

7.1 Celtic Seas Ecoregion – Ecosystem overview

Ecoregion description

The Celtic Seas ecoregion covers the northwestern shelf seas of the EU. It includes areas of the deeper eastern Atlantic Ocean and coastal seas that are heavily influenced by oceanic inputs. The ecoregion ranges from north of Shetland to Brittany in the south. Three key areas constitute this ecoregion:

- the Malin shelf;
- the Celtic Sea and west of Ireland;
- the Irish Sea.

The Celtic Seas ecoregion includes all or parts of the Exclusive Economic Zones (EEZs) of three EU Member States. Fisheries in the Celtic Seas are managed through the EU Common Fisheries Policy (CFP), with fisheries of some stocks managed by the North East Atlantic Fisheries Commission (NEAFC) and by coastal state agreements. 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 the International Council for the Exploration of the Sea (ICES), the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF), and the North Western Waters and Pelagic ACs. Environmental policy is managed by national governments and agencies and by OSPAR; advice is provided by national agencies, OSPAR, the European Environment Agency (EEA), and ICES. International shipping is managed under the International Maritime Organization (IMO).

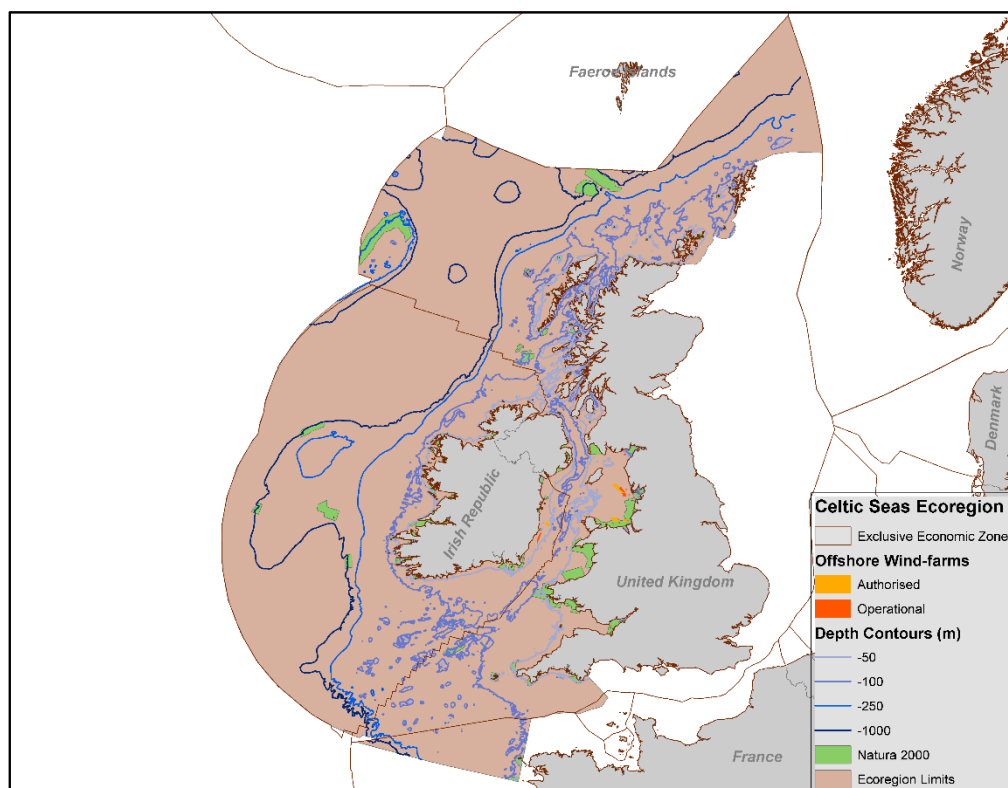


Figure 1 The Celtic Seas ecoregion, showing EEZs, larger offshore Natura 2000 sites, and operational and authorized wind farms.

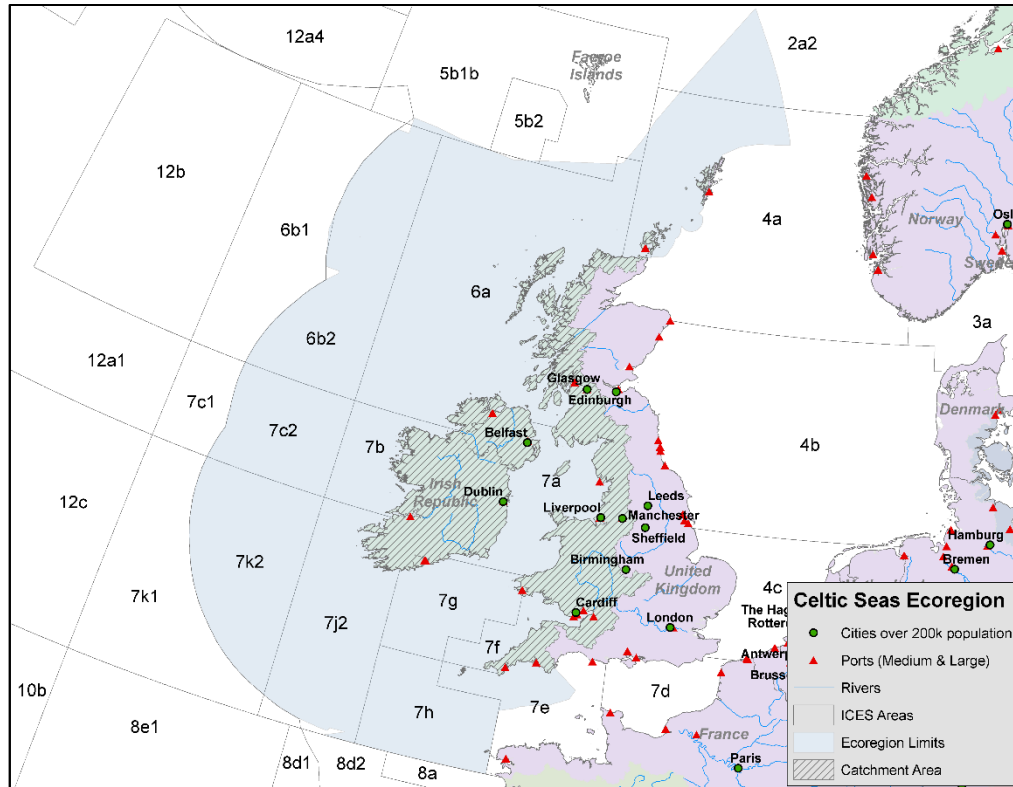


Figure 2 Catchment area for the Celtic Seas ecoregion, showing major cities, ports, and ICES areas.

Key signals within the environment and the ecosystem

- Long-term datasets from the Malin shelf (from 1959 on) and the upper 800 m of the Rockall Trough (from 1975 on) indicate an overall rise in sea surface temperature. Mean annual temperature of the Rockall Trough increased from ~9.3°C in 2001 to a peak 10.1°C in 2006. A steady cooling trend has been noted since then. In the last decade, the same trends are apparent on the Malin shelf. Salinity in the upper 800 m of the Rockall Trough has shown an increase from the early nineties until 2010, with a decrease in the following four years.
- Temperature affects the migration, distribution, and onset of spawning of blue whiting *Micromesistius poutassou*, Northeast Atlantic mackerel *Scomber scombrus*, western horse mackerel *Trachurus trachurus*, and boarfish *Capros aper*.
- Sea temperature affects the recruitment of some gadoids in the Irish Sea, Celtic Sea, and west of Scotland. The Celtic Seas ecoregion is at the edge of the geographical range of several species, potentially making these species more susceptible to environmental variation.
- Species richness (number of species) is higher in the Celtic Sea than in the rest of the ecoregion due to the number of warm-favouring Lusitanian species present here.
- Phytoplankton abundance and the abundance of diatom and dinoflagellate species in shelf and oceanic waters west of the European shelf show long-term declines since 1958, while diatom and dinoflagellate species abundances increased in coastal waters of the Malin shelf and southwest of Ireland between 1990 and 2010.
- There has been a decline in overall copepod abundance since 1958. The cold-water species *Calanus finmarchicus* and *Pseudocalanus* spp. have decreased in abundance; however, the warm-water copepod *C. helgolandicus* has increased in abundance and has spread northwards, presumably in response to ocean warming.
- The abundance of breeding seabirds has shown a broad downward trend since the early 2000s. Populations of grey seals have been increasing over at least the past thirty years, though the populations are becoming more stable now. Overall trends in the abundances of cetaceans and harbour seals are not known.

- Overall fishing pressure on the commercial fish and shellfish stocks in the Celtic Seas ecoregion has decreased since its peak in 1998 and the average F to F_{MSY} ratios for the combined demersal, flatfish, and pelagic stocks is now close to F_{MSY} .
- Overall biomass of commercial fish and shellfish stocks in the Celtic Sea has increased and the average SSB to $B_{trigger}$ ratio for the combined demersal, shellfish, and pelagic stocks in the Celtic Seas ecosystem is now above $B_{trigger}$.
- 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.

Pressures

The five most important pressures in the Celtic Seas ecoregion are selective extraction of species, abrasion, smothering, substrate loss, and nutrient and organic enrichment. These pressures are linked mainly to the following human activities: fishing, aquaculture, coastal construction, land-based industry, maritime transport, agriculture, dredging, and offshore structures for renewable and non-renewable energy sources. The pressures are described in the ICES glossary of principle pressures in ICES ecoregions (ICES, 2015a).

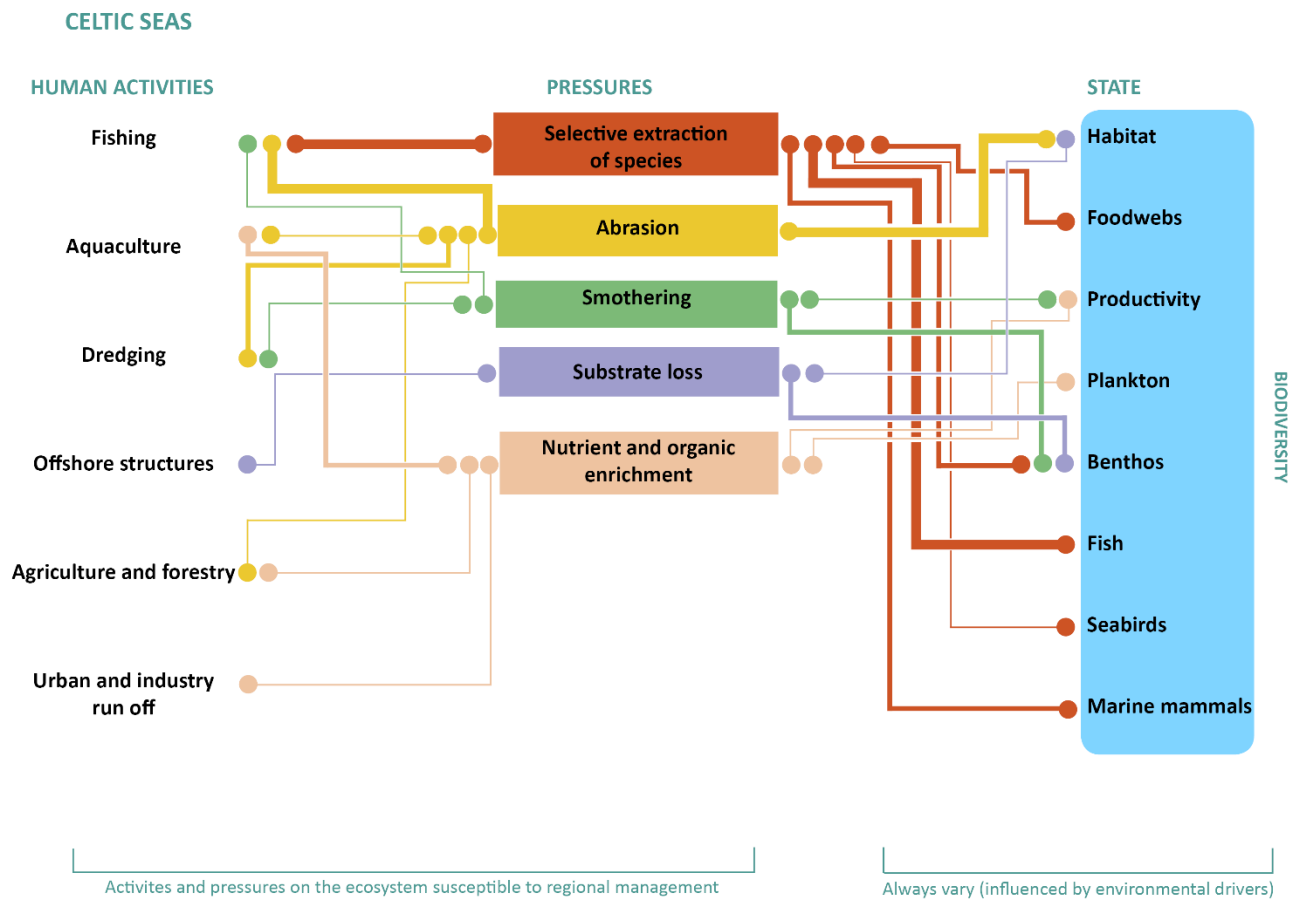


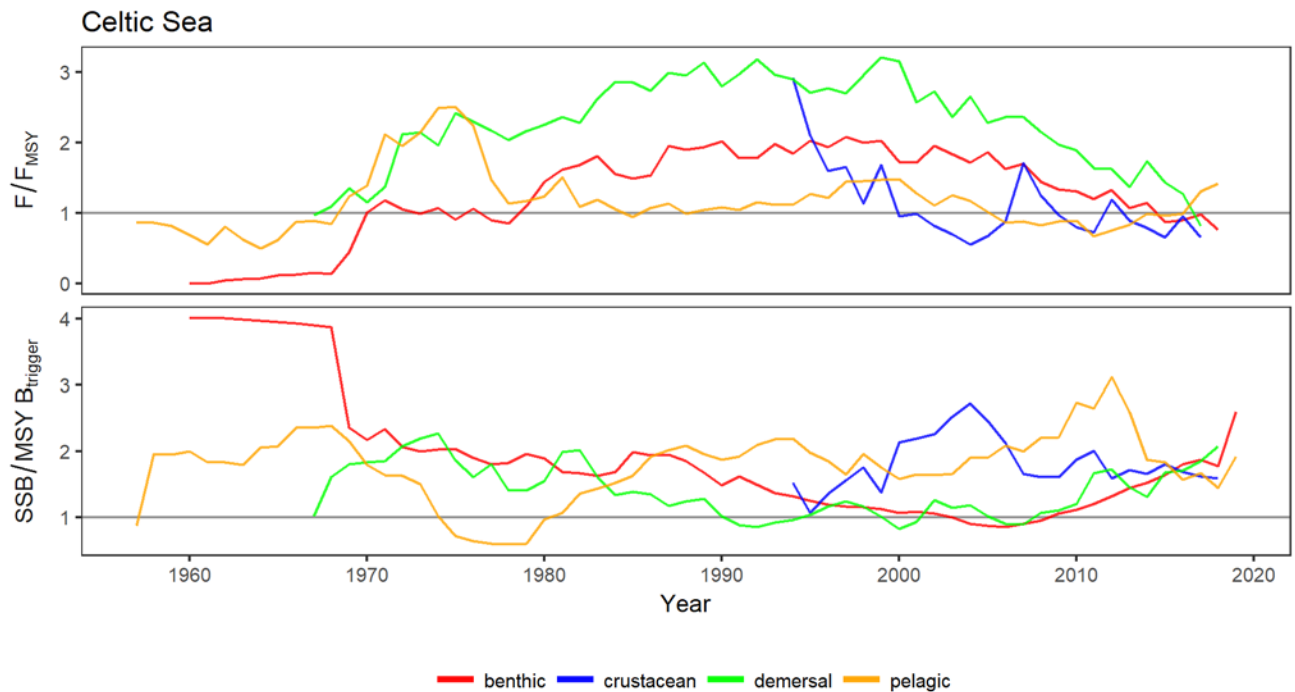
Figure 3 Celtic Seas ecoregion overview with the major regional pressures, human activities, and state of the ecosystem components. The width of lines indicates the relative importance of individual links.

Selective extraction of species

The main contributing activity to selective extraction of species in the Celtic Seas ecoregion is fisheries, with demersal and pelagic fisheries occurring in most parts of the ecoregion. There has been an overall reduction in fishing effort by the most used gears.

Impacts on commercial stocks

Overall fishing mortality (F) for shellfish, demersal, and pelagic fish stocks has reduced since the late 1990s (Figure 4) although the pelagic stock are now above the reference point. Mean F is now closer to the level that produces maximum sustainable yield (MSY). The fishing mortality on 45 stocks has been evaluated in Figure 4 against MSY reference points; of these, 30 stocks are now fished at or below MSY. The relative spawning-stock biomass has also increased since the late 1990s and is now above the biomass reference points used to assess 78% of the stocks in the Celtic Sea. A number of stocks still have very low stock biomasses, namely cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, and whiting *Merlangius merlangus* to the west of Scotland, cod and sole *Solea solea* in the Irish Sea, and herring *Clupea harengus* in ICES Divisions 6a, 7b, and 7c.



ICES Stock Assessment Database, November/2018. ICES, Copenhagen

Figure 4 Time-series of average of relative fishing mortality (F to F_{MSY} ratio) and biomass (SSB to B_{MSY} trigger ratio) by fisheries guild for benthic, demersal and pelagic stocks (see Annex A).

Impacts on threatened and declining fish species

Several fish species have been depleted by fishing in the past and are now on the OSPAR list of threatened and declining species (see full list below), including spurdog *Squalus acanthias*, the common skate complex *Dipturus* spp., angel shark *Squatina squatina*, porbeagle *Lamna nasus*, and some deep-water sharks. Although there are zero TACs or prohibited listings for these species, several of them remain vulnerable to existing fisheries. Spurdog and the common skate complex are caught as bycatch in mixed demersal trawl fisheries and gillnet fisheries, and deep-water sharks are caught in the mixed deep-water trawl fishery.

Impacts on seabirds and marine mammals

Longline fisheries pose the greatest threat to seabirds offshore, while inshore net fisheries may catch diving species. Large-scale bycatch of great shearwaters *Puffinus gravis* has been reported from the hake longline fishery on the Grand Sole fishing bank, and based on information from elsewhere, longline fisheries in waters west of Scotland would likely catch northern fulmars *Fulmarus glacialis*. Fisheries with high risk of cetacean bycatch in the Celtic Sea are bottom setnets (bycatch of harbour porpoises *Phocoena phocoena*) and pelagic trawls, particularly those for bass (bycatch of common dolphin *Delphis delphinus*). 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. Bycatch in both fisheries may have reduced in recent years due to less fishing activity and the use of acoustic alarms attached to fishing gear as a mitigation technique.

Abrasion

Abrasion is associated with bottom-contacting mobile and set fishing activities, in particular scallop dredging, beam trawling, and otter trawling and other activities such as anchoring, hydrodynamic dredging, and cable burial.

Physical disturbance of benthic habitats by bottom trawl fishing gear is described by using vessel monitoring system (VMS) and logbook data. The extent, magnitude, and impact of mobile bottom-contacting fishing gear on the seabed and benthic habitats varies geographically across the Celtic Seas (Figure 4). This figure excludes Spanish fishing effort. 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.

STECF data show that fishing effort with bottom mobile gears decreased by 35% from 2003 to 2012 in the Celtic Seas ecoregion. This has reduced the spatial fishing footprint and the average number of times the seabed is trawled per year. A reduction in spatial extent and intensity is particularly apparent for bottom otter trawling for the mixed demersal fishery in the area northwest of Scotland and beam trawling in the Irish Sea.

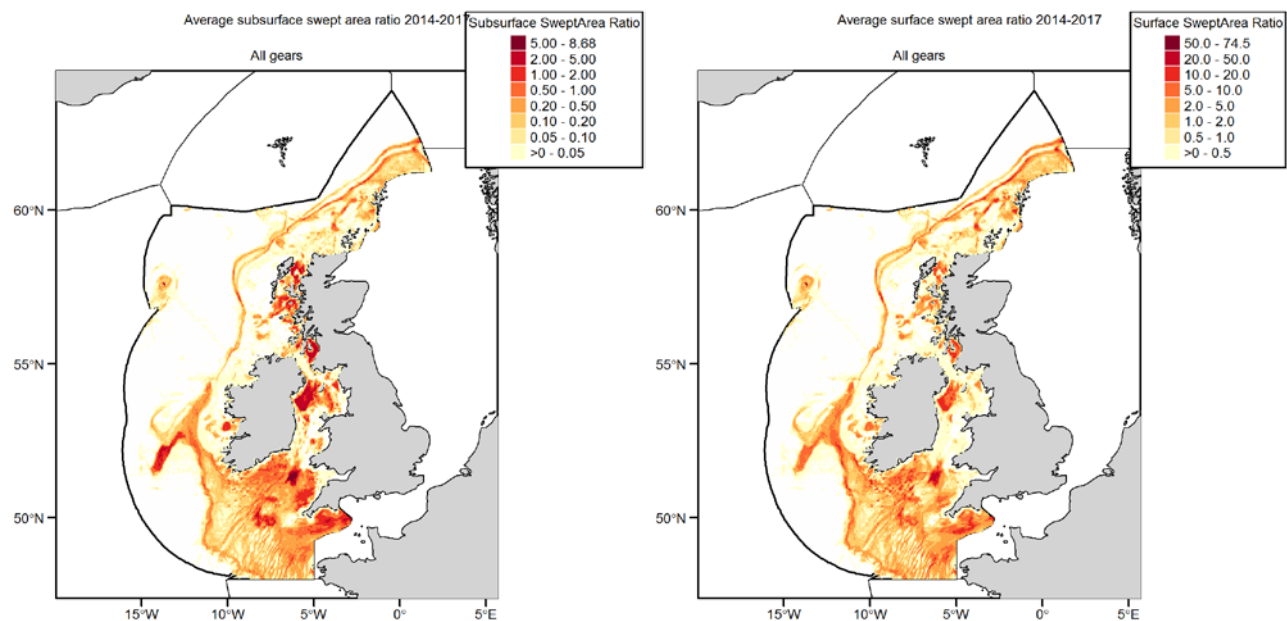


Figure 5 Average annual subsurface (left) and surface (right) disturbance by mobile bottom contacting fishing gear (Bottom otter trawls, Bottom seines, Dredges, Beam trawls) in the Celtic Seas during 2014–2017, expressed as average swept area ratios (SAR).

Smothering

Activities contributing to smothering and change in siltation in the Celtic Sea include dredging for shipping, disposal of materials to the seafloor, and commercial fishing. Maerl and aggregate extraction also occurred in the past.

Sediment accretion (land mass increases caused by water-borne sediment deposition) and sediment release issues associated with the growth of new species such as cordgrass *Spartina* spp have been known to cause significant siltation problems in coastal wetlands such as those in Cork Harbour.

Substrate loss

The Celtic Seas ecoregion has a large number of artificial structures along its coastlines (Figure 6). These include:

- land reclaimed for port and industrial zones;
- coastal defences such as dykes, seawalls, and beach nourishment schemes to prevent erosion and protect against flooding;
- aquaculture infrastructure;
- shipping channels;
- residential development;
- tourist accommodation;
- roads;
- piers;
- marinas and waste-water treatment facilities that cater for a growing population and tourism demands.

The presence of offshore installations such as wind farms also changes the substrate.

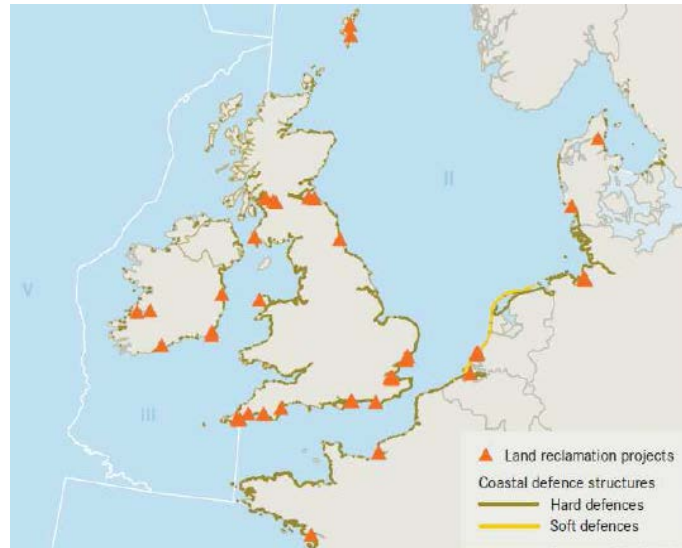


Figure 6 Location of land reclamation projects (orange triangle) and hard (green outline) and soft (yellow outline) coastal defence structures. (Source: OSPAR.)

Nutrient and organic enrichment

The urbanization of coastal areas is associated with nutrient releases and related pressures on the marine environment, e.g. from waste-water treatment plants or from economic activities. The most important sources contributing to eutrophication in the Celtic Seas ecoregion are agriculture, atmospheric deposition, urban waste water, industry, and aquaculture. 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. In the Celtic Seas ecoregion, eutrophication is restricted to inlets, estuaries, and harbours, in particular in areas of higher population densities and intensive agricultural activities.

Other pressures

Other pressures of potential concern in the Celtic Sea ecoregion are the introduction of contaminating compounds: the introduction of non-indigenous species, litter, and underwater sound. Contaminants are localized and restricted to coastal areas, with levels of most contaminants declining. However, polychlorinated biphenyls (PCBs) in both killer whales *Orcinus orca* and bottlenose dolphins *Tursiops truncatus* are at levels that will inhibit reproduction.

State of the ecosystem

Substrate

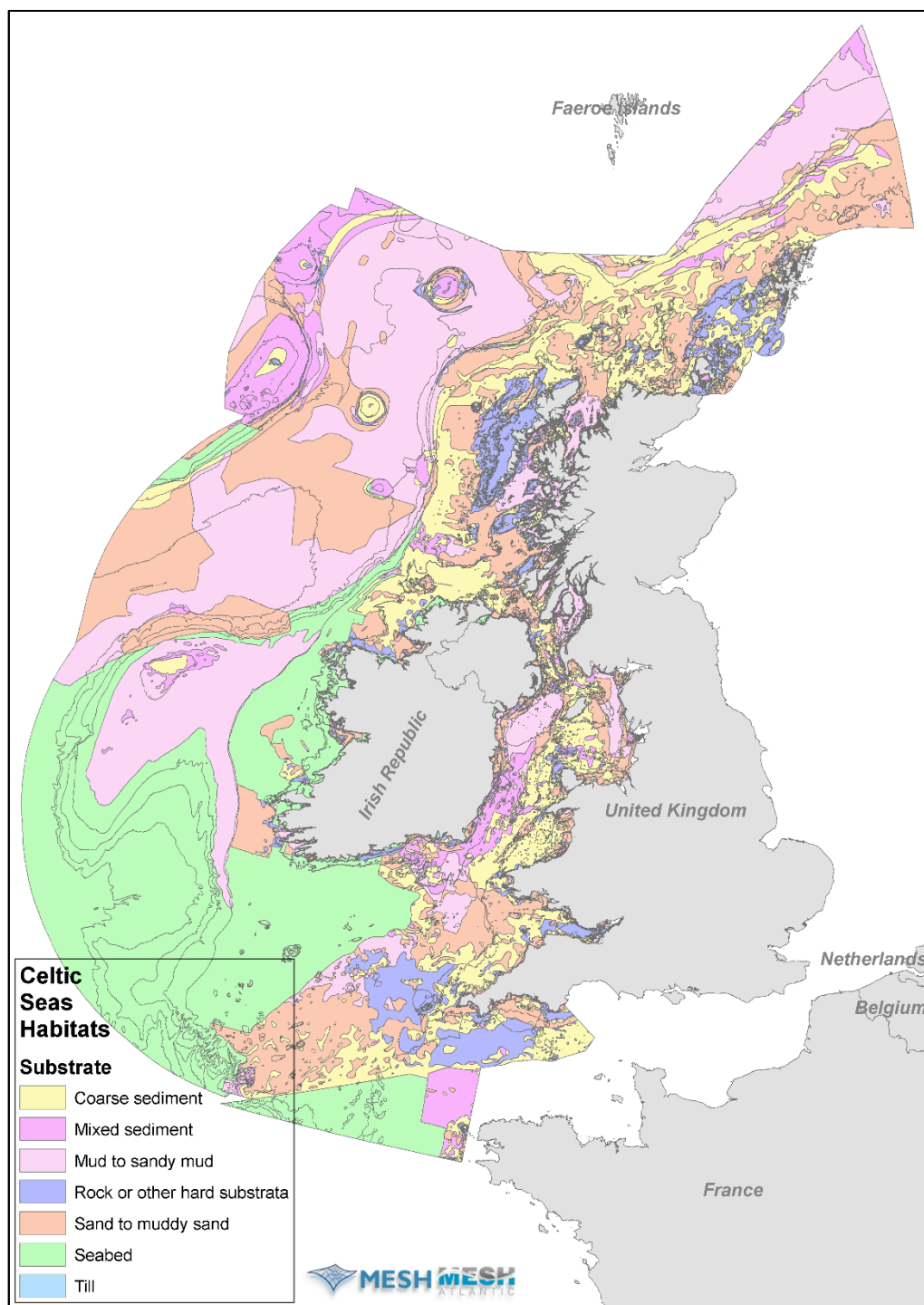


Figure 7 Broad-scale substrate map of the Celtic Seas ecoregion as compiled by MESH Atlantic (www.meshatlantic.eu).

The seabed of the Celtic Seas ecoregion is primarily comprised of sediments with extensive areas of mixed sediments: coarse and sandy to muddy areas on the Malin shelf, coarse and mixed sediments with some muddy patches in the Irish Sea, and coarse, rocky, and sandy to muddy sands in the Celtic Sea. Areas of rock and hard substratum are present in the northern and inshore parts of the ecoregion.

Benthic community

The soft sediments are characterized by burrowing megafauna; this includes sea pens and commercially important species (e.g. *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*.

Phytoplankton

Diatom and dinoflagellate species have declined since 1958 in both shelf and oceanic waters. Though there were no significant trends in phytoplankton abundance in the Irish Sea between 1996 and 2010, longer-term trends indicate a decline in both diatom and dinoflagellate abundance. Abundance of both species groups on the Malin shelf have increased since 2004; abundance also increased in the coastal waters of south and southwest Ireland between the years 1990 and 2010.

Zooplankton

Copepods such as *Calanus* spp. typically dominate the zooplankton community, but chaetognaths, siphonophores, medusae, appendicularians as well as meroplankton form a significant part of the zooplankton biomass throughout the year. Overall copepod abundance has declined since the start of records in 1958. There has been a gradual change to a warmer water zooplankton community over the last few decades. Cold-water species *Calanus finmarchicus* and *Pseudocalanus* spp. have decreased in abundance while the warm-water copepod *C. helgolandicus* has increased and spread northwards, probably in response to ocean warming. There has been a northward shift in the distribution of many other zooplankton species by more than 10° latitude over the past fifty years. This shift is particularly marked near the northward current along the European shelf edge. The seasonal timing of some plankton production has also altered in response to recent climate changes.

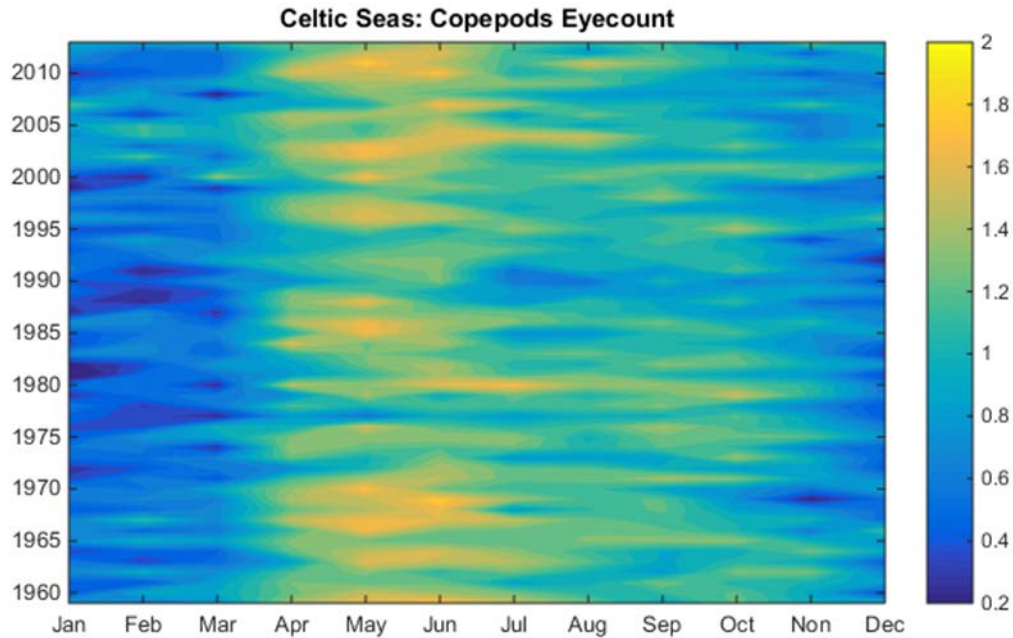


Figure 8 Long-term trends in copepod abundance from the CPR survey (log-mean abundance per cubic meter) aggregated for the ICES Celtic Seas ecoregion 1958–2014. (data source: <https://www.cprsurvey.org/>).

Cephalopods

The most abundant cephalopod species in the area are long-finned squid *Loligo forbesi* and southern shortfin squid *Illex coindetii*, which are mainly found close to the shelf break, while *Alloteuthis subulata* is a common species found in coastal waters. The main exploited species is the cuttlefish *Sepia officinalis*.

Fish

The Celtic Sea groundfish community consists of over a hundred species, but the 25 most abundant of these account for 99 percent of the total estimated biomass. The most abundant species are haddock, whiting, and pout *Trisopterus* spp. Common flatfish species in this ecoregion include dab *Limanda limanda*, plaice *Pleuronectes platessa*, and several species of sole and megrim. Pelagic fish species along the shelf edge are boarfish, blue whiting, mackerel, and horse mackerel while 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 parts of the foodweb in this ecoregion and changes in their abundance can have significant consequences for the marine food chain. Trends in fishing pressure and stock size are presented in the 'Selective extraction of species' section.

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*, British storm-petrel *Hydrobates pelagicus*, and northern gannet *Morus bassanus*. Trends in the numbers of many breeding species have been downwards in the past decade. The variation in habitats (from coastal to shelf break and deep seas) mean that the seas are also used during the non-breeding season by many further species and by seabirds that breed elsewhere.

Marine mammals

Two species of seal occur commonly in the Celtic Seas: grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina*. Thirteen cetacean species occur commonly or are resident in the Celtic Seas: minke whale *Balaenoptera acutorostrata*, fin whale *Balaenoptera physalus*, harbour porpoise, short-beaked common dolphin *Delphinus delphis*, white-beaked dolphin *Lagenorhynchus albirostris*, Atlantic white-sided dolphin *Lagenorhynchus acutus*, sperm whale *Physeter macrocephalus*, long-finned pilot whale *Globicephala melas*, northern bottlenose whale *Hyperoodon ampullatus*, Sowerby's beaked whale *Mesoplodon bidens*, killer whale, Risso's dolphin *Grampus griseus*, and bottlenose dolphin. The abundance of grey seals in the Celtic Seas ecoregion is stable, and there is little information on the overall trends of harbour seals and of cetaceans.

Non-indigenous species

This region has 168 non-indigenous and cryptogenic (obscure or of unknown origin) species. The majority (148 species) were found between 1950 and 1999. Since 2000, a total of 37 new species have been recorded, of which approximately a third (14 species) are recorded in Europe for the first time. The annual rate of discovery of non-indigenous species was ≈ 3.0 species in 1950–1999 and ≈ 2.5 species in 2000–2014.

The principal vectors/pathways transmitting species into this region are thought to be vessels (biofouling and ballast water), regional oyster and mussel stock movements, and commercial activities as well as water currents (secondary spread from neighbouring areas).

The most impacting species are oyster disease agents and predators which result in summer mortalities of Pacific oyster stocks and oyster diseases that have led to the demise of the native flat oyster production. Other species cause trophic competition with native species, changes in communities, habitats and ecosystem functioning, and fouling problems.

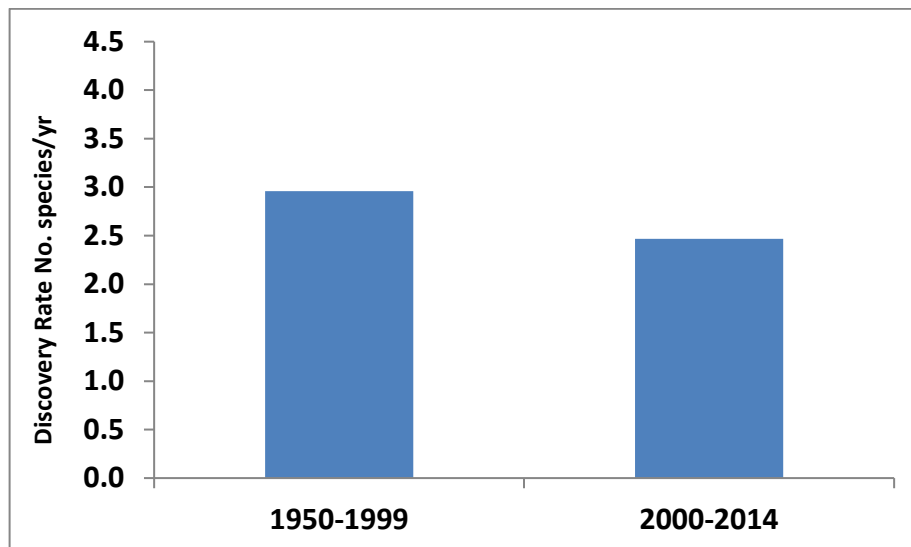


Figure 9 Annual rate of new non-indigenous and cryptogenic species discoveries in the Celtic Seas during 1950–1999 and 2000–2014.

Threatened and declining species and habitats in the Celtic Sea

The threatened and declining species in the Celtic Sea according to OSPAR are shown in the table below (includes OSPAR Regions III and V).

SCIENTIFIC NAME	COMMON NAME
INVERTEBRATES	
<i>Arctica islandica</i>	Ocean quahog
<i>Nucella lapillus</i>	Dog whelk
<i>Ostrea edulis</i>	Flat oyster
SEABIRDS	
<i>Larus fuscus fuscus</i>	Lesser black-backed gull
<i>Puffinus mauretanicus</i>	Balearic shearwater
<i>Rissa tridactyla</i>	Black-legged kittiwake
<i>Sterna dougallii</i>	Roseate tern
<i>Uria lomvia</i>	Thick-billed murre
FISH	
<i>Alosa alosa</i>	Allis shad
<i>Anguilla anguilla</i>	European eel
<i>Centroscymnus coelolepis</i>	Portuguese dogfish
<i>Centrophorus granulosus</i>	Gulper shark
<i>Centrophorus squamosus</i>	Leafscale gulper shark
<i>Cetorhinus maximus</i>	Basking shark
<i>Dipturus batis</i> (synonym: <i>Raja batis</i>)	Common skate
<i>Raja montagui</i> (synonym: <i>Dipturus montagui</i>)	Spotted ray
<i>Gadus morhua</i>	Cod
<i>Hippocampus guttulatus</i> (synonym: <i>Hippocampus ramulosus</i>)	Long-snouted seahorse
<i>Hippocampus hippocampus</i>	Short-snouted seahorse
<i>Hoplostethus atlanticus</i>	Orange roughy
<i>Lamna nasus</i>	Porbeagle
<i>Petromyzon marinus</i>	Sea lamprey
<i>Raja clavata</i>	Thornback skate / ray
<i>Rostroraja alba</i>	White skate
<i>Salmo salar</i>	Salmon
<i>Squalus acanthias</i>	[Northeast Atlantic] spurdog
<i>Squatina squatina</i>	Angel shark
<i>Thunnus thynnus</i>	Bluefin tuna
REPTILES	
<i>Caretta caretta</i>	Loggerhead turtle
<i>Dermochelys coriacea</i>	Leatherback turtle
MARINE MAMMALS	
<i>Balaenoptera musculus</i>	Blue whale
<i>Eubalaena glacialis</i>	Northern right whale
<i>Phocoena phocoena</i>	Harbour porpoise

Threatened and declining habitats in the Celtic Seas according to OSPAR (includes OSPAR Regions III and V)

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

Sources and acknowledgments

The content for the ICES regional ecosystem overviews is based on information and knowledge generated by the following ICES processes: Workshop on Benchmarking Integrated Ecosystem Assessment (WKBEMIA) 2012, ACOM/SCICOM Workshop on Ecosystem Overviews (WKECOVER) 2013, Workshop to draft advice on Ecosystem Overviews (WKDECOVER) 2013, and Advice drafting group to finalize draft Ecosystem Overviews (ADGECO) 2015, which provided the theoretical framework and final layout of the documents. The ICES integrated ecosystem assessment Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS) contributed to the main sections of this overview. The following working groups contributed to draft the subsections on the state of the ecosystem components: Benthos Ecology Working Group (BEWG), Working Group on Multispecies Assessment Methods (WGSAM), Working Group on Zooplankton Ecology (WGZE), Working Group on Cephalopod Fisheries and Life History (WGCEPH), Working Group on Marine Mammal Ecology (WGMME), and Working Group on Introductions and Transfers of Marine Organisms (WGITMO).

The maps and GIS products produced by the ICES Secretariat used data from:

1. Exclusive Economic Zones. *Marineregions.org* (VLIZ).
2. Offshore Wind-farms. *OSPAR Commission*.
3. Depth Contours. *General Bathymetric Chart of the Oceans* (GEBCO).
4. Natura 2000. *European Commission*.
5. Ecoregions. *International Council for the Exploration of the Sea* (ICES).
6. Ports. *Global Shipping Lanes and Harbors* (ESRI).
7. Cities. *World Cities* (ESRI).
8. Rivers. *WISE Large Rivers and large lakes*. *European Environment Agency* (EEA).
9. ICES Areas. *International Council for the Exploration of the Sea* (ICES).
10. Catchment Area. *European Environment Agency* (EEA). *European Topic Centre on Inland, Coastal and Marine waters* (ETC/ICM).
11. Substrate maps. EU EMODNET seabed habitats; www.emodnet-seabedhabitats.eu.
12. Non indigenous species. AquaNIS; <http://www.corpi.ku.lt/databases/index.php/aquanis>.

Sources and references

- Beaugrand, G., Reid, P. C., Ibanez, F., Lindley, A. J., and Edwards, M. 2002. Reorganization of North Atlantic Marine Copepod Biodiversity and Climate. *Science*, 296: 1692–1694.
- Brunel, T., and Boucher, J., 2007. Long-term trends in fish recruitment in the north-east Atlantic related to climate change. *Fisheries Oceanography*, 16: 336–349.
- Devoy, R. J. N. 2008. Coastal vulnerability and the implications of sea-level rise for Ireland. *Journal of Coastal Research*, 24: 325–341.
- Drinkwater, K. F. 2005. The response of Atlantic cod (*Gadus morhua*) to future climate change. *ICES Journal of Marine Science*, 62: 1327–1337.
- Edwards, M., Helaouet, P., Johns, D. G., Batten, S., Beaugrand, G., Chiba, S., Hall, J., *et al.* 2014. Global Marine Ecological Status Report: results from the global CPR survey 2012/2013. SAHFOS Technical Report, 10: 1–37. Plymouth, UK. ISSN 1744-0750.
- Foden, J., Rogers, S. I., and Jones, A. P. 2009. Recovery rates of UK seabed habitats after cessation of aggregate extraction. *Marine Ecology Progress Series*, 390: 15–26.
- Gerritsen, H. D., Minto, C., and Lordan, C. 2013. How much of the seabed is impacted by mobile fishing gear? Absolute estimates from Vessel Monitoring Systems (VMS) point data. *ICES Journal of Marine Science*, 70: 523–531.
- Hátún, H., Payne, M. R., Beaugrand, G., Reid, P. C., Sandø, A. B., Drange, H., Hansen, B., *et al.* 2009. Large biogeographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales. *Progress in Oceanography*, 80: 149–162.
- Hátún, H., Payne, M. R., and Jacobsen, J. A. 2009. The North Atlantic subpolar gyre regulates the spawning distribution of blue whiting (*Micromesistius poutassou*). *Canadian Journal of Fisheries and Aquatic Sciences*, 66: 759–770.
- ICES. 2012a. Report of the Working Group on Oceanic Hydrography (WGOH), 21–22 March 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGEF:03. 168 pp.
- ICES. 2012b. Report of the Workshop on Benchmarking Integrated Ecosystem Assessments (WKBEMIA), 27–29 November 2012, ICES Headquarters, Copenhagen, Denmark. ICES CM 2012/SSGRSP:08. 28 pp.
- ICES. 2013a. Ecological quality objective for seabird populations in OSPAR Region III (Celtic Seas). *In* Report of the Advisory Committee 2013. ICES Advice 2013, Book 1, Section 1.5.6.1.
- ICES. 2013b. Report of the Working Group on the ICES ACOM/SCICOM Workshop on Ecosystem Overviews (WKECOVER), 7–11 January 2013, ICES HQ, Copenhagen, Denmark. ICES CM 2013/ACOM/SCICOM:01. 131 pp.
- ICES. 2013c. Report of the ICES Workshop to draft Advice on Ecosystem Overviews (WKDECOVER), 4–7 November, ICES HQ, Copenhagen. ICES CM 2013/ACOM/SCICOM:03. 11 pp.
- ICES. 2013d. Report of the Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS), 11–15 February 2013, Lisbon, Portugal. ICES CM 2013/SSGRSP:02. 164 pp.
- ICES. 2015c. First and Second Interim Reports of the Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS), 9–13 March 2015, 1. via WebEx and Correspondence 2. Cadiz, Spain. ICES CM 2015/SSGIEA:02. 32 pp.
- ICES. 2015d. Interim Report of the Benthos Ecology Working Group (BEWG), 4–8 May 2015, Calvi, Corsica, France. ICES CM 2015/SSGEPD:10. 64 pp.
- ICES. 2015e. Interim Report of the Working Group on Zooplankton Ecology (WGZE), 16–19 March 2015, Plymouth, UK. ICES CM 2015/SSGEPD:05. 44 pp.
- ICES. 2015f. Report of the Working Group on Marine Mammal Ecology (WGMME), 9–12 February 2015, London, UK. ICES CM 2015/ACOM:25. 114 pp.

- ICES. 2015g. Report of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO), 18–20 March 2015, Bergen, Norway. ICES CM 2015/SSGEPI:10. 195 pp.
- ICES. 2016. Interim Report of the Working Group on Multispecies Assessment Methods (WGSAM), 9–13 November 2015, Woods Hole, USA. ICES CM 2015/SSGEPI:20.
- ICES. 2016. Interim Report of the Working Group on Spatial Fisheries Data (WGSFD), 17–20 May 2016 Brest, France. ICES CM 2016/SSGEPI:18
- ICES. 2018a. ICES ecosystem overviews. *In* Report of ICES Advisory Committee, 2018. ICES Technical Guidelines, ICES Advice 2018, Section 16.2. 7 pp. <https://doi.org/10.17895/ices.pub.4663>.
- ICES. 2018b. Celtic Sea Ecoregion – Fisheries overview data. <https://doi.org/10.17895/ices.pub.4640>
- Jansen, T., Campbell, A., Kelly, C., Hátún, H., and Payne, M. R. 2012. Migration and fisheries of North East Atlantic Mackerel (*Scomber scombrus*) in Autumn and Winter. PLoS ONE 01(7(12)), e51541.
- McGinty, N., Power, A. M., and Johnson, M. P. 2011. Variation among northeast Atlantic regions in the responses of zooplankton to climate change: not all areas follow the same path. Journal of Experimental Marine Biology and Ecology, 400: 120–131.
- Newell, R. C., Seiderer, L. J., and Hitchcock, D. R. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: an Annual Review of Ecology and Systematics, 36: 127–178.
- O’Brien, T. D., Li, W. K. W., and Moran, X. A. G. 2012. ICES Phytoplankton and Microbial Plankton Status Report 2009/2010. ICES Cooperative Research Report No. 313. 196 pp.
- O’Brien, T. D., Wiebe, P. H., and Falkenhaus, T. 2013. ICES Zooplankton Status Report 2010/2011. ICES Cooperative Research Report No. 318. 208 pp.
- ODEMM. Options for Delivering Ecosystem-Based Marine Management. <https://www.liverpool.ac.uk/odemmm/> and <http://www.odemm.com/>.
- OSPAR. 2010. Quality Status Report. OSPAR Commission, London. 176 pp.
- Planque, B., and Fredou, T. 1999. Temperature and the recruitment of Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences, 56: 2069–2077.
- Reid, D. G., Walsh, M., and Turrell, W. R. 2001. Hydrography and mackerel distribution on the shelf edge west of the Norwegian deeps. Fisheries Research, 50: 141–150.
- Robinson, J. E., Newell, R. C., Seiderer, L. J., and Simpson, N. M. 2005. Impacts of aggregate dredging on sediment composition and associated benthic fauna at an off-shore dredge site in the southern North Sea. Marine Environmental Research, 60: 51–68.
- SAPHOS. Continuous Plankton Recorder Survey. Plymouth. <https://www.cprsurvey.org/>.
- STECF. 2013a. Scientific, Technical and Economic Committee for Fisheries (STECF) – Evaluation of Fishing Effort Regimes in European Waters – Part 2 (STECF-13-21). Publications Office of the European Union, Luxembourg, EUR 26327 EN, JRC86088. 863 pp.
- Stelzenmüller, V., Lee, J., South, A., and Rogers, S. I. 2010. Quantifying cumulative impacts of human pressures on the marine environment: a geospatial modelling framework. Marine Ecology Progress Series, 398: 19–32.
- Sutton, G. (ed.) 2008. Irish Sea Marine Aggregate Initiative (IMAGIN) Project Synthesis Report. Marine Environment and Health Series No. 36, Marine Institute, Galway. 66 pp.
- Sutton, G., and Boyd, S. E. 2009. Effects of Extraction of Marine Sediments on the Marine Environment 1998–2004. ICES Cooperative Research Report No. 297. 180 pp.

Hofstede, R., Hiddink, J. G., and Rijnsdorp, A. D. 2010. Regional warming changes fish species richness in the eastern North Atlantic Ocean. *Marine Ecology Progress Series*, 414: 1–9.

Van Dalen, J. A., Essink, K., Madsen, H. T., Birklund, J., Romero, J., and Manzanera, M. 2000. Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. *ICES Journal of Marine Science*, 57: 1439–1445.

Annex A

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

Stock Code	Stock Name	Fishery Guild
ghl.27.561214	Greenland halibut (<i>Reinhardtius hippoglossoides</i>) in subareas 5, 6, 12, and 14 (Iceland and Faroes grounds, West of Scotland, North of Azores, East of Greenland)	Benthic
lez.27.4a6a	Megrim (<i>Lepidorhombus spp</i>) in divisions 4.a and 6.a (northern North Sea, West of Scotland)	Benthic
lez.27.6b	Megrim (<i>Lepidorhombus spp.</i>) in Division 6.b (Rockall)	Benthic
meg.27.7b-k8abd	Megrim (<i>Lepidorhombus whiffiagonis</i>) 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 (<i>Lophius piscatorius</i>) in Subarea 7 and divisions 8.a-b and 8.d (Celtic Seas, Bay of Biscay)	Benthic
ple.27.7a	Plaice (<i>Pleuronectes platessa</i>) in Division 7.a (Irish Sea)	Benthic
ple.27.7e	Plaice (<i>Pleuronectes platessa</i>) in Division 7.e (western English Channel)	Benthic
ple.27.7fg	Plaice (<i>Pleuronectes platessa</i>) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)	Benthic
ple.27.7h-k	Plaice (<i>Pleuronectes platessa</i>) in divisions 7.h-k (Celtic Sea South, southwest of Ireland)	Benthic
sol.27.7a	Sole (<i>Solea solea</i>) in Division 7.a (Irish Sea)	Benthic
sol.27.7e	Sole (<i>Solea solea</i>) in Division 7.e (western English Channel)	Benthic
sol.27.7fg	Sole (<i>Solea solea</i>) in divisions 7.f and 7.g (Bristol Channel, Celtic Sea)	Benthic
sol.27.7h-k	Sole (<i>Solea solea</i>) in Divisions 7.h-k (Celtic Sea South, southwest of Ireland)	Benthic
nep.fu.11	Norway lobster (<i>Nephrops norvegicus</i>) in Division 6.a, Functional Unit 11 (West of Scotland, North Minch)	Crustacean
nep.fu.12	Norway lobster (<i>Nephrops norvegicus</i>) in Division 6.a, Functional Unit 12 (West of Scotland, South Minch)	Crustacean
nep.fu.13	Norway lobster (<i>Nephrops norvegicus</i>) in Division 6.a, Functional Unit 13 (West of Scotland, the Firth of Clyde and Sound of Jura)	Crustacean
nep.fu.14	Norway lobster (<i>Nephrops norvegicus</i>) in Division 7.a, Functional Unit 14 (Irish Sea, East)	Crustacean
nep.fu.15	Norway lobster (<i>Nephrops norvegicus</i>) in Division 7.a, Functional Unit 15 (Irish Sea, West)	Crustacean
nep.fu.16	Norway lobster (<i>Nephrops norvegicus</i>) 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 (<i>Nephrops norvegicus</i>) in Division 7.b, Functional Unit 17 (west of Ireland, Aran grounds)	Crustacean
nep.fu.19	Norway lobster (<i>Nephrops norvegicus</i>) 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 (<i>Nephrops norvegicus</i>) in divisions 7.g and 7.h, functional units 20 and 21	Crustacean

Stock Code	Stock Name	Fishery Guild
	(Celtic Sea)	
nep.fu.22	Norway lobster (<i>Nephrops norvegicus</i>) in divisions 7.g and 7.f, Functional Unit 22 (Celtic Sea, Bristol Channel)	Crustacean
bli.27.5b67	Blue ling (<i>Molva dypterygia</i>) in subareas 6-7 and Division 5.b (Celtic Seas, English Channel, and Faroes grounds)	Demersal
bss.27.4bc7ad-h	Seabass (<i>Dicentrarchus labrax</i>) 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 (<i>Gadus morhua</i>) in Division 6.a (West of Scotland)	Demersal
cod.27.7a	Cod (<i>Gadus morhua</i>) in Division 7.a (Irish Sea)	Demersal
cod.27.7e-k	Cod (<i>Gadus morhua</i>) in divisions 7.e-k (eastern English Channel and southern Celtic Seas)	Demersal
had.27.46a20	Haddock (<i>Melanogrammus aeglefinus</i>) in Subarea 4, Division 6.a, and Subdivision 20 (North Sea, West of Scotland, Skagerrak)	Demersal
had.27.6b	Haddock (<i>Melanogrammus aeglefinus</i>) in Division 6.b (Rockall)	Demersal
had.27.7a	Haddock (<i>Melanogrammus aeglefinus</i>) in Division 7.a (Irish Sea)	Demersal
had.27.7b-k	Haddock (<i>Melanogrammus aeglefinus</i>) in Divisions 7.b-k (southern Celtic Seas and English Channel)	Demersal
hke.27.3a46-8abd	Hake (<i>Merluccius merluccius</i>) 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 (<i>Pollachius virens</i>) in Subareas 4, 6 and Division 3.a (North Sea, Rockall and West of Scotland, Skagerrak and Kattegat)	Demersal
whg.27.6a	Whiting (<i>Merlangius merlangus</i>) in Division 6.a (West of Scotland)	Demersal
whg.27.7a	Whiting (<i>Merlangius merlangus</i>) in Division 7.a (Irish Sea)	Demersal
whg.27.7b-ce-k	Whiting (<i>Merlangius merlangus</i>) in divisions 7.b-c and 7.e-k (southern Celtic Seas and eastern English Channel)	Demersal
dgs.27.nea	Spurdog (<i>Squalus acanthias</i>) in Subareas 1-10, 12 and 14 (the Northeast Atlantic and adjacent waters)	Elasmobranch
boc.27.6-8	Boarfish (<i>Capros aper</i>) in subareas 6-8 (Celtic Seas, English Channel, and Bay of Biscay)	Pelagic
her.27.6a7bc	Herring (<i>Clupea harengus</i>) in divisions 6.a and 7.b-c (West of Scotland, West of Ireland)	Pelagic
her.27.irls	Herring (<i>Clupea harengus</i>) 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 (<i>Clupea harengus</i>) in Division 7.a North of 52°30'N (Irish Sea)	Pelagic
hom.27.2a4a5b6a7a-ce-k8	Horse mackerel (<i>Trachurus trachurus</i>) 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 (<i>Scomber scombrus</i>) in subareas 1-8 and 14 and division 9.a (the Northeast Atlantic and adjacent waters)	Pelagic
whb.27.1-91214	Blue whiting (<i>Micromesistius poutassou</i>) in subareas 1-9, 12, and 14 (Northeast Atlantic and adjacent waters)	Pelagic