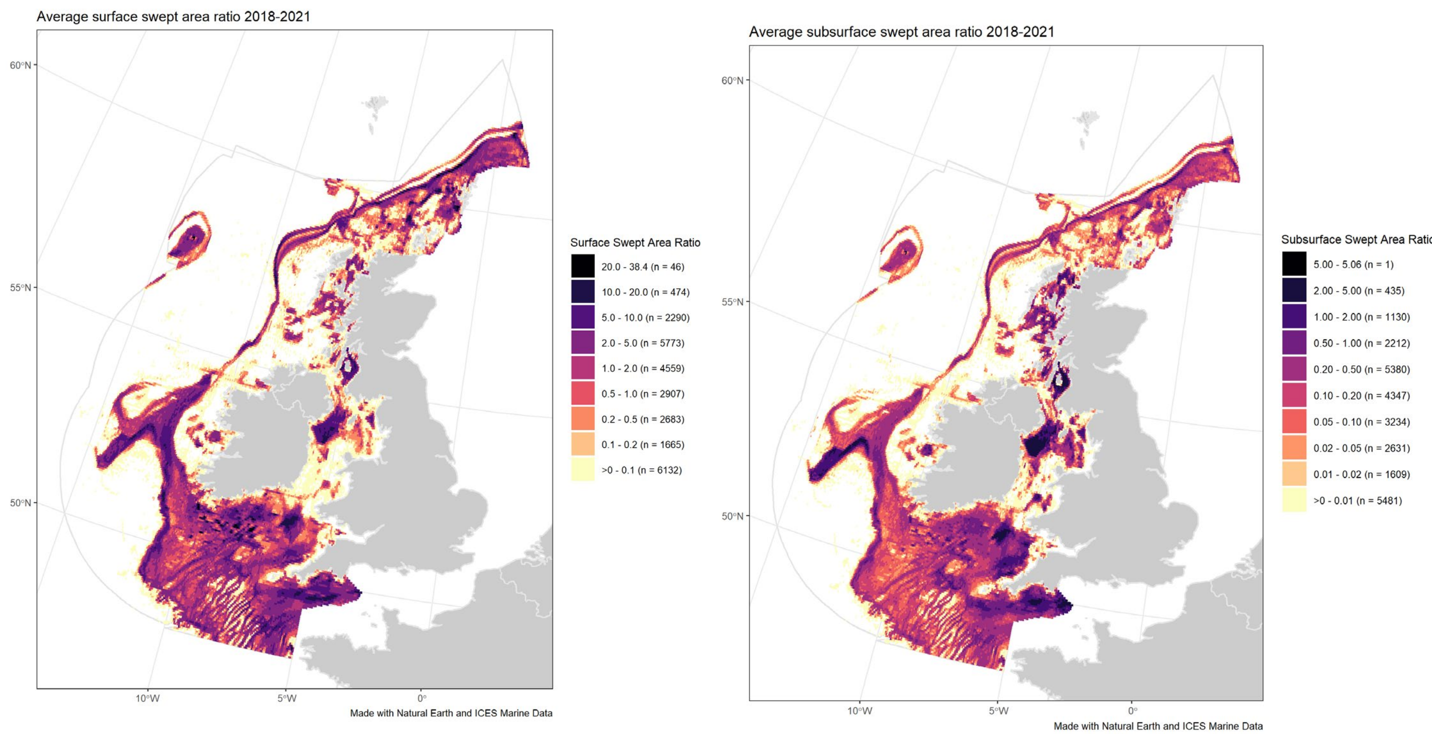

Figure 7 Average annual surface (left) and subsurface (right) disturbance by mobile bottom-contacting fishing gear (bottom otter trawls, bottom seines, dredges, beam trawls) in the Celtic Seas during 2017–2021 (with available data), expressed as average swept area ratios (SAR).

Continued physical disturbance as a result of mobile fishing activities, shipping, and dredging can negatively affect the community structure of shallow subtidal, shelf, and deep-water sediment habitats. Physical damage from bottom trawling and dredging also impact benthic habitats through displacement or overturning of boulders and cobbles, removing or damaging epifaunal species, disturbing sediments, and damaging fragile deep-sea communities including sponge aggregations, coral gardens, and deep-water coral reefs. Extensive areas of biogenic reefs may also have been impacted through direct contact e.g. *Modiolus modiolus* reefs in the Celtic Sea, *S. spinulosa* in the west of Scotland, maerl beds along the coasts of Ireland and Britain, and cold-water corals such as *Lophelia* sp. in deep-water habitats on the western shelf of the Celtic Sea ecoregion.

Effects on vulnerable marine ecosystems (VMEs)

All bottom-contacting gears that make contact with VMEs are assumed to impact them. Faunal communities in deep-sea sedimentary habitats live in cold waters with a relatively low supply of food, slow life-histories, low population growth, slow recovery rates and long lifespans. Even low fishing rates may have serious impacts under these conditions. Mobile gears such as trawls are known to have the greatest impact on VMEs. Declining condition (density, body size) of deep-sea sponge aggregations have been observed associated with the impacts of demersal fisheries. Extensive areas of biogenic reefs may also have been physically impacted, e.g., cold water corals such as Lophelia (i.e., *Desmophyllum pertusum*) in deep-water habitats on the western shelf of the Celtic Sea ecoregion.

Smothering due to resuspension of sediments can result also in physical loss and damage. The degree of permanence of any habitat changes will be dependent on the substrate type, the presence of sensitive or vulnerable communities, and the frequency of the activity.

Within the Celtic Seas ecoregion, the fishing footprint is extensive, covering almost all (88%) of the 400-800 m depth of the Celtic Seas ecoregion. 95% of areas with known VME occurrence or likely occurrence have been found to have been fished between 2009 and 2011. Fishing in the 400–800 m depth contour accounts for 11% (UK), 15% (Ireland), and 5% (France) of each country's fished area. Otter trawls constitute the dominant gear grouping spatially within this depth range, closely followed by static gears. Within otter trawls, the largest footprint within this depth range belongs to benthic directed fisheries. Within the static gears, the largest footprint belongs to gillnets, followed by longlines. Deep-sea bottom longlining has been shown to have a lower impact on VMEs, reducing bycatch of cold-water corals and limiting additional damage to benthic communities. However, as longlining mainly targets large colonies with complex morphologies (e.g., coral gardens), it may cause shifts in the faunal composition of VME habitats.

Climate change effects

Climate change is already observable within some parts of the Celtic Seas ecoregion. Long-term datasets from the Malin Shelf indicate an overall rise in historical coastal sea surface temperature, ranging from around 10–10.5°C from 1960 to 1990, to around 11°C since. In southwest Ireland and the western Channel, the trend has averaged around 13°C since 2003. Analysis of the time-series showed that there have been considerable changes in the physical environment and across multiple trophic levels in the Celtic Sea over the last 50 years, many of which are associated with ocean warming.

Mean annual sea surface temperature in the Celtic Seas ecoregion has shown an overall upward trend of about +0.5°C since 1975, with a steeper rise from 1980–2005 and a broadly flat trend since (Figure 8). Water temperatures are strongly influenced by the strength of the North Atlantic thermohaline circulation, itself influenced by complex ocean-atmospheric coupling resulting in alternating warming and cooling periods. Water temperatures on the shelves are influenced by the degree of cross-shelf transport, as well as local seasonal heating.

Within the Celtic Seas ecoregion, the IPCC Regional Concentration Pathway (RCP) 8.5 scenario projects a 1.5 to 2.5°C warming above mean conditions for years 2050–2099. There is, however, considerable spatial variability in projected warming.

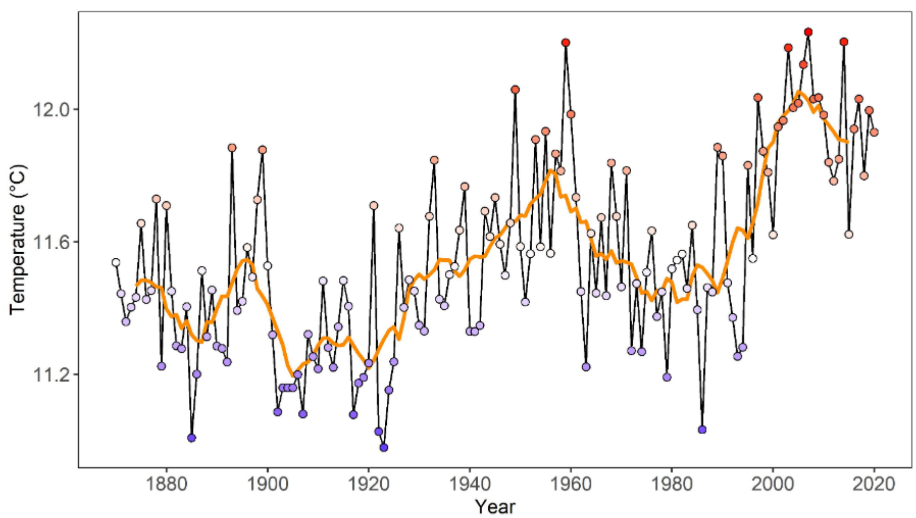

Figure 8 Mean annual sea surface temperature of the Celtic Seas (1970–2020) with a ten-year moving average (orange line). Within the Celtic Seas, there is little evidence of any major changes in salinity from long-term observation at the Western Channel Observatory.

Projections suggest increases in mean sea level, surges and storminess bringing increased risk of coastal flooding, coastal erosion, damage to vulnerable coastal habitats, and socioeconomic risk. If global warming continues, sea levels could rise by between 15 and 95 cm within this century, increasing the risk of flooding and coastal erosion in low-lying coastal areas.

Primary production

Net primary productivity (biomass of carbon produced per m^2 per day [NPP]) derived across the whole ecoregion shows a decline from just below 800 mg °C /m^2/day in the early 2000s to around 600–650 from 2006.

Phytoplankton

The positive trends in diatoms (see the 'State' section) are not significantly associated with sea surface temperature, while the decreasing trend of dinoflagellates are largely negatively correlated with temperature, particularly in offshore areas.

Zooplankton

The decline in the abundance of larger copepods and gradual change to a warmer water zooplankton community is likely driven at least in part by climate change. The abundance of meroplankton relative to holoplankton shows an increasing trend throughout most of the Celtic Seas offshore areas and adjacent regions. In the neighbouring North Sea, a strong correlation of the meroplankton increase with increasing SST has been taken as strong evidence that it is driven by climatic and oceanographic change. The decline in holoplankton is mainly driven by small copepods and may reflect a change in growing conditions associated with earlier blooms and lower/higher phytoplankton/picoplankton biomasses during summer (i.e. potential climate driven nutrition-related mismatch). The overall decline in holoplankton suggests a shift from pelagic to benthic productivity in the plankton community.

Fish

Temperature affects the migration, distribution, onset of spawning, and recruitment of commercially important widely distributed species such as, blue whiting, Northeast Atlantic mackerel, western horse mackerel (*Trachurus trachurus),* boarfish (*Capros aper*), Atlantic cod, sole, and plaice. Forecasting the consequences of climate change for recruitment and overall productivity of commercially targeted fish stocks remains challenging. To date, there are no examples of where environmental drivers are use to routinely forecast recruitment.
Based on the available information, species in the Celtic Sea are at risk from warming and lower primary production, while species west of Scotland are shifting northwards. Distributional shifts have been reported for most of the commercially important species in the ecoregion: cod, haddock (*Melanogrammus aeglefinus*), whiting, hake, monkfish (*Lophius* sp.), plaice, sole, megrim (*Lepidorhombus whiffiagonis*), blue whiting, herring, mackerel, and horse mackerel. Temperature has been suggested as the main driver of these changes but other processes such as density-dependent habitat selection, geographical attachment, and species interactions are also thought to play a role.

In recent decades several commercial fish species have shown changes in growth that have consequences for stock productivity and may indicate a change in ecosystem structure and functioning. Most notably, there was a sharp reduction in size-at-age of Celtic Sea herring from the mid-1970s to the 2000s, which was most strongly and non-linearly associated with temperature.

Knowledge gaps

Synoptic information on oxygen levels, pH, and nutrients is difficult to source for the Celtic Seas. Detailed knowledge about climate change interactions for marine mammals and seabirds is also a major gap. Biogeographic changes linked to climate change also require work. One initial study showed evidence that Lusitanian species were moving into the Celtic Sea, although boreal species were not diminishing.

Finally, understanding where climate change effects are expected to exacerbate the effects of other human pressures is not understood or sufficiently researched.

Social and economic context

Fishing

Fourteen nations currently target stocks within the Celtic Seas ecoregion. Fishing activity, represented as port landings and effort, is spread widely around the coasts of the Celtic Sea ecoregion (Figure 4a). The fleet varies in vessel size and time spent at sea, with busier ports indicated by larger circles in the figure. Analyses of the fishing activity in the ecoregion indicate that countries outside the ecoregion (i.e. those wihout a territorial border within the ecoregion) are responsible for 33% of effort allocated to the region and land around 43% by weight from the ecosystem (Figure 4b), indicating the interconnected and interdependent nature of European fishing activity. Of the fish caught in the ecosystem, 47% was landed into ports in UK and Ireland, while 53% was landed elsewhere.

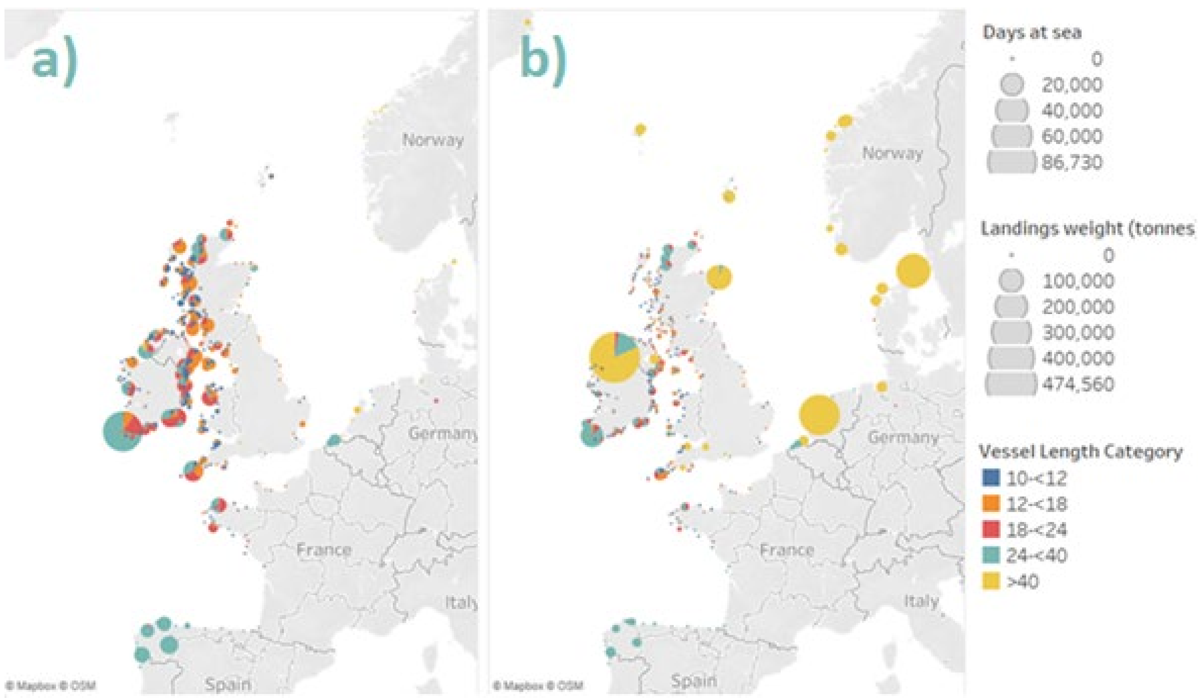

Figure 4 Fishing effort (days-at-sea; panel a, left) and landings by weight (panel b, right) for each port with vessels operating in the Celtic Seas ecoregion (2017–2019). The size of the circles indicates magnitude, colours indicate the vessel length category. Small scale fisheries (vessels < 10 m) are not included due to a lack of data. Note: days-at-sea were estimated for Ireland based on hours fished.

North Western Waters (data based on North Western Waters region fleet which covers ICES areas 5, 6, and 7)

Both fishing effort and landings have generally decreased in the region since 2008. Total fisheries full-time equivalent (FTE) employment in the North Western Waters (NWW) region decreased 6% from 12 315 in 2010 to 11 500 in 2018. Revenue (all income, including landings) generated by the fleets (based on available data) represented 21% of the total revenue for the EU fleet. The fleet operating in this region made EUR 309 million in gross profit in 2018; this represented a decrease of 18% compared to 2017 despite a generally increasing trend prior.

Based on value, the French, United Kingdom, and Irish fisheries have the largest landings in the North Western Waters region. Ireland has the highest total percentage of both national landed value (88%) and days-at-sea (98%), indicating its high dependency on this area. Belgium (43%), United Kingdom (60%), and France (29%) also have a high number of days-at-sea in the region. The fleet in this region consists of > 60% small scale fleet that account for 43% days at sea, provides job for around

22% of full-time equivalent employees and produced 14.2% of revenue. The rest of the fleet is represented by larger scale vessels that land around 93.5% of fish, or 86.6% of value. Total employment in NWW region in 2018 was estimated by STECF AER (Annual Economic Report) at 16 000 with the number of FTE employees at 11 500, an increase of 4% compared to 2017, but with a general decrease observed since 2008. The most important fleets in terms of overall employment correlate to those fisheries that have the highest dependency on this area (UK 4470 FTE, France 2837, Ireland 2465, and Spain 1245). Average wage per FTE for both the small and large scale fleet decreased in 2018 by 6% and 8% respectively (2017–2018). General trends indicate a slight downward trend for the small scale fleet and generally increasing wages for the large scale fleet (2008–2017).

Climate change

There have been no detailed assessments of the effects of climate change on fleets and fishery-dependent communities in the ecoregion. The main management implication of these distributional shifts is the mismatch between regional abundances and TAC allocation, with hake and mackerel being two examples. This mismatch, in combination with the landing obligation, could result in choke species issues and challenges the relative stability currently used to distribute quotas. The changes in mackerel distribution has complicated international management agreement and sustainability certification for the fishery.

An important development driven by the need to respond to climate change is the rapid increase in offshore renewables. This is especially marked in the North Sea, but there are also development proposals for tidal-stream, for floating wind to the west of Scotland, Irish Sea, and Celtic Sea. The development of large offshore renewables in the ecoregion is likely to affect fisheries because mobile gears are often excluded from such areas, although static gears may be compatible.

Specific socio-economic drivers

COVID-19 pandemic

Responding to the rapid spread of COVID-19 and its variants, governments throughout Europe took the decision to enter successive lockdowns, with the subsequent collapse of the HOtel, REstaurant and Catering (HoReCa) and export markets. Ensuing seafood demand contraction and market uncertainty (price volatility), as well as temporary disruptions in fish auctions functioning and transport logistics (delays and higher costs), proved to be a sizeable challenge for the fishing sector.

Despite diversity in the severity and timing of impacts between regions, the value of landings (most notably for demersal and shellfish species) decreased more severely than their volumes (volume/value of landings: −10%/−26% for the Irish fleet, −10%/−20% for the UK demersal fleet, −4%/−13% for French fleet in the Celtic Sea). The most impacted fleet segments were those targeting high-value species and/or selling to the HoReCa sector. On the contrary, largely industrialized pelagic (mackerel [*Scomber scombrus*], herring [*Clupea harengus*] and blue whiting [*Micromesistius poutassou*]) and deep-sea fisheries in the Northeast Atlantic could rely on long-standing robust processing/retailing partnerships and as a consequence were not adversely impacted.

The long-term and multidimensional impacts on the seafood sector have yet to fully materialize.

Withdrawal of United Kingdom from the European Union (Brexit)

As of the 1st of January 2021, UK became an independent coastal state with full responsibility over the waters of their EEZ, of which a significant portion is in the Celtic Seas ecoregion. Yet, under the United Nations Convention on the Law of the Sea, both UK and the EU have a duty to cooperate in the conservation and sustainable management of the ~100 stocks straddling their maritime boundaries, being further obliged to minimize economic dislocation for states whose nationals have habitually fished in the area.

Protracted and demanding Brexit negotiations have disrupted 2021 TAC-setting institutional processes until now, undermining the forecasting ability of both EU and UK seafood industries. While the Trade and Cooperation Agreement (TCA) guarantees full reciprocal access for a five-and-a-half-year period, it implies a significant quota transfer from the EU to the UK (by 2026 onwards, 25% of the value of pre-Brexit EU catches in the UK EEZ returns to UK). After the 1st of July 2026, access to waters will be decided in annual consultations. While the general framework of the new EU–UK relationship is established, practical implementation of the TCA remains a major challenge.

Although it is too early to appreciate the full extent of its consequences, Brexit is likely to impact the distribution of activity and profitability of EU fleet segments within the ecoregion during the upcoming years.

State of the ecosystem

Oceanographic conditions and circulation

The Celtic Seas are a transition zone between the Atlantic Ocean and coastal waters. The North Atlantic Oscillation (NAO) determines the position and intensity of the Atlantic storm track, westerly winds, and wave climate across the Atlantic, as well as oceanic circulation – all of which have an indirect effect on sea surface temperature (SST) and salinity (SSS) on a wide range of time scales (days to decades). In the Celtic Seas, stronger westerly winds generate stronger turbulence and higher waves during positive NAO phases, while a negative NAO is associated with slacker westerly winds.
The most prominent circulation pattern is the persistent poleward-flowing slope current, and oceanographic fronts (Figure 9). Currents on either side of fronts induce vertical flow resulting in biogeochemical and production hotspots, aggregations of plankton and higher trophic levels, and carbon export that sustain bottom communities.

West of Scotland

Shallow shelf coastal areas generally have lower salinities due to the influence of the Scottish Coastal Current and the freshwater input from rivers and land run-off. The Faroe-Shetland Channel exhibits a southward-flowing cold current at water depths below 500 m, and a northward-flowing warm surface current, with a complex area of turbulence between the two.

West of Ireland

The Irish Shelf thermohaline front separates coastal and oceanic waters (transition surface salinity signature of ~35.3). It is present all year round and strengthened with heating from late spring to late summer.

Irish Sea

The Irish Sea is separated from the Malin Shelf to the north and Celtic Sea to the south by tidally driven fronts, i.e., the Islay Front and Celtic Sea Front respectively. Seasonal stratification occurs predominantly in the western Irish Sea.

Celtic Sea

The clockwise flow of Irish coastal current is important, with strong subsurface narrow jets (located at ~25–30 m and ~15–20 km wide) developing offshore in summer. The Celtic Sea frontal system between the Celtic Sea and Irish Sea develops in late spring and breaks down with the onset of winter cooling and wind mixing. Similarly, a tidal front exists at the entrance to the English Channel between France and UK.

Recent trends

Celtic Seas regions that experience a strong influence of the conditions of the wider subpolar North Atlantic Basin were slightly cooler than average in 2020 (−0.6 and −0.4°C temperature anomalies in the Faroe-Shetland Channel and upper Rockall Trough, respectively; Figure 9). These upper waters stem from the adjacent North Atlantic, which exhibited an extreme freshening in 2016 due to anomalous atmospheric conditions driving changes in the subpolar North Atlantic circulation.

In the intermediate waters of the Rockall Trough (1500–2300 m depth), waters were extremely warm and saline in 2020. The origin of this signal is currently uncertain. On the shallow shelf in the south of the region (at the Western Channel Observatory) conditions were warmer and less saline than on average. A similar signal has been observed in the neighbouring Bay of Biscay. The ocean temperature on the Malin Shelf was above average in 2019, but no data are available for 2020 at the time of publication A time-series of temperature data is available from the M3 weather buoy; however, it is as yet too short to be standardized against a 30-year climatological average.

Further detail on temperature and salinity time-series can be viewed in ICES Report on Ocean Climate.

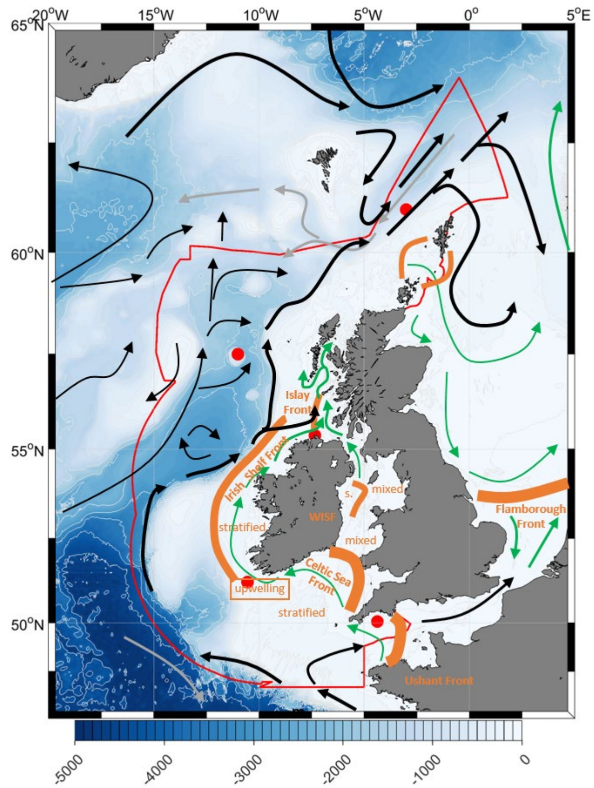

Figure 9 Map of the general circulation and oceanographic features of the Celtic Seas ecoregion and adjacent waters. The symbols indicate the locations of features (the ocean is dynamic and features may vary in their position in time and space). The black arrows indicate surface circulation features of waters of more oceanic origin. The grey arrows indicate near-bed currents in the oceanic regions. The green arrows indicate features of the coastal circulation, which is more seasonal in occurrence and strength. The thick orange lines represent frontal regions (mainly seasonal in their occurrence). The red dots indicate station locations (north to south) Faroe Shetland Channel - Shetland Shelf (North Atlantic Water), Extended Ellett Line - Rockall Trough, Malin Head Weather Station, M3 Marine Weather Buoy, Western Channel Observatory (WCO). Bathymetry data from EMODnet Bathymetry Consortium (2016).

Pelagic habitat and associated biota

Productivity

There is seasonality in the primary productivity of the ecoregion, which is linked to changes in sea surface temperature. Monthly means peak in May/June and begin to decrease in August.

Net primary productivity has generally been lower and below average in the 2010s compared to the 2000s but has been gradually increasing since 2013.

NPP is higher along the shelf break and within the shelf seas than deeper offshore areas, likely due to nutrient inputs and mixed water columns. The largest NPP values are observed in the Irish Sea.

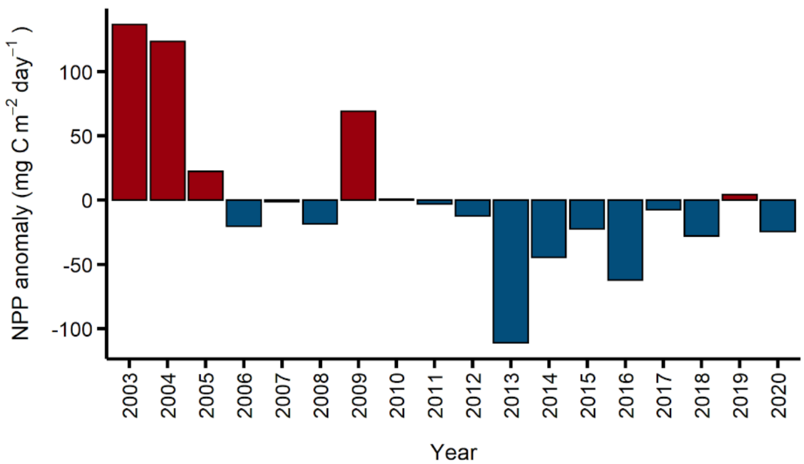

Figure 10 Net primary productivity (NPP; mg C per m^{-2} day^{-1}) anomaly plot for Celtic Seas ecoregion, illustrating variation from the mean of the entire time-series (2003 – 2020). Data provides depth integrated estimates of NPP from the surface to the euphotic zone. Data was not available for all ecoregions from November to January, so values from these months were excluded

Plankton

Evidence of a northward geographical shift of cold-water plankton assemblages was first documented in 2019 in the Northeast Atlantic, including the Celtic Seas. This pattern was associated with a decrease in the number of colder-water species, as well as phenological changes due to increase temperature.

Phytoplankton

Smaller picophytoplankton are increasing as a proportion of total phytoplankton biomass across Northeast Atlantic shelves. Continuous plankton recorder (CPR) and coastal station records show a decreasing trend in diatoms in the Celtic Sea and overall increasing trends in the West of Scotland subregion. There has been a large decline in armoured dinoflagellates in the Northeast Atlantic offshore areas including the Celtic Sea over a multi-decadal period. In some inshore regions, dinoflagellates have increased compared to diatoms in 2006–2015, a pattern that may be related to nutrients availability and indicates the importance of local conditions. The proportional increase of dinoflagellates may have implications for the frequency and intensity of inshore dinoflagellate events. Low levels of the brown-tide algae (*Aureococcus anophageferrens*) were detected during 2011–2014 monitoring.

Harmful algal bloom (HAB) events occur on an annual basis in the Celtic Seas ecoregion (Figure 11). Marine biotoxins produced by several toxigenic dinoflagellate and diatom species have led to closures of shellfish harvesting facilities due to toxin levels exceeding EU regulatory limits, primarily due to diarrhetic shellfish toxins. Closures due to paralytic shellfish toxins and amnesic shellfish toxins are more sporadic. The west coast of Ireland presents a particular hotspot of impacts from Azaspiracids.

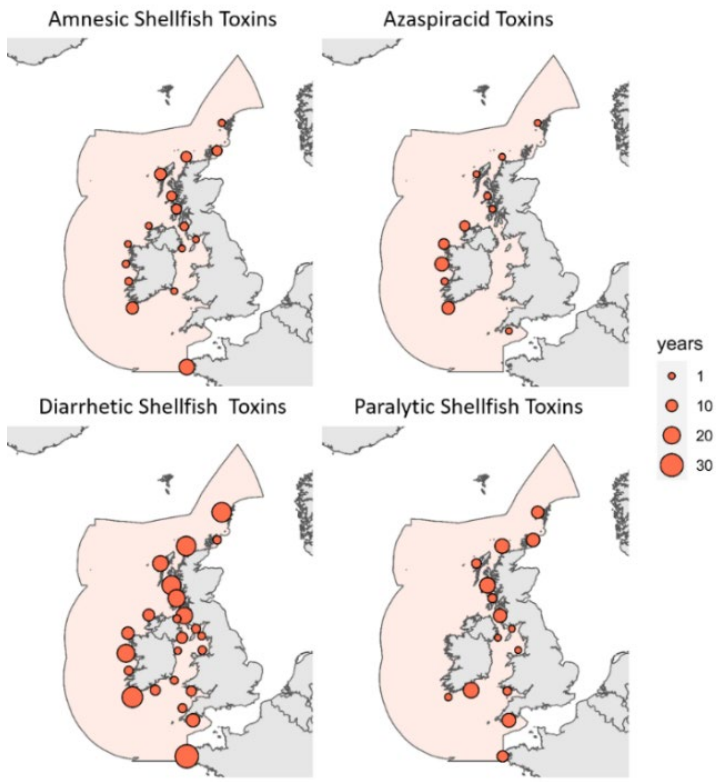

Figure 11 Number of years with a harmful algal bloom (HAB) event (1990–2020) per toxin group for the Celtic Seas.

Zooplankton

Copepods typically dominate the zooplankton community, with chaetognaths, siphonophores, medusa jellyfish, appendicularians and meroplankton forming a significant part of the zooplankton biomass throughout the year. Over the last 60 years copepod abundance has declined (Figure 12) and meroplankton abundance has increased in this ecoregion, consistent with wider-scale changes reported across the NE Atlantic/NW European Shelf. These changes are only partially attributable to northwards range shifts commensurate with the overall warming of this region. The extent of shifting ranges and phenology are extremely variable between taxa. Copepod declines have been found to be mainly a summer phenomenon linked to the indirect effects of temperature acting on food quality. Taxa that have increased in abundance include the more carnivorous genera that select for motile food (e.g. *Centropages* spp.), whereas the more herbivorous genera with a preference for diatoms (e.g. *Oithona* spp., *Para*- and *Pseudocalanus* spp.) have experienced the strongest decline. The two *Calanus* congeners show opposite trends with the cold-water *C. finmarchicus* being largely replaced by the warm-water *C. helgolandicus*. However, the combined abundance of copepodite stages I–IV from both Calanus species, declined by > 60%, in line with the overall loss of copepods in the ecoregion.

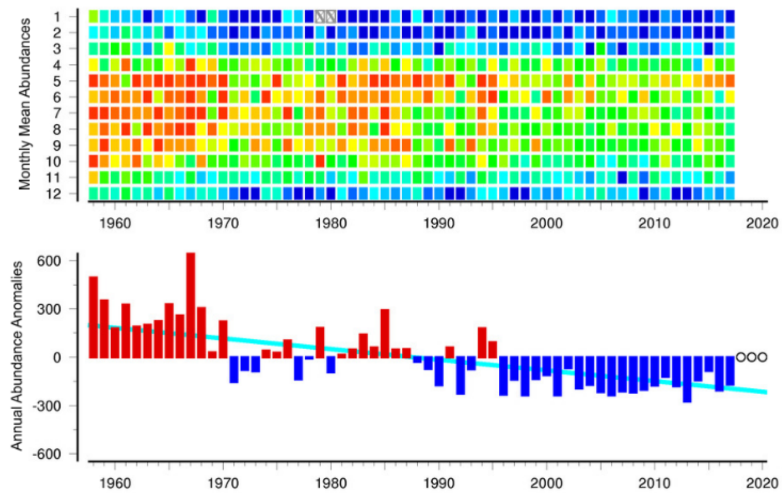

Figure 12 Total *small-copepods* (≤ 2 mm) from CPR standard areas C4, D4, and C3 to create a "Celtic Seas" average for the region. Upper panel: matrix of monthly mean (total copepod) abundances over time. Bottom panel: annual anomalies of total copepod abundance (#/m3) have exhibited a significant interannual decrease since 1958 ($p < 0.01$).

Benthic habitat and associated biota

Substrate

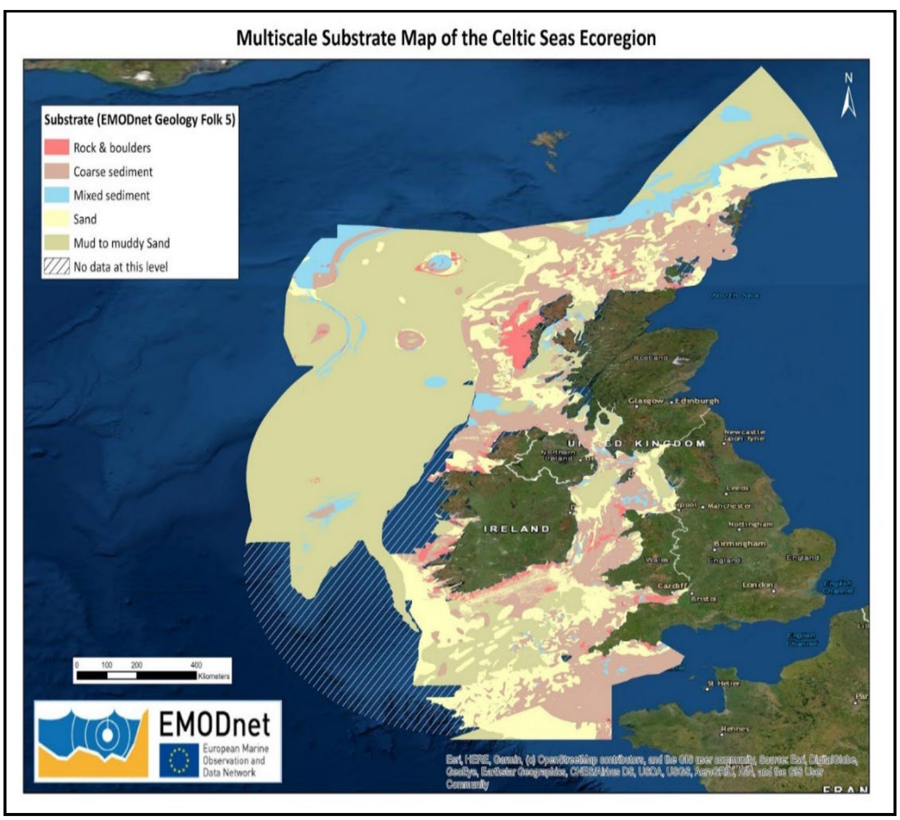

Figure 13 Multiscale substrate map of the Celtic Seas ecoregion.

The seabed of the Celtic Seas ecoregion is primarily comprised of sediments (Figure 13). Coarse sediments cover most of the Malin Shelf. Coarse sediments are also the main substrate type found in the Irish Sea along with patches of mud to muddy sand and rock, sandbanks are prominent features off the southeast coast of Ireland. Coarse sediment, sand and mud to muddy sands are found in equal measures in the Celtic Sea. Areas of rock and hard substratum are present in the northern (west of Shetland Islands) and inshore (west and south coasts of Ireland, south west England coastline) parts of the ecoregion. Mud to muddy sand sediments dominate the deeper, offshore areas.

Benthic community

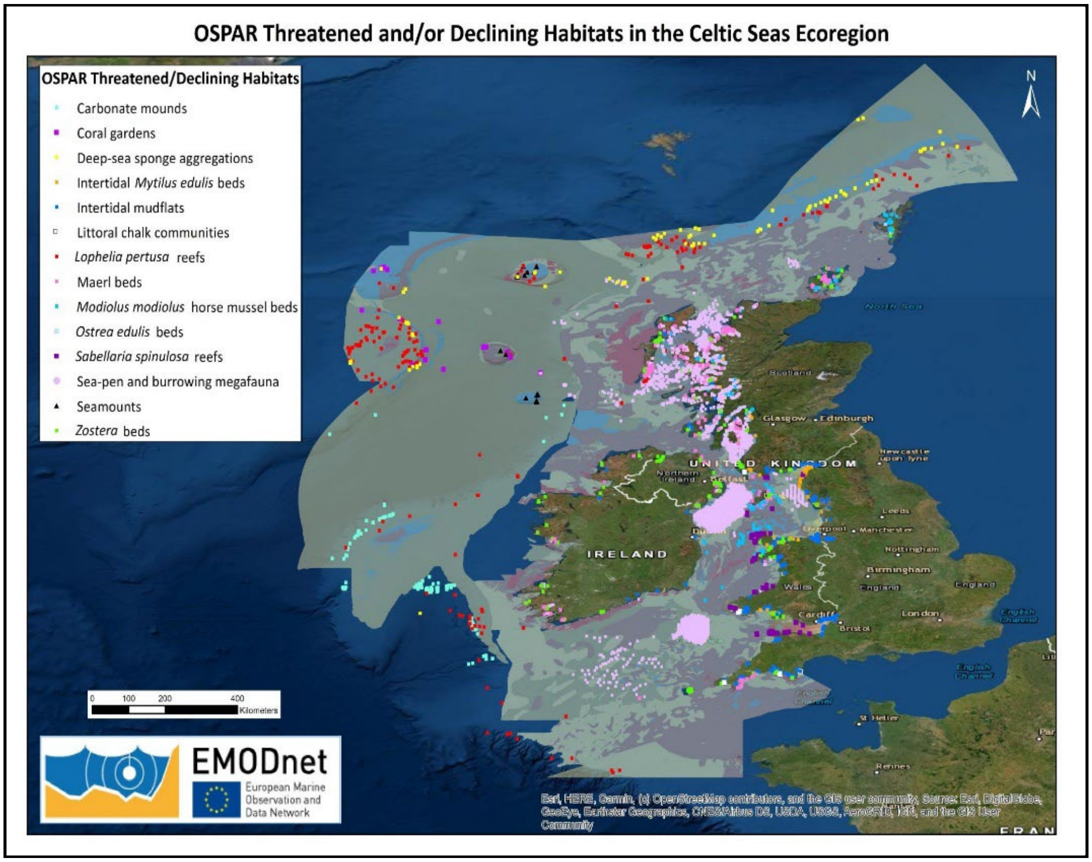

Figure 14 Distribution of OSPAR threatened and/or declining habitats in the Celtic Seas ecoregion.

The soft sediments are characterized by burrowing megafauna; this includes sea pens and commercially important species (e.g. Norway lobster [*Nephrops norvegicus*]), and also macrobenthos such as deposit-feeding polychaetes. The coarser sediments are habitats for commercially important shellfish species, e.g. *Pecten maximus* and *Aequipecten opercularis*, and to sensitive species and habitats, e.g. maerl, brittle star beds, *Modiolus modiolus* beds, and *Atrina fragilis*. The nearshore rocky habitats are characterized by algae and epifauna; however, some areas of rocky habitat in deep waters in the northern part of the region are characterized by hydroids, bryozoans, and cnidarians such as *Eunicella verrucosa* and *Swiftia pallida*. Structural changes in benthic communities and declines in native species have been observed as a result of the more than 200 non-indigenous and cryptogenic (unknown origin) species recorded in the region as a result of shipping, coastal water currents, and aquaculture.

Fishing-induced physical disturbance is estimated to have resulted in an overall decrease of invertebrate benthic biomass varying between 59% in offshore mud and 5% in sandy habitats compared to an unfished state. This impact is patchy and may be over 80% in the most heavily fished areas.

Vulnerable marine ecosystems (VMEs)

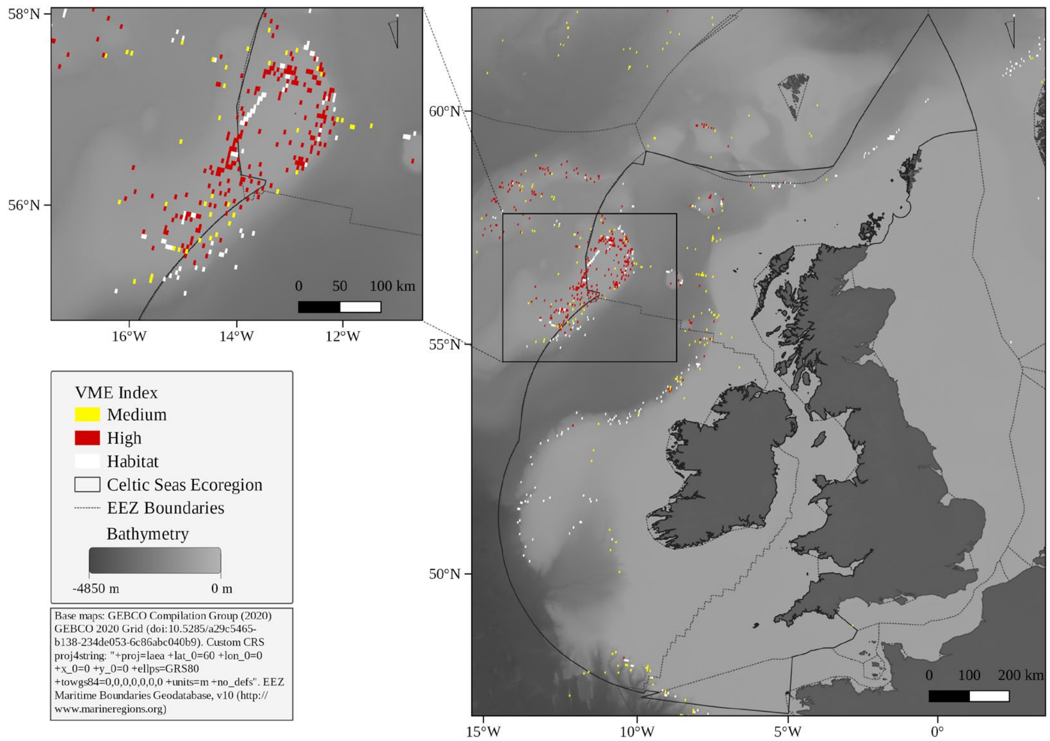

Figure 15 Areas of known VMEs (VME habitat) and high and medium likelihood of VME occurrence in the Celtic Seas ecoregion, identified via the cumulative VME index and mapped at the scale of C-square grids. The inset shows the northwest Rockall Bank.

There are 3091 records of VME habitats and 9278 records of VME indicator taxa in the Celtic Seas ecoregion below 200 m in depth. VMEs in regions shallower than 200 m may exist but are not recorded in the VME database. All records for the VME habitats come from the northwest of Scotland, west of Ireland, and the Celtic Sea while no records have been made for the Malin Shelf and the Irish Sea. However, a small portion of VME indicator records do arise from the Malin Shelf and the Irish Sea.

VME habitats include anemone aggregations, cold-water coral reefs, coral gardens, deep-sea sponge aggregations, sea pen fields, stalked crinoid aggregations, tube-dwelling anemone aggregations, and xenophyophore aggregations. VME indicator taxa recorded are: anemones, black corals, cup corals, gorgonians, sea pens, soft coral, sponges, stony corals, stylasterids (lace corals), and xenophyophores.

OSPAR threatened and/or declining habitats

Additional recorded occurrences (i.e. <200 m depth) of *Sabellaria spinulosa* reefs in the ecoregion are concentrated around the west coasts of England and Wales with a more scattered distribution around Scotland and Ireland (Figure 9). *Modiolus modiolus* beds occur patchily in the Irish Sea.

Cephalopods

Approximately forty species of cephalopod are known to occur in this ecoregion. Of these the main exploited species is the long-finned squid which is found mainly on the shelf and at Rockall. Catches in the last two decades have fluctuated markedly from around 700 to 2700 tonnes. Three species of short finned squid *Illex coindetii*, *Todaroipsis eblanae*, and *Todarodes sagittatus* are commonly commercially caught along the continental slope of the ecoregion. In the southeast of the ecoregion, there is an important commercial fishery for cuttlefish (*Sepia officinalis*) in the western channel. The stock status of all cephalopod species in the ecoregion are currently unknown; some abundance trends are available for the more common species and these tend to show large inter-annual fluctuations, which is consistent with the short life-span of the species. Loliginid discards are generally negligible and in 2019 discards represented only 1% of total catches.

Reptiles

Over 1000 individual turtles have been observed in Irish waters since 1966. At 80.1%, the majority were the critically endangered leatherback turtles (*Dermochelys coriacea*), with loggerhead turtles (*Caretta caretta*) at 5.6%, and Kemp's ridley sea turtles (*Lepidochelys kempii*) at 0.9%. There have also been single records of hawksbill sea turtles (*Eretmochelys imbricate*) and green turtles (*Chelonia mydas*). The Celtic Seas ecoregion is considered within the historical geographic distribution of the leatherback turtle, with all others currently considered vagrants. There is no trend information currently available.

Fish

On the shelf of the Celtic Sea ecoregion there is as diverse groundfish community with over a hundred fish species regularly caught in trawl surveys. The most abundant demersal species are hake, haddock, whiting, and pout (*Trisopterus* spp). Common benthic and flatfish species in this ecoregion include anglerfish, dab, plaice, sole, lemon sole (*Microstomus kitt*), and megrim. Sprat (*Sprattus sprattus*), herring, and sandeels (Ammodytidae) are abundant inshore and on the shelf. Widely distributed pelagic fish species are more abundant along the shelf edge and include boarfish, blue whiting, herring, mackerel, and horse mackerel. Mueller's pearlside (*Maurolicus muelleri*), glacial lantern fish (*Benthosema glaciale*), and lancet fish (Alepisauridae) are the dominant mesopelagic species. These pelagic and mesopelagic species are important components of the foodweb in this ecoregion, and changes in their abundance can have significant consequences for this foodweb.

Relative spawning-stock biomass has increased since the late 1990s for many stocks, and the average biomass ratio is above MSY $B_{trigger}$ for pelagic, demersal, benthic, and crustacean stocks (Figure 16). A number of stocks still have very low stock biomasses, namely cod and whiting to the west of Scotland, cod and whiting in the Irish Sea, and herring west of Scotland and in the Celtic Sea. The stock status of many elasmobranch species remains unknown.

Trends in fishing pressure are presented in the 'Selective extraction of species' section and in the Celtic Seas Fisheries Overview.

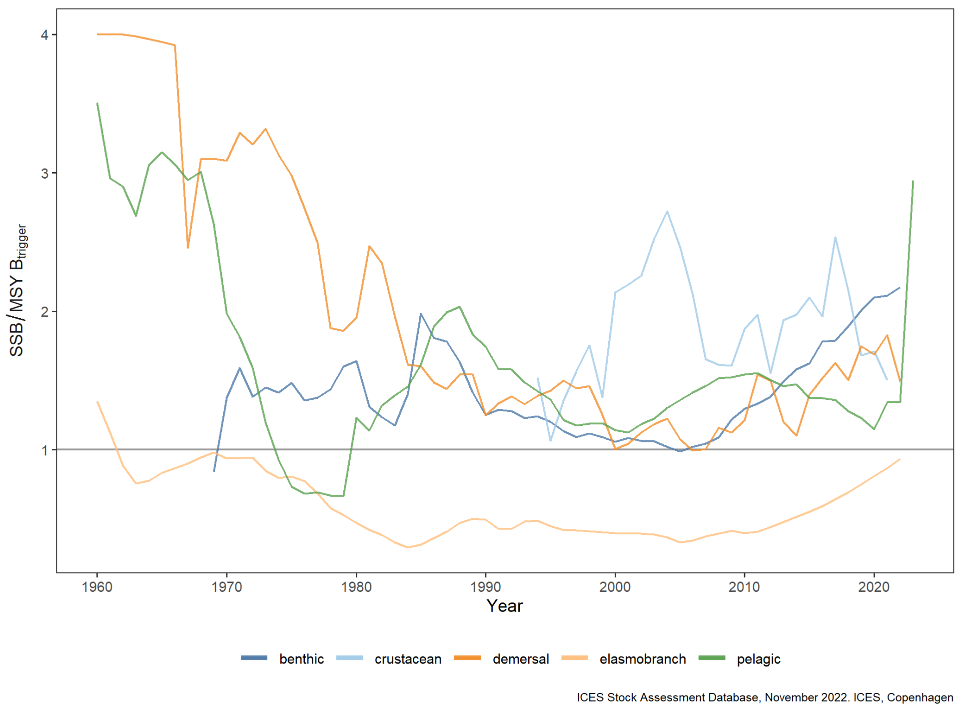

Figure 16 Time-series of annual biomass (SSB to MSY $B_{trigger}$ ratio) by fisheries guild for benthic, crustacean, demersal, elamobranch, and pelagic stocks. Table A1 in Annex 1 details which species belong to each fish category.

The Celtic Seas is an important migratory corridor for Atlantic salmon. Juvenile smolts migrate from rivers to northern oceanic feeding grounds, and the adults migrate back to natal rivers throughout the ecoregion. Knowledge of the role of the species in the ecosystem is limited. The North-East Atlantic Commission (NEAC) area has seen a general reduction in catches in both fres and marine waters since the 1980s, which reflects a decline in fishing effort as a consequence of management measures as well as a reduction in the size of stocks. Environmental conditions in both freshwater and marine environments have a marked effect on the status of salmon stocks. In the marine environment, return rates of adult salmon have declined since the 1980s and, for some stocks, are now at their lowest levels in the time-series, even after the closure of marine fisheries. Climatic factors modifying ecosystem conditions and the impact of predators of salmon at sea are considered to be the main contributing factors of lower productivity, which is expressed almost entirely in terms of lower return rates.

Seabirds

At least 23 seabird species breed on the coasts of the Celtic Seas. These colonies are particularly important in a global context of abundance for Manx shearwater (*Puffinus puffinus*), European storm-petrel (*Hydrobates pelagicus*), and northern gannet (*Morus bassanus*). The numbers of many breeding species have been declining in the past decade. Widespread seabird breeding failures are frequent in the Celtic Seas and have been documented at 25% or greater since 2010. The variation in habitats (from coastal to shelf break and deep sea) means that the ecoregion is also used during the non-breeding season by many further species and by seabirds that breed elsewhere. Declines may be related to prey availability and contaminant loads. For information on bycatch, see the 'Selective extraction of species' section.

Marine mammals

Two species of seal occur commonly in the Celtic Seas: grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*). Thirteen cetacean species either occur commonly or are regular visitors: minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), common dolphin, white-beaked dolphin (Lagenorhynchus albirostris), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), Risso's dolphin (*Grampus griseus*), long- finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*), northern bottlenose whale (*Hyperoodon ampullatus*), Sowerby's beaked whale (*Mesoplodon bidens*), Cuvier's beaked whale (*Ziphius cavirostris*), and sperm whale (*Physeter macrocephalus*). The abundance of grey seals in the ecoregion is stable, and there is little information on the overall trends of harbour seals and of cetaceans. For information on bycatch, see the 'Selective extraction of species' section.

Foodwebs

Foodwebs within the ecoregion span 4–5 trophic levels (from primary production to apex predators). Production by autotrophic organisms at trophic level 1 supports complex zooplankton and benthos communities (generally between trophic levels 2–3), followed by fish, seabirds, and mammals (trophic levels > 3). Toothed whales, seals, and sharks comprise the highest trophic levels, followed closely by highly predatory species including monkfish, hake, and cod. The foodweb has undergone substantial change over the last few decades in response to fishing pressure and environmental change. High fishing pressure from the mid- to late 20th century led to the depletion of species such as cod, whiting, sole, herring, and plaice. Species such as flapper skate and blue skate (*Dipturus* spp.), which were once considered abundant (i.e., 'common skate'), are now listed as Critically Endangered on the IUCN List of Threatened Species, largely as a consequence of removal by fisheries. While the biomasses of several stocks – including, hake, haddock, megrim, and monkfish – have recovered and are currently at high levels, some commercial stocks – including cod, whiting, and herring – remain depleted despite rebuilding measures. Complex ocean-atmosphere interactions driven by the North Atlantic Oscillation (NAO) and Atlantic Multidecadal Oscillation (AMO), combined with climate change, have led to changes in species ranges, interactions, and compositions. Recent studies suggest that environmental change, such as changes in temperature, predation pressure, and food availability, may have suppressed the overall production of commercial finfish in the Celtic Seas and thus dampened the rate of stock recovery.

The typical length indicator, which measures the size-structure of fish and elasmobranch communities, is decreasing under high fishing pressure. Mixed signals are observed within the Celtic Seas, with variation evident on a sub-ecoregional scale, and between pelagic and demersal species. While no subarea was homogenous, little long-term change was observed for pelagic species.

Sources and acknowledgments

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The maps and figures in this document are produced as follows:

Figure 1: produced by the ICES Secretariat; data used stems from:
- Depth contours. General Bathymetric Chart of the Oceans (GEBCO)
- Ecoregions. International Council for the Exploration of the Sea (ICES)
- Ports. Global Shipping Lanes and Harbors (ESRI)
- Catchment Area. European Environment Agency (EEA). European Topic Centre on Inland, Coastal and Marine waters (ETC/ICM).
- ICES areas. International Council for the Exploration of the Sea (ICES)

Figure 2: produced by ICES Secretariat; data used stems from:
- Exclusive Economic Zones; marineregions.org (VLIZ)
- ICES areas. International Council for the Exploration of the Sea (ICES)
- OSPAR areas; OSPAR Commission
- North Western Waters Advisory Council and Pelagic Advisory Council boundaries

Figure 3: produced by ICES Secretariat
Figure 4: produced by ICES Working Group on Social Indicators (WGSOCIAL)
Figure 5: Produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG
Figure 6: reproduced from OSPAR (2017)
Figure 7: produced by ICES Secretariat with available data
Figure 8: Produced with data from the UK Met Office Hadley Centre Sea Ice and Sea Surface Temperature dataset (HadISST)
Figure 9: produced using data from:
- EMODnet Bathymetry Consortium (2016)
- Circulation and features based on Hill *et al*. (2008), Holt and Umlauf (2008), González-Pola *et al*. (2020), Houpert *et al*. (2020), Jones *et al*. (2020), Moffat *et al*. (2020), Raine (2014)

Figure 10: produced using data from: Copernicus Eppley VGPM MODIS NPP, https://marine.copernicus.eu
Figure 11: produced using data from ICES-IOC-PICES Harmful Algal Events Database (IODE)
Figure 12: produced by ICES Working Group on Zooplankton Ecology (WGZE)
Figure 13: produced using data from EMODnet Geology **-** EMODnet Geology Multiscale
Figure 14: produced using data from Substrate maps. EMODnet Seabed Habitats Mapviewer
Figure 15: base map imagery GEBCO 2014 Grid, version 20150318. EEZ: Flanders Marine Institute (2020) Maritime Boundaries Geodatabase, version 11. Depth contours: GEBCO (2004). Map projection: EPSG:4326 - WGS 84. For further information on definitions of VME Index and Habitat, and breakdown on VME type, see WKEUVME report.
Figure 16: Produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG

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Annex 1 Stocks in the Celtic Seas ecoregion and their fisheries guilds

Table A1 Stocks with analytical assessments and guilds included in Figure 4 and Figure 16. Detailed information Celtic Seas fisheries is provided in the Celtic Seas Fisheries Overviews.

Stock code	Stock name	Fishery guild
ank.27.78abd	Black-bellied anglerfish (*Lophius budegassa*) in Subarea 7 and divisions 8.a–b and 8.d (Celtic Seas, Bay of Biscay)	Benthic
lez.27.4a6a	Megrim (*Lepidorhombus spp)* in divisions 4.a and 6.a (northern North Sea, West of Scotland)	Benthic
lez.27.6b	Megrim (*Lepidorhombus spp.)* in Division 6.b (Rockall)	Benthic
meg.27.7b-k8abd	Megrim (*Lepidorhombus whiffiagonis*) in divisions 7.b–k, 8.a–b, and 8.d (west and southwest of Ireland, Bay of Biscay)	Benthic
mon.27.78abd	White anglerfish (*Lophius piscatorius*) in Subarea 7 and divisions 8.a–b and 8.d (Celtic Seas, Bay of Biscay)	Benthic
ple.27.7a	Plaice (*Pleuronectes platessa*) in Division 7.a (Irish Sea)	Benthic
ple.27.7e	Plaice (*Pleuronectes platessa*) in Division 7.e (western English Channel)	Benthic
ple.27.7fg	Plaice (*Pleuronectes platessa*) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)	Benthic
sol.27.7a	Sole (*Solea solea*) in Division 7.a (Irish Sea)	Benthic
sol.27.7e	Sole (*Solea solea*) in Division 7.e (western English Channel)	Benthic
sol.27.7fg	Sole (*Solea solea*) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)	Benthic
nep.fu.11	Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 11 (West of Scotland, North Minch)	Crustacean
nep.fu.12	Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 12 (West of Scotland, South Minch)	Crustacean
nep.fu.13	Norway lobster (*Nephrops norvegicus*) in Division 6.a, Functional Unit 13 (West of Scotland, the Firth of Clyde and Sound of Jura)	Crustacean
nep.fu.14	Norway lobster (*Nephrops norvegicus*) in Division 7.a, Functional Unit 14 (Irish Sea, East)	Crustacean
nep.fu.15	Norway lobster (*Nephrops norvegicus*) in Division 7.a, Functional Unit 15 (Irish Sea, West)	Crustacean
nep.fu.16	Norway lobster (*Nephrops norvegicus*) in divisions 7.b–c and 7.j–k, Functional Unit 16 (west and southwest of Ireland, Porcupine Bank)	Crustacean
nep.fu.17	Norway lobster (*Nephrops norvegicus*) in Division 7.b, Functional Unit 17 (west of Ireland, Aran grounds)	Crustacean
nep.fu.19	Norway lobster (*Nephrops norvegicus*) in divisions 7.a, 7.g, and 7.j, Functional Unit 19 (Irish Sea, Celtic Sea, eastern part of southwest of Ireland)	Crustacean
nep.fu.2021	Norway lobster (*Nephrops norvegicus*) in divisions 7.g and 7.h, functional units 20 and 21 (Celtic Sea)	Crustacean
nep.fu.22	Norway lobster (*Nephrops norvegicus*) in divisions 7.g and 7.f, Functional Unit 22 (Celtic Sea, Bristol Channel)	Crustacean
bli.27.5b67	Blue ling (*Molva dypterygia*) in subareas 6–7 and Division 5.b (Celtic Seas, English Channel, and Faroes grounds)	Demersal
bss.27.4bc7ad-h	Seabass (*Dicentrarchus labrax*) in Divisions 4.b–c, 7.a, and 7.d–h (central and southern North Sea, Irish Sea, English Channel, Bristol Channel, and Celtic Sea)	Demersal
cod.27.6a	Cod (*Gadus morhua*) in Division 6.a (West of Scotland)	Demersal
cod.27.7e-k	Cod (*Gadus morhua*) in divisions 7.e–k (eastern English Channel and southern Celtic Seas)	Demersal
ghl.27.561214	Greenland halibut (*Reinhardtius hippoglossoides*) in subareas 5, 6, 12, and 14 (Iceland and Faroes grounds, West of Scotland, North of Azores, East of Greenland)	Demersal
had.27.46a20	Haddock (*Melanogrammus aeglefinus*) in Subarea 4, Division 6.a, and Subdivision 20 (North Sea, West of Scotland, Skagerrak)	Demersal
had.27.6b	Haddock (*Melanogrammus aeglefinus*) in Division 6.b (Rockall)	Demersal
had.27.7a	Haddock (*Melanogrammus aeglefinus*) in Division 7.a (Irish Sea)	Demersal
had.27.7b-k	Haddock (*Melanogrammus aeglefinus*) in Divisions 7.b–k (southern Celtic Seas and English Channel)	Demersal
hke.27.3a46-8abd	Hake (*Merluccius merluccius*) in subareas 4, 6, and 7, and divisions 3.a, 8.a–b, and 8.d, Northern stock (Greater North Sea, Celtic Seas, and the northern Bay of Biscay)	Demersal
pok.27.3a46	Saithe (*Pollachius virens*) in subareas 4, 6 and Division 3.a (North Sea, Rockall and West of	Demersal

Stock code	Stock name	Fishery guild
	Scotland, Skagerrak and Kattegat)	
whg.27.6a	Whiting (*Merlangius merlangus*) in Division 6.a (West of Scotland)	Demersal
whg.27.7a	Whiting (*Merlangius merlangus*) in Division 7.a (Irish Sea)	Demersal
whg.27.7b-ce-k	Whiting (*Merlangius merlangus*) in divisions 7.b–c and 7.e–k (southern Celtic Seas and eastern English Channel)	Demersal
dgs.27.nea	Spurdog (*Squalus acanthias*) in subareas 1–10, 12 and 14 (the Northeast Atlantic and adjacent waters)	Elasmobranch
aru.27.5b6a	Greater silver smelt in divisions 5.b and 6.a (Faroes grounds and west of Scotland)	Pelagic
her.27.irls	Herring (*Clupea harengus*) in divisions 7.a South of 52°30'N, 7.g–h, and 7.j–k (Irish Sea, Celtic Sea, and southwest of Ireland)	Pelagic
her.27.nirs	Herring (*Clupea harengus*) in Division 7.a North of 52°30'N (Irish Sea)	Pelagic
hom.27.2a4a5b 6a7a-ce-k8	Horse mackerel (*Trachurus trachurus*) in Subarea 8 and divisions 2.a, 4.a, 5.b, 6.a, 7.a –c,e–k (the Northeast Atlantic)	Pelagic
mac.27.nea	Mackerel (*Scomber scombrus*) in subareas 1-8 and 14 and division 9.a (the Northeast Atlantic and adjacent waters)	Pelagic
whb.27.1-91214	Blue whiting (*Micromesistius poutassou*) in subareas 1-9, 12, and 14 (Northeast Atlantic and adjacent waters)	Pelagic

Annex 2 Threatened and declining species and habitats in the Celtic Sea

The threatened and declining species in the Celtic Sea according to OSPAR (OSPAR Regions III and V) and modified for ICES Celtic Seas ecoregion are shown in the tables below.

Table A2.1 Threatened and declining species in the Celtic Sea

Scientific name	Common name
Invertebrates	
Arctica islandica	Ocean quahog
Nucella lapillus	Dog whelk
Ostrea edulis	Flat oyster
Seabirds	
Puffinus mauretanicus	Balearic shearwater
Rissa tridactyla	Black-legged kittiwake
Sterna dougallii	Roseate tern
Fish	
Alosa alosa	Allis shad
Anguilla anguilla	European eel
Centroscymnus coelolepis	Portuguese dogfish
Centrophorus granulosus	Gulper shark
Centrophorus squamosus	Leafscale gulper shark
Cetorhinus maximus	Basking shark
Dipturus batis (synonym: *Raja batis*)	Common skate
Raja montagui (synonym: *Dipturus montagui*)	Spotted ray
Gadus morhua	Cod
Hippocampus guttulatus (synonym: *Hippocampus ramulosus*)	Long-snouted seahorse
Hippocampus hippocampus	Short-snouted seahorse
Hoplostethus atlanticus	Orange roughy
Lamna nasus	Porbeagle
Petromyzon marinus	Sea lamprey
Raja clavata	Thornback skate/ray
Rostroraja alba	White skate

Salmo salar	Salmon
Squalus acanthias	[Northeast Atlantic] spurdog
Squatina squatina	Angel shark
Thunnus thynnus	Bluefin tuna
Reptiles	
Caretta caretta	Loggerhead turtle
Dermochelys coriacea	Leatherback turtle
Marine mammals	
Balaenoptera musculus	Blue whale
Eubalaena glacialis	Northern right whale
Phocoena phocoena	Harbour porpoise

Table A2.2 Threatened and declining habitats in the Celtic Sea

Habitats
Carbonate mounds
Coral gardens
Deep-sea sponge aggregations
Intertidal *Mytilus edulis* beds on mixed and sandy sediments
Intertidal mudflats
Lophelia pertusa reefs
Maerl beds
Modiolus modiolus beds
Oceanic ridges with hydrothermal vents/fields
Ostrea edulis beds
Sabellaria spinulosa reefs
Seamounts
Sea pen and burrowing megafauna communities
Zostera beds