## 10.1 Greenland Sea ecoregion – Ecosystem overview

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## Key signals

**Human activities and their pressures**

- Fishing is the most important human activity in the ecoregion. Fishing pressure is generally close to levels to achieve maximum sustainable yield for commercially harvested stocks, with the exception of pelagic redfish (*Sebastes mentella*).
- Hunting affects several marine mammal species and has contributed to population declines in several species in the ecoregion.
- The ecoregion has fewer types of human activities compared to other ecoregions, and it is a sink for contaminants and litter transported from global sources outside the ecoregion.

**State of the ecosystem**

- There are species-rich and structurally complex benthic communities present in the ecoregion. The high biomasses of large sessile species, constitute in some cases vulnerable marine ecosystems (VMS e.g. sponges and corals) that are susceptible to the impacts of mobile bottom-contacting fishing gear.
- The stock sizes of commercial species, with the exception of pelagic redfish species, are for the most part above the biomass trigger reference point at which fishing pressure must be further reduced.
- Several migratory whale species, e.g. fin whales (*Balaenoptera physalus*), blue whales (*Balaenoptera musculus*), humpback whales (*Megaptera novaeangliae*), minke whales *(Balaenoptera acutorostrata)*, and bowhead whales (*Balaena mysticetus*), are increasingly observed in the ecoregion.
- Abundance of the Greenland Sea hooded seal (*Cystophora cristata*), harp seal (*Pagophilus groenlandicus*), and narwhal (*Monodon monoceros*) populations remains at very low levels.
- Ivory gull (*Pagophila eburnea*), which is of conservation concern, has an overall stable breeding population in the ecoregion.

**Climate change**

- There is evidence of changing surface water temperature and salinity, with pronounced sub-regional differences and consequences for the timing and intensity of stratification throughout the ecoregion.
- The extent of both summer and winter sea ice has decreased over the past decades.
- These climate-induced modifications to the abiotic habitat have caused changes in the spatial distribution of several fish species, such as mackerel (*Scomber scombrus*) and bluefin tuna (*Thunnus thynnus*); marine mammals, like humpback whale; and seabirds, such as common eider (*Somateria mollissima*) and great cormorant (*Phalacrocorax carbo*).

**Environmental and socioeconomic context**

- Fisheries is the most essential economic sector for Greenland and is dominated by offshore fisheries in the ecoregion.
- Local communities in the ecoregion are dependent on inshore fishery and local hunting.

## Ecoregion description

The Greenland Sea ecoregion is the eastern part of Greenland's Exclusive Economic Zone (EEZ) and comprises continental shelf waters and offshore areas. The Denmark Strait between Iceland and Greenland separates the ecoregion into northern and southern subregions that differ in ice coverage, influence of polar and Atlantic waters, and anthropogenic activity. The ecoregion borders five other ICES ecoregions, indicated in Figure 1 (Oceanic Northeast Atlantic, Icelandic Waters, Norwegian Sea, Barents Sea, and Central Arctic Ocean).

- The northern subregion is characterized by cold and fresh polar waters, a broad continental shelf, year-round sea ice (in the northwest), and little human activity.
- The southern subregion is characterized by warmer and more saline waters, a narrower continental shelf in its southern part, and seasonal drift ice, as well as demersal and pelagic fishery activities.

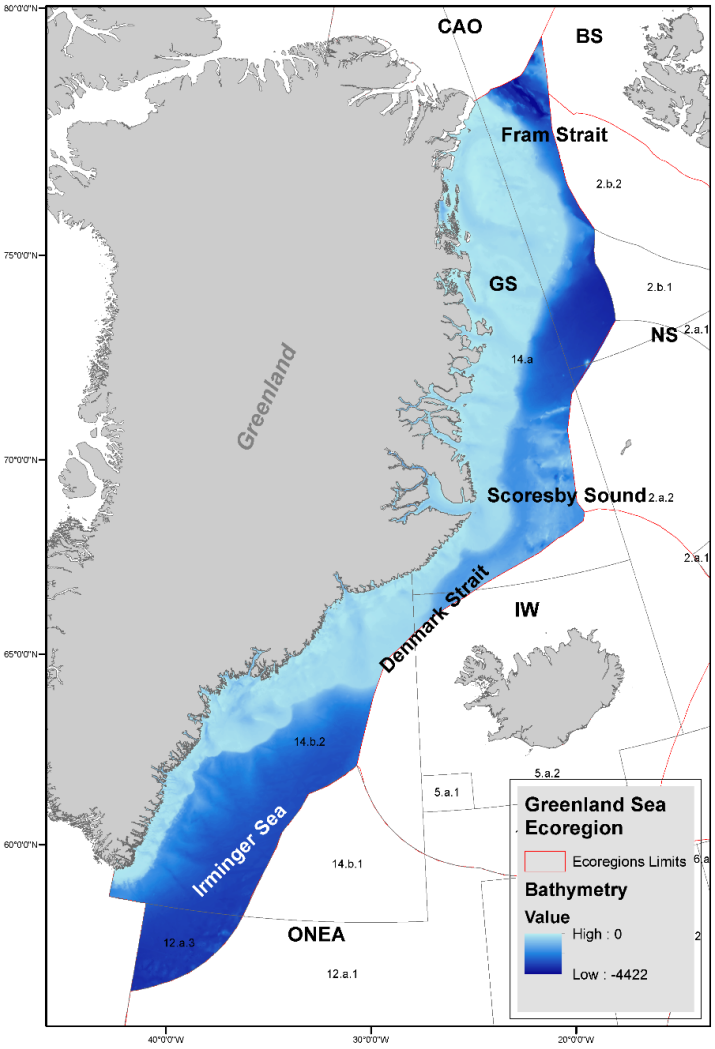


**Figure 1** The Greenland Sea ecoregion. The other ICES ecoregions indicated are: CAO (Central Arctic Ocean), GS (Greenland Sea), BS (Barents Sea), NS (Norwegian Sea), IW (Icelandic Waters), ONEA (Oceanic Northeast Atlantic).

### Management

The government of Greenland obtains advice for the fish and shellfish resources within the region from the International Council for the Exploration of the Sea (ICES) and the North Atlantic Fisheries Organization (NAFO), and on environmental

issues from the Commission of the Oslo–Paris Convention (OSPAR). The North Atlantic Marine Mammal Commission (NAMMCO) and International Whaling Commission (IWC) provide advice on marine mammals. As the ecoregion is within the Greenland EEZ, the management of marine resources and raw material extraction within the region are under Greenland authority. Management of living resources whose distribution extends outside the EEZ is conducted by several regional fisheries organizations and commissions.

North-East Atlantic Fisheries Commission (NEAFC) is involved in management of widely-distributed fish stocks such as herring (*Clupea harengus*), mackerel, pelagic redfish and a number of deep-sea species, while fish stocks distributed within the Greenland EEZ or adjacent EEZs like capelin (*Mallotus villosus),* demersal redfish, cod (*Gadus morhua*) and Greenland halibut (*Reinhardtius hippoglossoides*) are managed autonomously by Greenland or by coastal state agreements

Maritime activities such as international shipping are regulated by the Danish Maritime Authority and the government of Greenland, according to International Maritime Organization (IMO) conventions and Arctic Council agreements. Greenlandic laws concerning mining and hydrocarbon activities are aligned with OSPAR guidelines and recommendations and, therefore, require an environmental impact assessment process.

## Pressures

ICES has evaluated 17 human activities and nine pressures relevant to the Greenland Sea ecoregion. The remote location of the ecoregion and its few human settlements with low population numbers limit human activities and associated pressures compared with other ecoregions. Human activities occur mostly in the southern subregion and are linked to coastal and offshore fishing and hunting in the coastal area. The most important pressures in the ecoregion are the selective extraction of species and physical seabed disturbance associated with fisheries, jointly contributing to 76% of the total risk in the region; and the introduction of contaminant compounds (7%) as well as marine litter (4%) and, to a much lower extent, underwater noise (1%). These final two pressures are mainly introduced from outside the ecoregion by diffuse sources and from shipping (Figure 2). The main pressures identified in this section are described in the ICES Ecosystem Overviews Technical Guidelines[1].

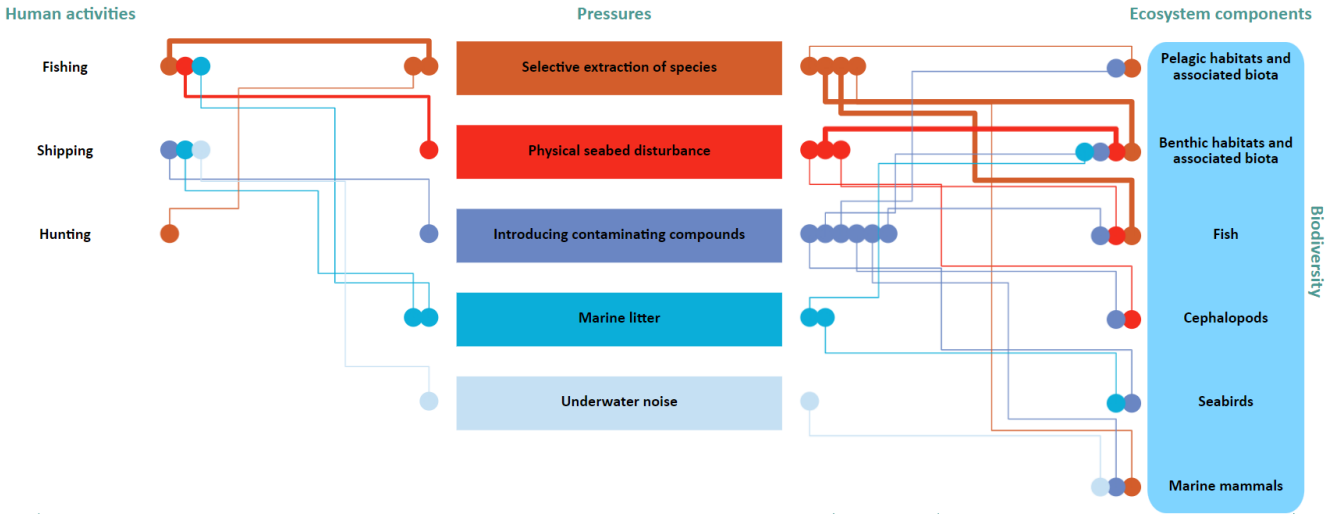


**Figure 2** Greenland Sea ecoregion overview with the major regional pressures, human activities, and state of the ecosystem components. The top linkage chains (the 23 linkages that contribute > 1% to overall risk score in the ecosystem assessment) are responsible for 89% of the risk score in the ecoregion and are illustrated in solid lines. The width of lines indicates the relative importance of individual links. The scaled strength of pressures should be understood as a relevant strength between the human activities listed and not as an assessment of the actual pressure on the ecosystem. Human activities and pressures are listed in decreasing order of their relative contribution to the total risk score. Climate change affects human activities, the intensity of the pressures, and some aspects of state, as well as the links among these. Ice habitat was considered in the case of marine mammals.

[1] https://doi.org/10.17895/ices.pub.22059803

**Selective extraction of species**

The main activity contributing to the selective extraction of species in the Greenland Sea ecoregion is commercial fisheries. Total annual catch in the ecoregion varied between 26 000 and 152 000 tonnes during the last 10 years (Figure 3). The main exploited species are mackerel, herring, cod, Greenland halibut, redfish (*Sebastes* spp.), and northern shrimp (*Pandalus borealis*); these are listed in Annex 1. While the number of fishing vessels has declined over the past decades, the size of those vessels has increased.

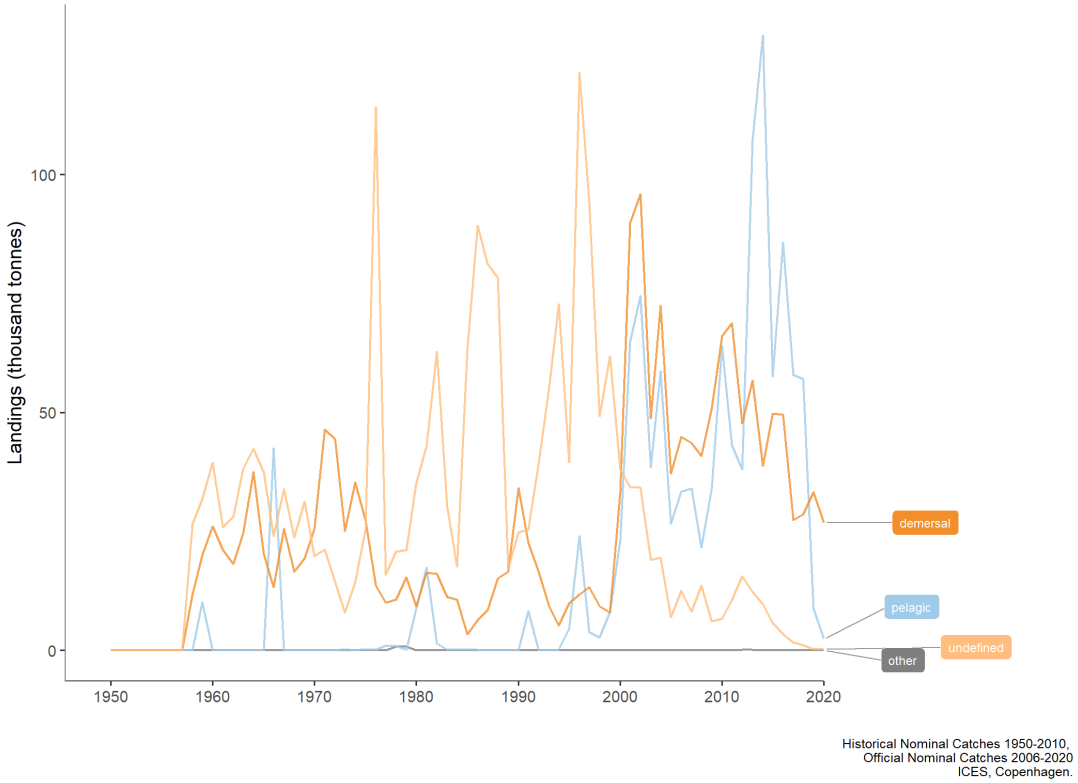


**Figure 3** Landings (thousand tonnes) in the Greenland Sea ecoregion (ICES divisions and subdivisions 12.a.3, 14.a, and 14.b.2) from 1950–2020, by fish category. Note that capelin catches are not included.

Demersal fishing mainly takes place in the southern subregion at depths between 400 m and 1000 m, mostly as bottom trawling. Pelagic fisheries targeting mackerel and herring, using mid-water trawl or purse seining, are mostly concentrated in waters close to the Icelandic EEZ (Figure 4). The landings of commercial species and their locations can be assumed to represent to some degree the magnitude of the pressure on the ecosystem.

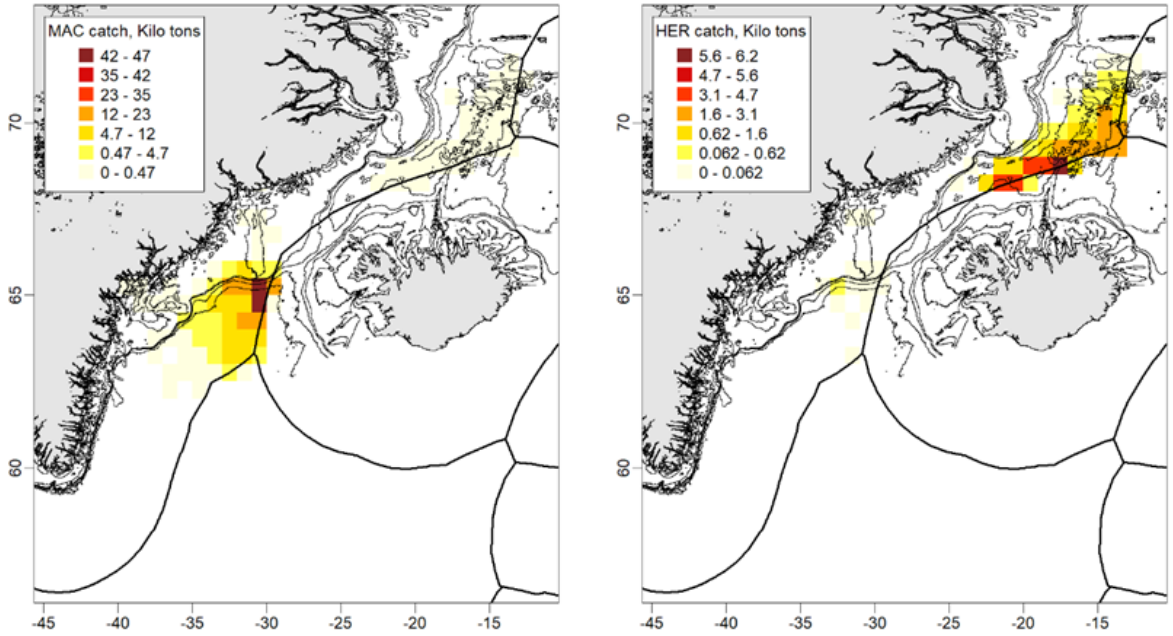


**Figure 4** Spatial distribution of mackerel (MAC) and herring (HER) catch within the Greenland Sea ecoregion during 2010–2021. Black lines indicate the EEZ.

Some hunting of seabirds and mammals for local consumption also occurs near the few settlements off East Greenland, in the southern subregion.

**Effects on commercial stocks**

Out of the nine stocks with fishing pressure (F) reference points, seven were fished above or close to sustainable targets ($F_{MSY}$) in 2021. Fishing pressure has fluctuated around $F_{MSY}$ for all pelagic stocks (Figure 5), with the exception of beaked redfish, for which fishing pressure has gradually increased since 1990. Among demersal fish, fishing pressure has generally been around or above $F_{MSY}$ since 1990 for all stocks other than cod. Fishing pressure on cod has only markedly increased in the recent decade (Figure 6).

Sorting grids have been mandatory in the shrimp fishery since the 1990s; this is to avoid bycatch of juvenile fish in particular. Areas closed to trawling have been put in place to protect spawning concentrations of cod, aimed at rebuilding the stock. Detailed information on fisheries is provided in the Greenland Sea ecoregion fisheries overview[2].

*Effects on non-target species*

The fisheries in the ecoregion are mainly targeting single stocks. Bycatch for most fisheries in the ecoregion, both in numbers of species and weight, is low (usually below 2% by weight).

A number of elasmobranchs species have been registered as bycatch in the ecoregion, including the Greenland shark (*Somniosus microcephalus*), Portuguese dogfish (*Centroscymnus coelolepis*), sailray (*Rajella lintea*), common skate (*Dipturus batis*), leafscale gulper shark (*Centrophorus squamosus*), and thornback ray (*Raja clavata*). In addition, Atlantic bluefin tuna are occasionally caught as bycatch in the mackerel fishery. The cephalopod *Gonatus fabricii* occurs as a bycatch in the shrimp fisheries.

[2] https://doi.org/10.17895/ices.advice.21640769

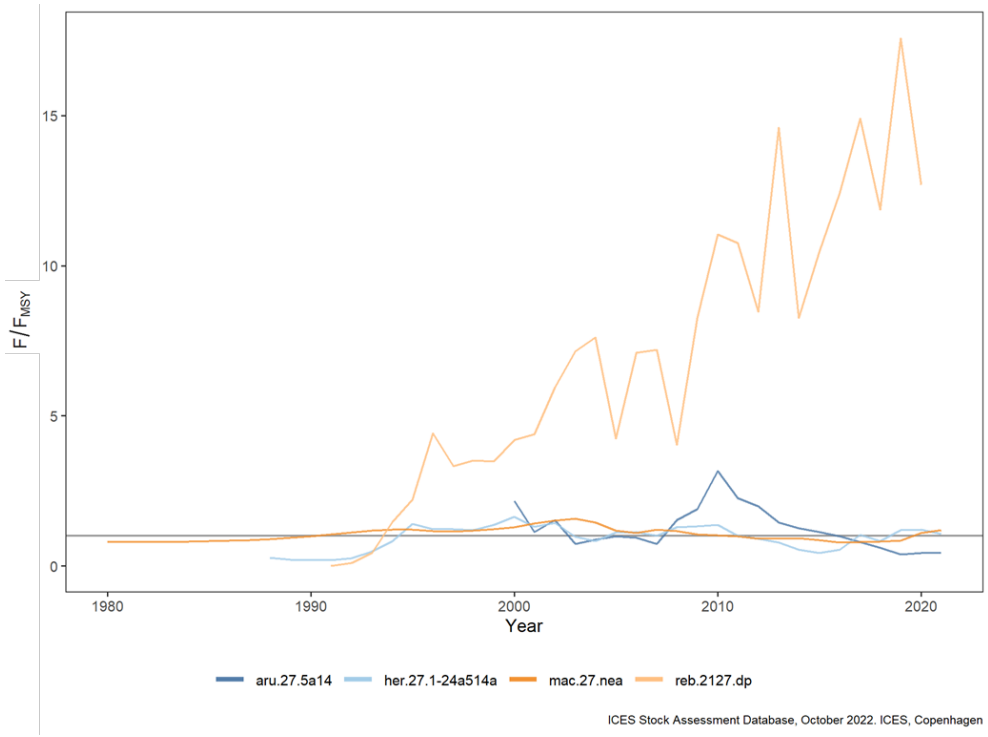


**Figure 5** Time-series of relative fishing mortality (F to $F_{MSY}$ ratio) for the main pelagic fish species: greater silver smelt (aru.27.5a14), Atlanto-Scandian herring (her.27.1-24a514a), NEA mackerel (mac.27.nea), and beaked redfish (reb.2127). Stock details in Table A1 of Annex 1.

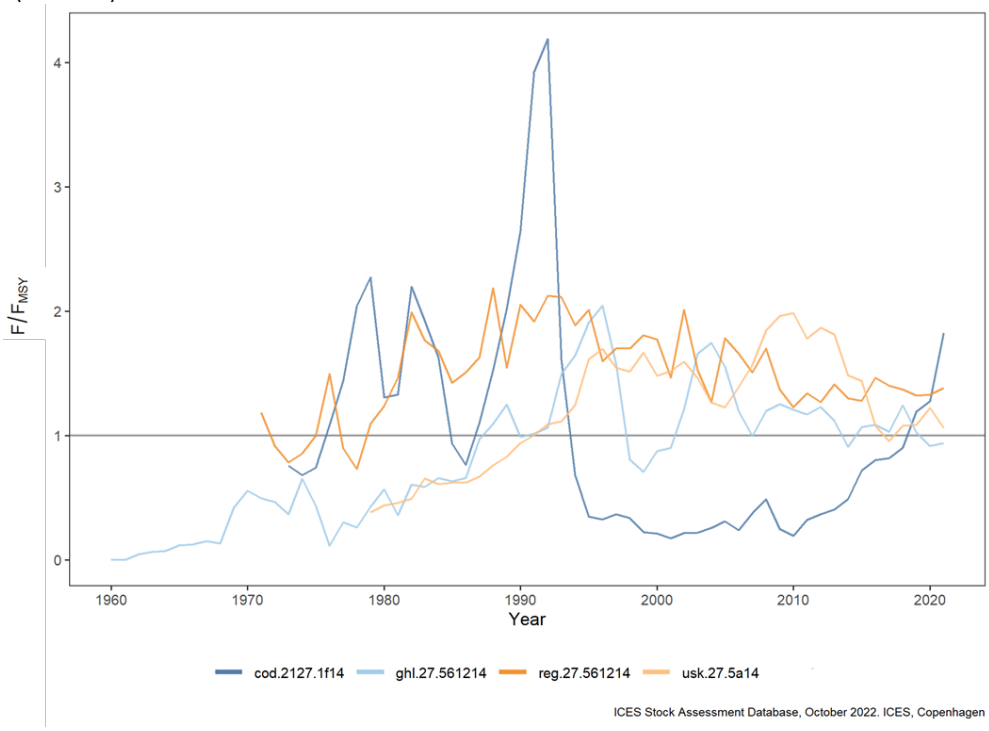


**Figure 6** Time-series of relative fishing mortality (F to $F_{MSY}$ ratio) for the main demersal fish species: cod (cod.2127.1f14), Greenland halibut (ghl.27.561214), golden redfish (reg.27.561214), tusk (usk.27.5a14). Stock details in Table A1 of Annex 1.

*Discarding by commercial fisheries*

According to regulations, discarding is prohibited in the ecoregion and is assumed to be negligible.

*Recreational fishing*

Some subsistence fishing takes place in the southern subregion. Atlantic cod, arctic char (*Salvelinus alpinus),* and capelin are among the species caught in this fishery. The impact of recreational fishing on the Greenland Sea ecosystem components is considered to be negligible.

**Physical seabed disturbance**

The greatest physical disturbance of the seabed and benthic habitats is caused by mobile bottom-contacting fishing gear. Most demersal fisheries in the ecoregion are bottom-trawl fisheries. Figure 7 shows the effort by bottom trawlers in the recent decade (2010–2021) on the main targeted species. Mapping of benthic habitats is currently limited in the ecoregion. There is a high degree of overlap between the trawl fishery footprint for cod and demersal redfish, and the habitats of corals and sponges on the continental slope (Figure 8).

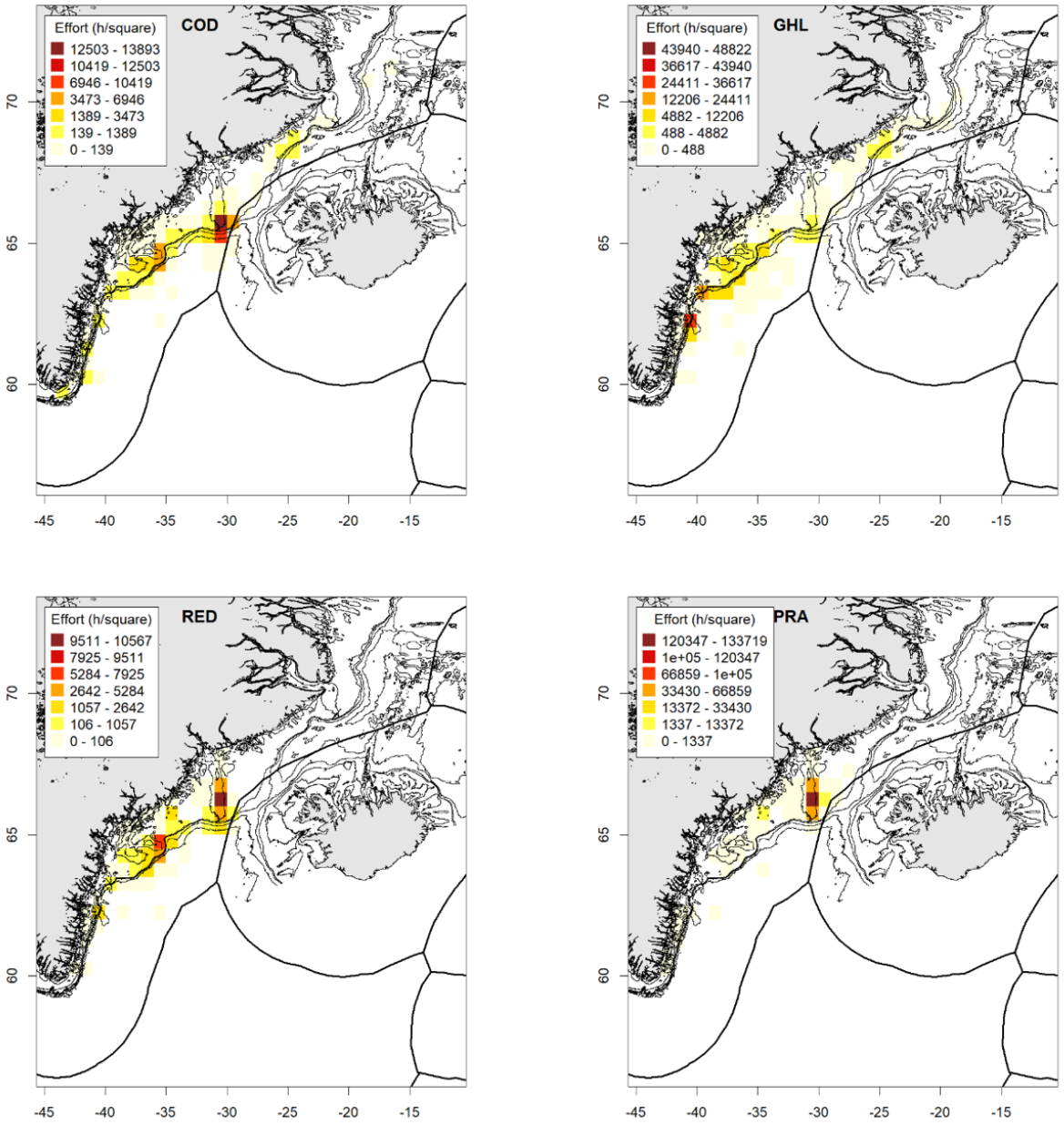


**Figure 7** Bottom-trawling effort distribution for four demersal species in the Greenland Sea ecoregion during 2010–2021. Upper panels: cod and Greenland halibut (GHL). Lower panels: redfish (*Sebastes* spp.; RED) and northern shrimp (PRA). The Greenland and Iceland EEZ borders are shown (black lines).

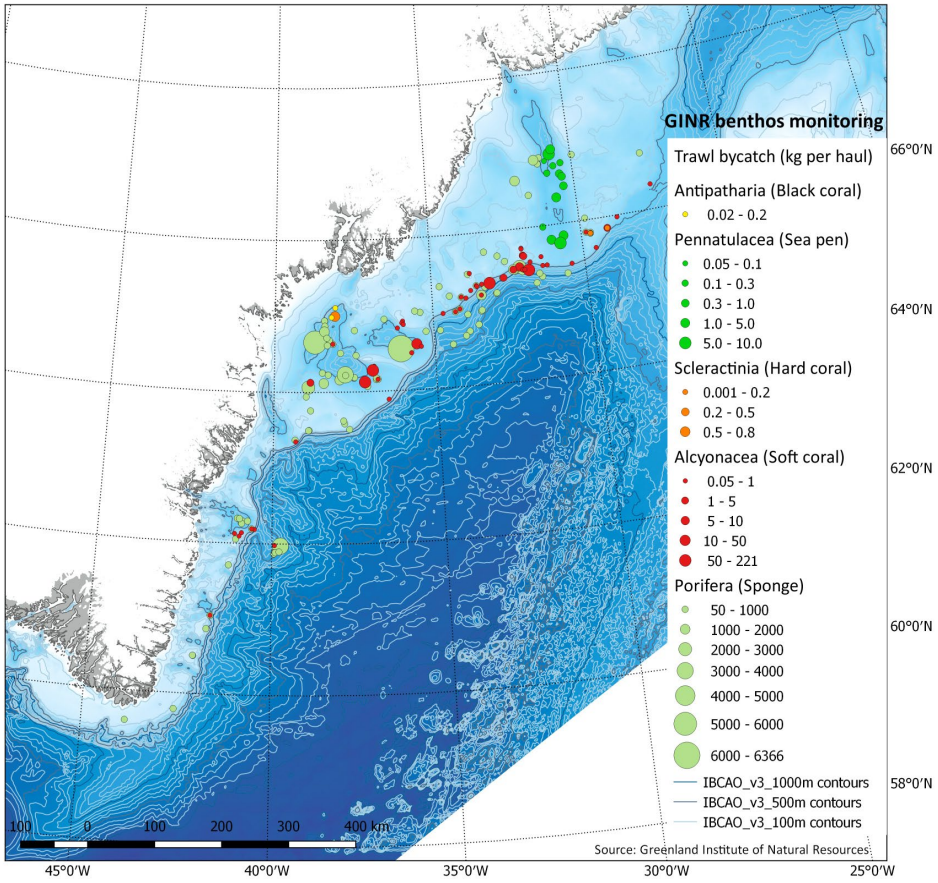


**Figure 8** Overview of observations of corals and sponges collected as trawl bycatch on research surveys conducted by the Greenland Institute of Natural Resources (GINR) in East Greenland.

**Introduction of contaminating compounds**

Data on sources of contamination in the ecoregion are limited because monitoring is sporadic and not comprehensive across trophic levels and contaminant types. Despite being relatively low compared to other ecoregions, contamination is considered to be an important pressure due to the ecoregion's remoteness and small human population, as well as to the presence of animals at high trophic levels that bioaccumulate contaminants. Although there is currently no mining activity, there are metal ores in the region. Rock weathering, such as that observed in Northeast Greenland (Citronen Fjord), introduced high concentrations of zinc into the ecosystem. A lead and zinc mine in the northern subregion (Kong Oscars Fjord, active 1956–1963) resulted in contamination of the fjord that, though in decline, still persists.

Available evidence suggests that contamination in the ecosystem mainly originates from faraway diffuse sources. This limits the contaminants to those chemicals that can be transported over long distances and that bioaccumulate in the food chain. Arctic waters flowing through the ecoregion have higher mercury concentrations compared to Atlantic waters. Mercury levels in marine mammals in the European Arctic and in this ecoregion have generally decreased over the last decades. The mercury content in polar bears is monitored in the ecoregion and has increased since the 2000s.

**Marine litter**

Marine litter in the Greenland Sea ecoregion originates from populated areas, fishing vessels, and neighbouring regions transported by currents.

Ocean drift modelling indicates that buoyant microplastics will flow from European rivers to the northern part of the Greenland Sea ecoregion. Microplastic was found in all sub-surface water samples and in the gastrointestinal tracts of 25% of fish examined in Northeast Greenland. In the adjacent Faroese ecoregion, 91% of fulmars had plastic in their stomachs.

**Noise**

Underwater noise from shipping, seismic surveys, and fishing covers a wide range of frequencies that have been demonstrated to influence marine organisms, in particular marine mammals. For example, underwater noise affects the ability of marine mammals to communicate effectively, as well as impacting on their behaviour as evidenced by changes in the movement patterns of narwhals in the ecoregion.

## Climate change effects

There is evidence of temporal trends in surface water temperatures and salinities throughout the ecoregion. A long-term warming trend (since the 1980s) increased sea surface temperatures by 1–2°C across the ecoregion. Decadal-scale regional oceanographic oscillations are superimposed on this, causing regional differences or offsets to the trend. Since 2007, the surface waters of the northern part of the ecoregion have been warming, while those in the southern subregion have been cooling (Figure 9).

Surface salinity over the Northeast Greenland Shelf has decreased by 1.8 g $kg^{-1}$ since the early 2000s. Since 1980, the Southeast Greenland Shelf and deep waters in the northern subregion have experienced an increase in surface salinity of up to 0.2 g $kg^{-1}$ $decade^{-1}$ (Figure 10).

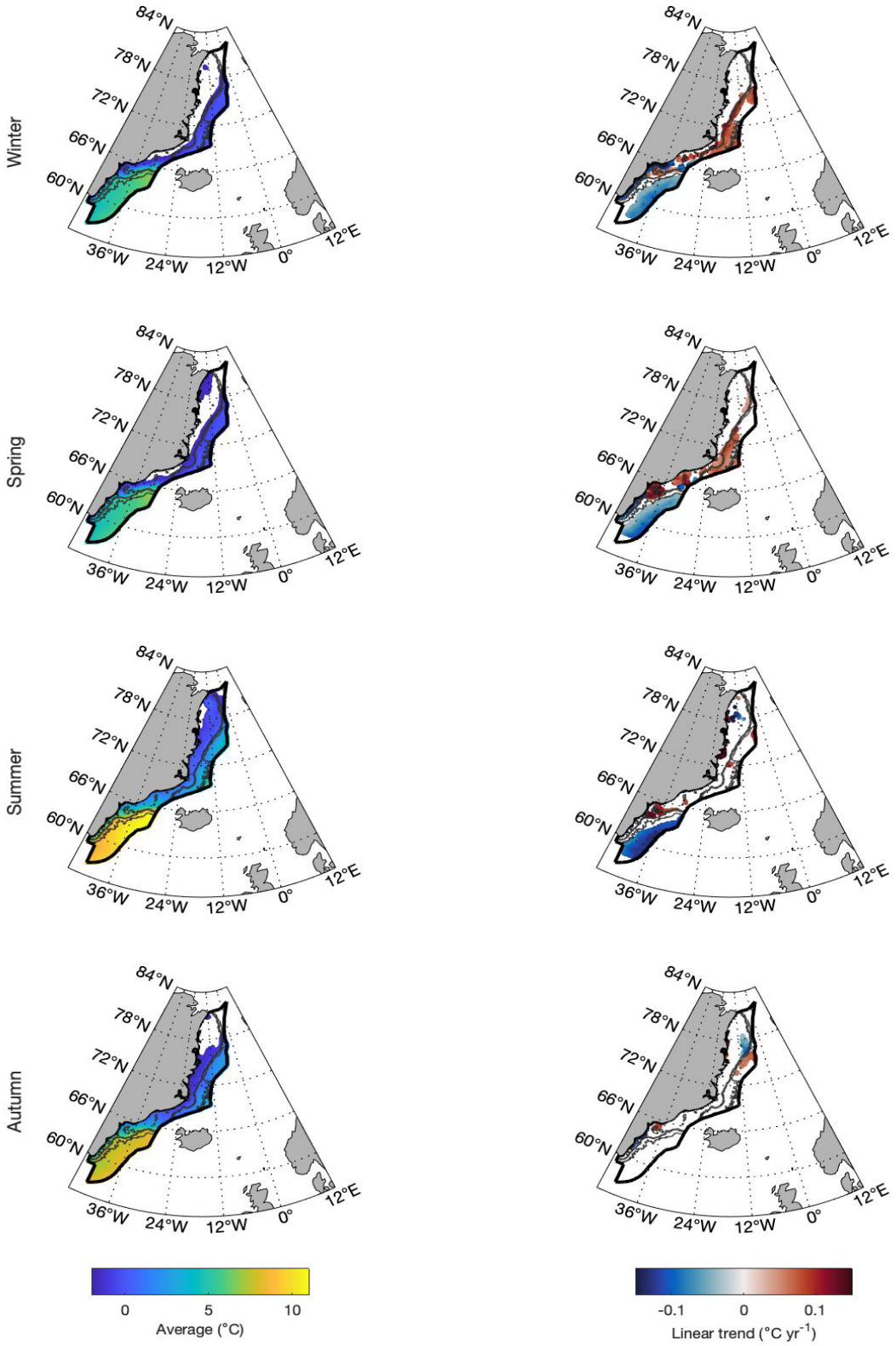


**Figure 9:** Average (left column) and linear trends (right column) in sea surface temperature for winter (December-February), Spring (March-May), Summer (June-August) and Autumn (September-November) calculated over 2007-2020. Areas with average sea-ice fraction greater than 75% have been excluded. Only significant trends are shown. Based on data from the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) data product: https://data.marine.copernicus.eu/product/SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001/description.

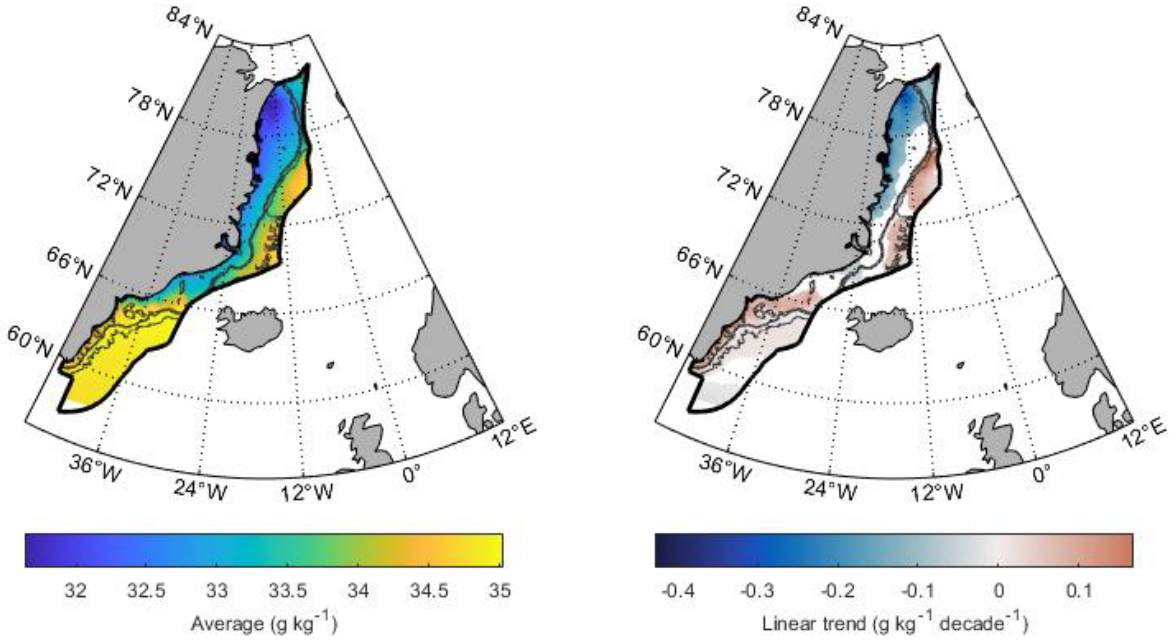


**Figure 10** Average (left) and linear trend (right) in sea surface salinity calculated over 1980-2020. Only significant linear trends are shown. Based on data from Ocean Reanalysis System 5 (ORAS5): (https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-oras5?tab=overview).

Changes in surface water stratification (0–100 m) have mainly been in response to changes in salinity across the ecoregion. On the Northeast Greenland Shelf, the reduction in salinity has resulted in an increase in stratification. The Southeast Greenland Shelf and the deep waters in the northern subregion, meanwhile, have experienced a weakening in stratification due to increasing surface salinity. The interaction between salinity and temperature has delayed the timing of the maximum in stratification up to two months on the Southeast Greenland Shelf and shifted it a month earlier in the deep waters in the northern subregion (relative to 1980–2000 baseline condition).

Sea ice coverage has declined over the past decades in the Greenland Sea ecoregion and adjacent areas (Figure 11). The summer sea ice minimum reflects the export of sea ice from the Arctic Ocean, while the winter sea ice has a contribution of locally formed sea ice. There has been a decrease in winter maximum sea ice extent since 1979 (the start of satellite records) and a small decline in summer minimum ice extent since 2006 (Figure 11). Both the summer and winter sea ice minima have occurred in the last decade.

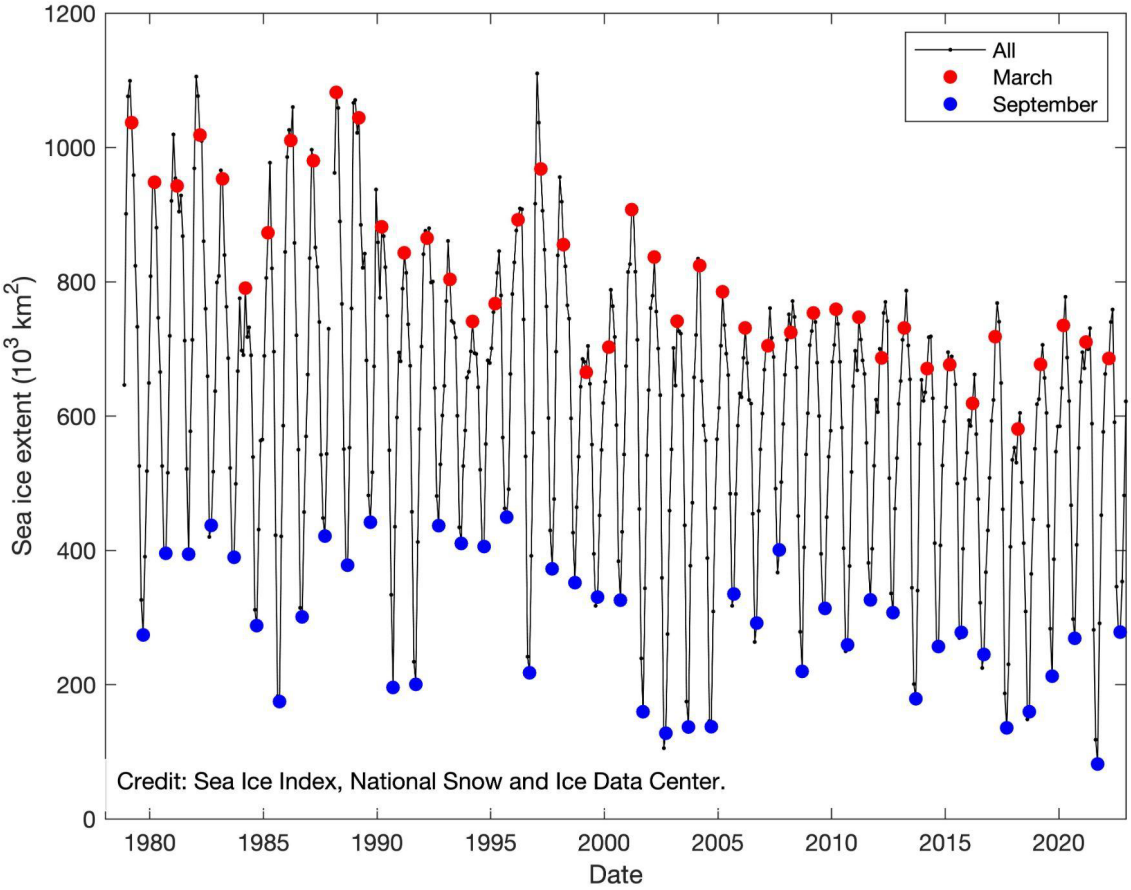


**Figure 11** Monthly average of the sea ice extent for the area covering the Greenland Sea, Icelandic Waters, and the Norwegian Sea (western part) ecoregions.

It is likely that the changes in ice cover and stratification will induce changes in primary production due to their influence on light and nutrient availability.

A seasonal occurrence, observed in the 2010s, of bluefin tuna in the ecoregion is associated with warming sea surface temperatures in the southern subregion and the consequent migration of Atlantic mackerel to the area, increasing prey availability.

There has been a persistent westward shift in capelin distribution since the 2000s, from the Icelandic Waters and Norwegian Sea ecoregions to the Greenland Sea ecoregion. In addition, most of the nursery grounds for juvenile capelin have also moved to the southern subregion, and the summer feeding grounds for adult capelin are now mainly in the northern subregion. These changes are associated with the regional climate-induced changes.

Several boreal species, such as Atlantic cod, beaked redfish, and deep-sea shrimp, recently found on the Northeast Greenland shelf, could originate from the Barents Sea. These changes are thought to be a response to large-scale ocean climate changes resulting from global warming.

The increasing occurrence of humpback whales on the East Greenland shelf has been linked to climate-induced retreating sea ice and an increase of cold-water capelin, known to be an important prey species.

There is evidence of northward shifts in some breeding populations of seabirds in East Greenland in recent decades, including the immigration of at least two bird species, great cormorant (*Phalacrocorax carbo*) and lesser black-backed gull (*Larus fuscus*), to the southeastern part of the ecoregion. Also, the breeding areas of common eider have expanded more than 200 km northwards recently.

## Social and economic context

Overall, Greenland's fisheries sector is an essential industry of economic, political, social, and cultural importance and the economies and residents of many settlements depend on it. There are two categories of fisheries that account for 95% of the country's exports: an inshore fishery important to local communities, and an offshore fishery composed of larger vessels particularly important to the economy of Greenland.

Offshore fishing is carried out by about 40–60 large factory vessels (50+ metres in length). Vessels from the EU, Faroe Islands, Norway, and the Russian Federation operate in the ecoregion according to bilateral agreements, with Greenland taking the majority of the catches in recent years. Since 1980 and in the past decade, production in both inshore and offshore fisheries in Greenland has maintained a positive growth trend. Less than 10% of the total population live in East Greenland and are dependent on inshore fishery and hunting. These activities are limited and spatially separated from the offshore activities.

In the 1970s, a dual fishery policy allocating direct subsidies to fisheries was introduced to support both the emerging nation-state and indigenous coastal Greenlandic societies. Greenland's economy is vulnerable, due to its strong dependence on a fishery industry susceptible to both overfishing and fluctuating market prices. The main challenge, therefore, is to diversify the Greenlandic economy by placing more emphasis on the growing tourism industry.

## State of the ecosystem

### Oceanographic conditions and circulation

The oceanography of the northern subregion is greatly influenced by cold and low salinity polar water originating from the Arctic Ocean, which occupies the upper layer of the East Greenland Current and covers a large part of the surface waters of the shelf (Figure 12). In the southern subregion, warmer and more saline Atlantic waters, originating from the Irminger Current, are prevalent, with the polar waters being constrained to the relatively narrow coastal region on the shelf (Figure 12).

The northern subregion is dominated by an inflow of sea ice from the Central Arctic Ocean, with maximum and minimum coverage occurring in March and September, respectively. In the winter, there is near total sea ice coverage except for polynyas (an area of open water surrounded by sea ice). In the southern subregion, drift ice is seasonally (early spring) imported from the northern subregion via the East Greenland Current.

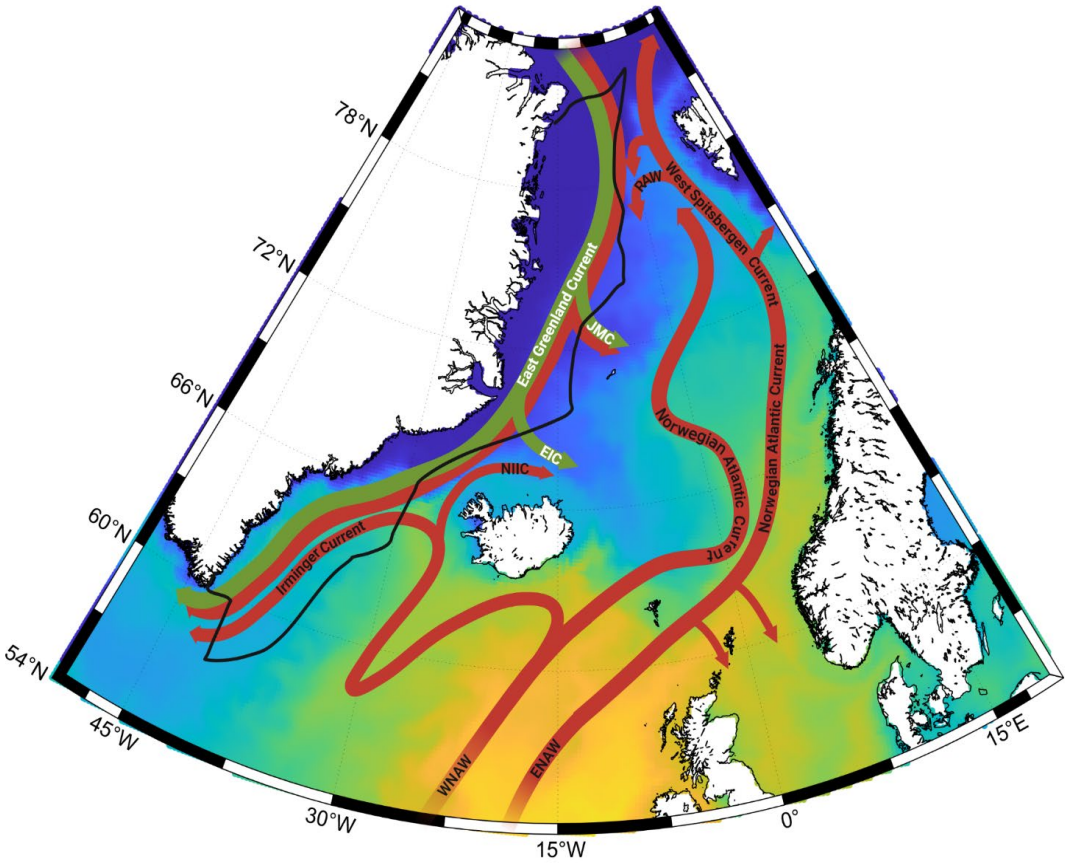


**Figure 12** General pattern of the surface ocean circulation (depth range 0–1000 m) and relative sea surface temperature in the Greenland Sea ecoregion and adjacent areas. Green arrows represent cold currents from the polar region and red arrows warm currents from the Subpolar Gyre (RAW: Recirculating Atlantic Water; JMC: Jan Mayen Current; EIC: East Icelandic Current; NIIC: North Icelandic Irminger Current; WNAW: West North Atlantic Water; ENAW: East North Atlantic Water).

## Pelagic habitat and associated biota

*Phytoplankton*

Plankton production in the ecoregion reflects a stratified ocean circulation and sea ice coverage that controls nutrient and light availability. The cold and less saline surface polar waters are nutrient depleted during summer, so much of the phytoplankton production is associated with warmer and more saline subsurface Atlantic layers.

In the northern subregion, peak phytoplankton biomass is observed where warmer waters of Atlantic origin mix with the colder waters of the East Greenland Current at the shelf break. A similar pattern of high phytoplankton biomass and productivity along the shelf break is expected for the southern subregion due to comparable nutrient upwelling processes. Recent modelling results indicate a strong south–north gradient of annual net primary production rates and phytoplankton bloom initiation. In the southern Greenland shelf waters, annual net primary production rates are higher (~80 g C $m^2$ $yr^{-1}$) and phytoplankton bloom begins in April; while, in the northern part, annual net primary production rates are approximately halved (~33 g C $m^2$ $yr^{-1}$) and bloom initiation begins in late June. The Irminger Sea exhibits low primary production.

Phytoplankton abundance and primary production data have poor temporal and geographical coverage, due to a limited number of observations and the inability of remote sensing approaches to capture deep chlorophyll maxima and under-ice blooms (the latter is particularly relevant for the northern region). Available estimates indicate a significantly increasing trend of chlorophyll levels over 1998–2006 in the ecoregion and adjacent areas, concomitant with increasing average temperature.

*Zooplankton*

The zooplankton community composition is driven by the regional ocean circulation and primary production, with differences in dominant copepod species between Atlantic and polar waters. In the northern part of the ecoregion, copepods dominate the mesozooplankton biomass, with the highest values generally being found along the shelf break area. Large-bodied *Calanus* species are the most abundant among the copepods. Other abundant species are recorded within the *Pseudocalanus* and *Microcalanus* taxa and for the species *Oithona similis*, *Oncaea borealis*, and *Metridia longa*. Macrozooplankton, dominated by krill (*Meganyctiphanes norvegica*, *Thysanoëssa inermis*, *T. longicaudata*), amphipods (*Themisto libellula* and *T. abyssorum*), and Chaetognatha, has elevated biomass not only in the shelf break area, but also at the near-shore regions. In the Irminger Sea, ciliates and other microzooplankton are major grazers of primary production and contribute significantly to the diets of holo- and mero-mesozooplankton.

**Benthic habitat and associated biota**

Information on benthic habitats and associated biota in the ecoregion is limited. Evidence from the monitoring of benthic invertebrates, which was initiated in the southern subregion in 2015 indicates the presence of a species-rich and structurally complex benthic community with high biomasses of large sessile species (Figure 8). These include corals and sponges that are indicators of vulnerable marine ecosystems and are susceptible to the effects of mobile bottom-contacting fishing gear. Benthic habitats south of 69°N latitude (southern subregion) may, therefore, be affected by abrasion from bottom trawling on the outer shelf and the slopes at approximately 400–1000 m depth (Figure 7).

**Fish**

The main commercial demersal species in this ecoregion are Greenland halibut, Atlantic cod, beaked redfish, golden redfish (*Sebastes norvegicus*), and northern shrimp. The mean relative spawning stock biomass (SSB) for Greenland halibut, Atlantic cod, and golden redfish has generally increased since the 2000s and is now in a good condition, i.e. above the biomass reference point where fishing pressure needs to be further reduced (SSB to $B_{MSY\ trigger}$ ratio > 1; Figure 13). The status for the demersal beaked redfish is at historically low levels and so is below biomass reference points. The biomass of northern shrimp in the ecoregion is currently high but below the trigger biomass where fishing pressure needs reduction. Detailed information on the status of fish stocks is provided in the Greenland Sea ecoregion fisheries overview[3].

Biomasses of mackerel and herring have been decreasing during the last decade but are still in good condition and are above the biomass trigger point where fishing pressure needs to be reduced. Both the deep and shallow pelagic redfish stock biomasses are low and below levels where recruitment is impaired. After a period of low productivity (2002–2018), capelin has shown signs of improved recruitment since 2019, which has led to increased spawning biomasses.

The spatial distribution of most pelagic fish species has changed within the last decades as they have become more regular seasonal visitors in the ecoregion. Mackerel and herring now occasionally migrate into the ecoregion (June to September) during their feeding migrations west and northward from the British Isles and Norway, respectively. However, the abundance as measured from surveys as well as the catches of herring and mackerel in this ecoregion has decreased in recent years and was very low in 2021-2022. Also, capelin has changed its feeding and nursery grounds westward into the ecoregion.

The species interact in various ways, both through predation and through competition. The interactions between different species and the environment are understood to some degree, but potential effects propagating through the ecosystem are not quantified. Bluefin tuna, for example, is known to follow and prey on mackerel during its feeding migration into the ecoregion. The southern subregion is an important area for the drift of fish eggs and larvae of Atlantic cod, redfish, Greenland halibut, and capelin; changes in temperature and current velocity affect the feeding conditions and the subsequent survival of the larvae.

The non-indigenous pink salmon (*Oncorhynchus gorbuscha)* has been observed in several fjords/rivers in the southern part of the ecoregion and is a potential competitor to the Arctic char in the rivers.

[3] https://doi.org/10.17895/ices.advice.21640769

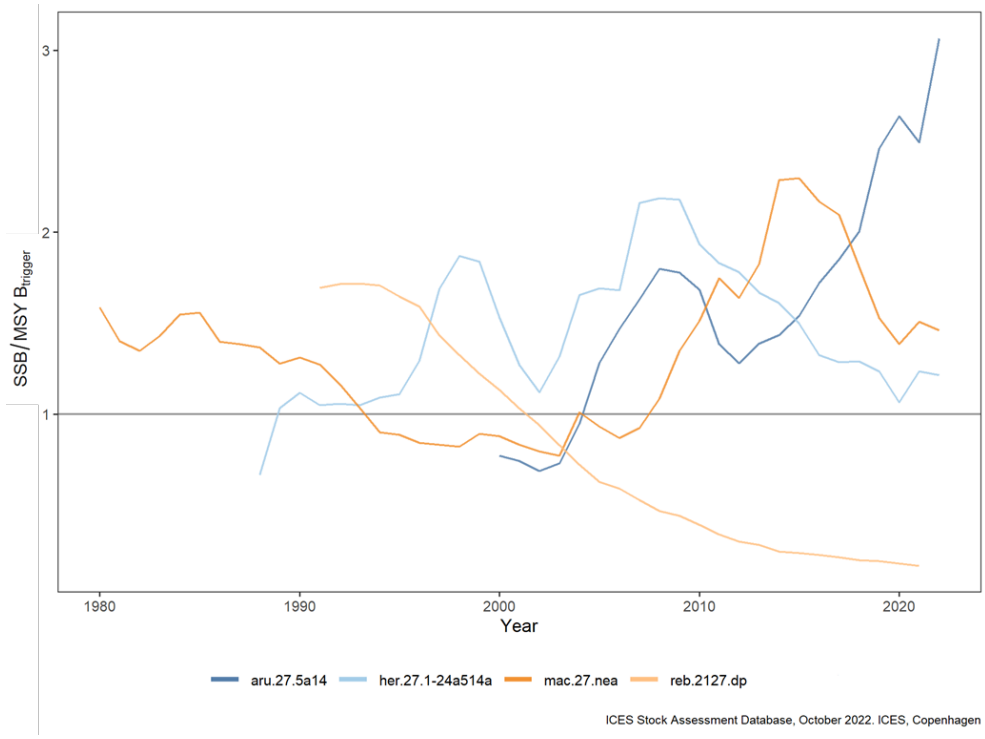


**Figure 13** Time-series of relative biomass (SSB to MSY $B_{trigger}$ ratio) for the main pelagic fish species: greater silver smelt (aru.27.5a14), Atlanto-Scandian herring (her.27.1-24a514a), NEA mackerel (mac.27.nea), and beaked redfish (reb.2127). Stock details in Table A1 in Annex 1.

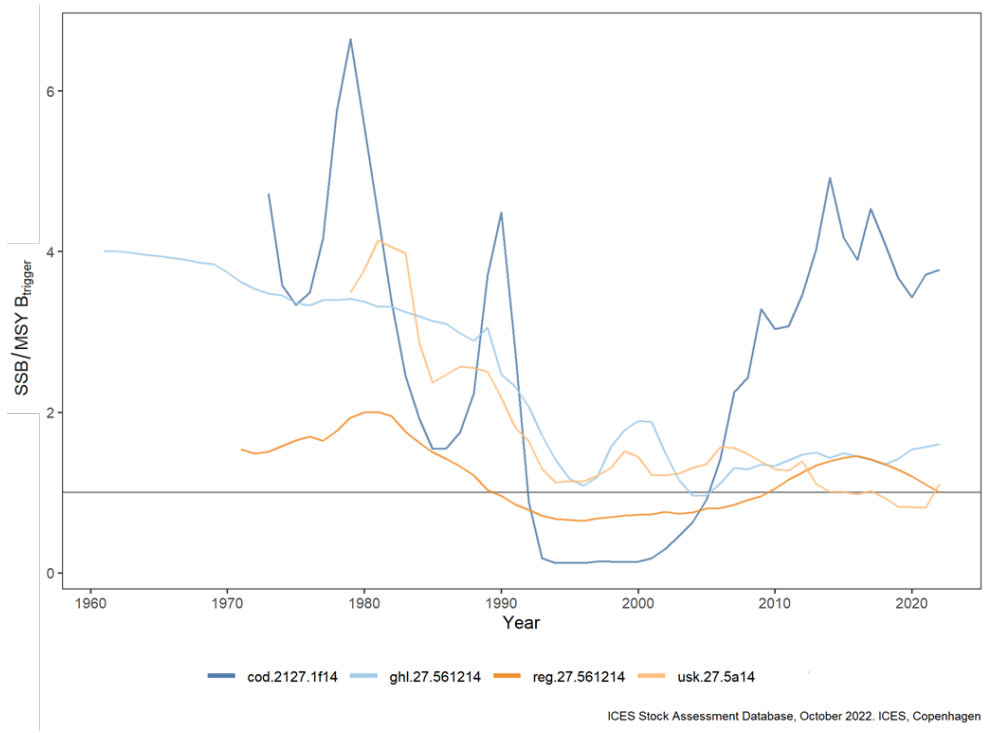


**Figure 14** Time-series of relative biomass (SSB to MSY $B_{trigger}$ ratio) for the main demersal fish species: cod (cod.2127.1f14), Greenland halibut (ghl.27.561214), golden redfish (reg.27.561214), and tusk (usk.27.5a14). Stock details in Table A1 in Annex 1.

**Cephalopods**

There are 15 known cephalopod species in Greenland waters and at least five are known to inhabit the Greenland Sea ecoregion, including *Bathypolypus arcticus*, *Opisthoteuthis borealis*, *Cirroteuthis muelleri*, *Stauroteuthis syrtensis*, and *Gonatus fabricii*. Squid taken as bycatch in the shrimp fishery are often used as bait, and there is no targeted fishery on cephalopods in the ecoregion. The squid *Gonatus fabricii* has been shown to bioaccumulate trace elements, including mercury.

**Seabirds**

Seventeen seabird species are known to breed in the ecoregion. Seabird densities in the breeding season are higher in coastal areas than in offshore areas. The majority of these are colonial breeders, and nearly 800 breeding sites have been located. As seabirds are dependent on open (ice-free) water for feeding, seabird colonies are mainly distributed in the proximity of large polynyas in the northern subregion (e.g. off Scoresby Sound, Young Sound, and in the Fram Strait's Northeast Water Polynya).

The little auk (*Alle alle*) is the most abundant bird species in the ecoregion, with an estimated breeding population of 3.5 million individuals. The common eider, Arctic tern (*Sterna paradisaea*), and black guillemot (*Cepphus grylle*) are the next most abundant species, with respective populations of 16 000, 12 000 and 10 000 individuals. Population abundance of other species are estimated to be fewer than 5 000 individuals. The ivory gull, which is included in the OSPAR list of threatened and declining species, has a stable breeding population in the land adjacent to the Northeast Water Polynya and a smaller decreasing population in Southeast Greenland. The black-legged kittiwake (*Rissa tridactyla)*, which is included in the OSPAR-list of threatened and declining species, and the northern fulmar (*Fulmarus glacialis*) are the dominant bird species in offshore areas.

As well as locally-breeding seabirds, the ecoregion is utilized by a large number of migrating seabirds that breed in Svalbard or further east; these are mainly little auks and thick-billed murres (*Uria lomvia*).

**Marine mammals**

At least 12 species of whales, five pinnipeds (four species of seals and one walrus species, *Odobenus rosmarus*), and the polar bear (*Ursus maritimus*) occur in the ecoregion. Harp seals and white-beaked dolphin (*Lagenorhynchus albirostris*) are currently the most abundant marine mammal species (Figure 15).

Migratory species like fin whales, blue whales, humpback whales, and minke whales feed in the ecoregion during summer. Bowhead whales are present throughout the year in the ecoregion. Historically, most whale species have been severely depleted by hunting. It is unclear whether increases in observations of whale species in the ecoregion are due to local population recovery, migration favoured by changing environmental conditions, or both. Abundance of the ice-dependent narwhals, which form a genetically distinct population in the ecoregion, has declined as a result of hunting over the last 50 years; the population is close to extinction in its southern ecoregion distribution.

The three most abundant seal species in the ecoregion are the hooded seal, the harp seal, and the ringed seal (*Pusa hispida*). The Greenland Sea hooded seal population remains at a historically low level (less than 10% of the 1946 baseline) despite no hunting since 2007. Estimated pup production of the Greenland Sea harp seal population, for which some commercial hunting is ongoing in the pack ice breeding areas off East Greenland (Greenland Sea and Norwegian Sea ecoregions), has declined by approximately 50% from 2007 to 2018. There is no information on trends in abundance for ringed seals in the ecoregion.

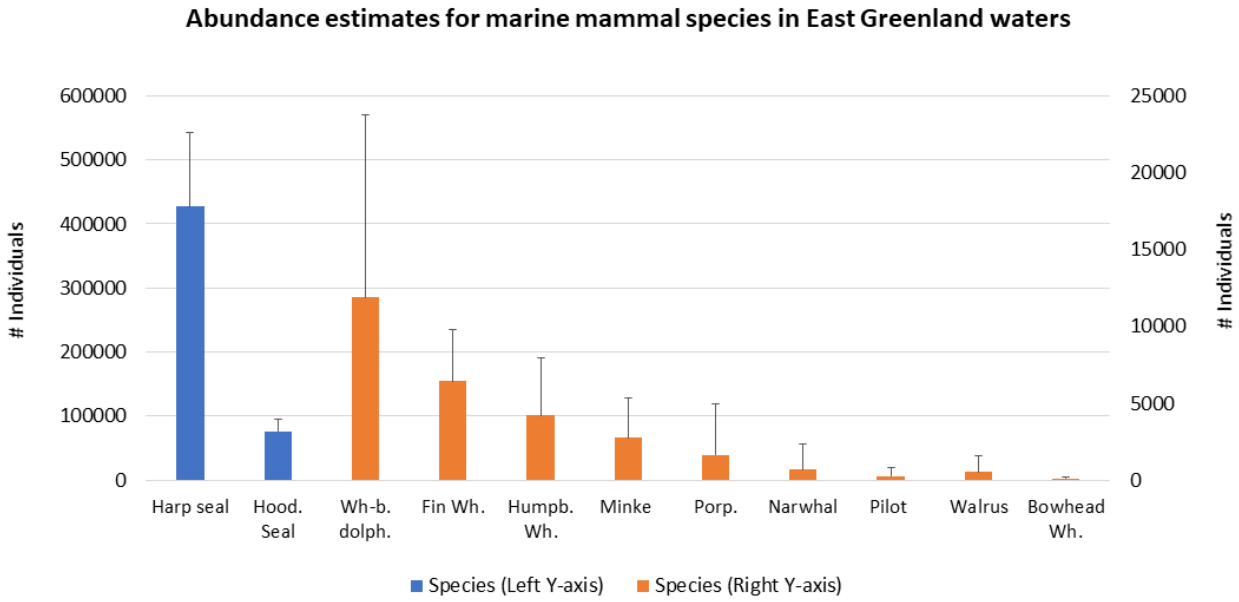


**Figure 15** Abundance estimates for 11 marine mammal species in East Greenland Sea. With the exception of walruses, error bars show approximate upper 95% confidence limit, according to either an original reference or calculated as 2 × standard deviation based on reported coefficients of variation (CVs) or standard deviations. For walruses, the error bar shows an upper 90% confidence limit. Abbreviations: Hood. Seal = Hooded seal; Wh-b. dolph = White-beaked dolphin; Fin Wh. = Fin whale; Humpb Wh = Humpback whale; Porp = Harbour porpoise (*Phocoena phocoena*); Bowhead Wh = Bowhead whale.

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The maps and figures in this document have been produced as follows:

Figure 1: produced by ICES Secretariat GIS with data from:

- General Bathymetric Chart of the Oceans (GEBCO), for the depth contours.
- International Council for the Exploration of the Sea (ICES), for ecoregions and ICES areas
- Exclusive Economic Zones. Marineregions.org (VLIZ)

Figure 2: produced by ICES Secretariat

Figure 3: produced by ICES Secretariat. Data: https://www.ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx

- Historical Nominal Catches 1950-2010
- Official Nominal Catches 2006-2020

Figure 4: produced by WGIEAGS 2022. Exclusive Economic Zones. Marineregions.org (VLIZ)

Figure 5: produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG

Figure 6: produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG

Figure 7: produced by WGIEAGS 2022. Exclusive Economic Zones. Marineregions.org (VLIZ)

Figure 8: Figure modified from Blicher and Hammeken Arboe, 2017

Figure 9: Based on data from the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) data product https://data.marine.copernicus.eu/product/SST_GLO_SST_L4_NRT_OBSERVATIONS_010_001/description.

Figure 10: Based on data from Ocean Reanalysis System 5 (ORAS5) https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-oras5?tab=overview

Figure 11: Sea Ice Index, National Snow and Data Centre https://nsidc.org/home. Meier *et* al. 2007

Figure 12: produced by WGIEAGS 2022. Depth Contours. General Bathymetric Chart of the Oceans (GEBCO)

Figure 13: produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG

Figure 14: produced by ICES Secretariat. Data: Stock Assessment Graphs: SAG

Figure 15: Data from: Hansen *et* al. 2018; Boertmann *et* al. 2015; ICES 2019; NAMMCO 2018; NAMMCO 2019.

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## Annex 1 Stocks and fisheries guilds

**Table A1** Stocks with analytical assessments and guilds. Detailed information on the fisheries of the Greenland Sea is provided on the Greenland Sea ecoregion Fisheries Overviews[4].

| Stock Code | Stock Name | Fishery Guild |
|---|---|---|
| cod.2127.1f14 | Cod (*Gadus morhua*) in ICES Subarea 14 and NAFO Division 1.F (East Greenland, South Greenland) | 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 |
| reg.27.561214 | Golden redfish (*Sebastes norvegicus*) in subareas 5, 6, 12, and 14 (Iceland and Faroes grounds, West of Scotland, North of Azores, East of Greenland) | Demersal |
| aru.27.5014 | Greater silver smelt (*Argentina silus*) in Subarea 14 and Division 5.a | Pelagic |
| reb.2127.dp | Beaked redfish (Sebastes mentella) in ICES subareas 5, 12, and 14 (Iceland and Faroes grounds, north of Azores, east of Greenland) and in NAFO subareas 1 and 2 (deep pelagic stock > 500 m) | Pelagic |
| her.27.1-24a514a | Herring (*Clupea harengus*) in subareas 1, 2, 5 and divisions 4.a and 14.a, Norwegian spring-spawning herring (the Northeast Atlantic and Arctic Ocean) | Pelagic |
| mac.27.nea | Mackerel (*Scomber scombrus*) in subareas 1-8 and 14 and division 9.a (the Northeast Atlantic and adjacent waters) | Pelagic |
| NAFO stock | Northern shrimp (*Pandalus borealis*) in Denmark Strait and off East Greenland | Demersal |
| usk.27.5a14 | Tusk (*Brosme brosme*) in Subarea 14 and Division 5.a | Demersal |

## Annex 2 Threatened and declining species and habitats

The threatened and declining species and habitats in the Greenland Sea according to OSPAR are shown in the tables below.

**Table A2.1** Threatened and declining species in the Greenland Sea ecoregion according to OSPAR

| Scientific name | Common name |
|---|---|
| Seabirds | |
| *Pagophila eburnea* | Ivory gull |
| *Rissa tridactyla* | Black-legged kittiwake |
| *Uria lomvia* | Thick-billed murre |
| Fish | |
| *Anguilla anguilla* | European eel |
| *Centroscymnus coelolepis* | Portuguese dogfish |
| *Centrophorus squamosus* | Leafscale gulper shark |
| *Cetorhinus maximus* | Basking shark |
| *Dipturus batis* (synonym: *Raja batis*) | Common Skate |
| *Hoplostethus atlanticus* | Orange roughy |
| *Lamna nasus* | Porbeagle |
| *Petromyzon marinus* | Sea lamprey |
| *Salmo salar* | Salmon |
| *Squalus acanthias* | [Northeast Atlantic] spurdog |

[4] https://doi.org/10.17895/ices.advice.21640769

| Mammals | |
|---|---|
| *Balaena mysticetus* | Bowhead whale |
| *Balaenoptera musculus* | Blue whale |
| *Eubalaena glacialis* | Northern right whale |

**Table A2.2** Threatened and declining habitats in the Greenland Sea ecoregion according to OSPAR

| Habitats |
|---|
| Coral gardens |
| Deep-sea sponge aggregations |
| Intertidal mudflats |
| *Lophelia pertusa* reefs |
| *Modiolus modiolus* beds |
| Seamounts |