OSPAR COMMISSION

Benthic Habitats Thematic Assessment

OSPAR
QUALITY STATUS REPORT 2023

2023

OSPAR's Quality Status Report 2023

Benthic habitats Thematic Assessment

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Convention OSPAR

La Convention pour la protection du milieu marin de l´Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d´Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. Les Parties contractantes sont l´Allemagne, la Belgique, le Danemark, l´Espagne, la Finlande, la France, l´Irlande, l´Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume- Uni de Grande Bretagne et d´Irlande du Nord, la Suède, la Suisse et l´Union européenne

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Executive Summary

Benthic habitats and the integrity of the seafloor

Many benthic habitats within the OSPAR Maritime Area are under threat from various pressures (see: **Table S.2** in the State section). These include physical disturbance, modification of substrate or loss (such as abrasion by bottom trawling, sediment extraction or man-made structures) and chemical (by nutrients enrichment or contaminants) and biological impacts (e.g., spread of non-indigenous species or native species exploitation). Their impact is not uniform, and thus the state of benthic habitats and the level of threat varies across the OSPAR Regions. The indicators, data and methodology that support this thematic assessment also differ across the OSPAR Regions. The results of this thematic assessment should therefore be considered on Region by Region and cannot be directly compared.

This assessment, both for broad-scale habitats and those identified as threatened and declining, shows that (see: **Table S.2** in the State section) many are in poor status, although some areas also show good status for a specific pressure and impact (eutrophication). All but one of the eighteen benthic habitats that OSPAR has identified as threatened and/or declining show no signs of improvement in the regions where they occur. Some habitats (e.g., oyster beds and seagrass beds) also show a decrease in distribution and extent in some Regions.

In those areas where the OSPAR Common Indicators were applied, physical disturbance remains the main pressure contributing to widespread reduction in diversity and changes in sensitive benthic communities. The Common Indicators assessing physical disturbance to the seabed by bottom trawling (BH3a) and changes to sensitive species (BH1) showed that most benthic habitats in areas where such fishing activities take place are under significant threat or impact. The diversity of benthic communities (BH2b) is particularly poor in inshore habitats of the Greater North Sea Region (the only one assessed with this indicator). Coastal waters show mainly high/good status for benthic vegetation and invertebrates with regard to eutrophication, but this remains an issue in the eastern part of the Greater North Sea, including Kattegat, and the Channel (BH2a). However, in the Arctic Waters Region climatic factors are the most significant variables driving the trends detected in benthic habitats.

In the face of climate change and ocean acidification, as well as increasing production of food and energy there is more than ever an urgent need to lower the pressures on benthic habitats. This can be achieved through a combination of responses including effective area-based management, sustainable use and other regulation of human activities and innovations. Where they are assessed, i.e., in the Greater North Sea, Celtic Seas, Bay of Biscay and Iberian Coast, benthic habitats are already impacted by human activities.

It is difficult to assess the effectiveness of measures to improve the status of benthic habitats, due to the multiple activities and pressures involved. In addition, the effects of measures on the recovery of habitats may take a long time to become evident. However, the lack of clear signs of improvement reported here suggests that current measures have been inadequate or ineffective.

This assessment provides an evidence base to help develop future response measures, for example targeted action plans. These need to be supported by improved monitoring and access to data alongside better resolution and geographic coverage in the next iteration of assessments and measures.

Q1. Identify the problems? Are they the same in all OSPAR regions?

Benthic habitats and the integrity of the seafloor are under pressure from physical, biological and chemical stressors. These arise from human activities driven by society's need for food, health and wellbeing, recreation, energy, materials, communication, and trade. This means that tackling problems resulting from these anthropogenic pressures is a multi-faceted challenge involving many aspects of our society.

OSPAR has a vision of a clean, healthy and biologically diverse North-East Atlantic Ocean which is productive, used sustainably and resilient to climate change and ocean acidification. Fisheries are an important activity in the OSPAR Maritime Area that contributes to societies' need for food and should be managed to ensure sustainable use. However, fishing impacts the ecosystem and its food webs and, even when considered sustainable, will leave a "footprint".

The physical disturbance caused by bottom-contacting fishing gear was shown to persist as the main pressure causing a widespread reduction in biodiversity and changes to the sensitive benthic communities in the areas of the OSPAR Maritime Area that were assessed (see: **Table S.2** in the State section).

The Quality Status Report 2010 (QSR 2010) identified damage to benthic habitats resulting from fishing activity as a key issue. Protection of benthic habitats from disturbance, including from future pressures such as deep-sea mining, was seen as a challenge, one further exacerbated by limited knowledge of deep-sea ecological functioning, data paucity for those habitats and limited biodiversity conservation measures and actions. QSR 2023 acknowledges that the state of benthic habitats, and thus the need to develop and implement protective measures, varies across OSPAR Regions. This variation was also observed in OSPAR's 2017 Intermediate Assessment. It did not report trends, being the first quantitative assessment of benthic indicators for which data and resources were available but identified physical disturbance as the main pressure in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast.

Benthic habitats are also very sensitive to the effects of climate change, particularly those that are already exposed to multiple anthropogenic pressures. Sensitivity to climate-driven pressure is directly influenced by the species and associated biological communities that characterise the habitat (see: **Table CC.2**). Increases in temperature (and marine heat waves), lowered and/or increased variability of pH (and altered carbonate or nutrient cycle chemistries), variations in salinity, sea-level rise and storminess are the main current and projected threats to benthic habitats. This is anticipated in general for most of the broad habitat types, with exacerbated effects near the coast, but also for threatened biogenic habitats such as cold-water corals, maerl beds, *Modiolus* beds, *Zostera* beds and kelp forests.

The physical disturbance caused by bottom-contacting fishing gear causes changes to the sensitive benthic communities. © Shutterstock

Q2. What has been done?

OSPAR has identified eighteen habitats considered to be of concern in the coastal, shelf and deep waters of the North-East Atlantic. Recommendations for actions to be taken by Contracting Parties nationally and collectively to protect and conserve these habitats have been adopted. These recommendations are broad in nature and address a range of human activities and pressures. They include:

- steps to report appropriate national legislation for the protection of a given habitat;
- consideration of how to strengthen the knowledge base, monitoring and assessment;
- steps to manage key human activities;
- a call for the designation of Marine Protected Areas (MPAs) and cooperation with relevant competent organisations to address key activities (such as fishing and shipping).

Current measures being taken by OSPAR and other competent bodies to support improvement in the state of benthic habitats focus in particular on fisheries extraction, eutrophication, mineral extraction near to shore, dredging, oil and gas extraction and cable placement.

The OSPAR Network of Marine Protected Areas is an important response for improving the status of benthic habitats, including, but not limited to, those habitats identified in the OSPAR List of threatened and/or declining species and habitats. This network is progressing according to regional and global targets in some OSPAR Regions, under a commitment to fill gaps, expand the network to include other effective area-based conservation measures (OECMs) and cover at least 30% of the OSPAR Maritime Area by 2030. Some habitats such as *Cymodocea* meadows are naturally region-specific, and others, like carbonate mounds, are not sufficiently known or included, making an assessment of the ecological coherence of the MPA network challenging.

The Collective Arrangement has proved to be a useful framework for facilitating cooperation with other competent authorities on the management of human activities that can affect benthic habitats but lie outside the competence of OSPAR. One example is the fishery closures and restrictions adopted by the North-East Atlantic Fisheries Commission (NEAFC) to protect vulnerable benthic habitats in some areas beyond national jurisdiction.

Q3. Did it work?

There are few indications at this stage that the existing measures and their current levels of implementation will be sufficient to improve the status of the assessed benthic habitats (see: **Table S.2** in the State section).

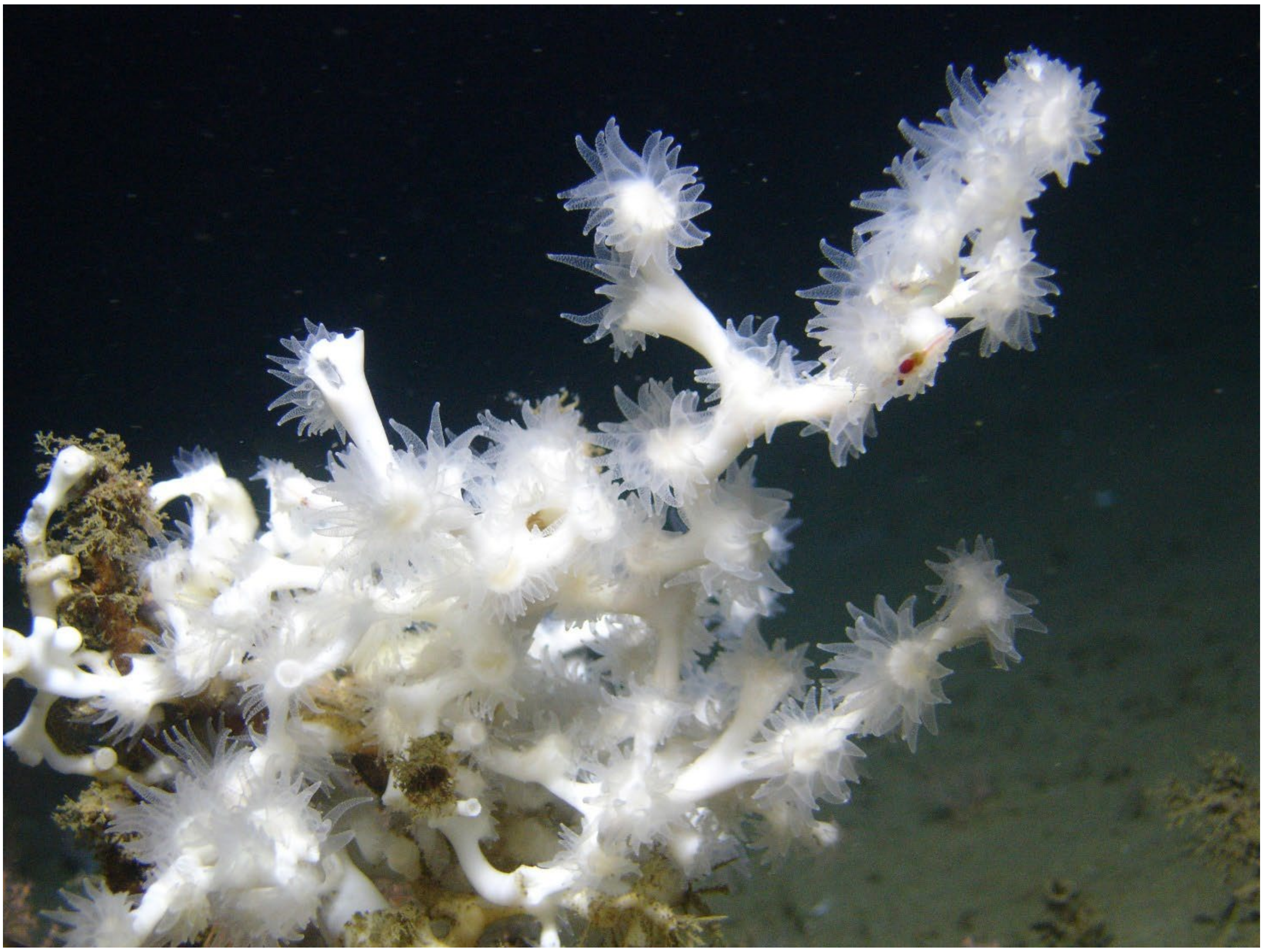
Despite recent progress, the current limitations in terms of available data and agreed methods mean that it is still a complex matter to assess precisely whether current measures are either able or sufficient to reduce the pressures and human activities that continue to affect the state of benthic habitats in the North-East Atlantic.

This largely relates to how the measures have been designed and are reported. Several measures have been developed to address several activities and related pressures. Due to the complex interactions within the marine environment, improvements to benthic habitats based on measures taken now are difficult to estimate and may not be recorded until a long time after implementation. Some measures, such as closing areas for specific activities or designating and managing MPAs, are being implemented, at least partly, but only for limited areas and habitat types, and years of relevant monitoring and policy controls will be needed to assess their effectiveness. Unless reporting is very explicit it is not easy, or in many cases even possible, to identify which measure specifically addresses which activity or pressure, especially in the context of climate change and ocean acidification, and because the same action may also be reported as a response to multiple measures. This emphasises the need to apply the precautionary principle, one of the guiding principles for the implementation of the OSPAR Convention.

Q4. How does this field affect the overall quality status?

The current assessment reports several continuous and wide-scale pressures from human activities affecting most benthic habitat types at various intensities in the areas where OSPAR Common Indicators have been applied (see: **Table S.2** in the State section). The OSPAR listed threatened and /or declining habitats (such as *Lophelia* reefs or *Zostera* beds) are typically either stable or declining, and in poor quality status, in all OSPAR Regions. For the Arctic Waters Region there is limited historical data available on benthic habitat distribution and condition, but baseline information is available (for example on megabenthos species larger than 1 cm) for use in future work.

It is not possible to evaluate changes in benthic habitats against the outcomes of QSR 2010, as common quantitative benthic indicators were not available at that time and have been developed subsequently. Common Indicator Assessments have been undertaken by EU member states for each broad-scale habitat type under the European Union Marine Strategy Framework Directive (EU MSFD) in the Greater North Sea, the Celtic Seas and the Bay of Biscay and Iberian Coast, where data monitoring and other *ad hoc* data sources were made available. The coastal habitats in all those Regions have been assessed as generally in good biological status, although it was noted that local areas negatively impacted by nutrient and organic pollution were also found and that there were still several areas with unassessed water bodies. Physical disturbance remains the main pressure contributing to widespread biodiversity loss in the benthic communities, with details varying according to the data available or the indicator chosen: decreased biodiversity in the coastal habitats of the Greater North Sea, and significant changes to typical species composition in the Bay of Biscay and Iberian Coast.



Lophelia Pertusa. © NOAA

Q5. What do we do next?

In the North-East Atlantic Environment Strategy (NEAES) 2020-2030 (OSPAR NEAES) (see: Response section). OSPAR acknowledges the consensus among scientists that the health of the North-East Atlantic is at risk and that urgent action is needed to address the loss of biodiversity and improve ecosystem functioning.

Within NEAES 2030, OSPAR expresses its ambition to conserve marine biodiversity and ecosystems in order to achieve good status of benthic habitats (Strategic Objective 5; S5), to restore degraded benthic habitats so as to increase their resilience to climate change and ocean acidification (S6), to ensure sustainable use of the marine environment, in particular with a view to assessing the effects and addressing cumulative impacts

(S7), and to prevent significant loss and disturbance of benthic habitats (S9). OSPAR has committed to regional coordination and to facilitating the implementation of the EU MSFD, by developing compatible standards and assessments for those Contracting Parties that are also EU member states (Sx), and to applying an ecosystem-based management approach in coordination with fishery management bodies and other competent organisations.

The Strategic Objectives (S) in the NEAES are to be achieved through Operational Objectives (O), as follows:

- expand the MPA network including OECMs to cover at least 30% of the OSPAR Maritime Area (S5.O1), improve MPA management (S5.O2 and 3, S11.O2) and increase the relevant ecosystems' resilience to climate change and ocean acidification (S11.O1);
- implement agreed measures that allow threatened and declining benthic habitats to recover (S5.O5);
- revise the list of threatened and declining benthic habitats to consider climate change and ocean acidification impacts (S11.O3);
- reduce pressure on benthic habitats to allow them to achieve good environmental status (S5.O4);
- identify benthic habitats that are suitable for restoration and develop and implement a regional approach to achieve restoration (S6.O1 and 2);
- (further) develop methods to analyse cumulative impacts on benthic habitats and use the resulting knowledge to reduce and/or prevent the severity of cumulative pressures on benthic habitats (S7.O1 and 2); develop an evidence base to reduce and prevent direct benthic habitat loss and disturbance due to human activities (S9.O1);
- support the development of common principles and guidance to promote and facilitate the sustainable development of benthic habitats, with particular attention to the scaling-up of offshore renewable energy, minimised cumulative environmental impacts (S12.04) and the development of nature-based solutions to promote the sequestration of nutrients in benthic systems (S12.01).

The effective implementation of many of these objectives will mainly depend on national actions. These should continue to be reported through, for example, the implementation of the recommendations on listed threatened and declining species and habitats.

OSPAR recognises the need to increase its focus on identifying and implementing collective actions which add value both to existing national actions and to the efforts of other international organisations. Many of the current actions focus only on monitoring and assessment and relatively few on response, and in either case there has been only modest progress, as seen in the biodiversity thematic assessments of the QSR 2023. Although there is a good level of engagement in implementing national actions under the recommendations, the level of engagement in collective actions is clearly at a lower level, with some of the more challenging actions not having been progressed and implemented. OSPAR will therefore have to develop a series of biodiversity action plans which comprehensively address all benthic habitats exposed to anthropogenic pressures, in order to identify effective high-priority response measures.

This assessment provides a major evidence-based tool for developing clearly defined and targeted action plans and responses. OSPAR will have to strengthen its resources and capacity to use this evidence base and all future assessments in order to support engagement with its Contracting Parties and other international partners. The development of a practical approach to ecosystem-based management should provide the opportunity and the mechanism to share evidence and common objectives to ensure more sustainable use of the marine environment.

Progress made against all these challenging biodiversity objectives will be evaluated through future OSPAR assessments of the health of the North-East Atlantic, driven by the successful implementation of the NEAES and its strategic and operational objectives.

A review currently planned for 2025 should provide an opportunity to adjust the NEAES and, if necessary, take further action to protect and conserve marine biodiversity. The review should include the risks of large-scale ecosystem impacts arising from future offshore renewable energy developments.

D - Drivers

Drivers behind human activities affecting benthic habitats

All social and economic drivers have the potential to influence the status of benthic species and habitats. Society's need for food, materials, energy, global communications and trade drives human activities which, in turn, may exert physical and biological pressures on the seabed. The need for energy, health and wellbeing, materials and trade also drives various human activities which can input or spread chemical pollutants, non-indigenous species, heat, litter, and other stressors. In managing human activities, policy responses need to consider all these driving forces in order to meet society's needs while reducing pressures and in turn reducing the risks associated with physical disturbance and habitat loss and facilitating mitigation and adaptation to climate change.

A – Activities

Human activities exerting pressures on benthic habitats

Benthic habitats are impacted by activities operating and/or interacting with the biotic and abiotic components of the seafloor, sometimes over multiple spatial and temporal scales. The nature, periodicity and scale of these activities will determine the degree and extent of the impacts. The characteristics of key activities of particular relevance to benthic habitats are summarised in **Table A.1** and the following sections.

Table A.1: Characteristics of the main anthropogenic activities affecting benthic habitats in the OSPAR Maritime Area as adapted from the Human Activities Thematic Assessment. H = High, M = Medium and L = Low intensity. The arrow is used to show if the trend is increasing (↑) or decreasing (↓). The symbol ↔is used where there has been little change in intensity since QSR 2010; the symbol ? is used where future trends are uncertain

Main activities	Arctic Waters	Greater North Sea	Celtic Seas	Bay of Biscay and Iberian Coast	Wider Atlantic
Fish and shellfish harvesting *Intensity* *Trend since QSR2010* *Trend to 2030*	H ↓ ?	H ↑ ?	H ↑ ?	M ↔ ?	L ↔ ?
Extraction of minerals *Intensity* *Trend since QSR2010* *Trend to 2030*	L ↔ ?	H ↓ ?	M ↔ ?	M ↑ ?	L ↔ ?
Agriculture *Intensity* *Trend since QSR2010* *Trend to 2030*	L ↔ ↔	H ↔ ↔	M ↔ ↔	M ↔ ↔	L ↔ ↔
Aquaculture *Intensity* *Trend since QSR2010* *Trend to 2030*	H ↑ ↑	H ↑ ↑	M ↔ ↑	M ↑ ↑	L ↑ ↑
Oil and gas *Intensity* *Trend since QSR2010* *Trend to 2030*	M ↔ ↔	H ↔ ↔	M ↔ ↔	L ↔ ↔	L ↔ ↔
Renewable energy *Intensity* *Trend since QSR2010* *Trend to 2030*	L ↑ ↑	H ↑ ↑	M ↑ ↑	L ↑ ↑	L ↔ ↔
Shipping *Intensity* *Trend since QSR2010* *Trend to 2030*	M ↔ ?	H ↔ ?	H ↔ ?	H ↔ ?	L ↔ ?
Tourism and leisure *Intensity* *Trend since QSR2010* *Trend to 2030*	L ↑ ↑	H ↑ ↑	M ↔ ↔	H ↑ ↑	L ↑ ↑

The main anthropogenic activities interacting with benthic ecosystems are described in the following sections.

Fish and shellfish harvesting (professional, recreational) [Extraction of living resources]:
Human activities such as fishing can have adverse effects on marine environments and natural resources. For example, the effects of bottom trawling have the potential to cause physical disturbance to a broad variety of marine species and habitats (see: OSPAR Feeder Report 2021- Fisheries). Pressures associated with bottom-contact fishing are categorised by métier-specific penetration depths, depending whether they cause

surface or subsurface abrasion (JNCC, 2011; Church *et al.,* 2016). Surface abrasion pressure can be caused by fishing gear, including trawling nets, and can damage benthic communities on the seafloor surface and upper layers of sediment (< 2 cm in depth) (ICES, 2021). Subsurface abrasion pressure can be caused by gear types including beam trawls and is defined as the penetration of substrate ≥ 2 cm below the surface (Church *et al.,* 2016); it can potentially damage communities living within the sediment, such as burrowing bivalves.

Physical pressures from fishing can result in both permanent and potentially reversible changes to the original morphological state of the seabed (e.g., secondary succession and shifting baselines following trawl events). The degree of impact associated with fishing is conditioned by the type of fishing (e.g., the type of gears used in mobile fisheries) and the biological traits of the affected organisms, such as life stages and physical structure (Collie *et al.,* 2001; Lambert *et al.,* 2014; van Denderen *et al.,* 2015). Various traits of marine species and habitats define their ability to tolerate or resist changes (resistance) and their ability to recover (resilience) (Tillin *et al.,* 2010; BioConsult, 2013; Eno *et al.,* 2013; Lambert *et al.,* 2014; Tillin and Tyler-Walters, 2014a and 2014b; Tyler-Walters *et al.,* 2018). For example, sessile, free-standing epibenthic organisms cannot move out of the way of trawl doors or towed nets and may thus sustain direct injuries and/or mortalities, indicating low resistance to the impact. (See: Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears – Results – Figures 3 and 4)

Sessile, free-standing epibenthic organisms cannot move out of the way of trawl doors and may thus sustain direct injuries and/or mortalities. © Shutterstock

Extraction of minerals - coastal and shelf (rock, metal ores, gravel, sand, shell) [Extraction of non-living resources]:

The extraction of materials from the seabed will directly impact benthic habitats in the relevant locations. The physical extraction of resources from the seafloor can have deleterious effects on benthic organisms and the structure of habitats, through the removal of substrate and the modification of the surrounding environment (Newell *et al.,* 1998; Desprez, 2000; Newell and Woodcock, 2013). The nature and degree of the impact is dependent on the intensity of the activity and the associated method of extraction. The most common extraction method used in offshore marine environments is trailing suction hopper dredging, which creates shallow furrows that extend for several kilometres (initially 0,5 m deep and generally 2-3 m wide, depending on the type of resources being extracted) (Tillin *et al.,* 2011; Last *et al.,* 2011; Newell and Woodcock, 2013). The associated physical impacts can extend for many kilometres, potentially lowering the seabed by several metres through consistent and repeated dredging within a given location (Tillin *et al.,* 2011; BMAPA and TCE, 2017). By contrast, the less common static suction dredging, or 'anchor dredging', can create deep (5-10 m) depressions in the seabed and can be used to target specific types of sediment (Tillin *et al.,* 2011; Last *et al.,* 2011; Newell and Woodcock, 2013). Dredging depressions can create morphological irregularities in the seabed, with infill and degradation rates varying according to local and regional hydrodynamic and sedimentation regimes (BMAPA and TCE, 2017). Monitoring suggests that trailer dredge furrows can degrade over durations of three to seven years following impact (dependent on initial and resulting sedimentology) (Cooper *et al.,* 2005). By contrast deeper, more prominent depressions, often associated with static dredging, can degrade over longer time frames, sometimes resulting in a permanent lowering of the seabed (Cooper *et al.,* 2007). (See: OSPAR Feeder Report 2021 – Extraction of non-living resources, Extent of Physical Disturbance to Benthic Habitats: Aggregate Extraction (BH3b), Pilot Assessment of Area of Habitat Loss (BH4))

Extraction of minerals - deep-sea mining [Extraction of non-living resources]:
Within the OSPAR Maritime Area, several zones have been identified as potential targets for future mineral exploration and exploitation (OSPAR, 2021). Deep seabed mining of seafloor mineral resources therefore has potential for development in the OSPAR Maritime Area, although concerns have been raised about the potential impacts on these poorly known and very sensitive deep-sea habitats owing to their stable environmental conditions and fragile natural biological communities.

The deep sea (> 200 m depth) contains highly specific and sensitive habitats, owing to environmental conditions characterised by very little exposure to natural disturbances and an absence of light. Direct mining in benthic ecosystems could cause notable local mortality and removal of inhabiting fauna, removal of substrata and habitat loss, habitat fragmentation and modification (i.e., change of mineral and sediment composition, topography, chemical regimes). Smothering or entombment of benthic fauna, clogging of suspension feeders or dilution of deposit feeders' food resources could also occur (Sharma 2015, Gollner *et al.,* 2017, 2022). Additionally, mining activities can promote the input of certain substances (such as the release of sediment-bound toxic metals into the water column and sediment) as well as an increase in anthropogenic inputs of energy, like sound and light (OSPAR, 2021). Mining activities of interest within the OSPAR Maritime Area might also overlap with rare and relatively understudied habitats, such as hydrothermal vents rich in polymetallic sulphides (Boschen *et al.,* 2013), or biodiversity hotspots such as rock substrates with cobalt-rich ferromanganese crusts on seamounts (Gollner *et al.,* 2017). Mining of these crusts typically occurs in hard rock habitats on seamounts which have a rich and specific biodiversity characterised by long-lived and slow-growing species (e.g., biogenic structures) and are thus highly sensitive and vulnerable.

The British trailing suction hopper dredger Arco Avon in the Boudewijn canal (Belgium). © Marc Ryckaert

Restructuring of seabed morphology, including dredging and deposition of materials [Physical restructuring of rivers, coastline or seabed, notably for water management]:

The dredging and deposition of materials at sea, predominantly associated with the maintenance of navigable channels, will directly impact the exposed benthic habitats and their surrounding environment. Benthic communities are physically removed and/or covered by sediment, which often means a loss, or at least significant physical disturbance, of the impacted habitat. Several ongoing dredging works are associated with periodical maintenance activities at fixed disposal sites; they require preliminary and ongoing environmental impact assessment studies. As a consequence, habitat quality might be (semi) permanently in a poor condition, even though some examples exist of replacement by specific benthic communities which flourish under these conditions, such as on the 'artificial' steep walls associated with high water currents. Changing seabed morphology can have an impact on larger scale hydrodynamic conditions, with consequences for seabed shear-stress, sedimentation/erosion patterns and characteristics (type of sediment). In the case of several dredging and/or deposition sites, this can result in a pattern of interactions with substantial consequences. The risks of impacts on benthic habitats are higher in unnaturally confined areas like modified estuaries and inlets. Exposed ecosystems typically reach unbalanced or altered condition when dredging is deeper. The deposition of materials very different from the naturally occurring materials that are originally present typically leads to the highest impacts. (See: Assessment of Data on the Management of Wastes or Other Matter (Dredged Material) 2008 - 2020)

Tourism and leisure infrastructure [Tourism and leisure]:
Infrastructure related to tourism, such as marinas, piers, parking, beaches and coastal pathway facilities, can affect benthic habitats (‘loss and disturbance´) through the introduction of structures and increased human activities, and through the introduction of non-native species in some cases.

Tourism has shown a non-linear increase in the last century, especially since 1950 when there has been an exponential 28-fold rise in international tourism (Davenport and Davenport, 2006). According to Davenport and Davenport (2006) the greatest ecological threats from mass tourism are the infrastructure and transport arrangements required to support it. This can cause major impacts on marine habitats, notably through the development of marinas, associated coastal defences, the water treatment and desalination plants (including their waste product of highly concentrated brine) needed to supply fresh water to a growing population, and the associated increased inputs of organic and nutrient pollution.

Even some leisure activities which seem sustainable, such as sailing or diving, may have impacts on marine habitats when carried out in especially sensitive marine habitats. Diving in submarine caves can affect the distribution of benthic assemblages within them by reducing the abundance of erect growth form organisms (Guarnieri *et al.,* 2012). Anchoring in sensitive marine biogenic habitats such as *Zostera* spp. or *Posidonia oceanica* seagrass beds can also have important negative impacts (Francour *et al.,* 1999; Milazzo *et al.,* 2004). In general, numbers of recreational boats, and their engine sizes, are increasing. This leads to negative environmental effects such as increased congestion, the development of piers, berths and floating bridges, and disturbance caused by higher speeds, swell and beach erosion. Additionally, most recreational boats directly emit exhaust fumes directly into the water which can contain a cocktail of toxic and environmentally harmful substances, including polycyclic aromatic hydrocarbons (PAHs), several of which are toxic, carcinogenic and / or mutagenic. The exhaust gases also contain soot, unburned oils and fuels, fertilising and acidifying nitrogen compounds as well as carbon monoxide and carbon dioxide. In areas with the highest leisure boat traffic, this has resulted in elevated PAH levels of in sediments, for example. In the West Coast region of Sweden there are approximately 110 000 leisure boats of all types (Swedish Transport Agency, 2021) many of them powered by gasoline or diesel fuels. The natural harbours on the Swedish coast are popular alternatives to urban harbours and marinas, as the legal right of public access makes it possible to anchor, moor and spend the night in a scenic archipelago, which leads to significant local physical stress for benthic habitats. (Nordberg *et al.,* 2022). (See: OSPAR Feeder Report 2021 – Recreation and Tourism in the North-East Atlantic).

Transmission of electricity and communications (cables) [Production of energy]:
The placement of cables for electricity and telecoms is driven by worldwide communications and energy transmission and is expected to increase due to predicted growth in the marine renewable energy sector. The cable installation, maintenance, and decommissioning phases introduce noise, pollution, turbidity and physical disturbance to the seafloor. Electromagnetic fields, heat emission, pollution and reef effects are associated with the operational life of the cable.

The majority of marine cables are buried to mitigate the risk of damage from fishing activities and anchoring. Impacts to benthic habitats and the seafloor include disturbance, sediment alteration, loss of habitat, and the introduction/spread of non-native species (introduction via maintenance vessels or spread via the installation of artificial substrate in the form of cables or cable protection). Other indirect effects include induced magnetism, noise, thermal radiation, or chemical and physical interactions between seawater and the cable insulation or protection layers (Vasilescu and Dinu, 2021). Disturbance to the seafloor is generally limited to the cable corridor (around 10 m) and is generally temporary. However, longer-term effects may also be experienced, with unburied cables acting as dragging features when shifted by tides and wave actions (Merck and Wasserthal, 2009). The impact of electromagnetic fields on the orientation and migratory habits of fish and surrounding benthic fauna is poorly understood (Copping *et al.,* 2020).

Coastal defence and flood protection [Physical restructuring of rivers, coastline or seabed (water management)]:
Coastal defence and flood protection works include the construction, operation and decommissioning of, for example, seawalls, flood doors and embankments. Structures may be constructed on or adjacent to benthic habitats. Their installation can cause both direct and indirect impacts on benthic habitats (Martin *et al.,* 2005), and is one of the main sources of habitat loss. When placed on soft sediments, coastal defences change the original benthic habitat by installing hard substrate, greatly changing the associated community. Furthermore, coastal defences produce important indirect effects by modifying the wave and deposition regime, altering sedimentation processes and potentially generating habitat loss away from the location of the activities. The effects of coastal defences in several European countries were analysed by Martin *et al.,* in 2005. These authors identified a general trend across all locations and countries showing that changes in sediment and infauna associated with coastal defences seemed to be inevitable and usually induced negative changes, particularly on the landward side and in the presence of additional structures.

Renewable energy generation (wind, wave and tidal power), including infrastructure [Production of energy]:
Construction, operation, and decommissioning activities associated with renewable energy developments may directly interact with benthic habitats and/or may affect habitat conditions.

Offshore wind has proven to be a valuable source of renewable and clean energy. European seas host over 75% of the global capacity (GWEC, 2019), implying the widespread installation of infrastructure. This comprises multiple turbines (with their foundations) as well as complex systems of undersea cables and transformers for energy transmission and distribution (the latter occurring only on land). The majority of installations are found in the Greater North Sea Region– a global multi-source renewable energy hotspot. The first impact on the benthic habitat is caused by the sealing of the seafloor by benthic infrastructure, causing a loss of habitat (generally siliciclastic seafloor habitats are replaced by artificial substrates) (Galparsoro *et al.,* 2021). Consequently, wind and tidal energy structures are responsible for altering the initial benthic community (Baker *et al.,* 2020; Coolen *et al.,* 2022) by introducing intertidal and subtidal artificial hard substrate habitats for epifaunal and colonising organisms (Degraer *et al.,* 2020) and creating the potential for invasive species (De Mesel *et al.,* 2015). The feeding activity of these newly introduced fauna may lead to habitat alterations through organic enrichment resulting from their filter-feeding and excretion behaviour (see e.g., Project OUTFLOW). This might be more prominent in the near field (i.e., the immediate vicinity of the foundations and turbines), while the extent of the far-field effects will be linked to the local hydrodynamics, although this remains poorly studied and thus poorly understood. The potential for large-scale (i.e., basin-scale) habitat alteration is significant given the forecast increase in offshore infrastructural development involved in the decarbonisation of energy production in Europe. (See: OSPAR Feeder Report 2021 - Offshore Renewable Energy Generation).

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Extraction of oil and gas, including infrastructure [Extraction of non-living resources]:
The need for energy security has meant that oil and gas development has remained constant in most of the OSPAR Maritime Area, although there are decreases in some parts. Most installations are located in the Greater North Sea, followed by the Arctic Waters (south of the ice edge) and Celtic Seas. Exploration, operation, decommissioning and the associated infrastructure can directly interact with benthic habitats. Physical impacts result from the placement of installations, pipelines and associated structures. The sealing of the seabed leads to loss of soft sediment habitats. Changes of the physical habitat also occur due to scouring or protections around structures. The physical presence of installations leads to changes of benthic community structures, notably favouring species associated with hard substrates. Epibenthic filter feeders settle on platform legs, while suspension-feeding organisms in particular prevail on the surrounding seabed. These notably benefit from the organic material provided by other species colonising the foundation structures. As a consequence, related benthic predators also increase and contribute to changes in the local food web.

Operational platforms impact benthic organisms through discharges of produced water, oil, chemicals and drill cuttings. The drilling process involves the discharge of drilling fluids along with drill cuttings, which may cause smothering in the near vicinity of the well location. The contamination results in lower diversity and abundance of benthic organisms and an increased dominance of tolerant opportunistic species for several square kilometres around the well location. (See: Assessment of impacts of the offshore oil and gas industry on the marine environment).

Marine aquaculture [Cultivation of living resources]:
This activity may affect benthic habitats through placement of structures (physical), nutrient and organic enrichment (physical and chemical inputs), and also as one of the main vectors for the introduction of non-indigenous species (biological pressure). This type of activity has increased very rapidly over recent decades, alongside a diversification of techniques and the addition of new farmed species, which could lead in turn to wider and sometimes negative impacts on ecosystem services (Gentry *et al.,* 2022; Naylor *et al.,* 2021). The impacts on benthic habitats are often very locally documented but the few reviews conducted at wider scales highlight both direct and indirect effects on benthic communities and habitats (McKindsey *et al.,* 2011), notably in intertidal or estuarine areas (Simenstad and Fresh, 1995). (See: OSPAR Feeder Report 2021 - Aquaculture, Human Activities Thematic Assessment)

Agriculture [Cultivation of living resources]:
Agriculture has been an important social and economic feature of European societies since prehistoric times. Nitrogen pollution of water has increased greatly from various sources, notably the large amounts of mineral fertilisers applied since the 1950s to boost agricultural food and feed production (Marshall Plan of 1947; Common Agricultural Policy (CAP) of 1957, which entered into practice in 1962; FAO, 2018), resulting in intensification and specialisation of agriculture (JRC, 2022). The scientific literature dealing with the land-to-sea continuum integrating diffuse nutrient loading from agricultural activities into the watershed, including their effects on the coastal zone, describes these various aspects and their related impacts (e.g., Blann *et al.,* 2009; Fierro *et al.,* 2021). Inputs of nutrients and organic matter from agriculture may lead to eutrophication of benthic habitats, particularly those in coastal areas or under direct influence from freshwater inputs. (See: OSPAR Feeder Report 2021 - Agriculture, Human Activities Thematic Assessment).

Urban uses, Industrial uses, Waste treatment and disposal [Urban and industrial uses]:
Clean water supply and waste water treatment have required huge investment across Europe in recent decades. Much has been done to provide for the collection and treatment of urban waste water, but new pressures (such as adapting to climate change, providing facilities in urban and rural areas and tackling newly identified pollutants) require substantial investment over and above the maintenance of the existing infrastructure (EEA, 2021). The European Union Water Framework Directive (EU WFD) (2000/60/EC) and all the national programmes related to water quality have established a framework for the protection of rivers, lakes, transitional waters (estuaries), coastal waters and groundwater. The EUWFD aims to ensure that all surface water bodies achieve good chemical and ecological status and display minimal signs of impact from human development. The requirements of the EU WFD and any related national programmes constitute the baseline for managing water pollution coming from urban areas. Benthic habitats exposed to urban and

industrial contaminated waste waters are affected by various pollutants (e.g., nutrient and organic enrichments, contaminants, microbial pathogens), which are described in other dedicated thematic assessments. (See: OSPAR Feeder Report 2021 – Waste water, Human Activities Thematic Assessment, Eutrophication Thematic Assessment and Hazardous Substances Thematic Assessment).

Transport infrastructure [Transport]:

Transport infrastructure, such as ports or any related facility, can affect benthic habitats through pressures resulting from the construction and operational phase of associated structures. Environmental alteration or the replacement of benthic habitat by constructed infrastructure leads to a reduction in ecosystem functioning. Marine artificial infrastructure is progressively colonised by biota; however, this infrastructure does not function as an alternative to a natural hard substrate. The introduction of hard infrastructure along a sedimentary coastline can modify local biodiversity patterns and facilitate the establishment of non-indigenous species (Bacchiocchi and Airoldi, 2003). The alteration of a naturally sloping habitat to a general vertical habitat can have several adverse effects, such as modified distribution of plants and biota, food web interactions, and abnormal densities of organisms, which may result in turn in reduced size or reproductive output (Bulleri and Chapman, 2010). The addition of infrastructure often also leads to natural habitat fragmentation which reduces dispersal and movement across the landscape, resulting in a reduction of unique taxa and species variability (Goodsell, Chapman and Underwood, 2007). (See: Human Activities Thematic Assessment).

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P – Pressures

Pressures affecting benthic habitats

Impacts on benthic habitats and seafloor integrity are caused by several anthropogenic pressures. In the past few years, a great deal of attention has been given to pressures that cause seafloor abrasion and habitat loss, as well as those causing eutrophication and nutrient enrichment. The effects of these pressures on seafloor habitats are currently being assessed through a set of benthic indicators, although these are subject to further development. However, other pressures are also important, in particular inputs of heavy metals and contaminants, the extraction of living resources, the impact of introduced species, litter on the seafloor, and input from some forms of energy, such as thermal energy. Pressures from climate drivers and ocean acidification, such as increased coastal erosion or decreases in pH levels, are also a major driver of changes. The currently available evidence on the effects of these pressures is included in the Climate Change section of this assessment.

Physical disturbance to seabed (temporary or reversible) [Physical]:

Physical disturbance is understood as a change to the seabed from which it can recover, if the activity causing the disturbance ceases. The recovery time from physical disturbance should last, or is expected to last, for less than 12 years in order for the disturbance to be considered "temporary or reversible" (European Commission Decision 848/2017).

The extraction of living and non-living resources can result in interactions with the seabed and benthic habitats. Fish and shellfish harvesting are driven by the need for food security; they cover all aspects of catching wild fish and shellfish, whether with active or static gear or by hand gathering. Fishing gear such as trawls and dredges that drag across or penetrate the seabed can alter the seabed topography (e.g., scouring/scarring of sediments) and have major impacts on benthic communities. Bottom trawling leads to a decline of long-lived and large fragile species, whereas small and opportunistic species as well as scavengers are favoured. The persistence of such changes may depend on the gear type and prevailing site conditions (e.g., sheltered vs. exposed). Driven by construction and the demand for materials, the extraction of minerals (rock, metal ores, gravel, sand, shell) may also cause alterations to the seabed topography, changes in sediment composition, the removal of organisms and other temporary disturbance to benthic habitats, for example by mobilising and suspending sediments, thereby affecting water clarity and reducing the capability of benthic habitats to act as natural carbon sinks.

Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate) [Physical]:

Physical loss is defined as a permanent change to the seabed which has lasted or is expected to last for 12 years or more (European Commission Decision 848/2017). It Includes permanent habitat change (e.g., from input of hard substrate). The term "permanent change" of the seabed also covers instances in which recovery is only possible by active human intervention (e.g., coral, seagrass and kelp transplantations, removal of artificial structures, sand capping). The introduction of infrastructure to the marine environment for the purposes of coastal defence and flood protection, renewable energy generation, oil and gas extraction, tourism and leisure, and telecoms (cables) is driven by, respectively, the need for climate change mitigation, energy security, societal wellbeing, the creation of a digital society, and globalisation (telecoms). When infrastructure is introduced to the seabed, the result can be loss of the existing benthic habitat where the structures are present and the introduction of hard substrate to the location. There may also be subsequent indirect loss of benthic habitat (e.g., the introduction of hard seawalls prevents landward migration of intertidal habitats as sea levels rise). Direct benthic habitat loss may also result from the direct removal of seabed materials in order to extract minerals (e.g., sand and gravel extraction driven by construction and the need for materials) and from dredging and disposal (e.g., removal of sediments for navigational purposes, driven by trade and transport). These activities could also be classified as physical disturbance, depending on the duration of effects. Permanent changes of physical habitat caused by human activities (e.g., bottom trawling, aggregate extraction) or indirectly through the placement of man-made structures (e.g., hydrological changes) may also lead to physical loss of habitat types.

Fishing gear such as scallop dredges drag across or penetrate the seabed and alter the seabed topography. © Shutterstock

Input of nutrients - diffuse sources, point sources, atmospheric deposition, Input of organic matter - diffuse sources and point sources [Substances, litter and energy]:

Nutrient or organic enrichments may modify the growth, abundance and dynamics of plankton, algae and higher forms of plant life, which in turn may lead to a range of undesirable disturbances in the marine ecosystem including food webs. These can include oxygen depletion in bottom waters caused by the indirect death of impacted benthic species or significant shifts in the composition of the flora and fauna affecting both habitats and biodiversity. Several coastal waters of OSPAR Contracting Parties have, to a varying degree, been affected directly or indirectly by nutrient and / or organic enrichment due mainly to agriculture, urban and industrial waste waters and (more locally) marine culture. These can result in harmful or toxic algal blooms, change or loss of benthic vegetation owing to shading and competition for nutrients, or a drastic modification of benthic fauna communities (and associated functional aspects) due to specific sensitivities and population dynamics.

Pressures not currently and directly assessed by OSPAR benthic habitats indicators

Input of other substances [Substances, litter, and energy]:

Human activities can introduce a range of hazardous substances. This pressure type relates to increasing levels of contaminants in sediment or biota (e.g., PBDE, PAH, PCB, Metals, organotins) which can lead to changes in exposed benthic habitats and communities through their effects on differential mortalities, reduced breeding success or species fitness. (See: Hazardous Substances Thematic Assessment)

Focus on the heavy metals in fish, shellfish and sediment:

Metals are ubiquitous hazardous substances that occur naturally in the environment. In marine sediments, metals are a natural part of different minerals and can be slightly more prevalent for some habitat types. Metals can be found in sediment, shellfish, and fish in all OSPAR Regions. The most documented toxic metals for humans and animals are mercury, cadmium and lead, known as "heavy or trace" metals, which enter the marine environment from a variety of sources. Direct inputs of metals used as antifouling chemicals (mainly copper) and corrosion anodes (mainly zinc) cause hot spots of metal concentrations in and around harbours, marine installations and along shipping routes.

The OSPAR Hazardous Substances Thematic Assessment is based on measurements of metals in fish, shellfish and sediment collected between 1979 and 2020 from monitoring sites throughout the Arctic Waters, Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast Regions, with additional data from marine mammals and birds in the Arctic Waters and some birds in the Greater North Sea. Cadmium and lead concentrations in fish and shellfish were found to be statistically significantly below the background concentration in the Irish and Scottish West Coast, Celtic Seas and the Bay of Biscay and Iberian Coast, whereas lead was below the background concentration in the Irish and Scottish West Coast, Greenland-Scotland Ridge and Norwegian Sea. For mercury in fish and shellfish, no decreasing trends were observed for any sub-regions. On the contrary, increasing trends of 2 to 4% yearly change were observed in the Southern North Sea, the Channel and the Northern Bay of Biscay. Samples taken from sediment showed decreasing trends for mercury in both the Northern and Southern North Sea, the Irish Sea and the Irish and Scottish West Coast, with approximately - 3% yearly change. The increasing trend for fish and shellfish in the Southern North Sea is mainly due to increasing levels in the Wadden Sea area, the Channel, and the Northern Bay of Biscay, mainly along the coast of France. For the Northern Bay of Biscay, no sediment data were available for estimating temporal trends in mercury contamination.

In summary, mercury was found to be problematic in all areas for shellfish and fish, being above both the Background Assessment Concentration (BAC) for mussels and the Quality Standard (QS_{sp}) assessment criteria. Lead and cadmium were above background levels for shellfish and fish in most areas, except the Irish and Scottish West Coast. The Celtic Seas, Iberian Sea and Northern Bay of Biscay were above background levels for cadmium and the Norwegian Sea and Greenland-Scotland ridge for lead. In sediments, mercury and lead were above the Effects Range Low (ERL) assessment criteria in the Southern North Sea, the Channel, the Irish Sea and the Celtic Seas. For the Irish and Scottish West Coast, background levels were achieved in sediments.

Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities) [Biological]:

The commercial exploitation of fish and shellfish stocks can lead to reduced abundance of target and non-target benthic species. Documented examples include declines in scallop stocks (Howarth and Stuart, 2014) and in threatened and declining species and/or habitats such as *Ostrea edulis* (OSPAR, 2008). The use of mobile fishing gear targeting the queen scallop (*Aequipecten opercularis*) has caused damage and the eventual collapse of *Modiolus* beds in Northern Ireland and declines in the wider OSPAR Maritime Area (OSPAR, 2009, Fariñas-Franco *et al.,* 2018). Bottom fishing can lead to an influx of scavengers in recently fished areas, reduce community production, change the size/age structure of benthic species and trigger cascade effects altering the trophic structure and function of benthic habitats (Coleman and Williams, 2002; Sciberras *et al.,* 2018; Fennell *et al.,* 2021). The collection of mussel seed for aquaculture (e.g., poorly managed dredging) can have an impact on wild mussel populations. For example, past seed collection is associated with the declines in the mussel beds of the Wadden Sea (See: OSPAR Feeder Report 2021 - Aquaculture, OSPAR Feeder Report 2021 – Extraction of non-living resources).

Input or spread of non-indigenous species [Biological]:

Non-indigenous species (NIS) have the potential to outcompete native benthic species, altering community, habitat and ecosystem structures and functions. Genetically modified species and translocation of native species are also part of this biological pressure. New introductions occur in all OSPAR Regions every year, but their impacts on benthic habitats are rarely or only locally monitored and quantified. Climate change may facilitate the successful establishment and spread of several opportunistic NIS which benefit from its negative impacts on native species and communities. More details and references on this pressure and its drivers, impacts and responses are available in the OSPAR Non-indigenous Species Thematic Assessment. (See: OSPAR Indicator Assessment - Trends in New Records of Non-indigenous Species Introduced by Human Activities).

Input of litter (solid waste matter, including micro-sized litter) [Substances, litter, energy]:

Marine litter tends to sink and accumulate through time in benthic habitats (Thushari and Senevirathna, 2020). Marine litter (including plastics) can lead to the smothering of benthic habitats and generation of artificial hard substrate, altering the structure of benthic communities and leading to loss of biodiversity. Marine animals can ingest or become entangled in litter on or near the seafloor, resulting in death or injury, OSPAR Indicator Assessment - Composition and Spatial Distribution of Litter on the Seafloor; Consoli *et al.,* 2019). Plastic items are highly likely to degrade to micro-sized plastics that have a higher potential to accumulate on benthic biota, with adverse effects on survival and reproduction (Thushari and Senevirathna, 2020). Plastic items are potential sources of contaminants because of their chemical additives and because they can concentrate contaminants already present in the water column (Chen *et al.,* 2019); they can also cause habitat damage or act as a transport vector for invasive species (García-Gómez *et al.,* 2021). Plastic items related to fishing are reported as one of the most common forms of litter in the marine environment (OSPAR Intermediate Assessment 2017, Kammann *et al.,* 2018). Abandoned, lost or discarded fishing gear may represent one of the main causes of degradation of benthic habitats (Galgani *et al.,* 2018; Gilman *et al.,* 2021). (See: Marine Litter Thematic Assessment)

Input of other forms of energy (including electromagnetic fields, light and heat) [Substances, litter and energy]:

Heat, light, sound and electromagnetic fields can cause alterations to environmental conditions, and therefore have an adverse effect on benthic organisms.

Thermal input:
Thermal power plants require large inputs of water for cooling; consequently, they are often constructed near coastal areas. Seawater in most cases is pumped into the power plants and subsequently ejected back into the environment as heated thermal effluent (Poornima *et al.,* 2005). The impacts include reduction of biomass in the general vicinity of the discharge location, increases in invasive species, alteration of substrate type, community alteration and negative effects on recruitment (Kramer, 1994; Chou *et al.,* 2004).

Changes in current flow:
In suitable coastal locations, generators are built to convert the energy from the rise and fall of tides into electrical power. These generators can alter flow dynamics and sediment transport characteristics, leading to faunal changes (Baker *et al.,* 2020). The impact on benthic assemblages can occur at some distance from where the energy is produced, both for benthic individuals and pelagic larval stages.

Electromagnetic fields:
Interaction with electromagnetic fields (EMF), for example from offshore wind infrastructure, has the potential to induce behavioural, physiological and developmental effects in benthic and demersal biota. For example, altered sheltering behaviour and increased exploratory response have been observed in the American lobster (*Homarus americanus*) when exposed to high voltage EMF. Demersal and benthic species (e.g., certain elasmobranchs) can also be influenced by EMF and can show increased exploratory and foraging behaviour, thus increasing the predation on benthic fauna (Hutchison *et al.,* 2020)

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S – State

State of benthic habitats and seafloor integrity

Benthic ecosystems in the OSPAR Maritime Area are influenced by open Atlantic oceanic currents, geographical and topographical factors, depth variations and temperature and salinity ranges. This wide range of environmental conditions in turn produces a rich and diverse array of benthic ecosystems, from intertidal mudflats to biogenic reefs (https://www.emodnet-seabedhabitats.eu/).

Anthropogenic pressures have caused changes in the extent, distribution, condition and functioning of benthic habitats, with increased degradation in some, particularly those highly sensitive to human pressures. During recent decades, several habitats have been identified as in need of special protection and conservation measures, notably through European Union Directives and by other regional bodies: Natura 2000; Marine Strategy Framework Directive (MSFD), Baltic Marine Environment Protection Commission, Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and The Commission on the Protection of the Black Sea Against Pollution. For OSPAR, these habitats are listed under Threatened and/or Declining Species and Habitats.

For this Quality Status Report (QSR 2023), the assessments of the state of broad-scale and listed benthic habitats in the OSPAR Maritime Area have been undertaken using a variety of indicators and assessment methods applied at different scales. Most of the indicators have been further developed and improved since the publication of the 2017 OSPAR Intermediate Assessment. The key messages from the results of the indicator and listed habitat status assessments have been summarised for each of the five OSPAR Regions in **Table S.1**, including an overall assessment of confidence. The availability of habitat data and the limited access to high-resolution pressure data from anthropogenic activities present a key challenge to the assessment of benthic ecosystems. Currently, there are large areas of OSPAR Regions with very limited or no monitoring data. Pressure-state-impact relationships, particularly in regard to exposure levels and the recovery of some sensitive habitats, are not always well understood. This and data paucity are the key factors affecting the levels of confidence in the assessments results (**Table S.1**).

Table S.1: Regional assessment summaries of benthic Common Indicators and OSPAR listed threatened and /or declining habitats

Arctic Waters (Region I)			
Common Indicators	• No OSPAR Common Indicators have been developed. • Efforts are ongoing towards the development of methodological standards and common baselines. • The trends detected are mainly related to climatic impacts. Specific impacts from human activities have not so far been well studied and documented, but some impacts from pressures have been reported.		
Threatened and/or Declining Habitats	**Habitats in Poor Status**	**Habitats in Good Status**	**Habitats Not Assessed/Unknown Status**
Five out of eight OSPAR listed habitats assessed are in poor status	• *Zostera* beds • Deep-sea sponge aggregations • Coral gardens • *Lophelia pertusa* reefs Seamounts	• Oceanic ridges with hydrothermal vent fields	• Maerl beds (unknown) Intertidal mudflats (not assessed)
Confidence	**Low** - Assessment is based on status assessments of OSPAR listed habitats, expert judgement, published research and third-party assessments, but these assessments cover only a small part of this Region		

Greater North Sea (Region II)			
Common Indicators	• Coastal waters are showing mainly high/good status for benthic vegetation and invertebrates, but in the Southern North Sea, Kattegat and the Channel, status was mixed, as eutrophication is still an issue for some areas (BH2a). • The Margalef [species] diversity index (BH2b) indicates low relative diversity in infralittoral sand, mud and circalittoral sandy habitats, with moderate to high relative diversity in some offshore areas. • Assessments of bottom-contacting fishing activity (BH3a) showed widespread and generally high physical disturbance of benthic habitats. Lower levels of disturbance occurred in some areas of the Central North Sea. Offshore circalittoral mud is the most highly disturbed habitat across the Greater North Sea. • Disturbance from aggregate extraction activities (BH3b) was only measured in the Southern North Sea, the Channel, Kattegat and the Norwegian Trench. Not all areas were assessed due to lack of suitable data.		
Threatened and/or Declining Habitats	**Habitats in Poor Status**	**Habitats in Good Status**	**Habitats Not Assessed/Unknown Status**
Eight out of nine OSPAR listed habitats assessed are in poor status	• Maerl beds • Intertidal *Mytilus edulis* beds on mixed and sandy sediments • Intertidal mud flats • *Zostera* beds • Sea-pen and burrowing megafauna • Deep-sea sponge aggregations • Coral gardens • *Lophelia pertusa* reefs	None	• European Flat oyster (*Ostrea edulis*) beds (unknown)
Confidence	**Medium** - Multiple lines of evidence, indicators and status assessments of OSPAR listed habitats mostly agree, but gaps were observed in the spatial coverage of the biological information available		

Celtic Seas (Region III)			
Common Indicators	• Coastal waters are showing mainly high/good status for benthic vegetation and invertebrates (BH2a) although, in the Southern Celtic Seas, a large proportion of the total area of water bodies was not assessed. • Assessments of bottom-contacting fishing activity (BH3a) showed widespread and generally high physical disturbance of benthic habitats. Disturbance was higher in the Southern Celtic Seas, with more than 70% of the assessment unit disturbed by fishing. Offshore circalittoral mud and upper bathyal sediment were the habitats most affected. • Disturbance from aggregate extraction (BH3b) was only measured in a small number of areas. Not all areas were assessed due to lack of suitable data.		
Threatened and/or Declining Habitats	**Habitats in Poor Status**	**Habitats in Good Status**	**Habitats Not Assessed/Unknown Status**
Six out of seven OSPAR Listed habitats assessed are in poor status	• Maerl beds • European flat oyster (*Ostrea edulis*) beds • Intertidal mud flats • *Zostera* beds • Sea-pen and burrowing megafauna • *Lophelia pertusa* reefs	None	• Intertidal mussel beds (not assessed)
Confidence	**Medium** - Multiple lines of evidence, indicators and status assessments of OSPAR listed habitats mostly agree, but gaps were observed in the spatial coverage of biological information available		

Bay of Biscay and Iberian Coast (Region IV)			
Common Indicators	• Coastal waters are showing mainly high/good status for benthic vegetation and invertebrates (BH2a), although a large proportion of water bodies was not assessed in the Gulf of Cadiz and in the Bay of Biscay. • Assessments of physical disturbance to the seabed by fishing (BH3a) and changes to sensitive species (BH1) showed that a larger proportion of benthic habitats in areas where such fishing could occur was assessed as disturbed or under impact. • All offshore and circalittoral broad habitat types were disturbed to some extent (BH1 and BH3a). Some habitats such as offshore circalittoral mixed sediments, offshore circalittoral mud and circalittoral coarse sediment are showing more than 50% of the area assessed as 'highly disturbed' within an assessment period.		
Threatened and/or Declining Habitats	**Habitats in Poor Status**	**Habitats in Good Status**	**Habitats Not Assessed/Unknown Status**
All eight OSPAR Listed habitats assessed are in poor status	• Maerl beds • European flat oyster (*Ostrea edulis*) beds • Intertidal mud flats • *Zostera* beds • *Lophelia pertusa* reefs • Deep-sea sponge aggregations • Coral gardens • Seamounts	None	None
Confidence	**Medium** - Multiple lines of evidence, indicators and status assessments of OSPAR listed habitats mostly agree, but gaps were observed in the spatial coverage of biological information available		

Wider Atlantic (Region V)			
Common Indicators	• At present there are no OSPAR Common Indicators agreed for this Region. • A pilot assessment of physical disturbance caused by fishing (BH3a) was conducted in some areas within Contracting Parties' EEZs. It showed that a large proportion of habitats, mainly those classified as bathyal and abyssal, was undisturbed because fishing does not occur in these areas of the seabed. By contrast, the pilot assessment also indicated moderate to high levels of disturbance to offshore circalittoral mud and other soft sediments in areas where fishing activity is widespread. • It should be noted that a large proportion of broad-scale habitats in this Region have not been assessed.		
Threatened and/or Declining Habitats	**Habitats in Poor Status**	**Habitats in Good Status**	**Habitats Not Assessed/Unknown Status**
Five out of six OSPAR Listed habitats assessed are in poor status	• Deep-sea sponge aggregations • Carbonate mounds • Seamounts • Coral gardens • *Lophelia pertusa* reefs	• Oceanic ridges and hydrothermal vent fields	None
Confidence	**Low** - Data were assessed only in a small proportion of the total area of the Region. Status assessments of OSPAR listed habitats were also undertaken, but large areas were unassessed		

The OSPAR Common Indicators have not yet been adapted for and applied to the Arctic Waters (OSPAR Region I). Therefore, the ecosystem state of the Arctic Waters in the OSPAR Maritime Area has been assessed with the best available data and scientific knowledge.

There is some evidence available for selected areas of the Arctic Waters and the Wider Atlantic, but this is limited to third party assessments, the status of some of the OSPAR threatened and/or declining habitats and pilot assessments of candidate indicators. The spatio-temporal coverage of these assessments is limited, which in turn limits the comparability of the results.

For the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast, quantitative approaches have been applied through the use of regional Common Indicators, which represent an evaluation of status and assessment using common standards of methodology and data formats. Status assessments from the OSPAR-listed threatened and / or declining habitats are also available for these Regions. However, gaps still remain, in particular in terms of the types of pressures addressed, the limited data and the cumulative effects, which prevents the integration of indicators at this stage. The results from indicators cover a wide range of habitat types.

Thanks to the common methodological standards, the lines of evidence (Indicator Assessments, other assessments or third-party assessments) mostly concur, although a minor proportion show some deviation, notably due to differences in the indicators and related methods used between Regions (common and candidate indicators), knowledge gaps and current limitations in methods, which still enable some subjective interpretations of the results.

Despite the large amount of effort invested to develop indicators, quantitative integration is not possible at this stage. This is due to a combination of factors, in particular the lack of agreed regional thresholds alongside the limited coverage of indicator results across some of the assessment units.

To facilitate overall visualisation, the results of the Indicator Assessments are presented.

Table S.2 and **Figures S.2-S.6** highlight that not all indicators were assessed in all OSPAR Regions due to lack of data or lack of policy support. As previously noted, OSPAR Common Indicators have not yet been adapted for or applied to the Arctic Waters and Wider Atlantic Regions, although the availability of limited data has facilitated a pilot assessment for two indicators in discrete areas within the Arctic Waters and the Wider Atlantic to support the further development of these indicators for these regions.

The assessment of Common Indicators and the pilot assessment of candidate indicators (**Table S.2**) have been used to assess different aspects of benthic ecosystems, namely the level of disturbance and risks of physical loss to the seafloor (MSFD broad habitat types and OSPAR List of threatened and declining habitats), changes in benthic species diversity, impacts on sensitive species and the status of benthic communities in relation to eutrophication pressures (nutrient and organic enrichment). The assessment units (AUs) used in the analysis reflect the boundaries set up for MSFD and UK Marine Strategy reporting purposes (**Figure S.1**).

Table S.2: Overview of the availability per OSPAR Region of Common Indicator results (marked as X in white cells) and the pilot assessment of Common Indicators (marked as (X) in pale grey cells); or where there is no indicator at all (dark grey cell). AU = assessment units. UK = United Kingdom

	Arctic Waters (Region I)	Greater North Sea (Region II)	Celtic Seas (Region III)	Bay of Biscay and Iberian Coast (Region IV)	Wider Atlantic (Region V)
Sentinels of the Seabed (BH1)				X	
Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment (BH2a)	(X) coastal waters only	X	X	X	(X) coastal waters only
Condition of Benthic Habitat Communities: Margalef diversity in Region II (Greater North Sea) (BH2b)		X			
Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears (BH3a)	(X) UK waters only	X	X	X	(X) Atlantic Projection nd deeper habitats in other AUs
Extent of Physical Disturbance to Benthic Habitats: Aggregate Extraction (BH3b)		X	X		
Pilot Assessment of Area of Habitat Loss (BH4)		Pilot			

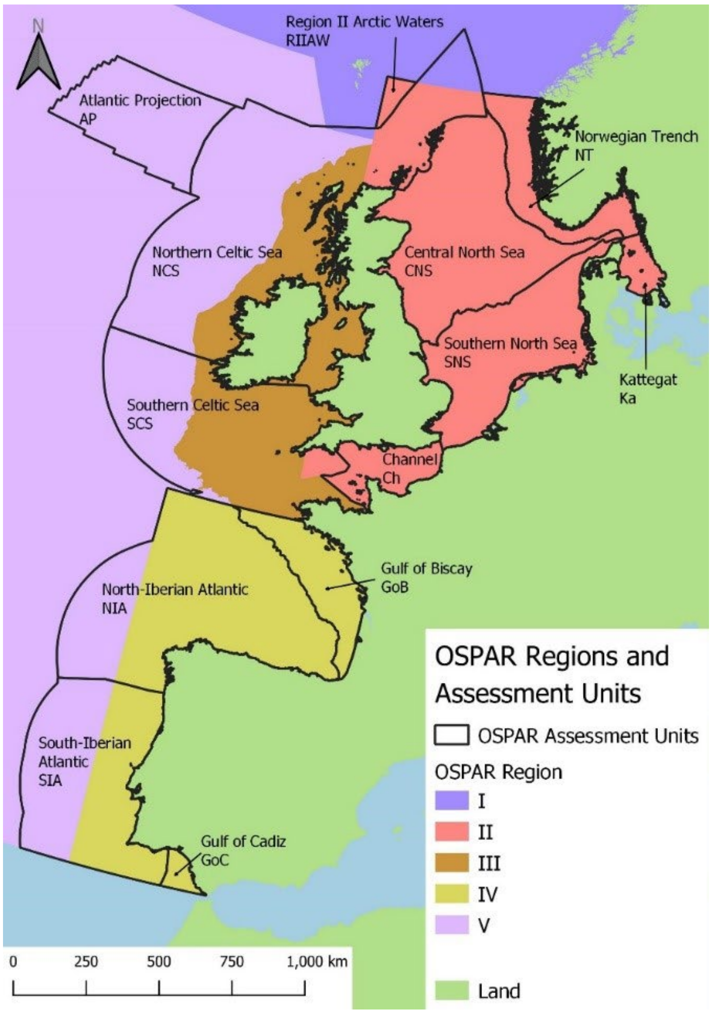

Figure S.1: Maps of the agreed benthic assessment units overlaying OSPAR Regions

The Sentinels of the Seabed (BH1) Common Indicator Assessment evaluated the level of disturbance to the main benthic habitats affected by bottom-contact fishing in the Common Indicator Assessment units in the Bay of Biscay and Iberian coast Region from 2009 to 2020 (QSR) and from 2016 to 2020 (MSFD).

The assessment showed that bottom trawling was widely distributed over the continental shelf of the area considered (**Figure S.2**). This geographical distribution results in the intensity of the fishing effort being primarily concentrated at depths shallower than 500 m and mainly shallower than 200 m. Consequently, the Gulf of Cadiz and the Gulf of Biscay assessment units, which mostly comprise the continental shelf, are trawled to a greater extent and thus have a greater disturbed area.

When considering disturbance across Broad Habitat Types (BHT) within the assessed area, high disturbance was most significant in circalittoral coarse sediment, offshore circalittoral mixed sediment and offshore circalittoral mud (80% highly or moderately disturbed). These disturbance results were the product of interaction between the moderate to high intensity of trawling and the sensitivity of the habitats to that pressure. The least disturbed habitat type was upper bathyal sediment, at 46% highly or moderately disturbed. The assessment of the South Iberian Atlantic was not reliable because of a lack of Portuguese data.

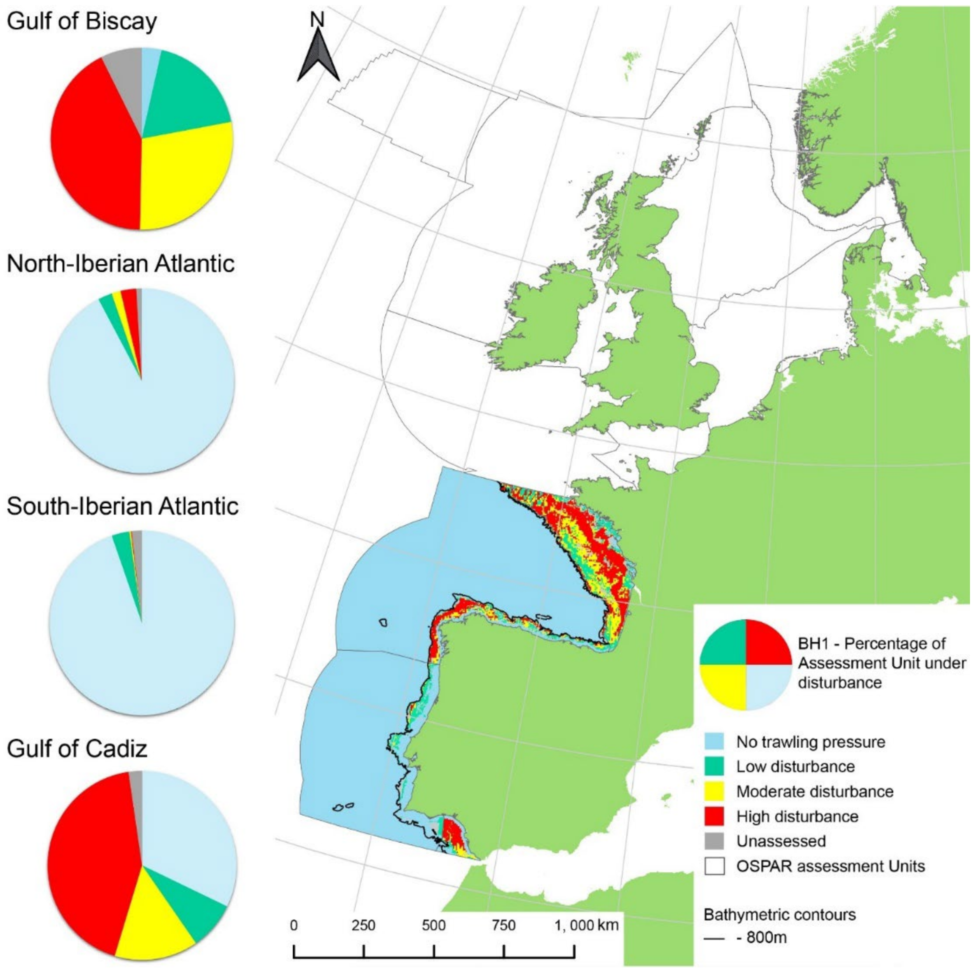

Figure S.2: Summary outputs of disturbance to benthic habitats for bottom trawling assessed by Sentinels of the Seabed (BH1) Common Indicator over the period 2009 to 2020 (QSR assessment period). The spatial distribution of disturbance across the Common Indicator Assessment units is presented on the map. The pie chart plots the percentage of assessment unit area for each disturbance level. This summary did not include data from the Portuguese fleet (VMS unavailable)

The results presented relating to the Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment (BH2a) in **Figures S.3 and S.4** indicate that most of the water bodies for which data were provided, in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast, have benthic habitats classified as in good biological status, according to the European Union Water Framework Directive (WFD, 2000/60/EC). For the three OSPAR Regions the assessment of invertebrates was applied to 72% of coastal water bodies (**Figure S.2**) and 59% of coastal water bodies for the condition of benthic vegetation (**Figure S.3**). The WFD quality status for the condition of benthic invertebrates was good or high in 79% of the coastal water bodies assessed. The condition of benthic vegetation was good or high in 86% of the coastal water bodies assessed. However, local eutrophication-impacted areas were highlighted in the 2010 and 2016 reporting cycles.

Despite the data gaps for many water bodies, this fine-scale Common Indicator Assessment (sub-regions and coastal water bodies) enabled the identification of regional variations and the main locally impacted areas for benthic invertebrates (**Figure S.2**) and vegetation communities (**Figure S.3**). The main impacted areas, notably for benthic vegetation, are persistent between 2010 and 2016, all along the Dutch and Danish coasts and the north-west coasts of France. The total area of assessed / reported water bodies increased significantly between 2010 and 2016 in most Regions (except the assessment unit Northern Iberian Atlantic), which led to better representativity, with both new good and bad WFD quality status areas.

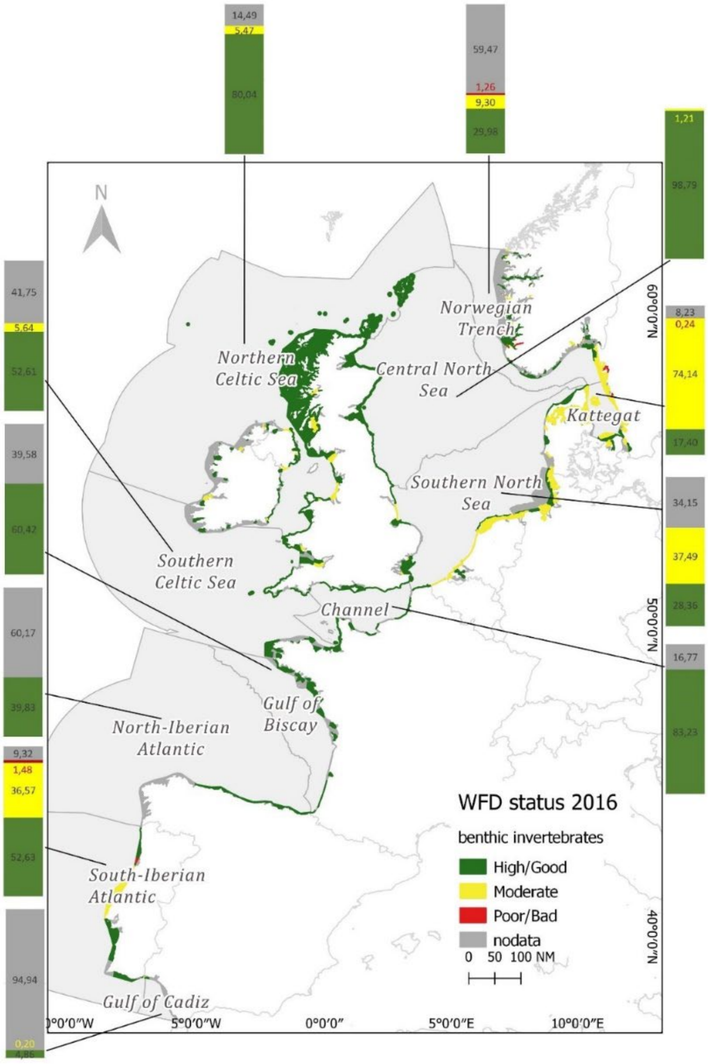

Figure S.3: Distribution of 2016 Water Framework Directive (WFD) quality status (condition) for benthic invertebrates (Common Iindicator BH2a) in intertidal and subtidal sediments in response to the (direct or indirect) effects of nutrient and / or organic enrichment, and proportion (area) of the quality status of coastal water bodies for each benthic habitat assessment unit in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast. Available at: ODIMS

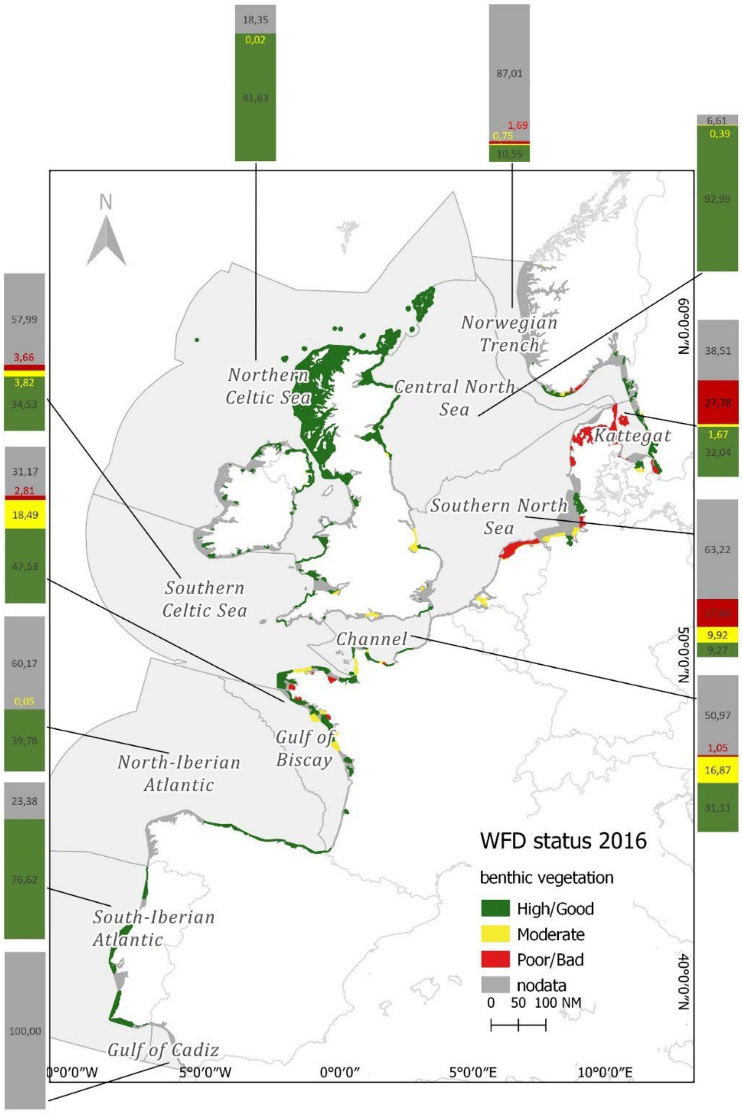

Figure S.4: Distribution of 2016 Water Framework Directive (WFD) quality status (condition) for benthic vegetation (Common Indicator BH2a) in intertidal and subtidal sediments, in response to the (direct or indirect) effects of nutrient and / or organic enrichment, and proportion (area) of the quality status of coastal water bodies for each benthic habitat assessment unit in the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast. Available at: ODIMS

The assessment of the Condition of Benthic Habitat Communities: Margalef diversity in Region II (Greater North Sea) (BH2b) **(Figure S.5)** has shown that the relative diversity of benthic communities is higher in offshore circalittoral habitats compared with circalittoral and infralittoral habitats, where low species diversity was found.

Relative diversity still seems to be in a moderate or rather good state in offshore circalittoral habitats, regardless of the expected relatively high fishing pressure. It should be noted that data from 2016-2021 were lacking for extensive areas, so on the basis of the impact assessments from BH3a (see also **Figure S.6**) a decrease in quality might be expected in the near future. Benthic diversity is relatively low in shallow coastal waters, where various pressures (e.g., eutrophication and diffuse pollution) can affect habitat condition even where fishing appears to be limited, according to the available pressure data. The pattern is especially evident in the Southern - and possibly Central – North Sea. The shallow benthic habitats of the Kattegat appear to be in a poor state; besides fisheries, it is expected that increased variability in low salinity water inflow from the Baltic plays a role. In general, benthic habitat quality status seems better in the Channel (regardless of high fishing pressure) and the Norwegian Trench. There and in the Central North Sea, efforts to improve the representativity of benthic community sampling programmes could improve the reliability of assessments.

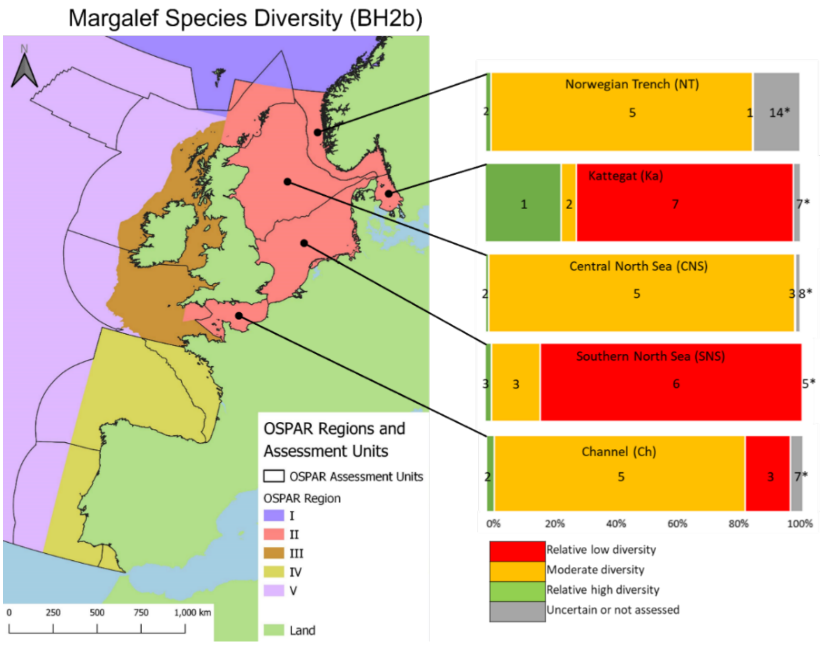

Figure S.5: Summary outputs of the Margalef Species Diversity (BH2b) assessment (2016-2021). Bars show proportion (area) of assessment unit with relative diversity level, where the number of assessed habitats under each diversity category is indicated

* The proportion of uncertain or unassessed area (grey bars) is slightly underestimated as it does not include two littoral BHTs for all assessment units and three lower bathyal and abyssal BHTs in the case of the Norwegian Trench.

Figure S.6 summarises the assessment outcomes for two BH3 indicators:

- BH3a: Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears;
- BH3b: Extent of Physical Disturbance to Benthic Habitats: Aggregate Extraction.

The assessment of indicator BH3a (red colourway, **Figure S.5**) evaluated the benthic habitat disturbance in the North-East Atlantic associated with bottom-contact fishing over two time frames (QSR:2009 to 2020; MSFD:2016 to 2020). Seafloor disturbance caused by fishing occurred in all broad habitat types, affecting 48% of the assessed area in 2016-2020, and 53% in 2009-2020.

The assessment indicated a ubiquitous distribution of anthropogenic pressure across parts of the OSPAR Maritime Area in habitats where bottom-contact fishing occurs (< 800 m deep). All Broadscale Habitat Types

(BHT) had high and/or moderate disturbance, with offshore circalittoral mud having the greatest proportion of high disturbance and offshore circalittoral coarse sediment the greatest proportion of low disturbance.

When considering the spatial distribution of disturbance, the greatest proportions of high and moderate disturbance occurring together were in the Gulf of Biscay and the Southern North Sea, whereas the greatest proportion of high disturbance alone was in the Gulf of Cadiz and the greatest proportion of low disturbance was in the Channel.

Zero disturbance was found in approximately half the total area of Common Indicator Assessment units in both the QSR (2009-2020) and the MSFD assessment (2016 – 2020) periods. However, gaps in the coverage of VMS (Vessel Monitoring System) data highlighted potential underestimations of disturbance in some areas and habitats. The aforementioned limitations associated with VMS data availability should be addressed in future assessments so as to facilitate more robust findings.

The results of Common Indicator Extent of physical disturbance to benthic habitats: Aggregate extraction (BH3b) are presented alongside the results from Common Indicator Extent of physical disturbance to benthic habitats: Fisheries with mobile bottom-contacting gear (BH3a) in **Figure S.5**, using a grey colour scheme. They show that disturbance from aggregate extraction was limited in extent, with high-intensity pressure localised to discrete licensed areas, where permitted by regulators. Disturbance could only be calculated where sufficient extraction pressure data were available. Owing to limitations in commercially sensitive extraction activity data, disturbance results are confined to the exclusive economic zones (EEZs) of the data providers.

Habitats impacted by extraction pressure typically showed moderate or high disturbance. Across all areas assessed, the sediments typically targeted by the aggregate industry (mixed sediment, coarse sediment, and sand) had the greatest proportions of area with disturbance. However, the total disturbance area for any single BHT across all assessment units remained less than 0,5% of the total habitat area. Additionally, within assessment units, the proportion of any habitat area under disturbance was also low, with offshore circalittoral rock and biogenic reef being the only BHTs with an area under greater than 1% disturbance in both the QSR and the MSFD assessments.

Changes in the areas of annual disturbance did not show any clear increasing or decreasing trends between 2009 and 2020. The variation in United Kingdom waters throughout the time series broadly followed the total active annual dredging area reported by the data provider (BMAPA, 2010 to 2021).

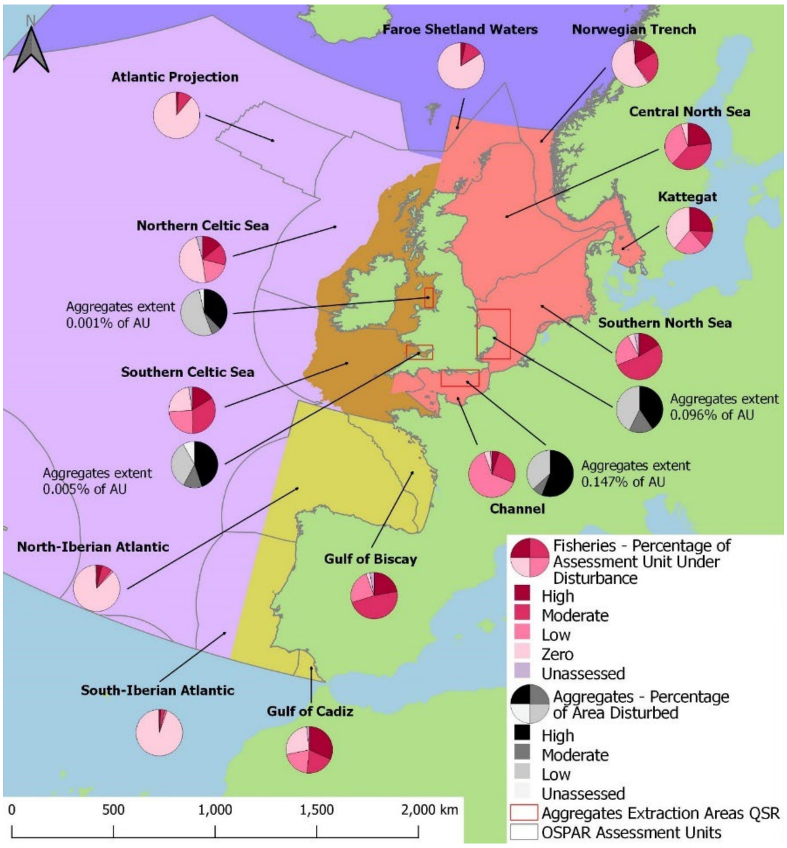

Figure S.6: Assessment results for risk of physical disturbance to benthic habitats, as calculated with the BH3a indicator for bottom-contact fishing gears and the BH3b indicator for commercial aggregate extraction, across the QSR 2023 assessment period (2009 to 2020). Disturbance caused by fishing activities is calculated as the percentage of the assessment unit under different levels of disturbance (red colourway), and disturbance caused by commercial aggregate extraction (grey colourway) is calculated as the percentage of disturbance in the areas where the activity is occurring (per assessment unit); shades of grey represent different levels of disturbance

Across all assessment units, abyssal habitats (deeper than 2 000 metres) have the highest habitat extent amounting to 30% of total habitat across all benthic broad-scale habitat types, followed by offshore circalittoral sand (18%) and upper bathyal sediments (14%) (**Figure S.7**). Physical disturbance remains the main widespread pressure caused by human activities and contributes to a reduction in diversity and changes in sensitive benthic species communities and habitats across the OSPAR Regions. This thematic assessment has highlighted that the highest levels of physical disturbance due to abrasion by bottom trawling fisheries occurred in infralittoral and circalittoral offshore soft habitat types, while coastal habitat benthic communities' diversity and structure were both affected by - probably - several pressure types.

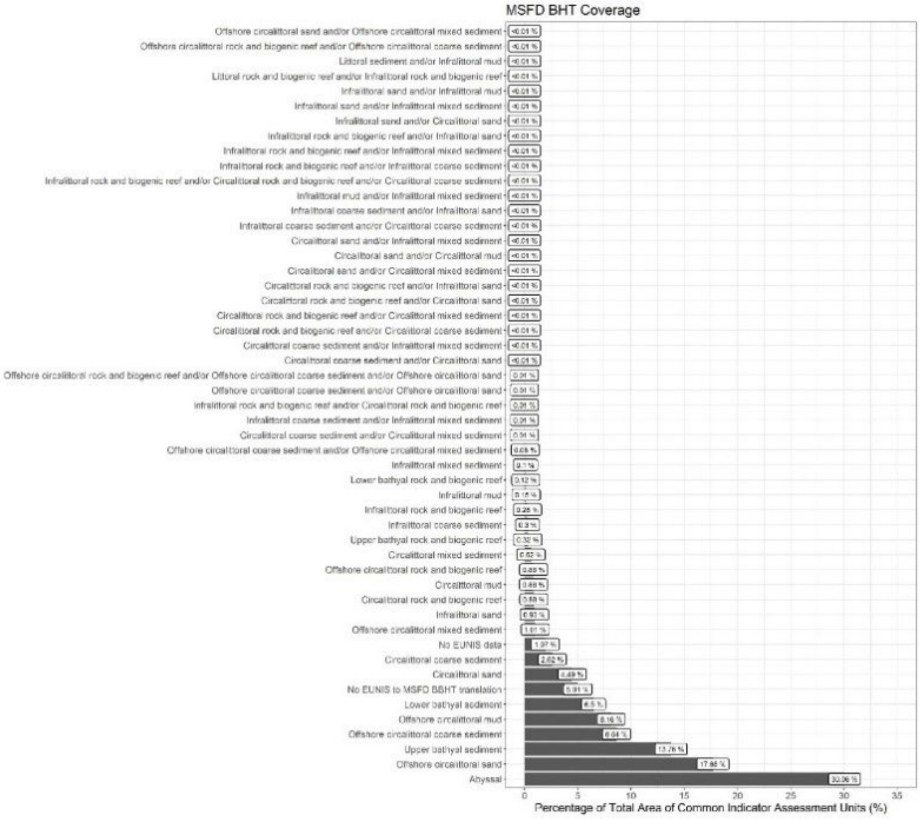

Figure S.7: The percentage of the total OSPAR Common Indicator area covered by each BHT. Additionally, the percentage of the total assessed area where there were no EUNIS data and where no EUNIS to BHT translation was possible is also represented

The recent status assessments of specific threatened and / or declining habitats (OSPAR Agreement 2008-06) indicate that these are generally in poor status. Most of the currently available evidence indicates a declining or not improved condition. Some habitats (such as *Ostrea edulis* and *Zostera* beds) also showed a decrease in distribution and extent in some regions. There has been no indication of any improved status in sea-pen and burrowing megafauna habitats. This is further supported by the BH3a indicator results for threatened and declining habitats, which showed that close to 90% of sea-pen and burrowing megafauna habitats were under high risk of disturbance in all assessment units where the habitat was present. Oceanic ridges and hydrothermal vents have been assessed as being in good status, their condition having improved since the last assessment. Detailed evidence and assessment results for these habitats can be found in the relevant sections below for each OSPAR Region.

Summary results of benthic habitat quality status by assessment unit and OSPAR Region

The OSPAR quality status assessments of benthic habitats, both broad habitat types and habitats listed as threatened and / or declining, were undertaken using a variety of assessment methods and scales developed over a number of years (See each indicator's CEMP guidelines and method section in the Indicator Assessment Sheets). Areas with sufficient data were assessed using common and candidate indicators for agreed pilot studies (**Table S.2**). All indicator results are summarised for each previously agreed assessment unit, which in some cases overlap OSPAR Regions (**Figure S.6**). Those habitats classified as threatened and declining by OSPAR Agreement 2008-06 were assessed using a combination of published data and expert judgement. The Arctic Waters section is compiled from a published OSPAR Third Party Assessment: State of the Arctic Marine Biodiversity Report. The Wider Atlantic section is mainly based on the assessment of OSPAR listed habitats and pilot studies of BH3a in several parts of overlapping assessment units.

Arctic waters: Polar benthic habitats

No Common Indicators or agreed assessment units with indicator results (only a small area with pilot assessment results for BH3a)

In Arctic Waters, no common OSPAR indicators have been developed. Without any European or OSPAR common methodological standards, almost all of this area was assessed using references to published studies, notably from the Arctic Council, local experts' judgement.

The status of benthic habitats in Arctic Waters is descriptive and based on a scientific article concerning the Polar Seas' baseline (Jørgensen *et al.,* 2022), together with information from the most updated ICES reports on benthic communities, and from the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) biodiversity working group. The trends detected are mainly related to climatic impacts which underlines the crucial role of climate change in Arctic benthic habitats. However, the specific impacts of human activities have not yet been well studied and documented. Therefore, this section mainly describes the state of the progress made towards methodological standards (e.g., indicators) and common baselines for Arctic benthic habitats.

According to the latest State of the Arctic Marine Biodiversity Report (CAFF, 2017), only one Arctic sub-region presents sufficient data to be assessed by CAFF. This is the Barents Sea, for which the changes over both long- and short-term time spans in macrobenthos spatial patterns are available. Outside the Barents Sea, there are only very limited data available on benthic habitats, biodiversity and abundance, thus pre-empting any assessment at OSPAR sub-regional scale or even by an Arctic third party.

Within the Arctic Waters of the OSPAR Maritime Area, Jørgensen *et al.,* (2022) present data from the eastern and western Barents Sea, Icelandic and Faeroe waters and north-east Greenland. The Norwegian Sea is not included at this time, since benthic mapping is at an early phase for the deeper waters and is mostly done near the Norwegian coastline and the continental slope towards the deep-sea basins central to the Norwegian Sea.

In 2022 a baseline of benthic community biodiversity was established (Jørgensen *et al.,* 2022). The baseline was created on the basis of megabenthic (organism size > 1 cm) data taxa groups reviewed at regional levels, as species diversity would have made comparisons difficult in this circumpolar study. Infauna and free-swimming taxa were excluded from the analyses. This megabenthos diversity baseline can be used to compare any change in status based on future monitoring efforts. The baselines for averaged standardised biomass were higher in Icelandic and Faeroese waters and lower in the Barents Sea. The lowest average standard abundance was found in the south-eastern Barents Sea and southern Iceland waters.

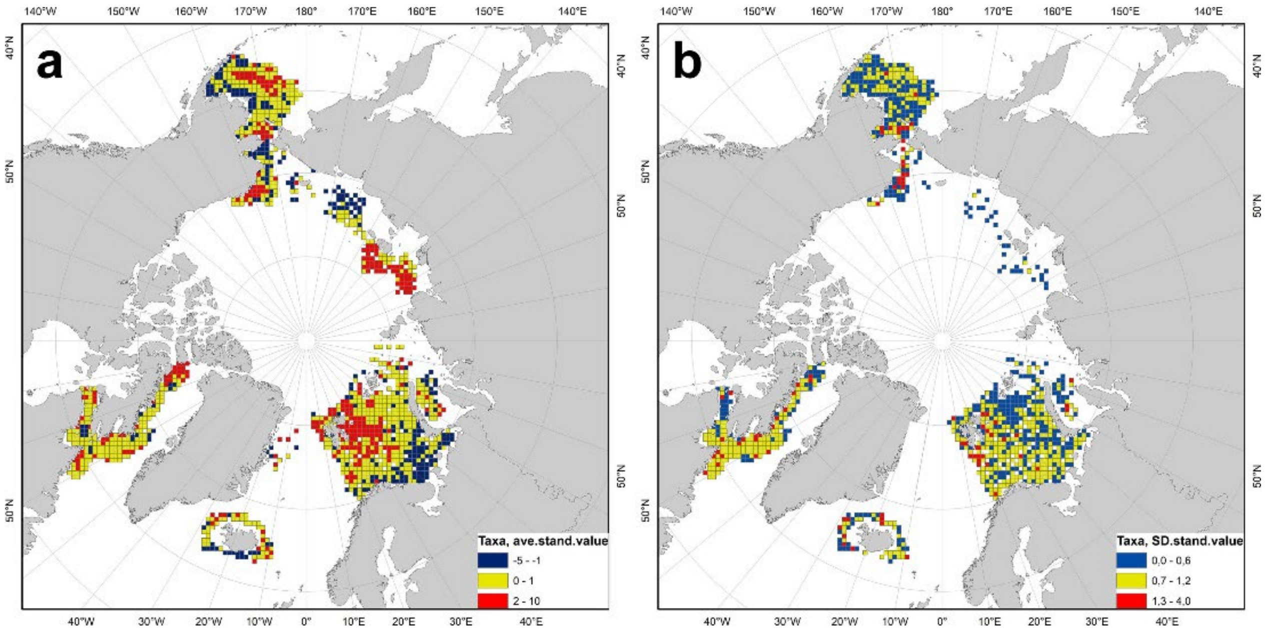

Figure S.8: Average standardized number of taxa (a) and standard deviation (SD) of average number of taxa (b) within each grid cell (50 km × 50 km). Note that this representation is based on a highly uneven effort among (and much less so within) regions and is intended to provide a cautious indication of patterns within regions. Source: Jørgensen *et al.,* 2022

Three megabenthic functional traits were selected – ‘body form’, ‘adult movement’ and ‘skeleton’ – as possible vulnerable traits for impacts. When the movement and body form traits were combined into a ‘sessile and upright’ combination, few areas had more than 50% of taxa with these traits, while the south-eastern Barents Sea usually had less than 25%. These trait combinations can reflect habitat / species vulnerability to seabed disturbances and may be considered to be used for future indicator development to assess this specific human activity impact.

The most recent ecosystem state report from Arctic waters is the ICES report from its Working Group on Integrated Assessments of the Barents Sea (WGIBAR) (ICES, 2022). The Group’s long-term monitoring data series on the dynamics of distribution, biomass and abundance shows that the large-scale distribution of megabenthos has been relatively stable since 2004. The biomass and species diversity of the main taxonomic groups generally followed previous spatial patterns of distribution. However, in 2020 the distribution and biomass/abundance of megabenthos were below the long-term mean. This information is linked to a moderate certainty since the surveys did not cover the entire Barents Sea. The fluctuation in biomass is positively correlated with increasing sea temperature due to climate change.

OSPAR acknowledges the need for a better understanding, based on quantity, periodicity and regionality of carbon supply and demand in the deep-water Arctic basins, in order to evaluate future changes in these benthic ecosystems. This need is also highlighted by ICES (2020). As change from permanently ice-covered to seasonally ice-covered regions occurs, such studies would also be crucial for assessing the state and trends in the benthos of these ecosystems.

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Assessment of the status of OSPAR listed threatened and/or declining habitats in Arctic Waters

The status of maerl beds in the Arctic Waters Region remains unknown. These species can form extensive beds, mostly in coarse clean sediments of gravels and clean sands or muddy mixed sediments, which occur either on the open coast, in tide-swept channels or in sheltered areas of marine inlets with weak current (OSPAR, 2019). However, some of the maerl beds in this Region exhibit the best condition in the OSPAR Maritime Area. More than in other regions where this habitat occurs, the status assessment predicts that increasing ocean acidification and temperatures will cause a slow but significant reduction in condition and distribution over coming decades.

The assessment of the coastal habitat eelgrass beds (*Zostera* beds) in the Arctic Waters Region shows an overall declining trend in distribution, extent and condition. However, the current status of the *Zostera* beds in Greenland is unknown. It is also concerning that there are significant data and knowledge gaps and that maps of eelgrass beds are patchy. The emerging impacts from climate change include darkening of coastal waters and sediment resuspension, which exacerbates the stressors on eelgrass beds and makes it even more important to manage the existing threats from eutrophication and coastal development and extraction, which are assessed as being on the increase in Arctic Waters. However, there is also a possibility that climate change is causing the northern distribution limit of *Zostera* beds to expand.

It should be noted that for the intertidal mudflats habitat no information was available to enable an assessment of its status in Arctic Waters at this stage.

The condition of deep-sea sponge aggregations was shown to decrease in a four-year study of the Schulz Bank, which indicated a decline in sponge density in areas affected by human activities. Deep-sea sponge aggregations occur at shallowed depths along the Norwegian fjords, more than anywhere else in the OSPAR Maritime Area. The same is true for *Lophelia* reefs, some of which occur at depths of 40 m along the Norwegian coast, while in other Regions they occur at depths of 200 to 1 200 m. Due to extensive mapping efforts since the last assessment in 2009, a significant number of new occurrences of *Lophelia* reefs have been detected in the Norwegian and Barents Seas. This is, however, not considered to be an indication of increased extent, and in fact the extent of the habitat within Arctic Waters is likely to still be decreasing due to fishing pressures. However, there are sub-regional differences indicating where activities to minimise destructive impacts on the marine ecosystems and *Lophelia* reefs are in place. (See case study for the Response measures (on benthic habitat) of the Norwegian EEZ (Region I)). Selected *Lophelia* reefs within Marine Protected Areas (MPAs) have been monitored regularly since 2012. This has revealed the overall health of the reefs to be in a good state and their condition is assessed as stable. In Arctic Waters, 13% of *Lophelia* reefs are assessed as being within MPAs.

Oceanic ridges with hydrothermal vent fields were assessed as remaining in good condition in Arctic Waters. There is an indication that longline fishing may be occurring along the upper bathyal ridges of vent fields, which could potentially result in fishing gear contacting the bottom and breaking the fragile vent chimneys. None of the known habitat occurrences are within MPAs. However, other protective measures are in place, such as local fisheries restricted areas (FRAs), where the pressure from fishing activities on benthic habitats appears to be slightly reduced. (See Case study for Norway Region I for more information).

Seamounts occur in the northern Arctic as well as along the Mid-Atlantic ridge. Few seamounts are of interest for commercial fishing activities, which have a negative impact on the communities associated with an exposed seamount, resulting in a deteriorating condition. There is a considerable knowledge gap regarding seamount communities, and for seamounts within national waters there are ongoing activities to collect more information through individual research programmes.

Table S.3: Summary results of the assessment of the OSPAR threatened and /or declining habitats in Arctic Waters

Arctic Waters	Maerl beds	Intertidal mudflats	*Zostera* beds	Deep-sea sponge aggregations	Coral gardens	*Lophelia pertusa* reefs	Oceanic ridges with hydrothermal vents	Seamounts
Distribution	?	N/A	↓	↔	↔	↔	↔	↔
Extent	?	N/A	↓	?	?	↔	↔	↔
Condition	?	N/A	↓	↓	↓	↔	↔	↓
Previous OSPAR status assessment	○	N/A	●	●	●	●	○	●
Status (overall assessment)	?	N/A	poor	poor	poor	poor	good	poor

Legend:

Previous status assessment:

Regions where species occurs (○) and has been recognised by OSPAR to be threatened and/or declining (●)

Trends in status (since the assessment in the background document):

↓ decreasing trend or deterioration of the criterion assessed

↑ increasing trend or improvement in the criterion assessed

↔ no change observed in the criterion assessed

? trend unknown in the criterion assessed

N/A not applicable (i.e. species not present during breeding or non-breeding season).

Status of Criterion assessed:

good	not good	unknown

The level of confidence for the assessment for the Arctic Waters is considered **Low**

- Level of evidence: **low.** The assessment is based on published research and third-party assessments, but gaps were observed in the spatial coverage of the biological information available.
- Degree of agreement: **low.** The status assessments of OSPAR listed habitats mostly agree with the summary overview but cover only a small part of this Region.

Greater North Sea - Sandy, muddy and productive benthic habitats

Five assessment units with indicator results: *BH2a, BH2b, BH3a, BH3b (pilot assessment BH4)*
The Greater North Sea Region is exposed to widespread and generally high intensity and frequency of disturbance from bottom trawling fisheries, except for the Central North Sea where there are generally lower levels of disturbance. Disturbance from aggregate extraction activities affects a small proportion of the Greater North Sea and is mostly concentrated in the Southern North Sea and the Channel. The offshore circalittoral mud areas, in particular, tend to be highly disturbed at OSPAR regional scale due to high-pressure levels in combination with expected high habitat sensitivity. In the Southern North Sea and the Channel, the habitats mostly exposed to high levels of disturbance are offshore circalittoral rock and biogenic reefs and circalittoral coarse sediments. The observed disturbance from fisheries is in line with the observed levels of diversity in the benthic community, which is mostly low or moderate in high-disturbance areas. In the Southern North Sea, however, circalittoral mud areas tend to have high diversity despite the observed high level of disturbance, although this could be caused by the limited data available for some areas.

Habitat loss from the placement of structures is highest in the Central and Southern North Sea, mainly induced by a higher density of oil and gas platforms and the pipelines needed for transporting the products. A higher probability of sediment changes caused by trawling is observed in the Channel and Southern North Sea, whereas in the Norwegian Trench and the Kattegat fishing pressure is considered to pose a lower risk of loss.

The eutrophication status of benthic habitats in coastal waters is generally good/high but, particularly in several areas of the Southern North Sea and Kattegat, eutrophication is still impacting benthic invertebrate communities and even more macrophyte communities.
OSPAR threatened and declining habitats are not in a good state and sometimes deterioration compared with the previous assessment has been observed (e.g., maerl beds).

The level of confidence for the assessment for the Greater North Sea is considered **medium**

- Level of evidence: **medium.** The assessment is based on multiple lines of evidence, but gaps were observed in the spatial coverage of the biological information available.
- Degree of agreement: **medium.** The indicators and status assessments of OSPAR listed habitats mostly agree, although a minor proportion show some deviation (i.e., the indicators BH3a and BH2b do not align for offshore circalittoral mud areas in the Southern North Sea).

Faroe-Shetland waters

This assessment unit (AU) was assessed using only indicator BH3a for disturbance caused by fishing activities. During 2009-2020, disturbance occurred in 15% of the area. Moderate disturbance covered the

largest proportion of the assessment unit (12%), followed by high and low (3% and <1% respectively). Zero disturbance occurred throughout 84% of the assessment unit due to areas with no reported swept area ratio values. However, most of the assessment unit consisted of deep-sea habitats where bottom contact fishing is unlikely to be possible due to the depth of the seafloor.
The percentage area disturbed by fishing activities decreased slightly to approximately 6% during 2016-2020. Moderate disturbance covered the largest proportion of the assessment unit (6%), followed by high and low (both <1%). A large proportion (92%) of this assessment was under zero disturbance.

The Central North Sea

The Central North Sea assessment unit (AU) is characterised by the presence of vast areas of offshore circalittoral habitat, with commonly occurring sandy (61% of the AU) and muddy (24% of the AU) substrates and smaller patches of coarse or mixed sediments or rocks. Smaller areas consist of upper bathyal habitats (typically towards the Norwegian Trench) and circalittoral habitat types (typically along the United Kingdom coasts and towards the Southern North Sea).

The assessment of Common Indicator BH2a specifically focuses on eutrophication of benthic habitats in coastal water bodies, including a large share of the circalittoral habitats in the case of the Central North Sea along the United Kingdom coastline. These coastal waters are considered to be almost entirely of high quality or in good status in terms of nutrient enrichment/eutrophication, with few unassessed areas, and regardless of whether assessments are based on invertebrates or vegetation. Minor areas (around 1% of the total assessed) are considered to be in moderate quality status.

In terms of diversity, as assessed with the relative Margalef diversity index (BH2b) the circalittoral and infralittoral waters are not considered to be in a good status. It should be mentioned that these results largely apply to the northern slope of the Dogger Bank and to the Danish EEZ in the south-eastern extension of the Central North Sea, as well as some observations from the most southern part of the United Kingdom coastline. Only the relative diversity of circalittoral muddy habitat is considered high, although sampling predominantly took place in areas with high fishing pressure. The vast areas of offshore habitat seem to be maintaining at least moderate levels of relative diversity.

The expected impacts from physical disturbance due to bottom-contacting fisheries (BH3a) are assessed as high to moderate in offshore circalittoral sandy and muddy habitats, due to observed high fishing pressure levels and, in the case of muddy habitats, the high sensitivity of the habitat type. This might contradict the findings for BH2b that are based on benthic community sampling. It should be noted that benthic community sampling efforts are restricted to certain areas and that it is largely unclear whether these can be considered representative of the entire Central North Sea. It seems that benthic community sampling in offshore circalittoral sandy habitats has taken place mostly in areas with relatively low fishing pressure. For offshore circalittoral habitat types, other than sandy or muddy, the expected impact of physical disturbance due to fisheries is in general considered to be low. For circalittoral coarse and mixed sediment habitats, the expected impact is generally considered lower, but increasing (as grain size decreases) from coarse to muddy sediment types, especially from higher intensity fishery activities.

The results from a pilot assessment of the candidate indicator BH4 indicate that risk of habitat loss is in general non-existent or low, with the exception of biogenic reefs, where the risk of loss in offshore circalittoral and circalittoral areas is in general moderate (which could suggest that these habitats are at risk).

Moreover, the exact locations of biogenic reefs are largely unclear and the potentially suitable areas (in the case of low pressure) probably underestimated. Most references are thus made to sea-pen and burrowing megafauna communities, but other types of biogenic reefs can also be expected to be at risk.

The Norwegian Trench

The Norwegian Trench assessment unit (AU) comprises a variety of broad-scale habitats from the littoral down to the upper bathyal at around 700 m depth. Most of the AU is in the upper bathyal zone, dominated by upper bathyal muddy sediments. The Norwegian Trench Upper Bathyal Sediments are rated as near-threatened in the Norwegian Red List for Ecosystems and Habitat Types, based on the occurrence of sea-pens and the bamboo coral *Isidella lofotensis*. Circalittoral rock and biogenic reef (cold-water coral reefs) are found in the western and eastern part of the AU. In the western part (western Norway), these reefs are not exposed to bottom trawling, but accidental contact with longlines and gill nets may cause some degree of damage. The coral reefs in the eastern part of the AU are located inside the Ytre Hvaler National Park that was protected in 2009.

The coastal zone (Water bodies according to the European Union Water Framework Directive (WFD) and other national equivalents of Contracting Parties not part of the EU) of this AU consists of many fjords, some very large, and large archipelagos with numerous islands. For this vast area, only around 40% (benthic invertebrates) and 13% (vegetation) of the total coastal area was assessed. From those, the majority of coastal area results are considered to be in high/good or moderate quality status (WFD status classes). Relative Margalef diversity (BH2b) is found to be moderate to high for those offshore circalittoral and upper bathyal habitats with some benthic community observations available, and low to moderate for infralittoral and circalittoral habitats. Data availability is, however, only considered sufficient to good in terms of representativity for offshore circalittoral and circalittoral mud, respectively. The offshore circalittoral mud is also the habitat type expected to be most impacted by fisheries (almost 70% of habitat expected to be highly impacted) due to expected high sensitivity for physical disturbance in combination with observed high fishing pressure (as indicated by the BH3a indicator). A large part of the infralittoral and offshore circalittoral sandy habitats is expected to be moderately impacted for at least 50%, and circalittoral sand and upper bathyal sediment contain a substantial area expected to be moderately impacted. All other BHTs in the Norwegian Trench are expected to be predominantly low-impacted or not impacted at all as fishing pressure is considered very low. However, fishing pressure there might be underestimated, as VMS data from the Norwegian fleet are not included in the assessments. The pilot assessment of the candidate indicator BH4 shows that sealed loss is local and that risk of unsealed loss (largely due to fishing activities) is low and rare.

The Kattegat

The Kattegat-Skagerrak is a transitional area between the brackish Baltic waters and the marine waters of the North Sea, resulting in periodic stratifications in the large shallower parts (< 20 m) and more stable and fully marine conditions in the deeper areas. These environmental conditions have a strong impact on the biota in the benthic habitats. The western part of Kattegat is dominated by shallow infralittoral sands, in contrast to the eastern deeper circalittoral muddy parts containing several highly diverse protected offshore banks. The deeper muddy areas around offshore banks are heavily impacted by bottom trawling except for a protected fishing-free zone (since 2009) in the south-eastern part and the Sound (Oeresund), where bottom trawling has been banned since 1932. This high fishing pressure is reflected in the expected high impact on most (93%) of the area of offshore circalittoral mud and moderate to high impact on more than half (54%) of the circalittoral muddy habitat (BH3), reflecting the expected high sensitivity of these broad habitat types (BHT). Substantial parts of several other BHTs (e.g., circalittoral or infralittoral mixed sediment, offshore circalittoral sand) are expected to be moderately to highly impacted as well. Disturbance from aggregate extraction was recorded in 0,067% of the total Kattegat area (not all suitable for this activity), with most habitats of interest exposed to low level of disturbance. It should be noted that there are limitations in the accuracy of the fishing pressure layers provided by the ICES due to the resolution of c-squares in confined areas, in particular in Skagerrak/Kattegat. This issue has been included under the knowledge gaps section of the BH3a indicator.

Due to the high fishing pressure, there is some (albeit low) risk of partial habitat loss for the indicated muddy habitats, but also for some of the coarse sediment habitats and for the largest part of the offshore circalittoral coarse sediments (pilot assessment BH4). Please note the caveats above regarding fishing pressure data layers.

The various pressure levels (fisheries, nutrient loads and anoxic conditions), combined with ‘natural' or climate-change induced increased variability in low-salinity water inflow from the Baltic, results in observed relatively low diversity levels for most of the infralittoral and circalittoral habitat types (BH2b). Relative diversity seems to be higher (moderate to high) for the offshore circalittoral habitat types.

Regarding nutrient and organic enrichments, the majority of the coastal waters area appears not to be in good quality status, based both on the invertebrate and the vegetation communities, with mainly poor/bad status arising from the vegetation assessment.

The assessment results in the Kattegat have to be treated with caution, since the indicator used to assess the coastal water quality may be sensitive to various pressure types, including physical ones. Besides, the underlying habitat map is of low quality and low resolution for Swedish waters, which also makes the assessment of physical pressures relative. The quality of the habitat map for Swedish waters needs to be improved ahead of the next assessments. Habitat mapping is underway and new data will be available in coming years. However, the low resolution of the underlying habitat map relates to national security and will probably not be improved in the near future.

The Southern North Sea

In the Southern North Sea, shallow sandy sediments prevail along the southern and western coasts and on the Dogger Bank. Deeper, offshore circalittoral areas are dominated by sands as well and include larger muddy areas in the central part of the assessment unit. Coarse and mixed sediments are mainly distributed along the English and Danish coasts. The extended littoral zone of the Dutch, German and Danish Wadden Sea represents a unique habitat in the OSPAR Region that is protected as the OSPAR listed threatened and/or declining habitat, “intertidal mudflats”.

Eutrophication in coastal waters is still impacting benthic invertebrates and, even more, macrophytes. Particularly along the Dutch, German and Danish coasts, benthic habitats are not in good status with regard to nutrients or organic enrichment (BH2a). Another major impact, on sublittoral and more offshore habitats, is the widespread disturbance by bottom trawling that covers 93% of the Southern North Sea (BH3a). The greatest proportion of the area (53%) is classified as having moderate disturbance from trawling, while 23%

of the area is estimated to be highly disturbed. Trawling disturbance is highest in the offshore mud habitats in the centre of this assessment unit. Offshore circalittoral mud and circalittoral mud are the habitats with the highest trawling disturbance due to high fishing pressure in combination with the expected high sensitivity of these habitats. Likewise, the risk of sediment changes from trawling, potentially leading to habitat loss, is estimated highest for these two habitats (BH4). The Southern North Sea is also a focus area for energy production, with an area of 40 km² (0,02% of the total assessment unit, but which is not all suitable for this activity) sealed by offshore structures. Extraction of sand and gravel is another anthropogenic activity that is carried out to a considerable extent in the Southern North Sea. The extraction of sediment impacts benthic organisms (BH3b) and may lead to habitat loss (BH4).

The overall impact of anthropogenic pressures is reflected in the condition of benthic habitats as assessed with the Margalef diversity index (BH2b). Most assessed habitats have low or moderate relative diversity. Mixed sediments are the only habitats considered to host high relative diversity. However, these habitats comprise only 2% of the assessment area. The predominant sandy habitats as well as coarse sediments are assessed as having low relative diversity.

The Channel

In the Channel, the total assessed area for coastal waters quality (BH2a) changed significantly between the two available reporting cycles: from 43,4% (invertebrates) and 0,02% (vegetation) to respectively 83,2% and 49,0% of the total area of coastal water bodies in this assessment unit (AU). During the assessment period 2010-2015, 83,2% of the total area of coastal water bodies in the AU was assessed as in high or good quality status based on benthic invertebrate compositions, while no data were available for the remaining area. Quality status as based on benthic vegetation was assessed to be high or good for 31,1%, moderate for 16,9% (The Solent, the eastern part of the Normano-Breton Gulf) and poor or bad status for 1,0% (western part of the Bay of Seine) of the total area of coastal water bodies. Data were, however, lacking for more than half (51,0%) of the coastal water bodies area.

Diversity assessed with the relative Margalef diversity index (BH2b) was low or moderate in the infralittoral habitats and several of the circalittoral habitats. Only in the circalittoral mixed sediment and in the circalittoral mud habitats was relative diversity assessed as high, although the monitoring and assessment was limited to a small proportion of the total habitat area.

Most of the Channel was assessed as disturbed by trawling (BH3a) mostly at moderate or low levels during the 2009-2020 assessment period. The greatest disturbance was observed in offshore circalittoral mud, with 99,53% of the area under high disturbance, although it should be noted that this habitat covered <1% of the Channel, so that the high disturbance extended to discrete areas only. More than 50% of the area of infralittoral coarse sediment, offshore circalittoral rock, biogenic reef, offshore circalittoral coarse sediment and offshore circalittoral mixed sediment were assessed as under low disturbance. The infralittoral mixed sediment has the largest area expected to be without disturbance (49,9%). In the 2016-2020 assessment period, the disturbance patterns were very similar, but the areas expected to be without impact were larger. This is because the 2009-2020 QSR assessment interval provided more years of VMS data overall, and therefore presented an increased likelihood of disturbance compared to the 2016-2020 period. The most disturbed areas were the south-east of the Isle of Wight as well as the coastal regions of England and France.

The area without disturbance was situated to the west of the Isle of Wight, and there was lower disturbance around Guernsey, Jersey and the coast of Normandy by comparison with the rest of the Channel. The Channel has the highest proportion of total disturbed area within an assessment unit due to aggregate extraction (BH3b) compared with other assessment units, with the greatest disturbance occurring on the south coast of England. It should be noted that only aggregate extraction data available from United Kingdom and Danish waters were used for the disturbance calculations. Other countries, for example Germany, the Netherlands and Belgium, have extraction activity, but the footprint data required for a detailed analysis of disturbance, were not available at the time of assessment. Therefore, comparisons between assessment units were the result of data availability. The most affected habitat was circalittoral coarse sediment, with the highest proportion of high disturbance (0,3%).

The risk of sediment changes leading to habitat loss (BH4) is estimated as low for most of the habitat types assessed. The highest risk was assessed for circalittoral mud, offshore circalittoral mud, infralittoral mud and infralittoral biogenic reef and ranged from 11% to 16%.

Assessment of the status of OSPAR listed threatened and/or declining habitats in the Greater North Sea

Maerl beds were assessed as being in poor status, while recognising that there was a lot of uncertainty in the assessment and gaps in the data. However, compared with the last assessment in 2010, when this habitat type was simply assessed as occurring in the Region but not as threatened and/or declining, the latest assessment points towards a deteriorating status.

The European flat oyster *Ostrea edulis* is native to the North-East Atlantic and occurs in intertidal and subtidal habitats from Norway to Morocco and has historically covered extensive offshore areas. For the Greater North Sea, it was not possible to conclusively determine the status of *Ostrea edulis* beds since they have been severely depleted. Some remnant populations occur in waters around the United Kingdom, France, the Netherlands and Denmark, whereas the oysters are considered functionally extinct in German and Belgian waters. Remnant oyster beds are generally supported by extensive reintroduction and restoration efforts.

Intertidal mussel beds were assessed to have improved compared with 2009 in the Dutch and German Wadden Sea, due to the management actions in those habitats, but show (local) declines in other areas, such as Scotland and Sweden.

Compared with the last report from 2009, the status of intertidal mudflats remains poor. While the geographical distribution and extent of the habitat is generally good in the Greater North Sea (stable) the condition of intertidal mudflats is poor due to anthropogenic pressures including climate change, nutrient enrichment, invasive species and hydrological changes (e.g., construction).

Sea-pen and burrowing megafauna habitats occur at productive muddy seafloor sites and there has been no indication of improved status. Towed, bottom-contacting fishing gear continues to be the most significant pressure, the use of which was assessed as increasing in the Greater North Sea. This pressure is assessed to have resulted from the absence of sensitive and large-bodied sea-pen species in muddy sediment habitats which would otherwise be suitable for them, for example the Fladen grounds between Scotland and Norway. Smaller-bodied sea-pens and burrowing crustaceans were found to be less sensitive to the pressure.

There are significant differences within the Greater North Sea Region in the health of eelgrass beds (*Zostera* beds). In some locations, the historically significant declines in distribution and extent are continuing. However, in southern parts of the Region, and in the waters of Denmark, the Netherlands and France, there might be a stable or slightly increasing trend when viewed over the past 10-year period. The condition of *Zostera* beds is notoriously complex to assess, and future work could focus on assessing ecosystem functions such as habitat provision and carbon sequestration as well as the density of the seagrass beds. The regeneration of *Zostera* beds takes place over much longer time scales than do reductions in coverage, and therefore it is more important to avoid further damage and loss than to rely on habitat restoration. The status of coral gardens is assessed as continuing to be in poor status due to the habitat's slow recovery rate. However, the assessment shows that for this habitat the pressure from fisheries has been decreasing recently.

Table S.4: Summary results of the assessment of the OSPAR threatened and /or declining habitats in the Greater North Sea

Greater North Sea	Maerl beds	Flat oyster and *Ostrea edulis* beds	Intertidal *Mytilus edulis* beds on mixed and sandy sediments	Intertidal mudflats	*Zostera* beds	Sea-pen and burrowing megafauna	Deep-sea sponge aggregations	Coral gardens	*Lophelia pertusa* reefs
Distribution	?	?	✳	↔	North ↓ Rest ↔ ?	↔	↔	↔	↔
Extent	?	?	✳	↔	North ↓ Rest ↔ ?	↔	?	?	↔
Condition	?	?	✳	↔	↓ ↔ ?	↔	↓	↓	↔
Previous OSPAR status assessment	○	•	•	•	•	•	•	•	•
Status (overall assessment)	poor	?	poor	poor	poor	poor	poor	poor	poor

Legend:

Previous status assessment:

Regions where species occurs (○) and has been recognised by OSPAR to be threatened and/or declining (●)

Trends in status (since the assessment in the background document):

↓ decreasing trend or deterioration of the criterion assessed
↑ increasing trend or improvement in the criterion assessed
↔ no change observed in the criterion assessed
✳ chaos symbol demonstrating that the available information is pointing in all directions within the specific region
? trend unknown in the criterion assessed
N/A not applicable (i.e. species not present during breeding or non-breeding season).

Status of Criterion assessed:

good	not good	unknown

Celtic Seas - Shelf edge benthic habitats

Two assessment units with indicator results: *BH2a, BH3a and BH3b*

The Celtic Seas (Region III) are home to a rich and diverse range of species and habitats. Warm southern waters mix with cold northern waters, resulting in high levels of productivity and a food-rich environment. The Celtic Seas Region contains a rich variety of physical habitats and associated species, ranging from shallow inshore reefs and sandbanks to canyons, seamounts, and cold-water coral reef in deeper waters. Deep-water habitats host slow-growing species which are highly sensitive to physical disturbance. Indicators BH2a and BH3a and BH3b were analysed for the Northern and Southern Celtic Sea assessment units.

The benthic vegetation and benthic invertebrates of coastal water bodies assessed (respectively 68% and 75% of the total area) in the Northern Celtic seas were in high/good status. In the Southern Celtic Sea, most of the total area of water bodies was not assessed (respectively 99,1 and 59,9% for invertebrates and vegetation), thus compromising any conclusion at this scale.

For the period 2009-2020, less than half of the Northern Celtic Sea was assessed as disturbed by bottom-contacting fisheries. Fishing disturbance in the Southern Celtic Seas was much higher, at more than 70% of the area. The broad habitat types that were most disturbed in both assessment units were offshore circalittoral mud and upper bathyal sediment. Disturbance from aggregate extraction was low in both areas (<0,01% of total area).

The level of confidence for the assessment for the Celtic Seas is considered **medium**

- Level of evidence: **medium.** The assessment is based on multiple lines of evidence, but gaps were observed in the spatial coverage of the biological information available.
- Degree of agreement: **medium.** The indicators and status assessments of OSPAR listed habitats results mostly agree.

The Northern Celtic Sea

The Northern Celtic Sea assessment unit was only assessed with the Common Indicators nutrient and organic enrichment(BH2a), physical disturbance from fishery(BH3a) and physical disturbance from aggregate extraction(BH3b).

Assessment of BH2a was conducted for data pre-2009 and for the period 2010-2015. The benthic vegetation and benthic invertebrates of coastal water bodies in the Northern Celtic Sea in 2009 were largely in high/good status (67% for invertebrates, 75% for vegetation), 6,5% (for invertebrates) were in moderate status, while 25,8% (invertebrates) and 24,9% (vegetation) were not assessed. During the period 2010-2015, for both components the proportion of water bodies in high/good status was approximately 80%. The remaining areas of the total coastal waters for invertebrates were in moderate status (5,5%) or not assessed (14,5%), while for vegetation they were not assessed.

When considering the extent of physical disturbance caused by fisheries and aggregates extraction (BH3), during the period 2009-2020, less than half (48%) of the Northern Celtic Sea was assessed as having disturbance from bottom-contacting fisheries, based on areas under low (19%), moderate (15%) and high (14%) disturbance. Just under half (48%) of the Northern Celtic Sea had zero disturbance, reflecting solely VMS data paucity, primarily around the coasts of the Republic of Ireland, Northern Ireland, Wales and England, the Rockall Plateau and the north and west of the assessment unit. Offshore circalittoral mud had the largest proportion of area under high disturbance, followed by upper bathyal sediments. The remaining proportion of the Northern Celtic Sea could not be assessed; this included the littoral rock and biogenic reefs and littoral sediments. Disturbance from aggregates extraction occurred in less than 0,1% of the Northern Celtic Sea, with circalittoral coarse sediments showing the largest extent of high disturbance (0,001%).

A similar picture was observed for the period 2016 to 2020: In total, 41% of the area of the Northern Celtic Sea assessment unit had disturbance from fisheries. Low disturbance covered the largest proportion of the assessment unit (17%), followed by high and moderate (both 12% of the area). Additionally, zero disturbance occurred across 56% of the assessment unit, mostly caused by the absence of VMS data. Habitats with the greatest proportions of their area under high disturbance included offshore circalittoral mud, followed by upper bathyal sediment, then circalittoral mixed sediment. Disturbance from aggregates extraction occurred only in small proportions of circalittoral and offshore circalittoral coarse sediments, with both habitats mostly under low levels of disturbance.

Southern Celtic Sea

The Southern Celtic Sea assessment unit was assessed by the indicators nutrient and organic enrichment(BH2a) physical disturbance from fisheries(BH3a) and physical disturbance from aggregate extraction(BH3b).

Assessment of BH2a was conducted for data pre-2009 and for the period 2010-2015. Benthic invertebrates were largely data-poor in 2009, meaning that status could be assessed only in less than 1% of coastal water bodies. For benthic vegetation, approximately 60% of water bodies were data poor, 31% in high/good status, 5% in moderate status and 4% in poor/bad status. More data were available during the period 2010-2015, with approximately 42% and 28% of water bodies being data-poor for benthic invertebrates and vegetation respectively, but still not sufficiently representative of the total area to create sufficient confidence in the assessment. When enough data were available, the largest proportion of water bodies was in high/good status both for invertebrates (53%) and benthic vegetation (34%).

Disturbance from fisheries in the Southern Celtic Sea during 2009-2020 occurred throughout 73% of the assessment unit area. Moderate disturbance was the greatest proportion (33%), followed by low (24%) and high (16%). Zero disturbance occurred in 24% of the area of the Southern Celtic Sea, due solely to VMS data paucity, predominantly in areas beyond the continental shelf, inshore areas in the south-west coast of Ireland, the Bristol Channel and inshore areas of France. The habitat with the greatest proportion of area under high disturbance was offshore circalittoral mud, followed by upper bathyal sediment. Disturbance from aggregates extraction was recorded in 0,005% of the Southern Celtic Sea. High disturbance accounted for 0,003% of the area, followed by low (0.002%) and moderate disturbance (less than 0,001%), respectively. Within habitats, the greatest proportion of high disturbance occurred in circalittoral sand (0,091%)

During the period 2016 to 2020, 68% of the Southern Celtic Sea area had disturbance from fisheries. Moderate disturbance covered the greatest percentage (28%) of area, followed by low (26%) and high (14%). Zero disturbance occurred in 29% of the Southern Celtic Sea, due to VMS data paucity alone, located largely in the Bristol Channel and Rockall Trough. Habitats with the largest proportion of area under high disturbance included offshore circalittoral mud, followed by upper bathyal sediment. Disturbance from aggregate extraction was recorded in 0,003% of the assessment unit and there were noticeably fewer discrete areas of activity than were found for the 2009 to 2020 period.

Assessment of the status of OSPAR listed threatened and/or declining habitats in the Celtic Seas

Some of the largest maerl bed occurrences within the OSPAR Maritime Area are in the Celtic Seas, where the habitat is listed as threatened. There may have been a misidentification of the habitat in the Northern Irish part of the Region, resulting in distribution estimates that are inaccurate (OSPAR, 2019). However, the condition of the habitats in this area has been assessed as declining. In the southern parts of the Celtic Seas, there has been a continued decline over the total extent since 2007 due to demersal fishing activities. In previous assessments, the decline of maerl has been attributed to impacts from commercial sand and gravel extraction, mariculture and demersal fishing. Maerl beds are formed by slowly growing coralline red algae and are very sensitive to pressures from human activities as well as being slow to recover. Due to these traits, the future trends predict a continued decrease in maerl beds.

The European flat oyster *Ostrea edulis* creates densely bedded habitats that are important for many other benthic species. The distribution and extent of *Ostrea edulis* beds has declined in the Celtic Seas. The last assessment in 2010 noted the habitat as occurring in the Region but did not consider it to be threatened. This most recent status assessment concludes that the status of the habitat is poor. The main threats behind this deterioration have been identified as the introduction of non-indigenous species and habitat damage.

The status of intertidal mussel beds in the Celtic Seas is not entirely clear due to a lack of data and information.

Compared with the last report from 2009, the status of intertidal mudflats is still poor, although little information is available. While the geographical distribution and extent of the habitat is generally good and stable in the Celtic Seas, the condition of intertidal mudflats is poor due to anthropogenic pressures including climate change, nutrient enrichment, invasive species and hydrological changes (e.g., construction).

The sea-pen and burrowing megafauna habitat covers large muddy seafloor areas in the north-western part of the Celtic Seas. The habitat is not considered to have been fully mapped, and therefore it is difficult to identify any change in extent or distribution.

Eelgrass (*Zostera*) beds exhibit an overall stable trend in distribution and extent and no significant improvement on the historically significant declines and signs of increasing pressures from fishing. In some smaller locations there are signs of further decline.

Deep-water *Lophelia pertusa* reefs at Mingulay are not in good status, with evidence present of damage from fishing activities. However, monitoring will chart progress following the designation of this location as a Special Area of Conservation and the implementation of fishery management measures (a prohibition on towed bottom-contacting fishing and the use of static gear, e.g., creels).

Table S.5: Summary results of the assessment of the OSPAR threatened and /or declining habitats in Celtic Seas

Celtic Seas	Maerl beds	Flat oyster and *Ostrea edulis* beds	Intertidal *Mytilus edulis* beds on mixed and sandy sediments	Intertidal mudflats	*Zostera* beds	Sea-pen and burrowing megafauna	*Lophelia pertusa* reefs
Distribution	?	?	?	↔	↔	↔	↔
Extent	?	?	✱	↔	↔	↔	↔
Condition	?	?	?	↓	↔	↔	↔
Previous OSPAR status assessment	•	○	•	•	•	•	•
Status (overall assessment)	poor	poor	?	poor	poor	poor	poor

Legend:

Previous Status Assessment:

Regions where species occurs (○) and has been recognised by OSPAR to be threatened and/or declining (●)

Trends in status (since the assessment in the background document):

↓ decreasing trend or deterioration of the criterion assessed

↑ increasing trend or improvement in the criterion assessed

↔ no change observed in the criterion assessed

✳ chaos symbol demonstrating that the available information is pointing in all directions within the specific region

? trend unknown

N/A not applicable (i.e. species not present during breeding or non-breeding season)

Status of Criterion assessed:

good	not good	unknown

Bay of Biscay and Iberian coast: Canyon, shelf and deep benthic habitats

Four assessment units with indicator results *BH1, BH2a, BH3a*

The bottom topography of the Bay of Biscay and Iberian Coast is highly complex, with a very narrow continental shelf (except in the northern part of the Region) alongside other features such as submarine canyons and seamounts. The abyssal plain covering most of the region contains a great variety of deep-sea ecosystems including several listed habitats. The assessments of the status of OSPAR threatened and/or declining habitats show that all the habitats assessed in this Region are in poor condition.

The results from the indicators also show that most of the assessed benthic habitats are not in good status and are under significant threat or impact. Physical disturbance caused by bottom trawling is the most extended pressure in this region and was evaluated using two different Common Indicators: Sentinel of the Seabed (SoS)(BH1) and Physical disturbance to benthic habitats (BH3a). Both indicators showed good general agreement in terms of the extent and distribution of the disturbance across habitats, although with some important differences in relation to the percentage of each benthic broad habitat type classified as highly disturbed. This is mainly due to differences in the condition ranges applied to define these categories for each indicator.

According to BH1, disturbance of benthic habitats related to trawling occurred in 17,5% (2009-2020) and 16,9% (2016-2020) of the total assessed area of the Bay of Biscay and Iberian Coast. In both assessment periods the proportions of disturbance in the assessed area were similar, with high disturbance accrued respectively in 6,8% and 6,9%, low 4,6% in both, and moderate in 4,2% and 3,7%, respectively, of the assessed area. In both periods, less than 2% of the disturbed area was not assessed. The area with no bottom trawling pressure covers 82,5% (2009-2020) and 83,1% (2016-2020) of the total assessed extent.

All offshore and circalittoral broad habitat types (BHT) in this OSPAR Region showed areas classified as highly disturbed, according to BH1. Three BHTs had more than 50% of their total extent classified as highly disturbed in only one of the periods. These were offshore circalittoral mixed sediment (2009-2020: 57,9%; 2016-2020: 63,8%), offshore circalittoral mud (2009-2020: 42,8%; 2016-2020: 50,4%) and circalittoral coarse sediment (2009-2020: 64,6%; 2016-2020: 66,3%). The least impacted in terms of total extent classified as low disturbance were offshore circalittoral sand (2009-2020: 32,4%; 2016-2020: 34,9%) and upper bathyal sediment (2009-2020: 27,5%; 2016-2020: 25,2%). Circalittoral mixed sediment (2009-2020:79,9%; 2016-

2020: 86,5%), circalittoral mud (2009-2020: 39,4%; 2016-2020: 41,1%) and upper bathyal sediment (2009-2020: 39,2%; 2016-2020: 44,3%) had the largest areas with no trawling pressure.

BH3a was also assessed across this whole region for disturbance caused by fishing activities. Aggregate extraction pressure (BH3b) was not assessed, as the activity is not currently occurring in this Region. The largest proportion of the area with disturbance was in the north-east part of the Region (Gulf of Biscay), with 94% disturbance for the assessed period, and in its south-eastern part (Gulf of Cadiz) with 72%; this applied to both assessment cycles (2009-2020, 2016-2020). Among all the assessment units, the Gulf of Cadiz had the greatest percentage of area with high disturbance (32% for the QSR period), which must be considered in the context of the proportion of area suitable for this activity between each assessment unit. In the Gulf of Biscay, the greatest percentage of area with high and moderate disturbance was approximately 70% for the QSR period. Similar disturbance values were found for the MSFD period (2016-2020). The habitat types under high levels of disturbance were offshore circalittoral mud, followed by circalittoral mixed sediments.

The BH3a indicator shows that the assessment of zero disturbance was most prevalent in the South-Iberian Atlantic (2009-2020: 94%; 2016-2020: 95%), mainly because of the extended areas of deep-sea habitat unsuitable for bottom trawling due to the depth of the seafloor.

The areas free of trawling are very numerous because the Bay of Biscay and Iberian Coast Region hosts a very extensive abyssal plain, with depths unsuitable for trawling. The percentages of total areas affected by trawling would be much higher if only areas shallower than 800 m of depth were assessed, or if these percentages were analysed by broad habitat type. For instance, the proportion of the area affected by trawling (regardless of intensity) in the offshore circalittoral coarse sediment for the period 2009-2020 reached values of 96,9% of total extent, followed by offshore circalittoral sand (94,3%) and circalittoral coarse sediment (93,2%). These percentages would be similar regardless of the indicator used.

Other pressures, such as organic enrichment, were also assessed across the Bay of Biscay and Iberian Coast using the BH2a indicator, revealing an increase in the assessed area between assessment periods (<2009, 2010-2015). The proportion of assessed area increased from 36% to 63% for the benthic invertebrate quality element and from 49% to 61% for the vegetation quality element. In both assessment periods, the majority of the assessed area was certified as in high or good quality status. In 2010-2015 the relevant levels were 49,7% (benthic invertebrates) and 53,4% (vegetation), compared with 36,2% and 48,8% respectively in < 2009. The bad or poor quality status of the assessed area (2010-2015) for benthic invertebrates was 0,5% and 1% for vegetation, while moderate quality status was respectively 6,5% and 13%. In the pre-2009 assessment period, bad or poor and moderate quality status for coastal water bodies was assessed in less than 0,5% of the area. The largest proportion of the assessed area (2010-2015) was in the South Iberian Sea 76,6% (vegetation) and 90,7% (invertebrates), and the lowest in the Gulf of Cadiz (less than 6%) and the Bay of Biscay (around 40%), thus compromising, for these two last assessment units, any confidence in the resulting proportions at these scales.

The level of confidence for the assessment of the Bay of Biscay and Iberian coast is considered **medium**

- Level of evidence: **medium.** The assessment is based on multiple lines of evidence, but gaps were observed in the spatial coverage of the biological information available and the absence of VMS and logbook fisheries data from Portuguese fleets.

- Degree of agreement: **medium.** Indicators and status assessments of OSPAR listed habitats mostly agree, although a minor proportion show some deviation (i.e. the indicators BH3a and BH1 do not align for all habitat types).

The Bay of Biscay

In the BH1 assessment (2009-2020) all assessed habitats had more than 29,6% of their areas under high disturbance. The highest proportion of such habitats was in offshore circalittoral mixed sediment (86,98%) and in circalittoral coarse sediment (69,16%). The greatest 'no trawling pressure' occurred in upper bathyal sediment, affecting 31,98% of the habitat area. The same pattern was observed during the 2016-2020 assessment period, but the proportion of disturbed area was slightly higher for circalittoral mixed sediment (88,24%) and in circalittoral coarse sediment (70,76%). In circalittoral sand, the proportion of highly disturbed areas declined from 53,12% in 2009-2020 to 19,67% in 2016-2020.

The BH2a assessment for the period 2010-2015 shows that 60,4% of the coastal water bodies area was in high or good status in respect of the benthic invertebrate quality element, while the remaining area was not assessed. The assessed areas significantly increased between reporting cycles, as in the previous assessment period only 8,22% of the assessment units' area had been covered. Concerning the assessment of benthic vegetation in 2010-2015, 47,53% of the area was in high or good status, 18,49% in moderate and 2,81% in poor or bad status. 31,17% of the total area of coastal water bodies was not assessed. This situation is worse than in the previous cycle, where a greater area of coastal water bodies was assessed and 80,9% of assessment unit areas were in high or good status.

The Gulf of Biscay had the greatest percentage of area under high and moderate disturbance from trawling (BH3a) in both assessment periods.

Disturbance was present throughout 94% of the Gulf, with the highest level occurring along the Armorican shelf and in the north-west portion of the assessment unit, bordering the North-Iberian Atlantic assessment unit. Only 3% of the assessment unit area had zero disturbance, largely around the inshore areas of France. Offshore circalittoral mud had the greatest proportion of area under high disturbance, followed by upper bathyal sediment and circalittoral coarse sediment in both assessment periods.

The North Iberian Atlantic

The assessments evaluated benthic habitat disturbance in the North Iberian Atlantic assessment unit in response to bottom-contact fishing over two assessment periods (QSR: 2009 to 2020; MSFD: 2016 to 2020). For the QSR period, the assessments estimated that around 10% of this assessment unit area had disturbance, with high disturbance covering a third of it. The areas under the highest disturbance were located along the Galician coast and the border with the Gulf of Biscay unit. Offshore circalittoral mud had the most significant proportion of area under high disturbance, followed by upper bathyal sediment. 'No trawling pressure' occurred in 90% of this assessment due to the remarkable extent of deep areas beyond the continental shelf (mainly abyssal habitat) in this assessment unit. However, it is also true that all the infralittoral and circalittoral habitats and the upper bathyal sediment had unpressured extensions of more than 10%. Offshore circalittoral habitats did not reach this unpressured percentage. For the MSFD period, the evaluations showed very similar results. The general percentage of the assessment unit under disturbance (~10%) and high disturbance (~3,3%) and the areas in which the disturbance is concentrated were maintained. Offshore circalittoral mud had the greatest proportion of area under high disturbance, followed by upper bathyal sediment and offshore circalittoral mixed sediment.

The benthic quality status of coastal water bodies against nutrient and organic enrichment was assessed over two assessment periods (1st assessment cycle before 2009; 2nd assessment cycle from 2010 to 2015). For both reporting cycles (2010, 2016) the evaluation determined that the vast majority (nearly 100% of the water bodies assessed, i.e., as long as data was available) had benthic habitats classified as in good/high biological status. In 2010 the status of coastal water bodies was good/high for 92% (invertebrates) and 40% (vegetation), but with respectively 7,7% and 60% of the total area not assessed. In 2016 the status of coastal water bodies was good/high for 39,83% (invertebrates) and 39,78% (for vegetation), but in both cases, 60% of the total area not assessed. Therefore, the six-year status decrease for benthic invertebrates can be explained by the reduction of the number and total area of water bodies evaluated in this assessment unit. This unit is one that presented a minor proportion of assessed coastal water bodies. No bad/poor and very few moderate quality status assessments were made in some areas for benthic invertebrates and vegetation communities in the North Iberian assessment unit.

The South Iberian Atlantic

The assessment of benthic habitat disturbance in the South Iberian Atlantic assessment unit from bottom-contact fishing was determined over two assessment periods (QSR: 2009 to 2020; MSFD: 2016 to 2020). VMS data from this assessment unit did not pass ICES quality checks. Therefore, some fleet activities may be absent and underrepresented. With this limitation, the determination of disturbance in this assessment unit lacks rigour. The assessment of this unit should thus be taken with caution. For the QSR period, the assessments estimated that around 5% of this assessment unit area had disturbance, with low or moderate disturbance covering the most significant proportion. Disturbance was predominantly located along the margin of the continental shelf, with the highest occurrences towards the north of the assessment unit. The habitat with the highest proportion of area under high disturbance was upper bathyal sediments. No trawling pressure occurred in 95% of this assessment due to VMS data paucity in the deeper waters beyond the continental shelf edge and coastal areas, which resulted in all the habitats assessed having unpressured extensions greater than 10%. For the MSFD period, the assessment showed very similar results. Four per cent of the unit area had disturbance, with moderate and low disturbances covering the largest proportion of the assessment unit, maintaining the geographical distribution of the disturbance. Upper bathyal sediment was again the habitat with the largest area under high disturbance.

The BH2a assessments determined the benthic quality status of the coastal water bodies in the South Iberian Atlantic assessment unit, involving nutrient and organic enrichment over two assessment periods (1st assessment cycle before 2009; 2nd assessment cycle from 2010 to 2015). For both assessment cycles (2010, 2016), the evaluation determined that the greatest proportion of the water bodies assessed had benthic habitats classified as in good/high biological status. In 2010 the status of coastal water bodies for benthic invertebrates was good/high for 33,35%, poor/bad for 0,02%, with 66,63% of the total area of coastal water bodies not having been assessed. The status for vegetation was good/high for 28,96% and moderate for 0,05%, with 28,96% of the total area of coastal water bodies not having been assessed. In 2016 the status of coastal water bodies benthic invertebrates was good/high for 52,63%, moderate for 36,57% and poor/bad for 1,48%, with 9,32% of the total area of coastal water bodies not having been assessed. The status for vegetation was good/high for 76,62%, with 23,38% of the total area of coastal water bodies not having been assessed. The status changes between the assessment cycles were mainly due to differences in the total assessed area of coastal water bodies and by a change in the ecological status of some coastal water bodies. The impacted areas for benthic invertebrate communities were found mainly in the South Iberian assessment unit.

The Gulf of Cadiz

In the Gulf of Cadiz only minor changes were observed in the BH1 assessment between assessment periods. The habitat most affected was offshore circalittoral mud, with high disturbance in 91% of the habitat area. The greatest 'No trawling pressure' occurred in the circalittoral sand in 41% of the habitat area.

The BH2a assessment was only carried out for benthic invertebrates during the latest assessment period (2010-2015). Only 5% of coastal water bodies were assessed, which compromises any estimate or conclusion concerning the distribution of quality status at this scale.

Regarding disturbance from bottom-contact fishing (BH3a), the Gulf of Cadiz had the highest proportion of area under high disturbance, in all assessment units. When combined with low and moderate disturbance groups, 72% of the Gulf of Cadiz was under this type of disturbance. Disturbance was predominantly located towards the Spanish coast, and higher in the north of the assessment unit. Zero disturbance occurred in 26% of the Gulf of Cadiz. The most affected habitats were offshore circalittoral mud and circalittoral mixed sediment, with respectively 98% and 96% of high disturbance in both assessment periods.

Assessment of the status of OSPAR listed threatened and /or declining habitats in the Bay of Biscay and Iberian Coast

The condition of the European flat oyster *Ostrea edulis* has been negatively impacted by diseases and parasites in the oyster beds along the coasts of France and Spain. The last assessment in 2010 noted that this habitat was occurring in the Region but was not considered to be threatened. This most recent status assessment concludes that the status of the habitat is poor. The same change in assessment outcome was seen for maerl beds, where the most recent assessment assigns it poor status. Commercial extraction has been identified as a continued threat to maerl beds in this Region, whereas this activity has been banned in other Regions where this habitat occurs.

Compared with the last report from 2009, the status of intertidal mudflats is still poor. The geographical distribution and extent of the habitat are generally good and stable in the Bay of Biscay and Iberian Coast, but its condition is poor due to anthropogenic pressures including climate change, nutrient enrichment, invasive species and hydrological changes (e.g., construction).

A likely effect of climate change on eelgrass (*Zostera*) beds may be a future contraction in the trailing edge of distribution in Portugal and Spain. The latest OSPAR status assessment has already detected a decreasing trend in the extent of eelgrass beds in this region.

Deep-sea sponge aggregations with populations of *Phakellia ventilabrum* in the Cantabrian Sea, both in the Avilés Canyon and Le Danois Bank, have a much lower genetic diversity than populations dominated by the same species in other OSPAR Regions. This is seen as an indication of deteriorating condition. However, it is also considered typical for this habitat to show a patchier distribution at lower latitudes compared with, for example, Arctic Waters.

Coral gardens have been mapped on the Galician Bank, and new survey efforts have also resulted in a substantial increase in the known records of the continental slope. The habitat is believed to be more widely spread on the slope than previously known. Most coral gardens are known about from point location data only. The seamount at Le Danois Bank in the Bay of Biscay shows evidence of coral garden habitat recovery after protective measures were introduced. The improvement in the condition of coral gardens at this location is not considered sufficient to indicate improvement across the whole Region. In addition to coral gardens, many other habitat types and species are associated with seamounts. Communities associated with seamounts are sensitive to fishing pressure, which can cause abrasion. For example, the fishing activities known to be prominent at the Gorringe Bank seamounts in southern parts of the Region have resulted in an assessment of a deteriorating condition for the habitat. The seamounts rise to 1 000 m or more above the surrounding seafloor.

Table S.6: Summary results of the assessment of the OSPAR threatened and / or declining habitats in Bay of Biscay and Iberian Coast

Celtic Seas	Maerl beds	Flat oyster and *Ostrea edulis* beds	Intertidal mudflats	*Zostera* beds	Deep-sea sponge aggregations	Coral gardens	*Lophelia pertusa* reefs	Seamounts
Distribution	?	↓	↔	↔	↔	↔	↑	↔
Extent	?	↓	?	↓	?	?	↔	↔
Condition	?	↓	↔	↔	↓	↓	↔	↓
Previous OSPAR status assessment	○	○	●	●	●	●	●	●
Status (overall assessment)	poor	poor[1,2,5]	poor[3,5]	poor[1,4,5]	poor	poor	poor	poor

Legend:

Previous status assessment:

Regions where species occurs (○) and has been recognised by OSPAR to be threatened and/or declining (●)

Trends in status (since the assessment in the background document):

↓ decreasing trend or deterioration of the criterion assessed

↑ increasing trend or improvement in the criterion assessed

↔ no change observed in the criterion assessed

? trend unknown in the criterion assessed

Status of Criterion assessed:

good	not good	unknown

Method of assessment:

1 direct data driven
2 indirect data driven
3 third party assessment, close-geographic match
4 third party assessment, partial-geographic match
5 expert judgement

The Wider Atlantic: Abyssal plains, seamounts and the Mid-Atlantic Ridge

No Common Indicators, some parts of agreed assessment units overlapping this region, with indicator results *(candidate BH3a results)*

The Wider Atlantic, is one of the largest OSPAR Regions. It is mainly composed of deep-sea habitats such as those found in the abyssal plains, although shallower habitats can be found around the Azores Archipelago. Data on the extent and distribution of habitats is available for some areas, but most of this Region is unknown (Figure S.4). Most of its habitats are considered to be highly sensitive to human activities owing to their low exposure to natural disturbance and the slow growth rates of many deep-sea species (Brett, 2001; Althaus *et al.,* 2009; Orejas *et al.,* 2011). There is an overall lack of knowledge about the status of deep-sea habitats. However, the knowledge base has been increasing since the last assessment, in 2010, of the OSPAR List of threatened and / or declining habitats. The latest assessments of these habitats indicate poor or unimproved conditions for deep-sea sponge aggregations, carbonate mounds and seamounts, coral gardens and *Lophelia pertusa* reefs. Detailed assessments can be found in the section below.

There are no OSPAR Common Indicators for benthic habitats in the Wider Atlantic Region, but the BH3a (Physical disturbance by fisheries) indicator has been assessed as a candidate indicator in some areas, namely the "Atlantic projection" assessment unit and deep habitats in the Northern Celtic Seas, Southern Celtic Sea, North Iberian and South Iberian Atlantic assessment units.

Results based on the BH3a indicator show that a large proportion of habitats, mainly those classified as bathyal and abyssal, are undisturbed by bottom-fishing gear as they are not suitable for this activity and are under bottom-fishing restrictions imposed by the North-East Atlantic Fisheries Commission (NEAFC). By contrast, moderate to high disturbance was found in circalittoral mud, upper bathyal sediment, and lower bathyal sediment all around the open Atlantic areas assessed, where this activity is widespread. In the habitats off the coast of Ireland (e.g., Porcupine Bank / Seabight), high to moderate disturbance was assessed mostly in offshore circalittoral sand, upper bathyal sediment and deep-sea habitats. Surface abrasion during the 2009 – 2020 period was also measured in areas outside the assessment units mentioned above **(Figure S.6),** with some areas evaluated as under constant fishing **(Figure S.7),** but it should be noted that the BH3a indicator method of assessing the disturbance caused in those areas, based on exposure to sensitivity ranges, was not applied due to lack of resources.

The level of confidence for the assessment for the Wider Atlantic region is considered **low**

- Level of evidence: **low.** Habitat and human activity data were assessed only in a small proportion of the total area of the region (the "Atlantic Projection" assessment unit and the deeper parts of the Northern and Southern Celtic Seas and the North Iberian and South Iberian Atlantic assessment units). Status assessments for some OSPAR listed habitats were also undertaken. However, large parts of the seabed habitats are unassessed.
- Degree of agreement: **low.** The indicators and status assessments for OSPAR listed habitats mostly agree, but they are limited to a small proportion of this Region.

Atlantic Projection assessment unit

The Atlantic Projection was assessed only by the indicator BH3a for physical disturbance caused by bottom-contacting fisheries on offshore circalittoral, bathyal and abyssal habitats. BH3a is a candidate indicator in this assessment unit.

The large proportion of area assessed was classified as undisturbed by fishing. This is because the deep-sea habitats were in most cases too deep for this activity and, as established by the NEAFC, the vast majority of deep-sea fisheries currently operating are found in EEZs rather than Marine Areas Beyond National Jurisdiction (ABNJs). This finding is also based on an assessment of existing fishing activities over a 20-year period (1987-2007) carried out under Recommendation 19:2014 on Vulnerable Marine Ecosystems (as in the latest update from 2023 Recommendation 07:2023. During the period 2009-2020, 11% of the assessment unit was under some level of disturbance, and 6% for the period 2016-2020. In both periods, the observed disturbance levels are generally moderate and limited to the broad habitat types where fishing activity occurs. (See: Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears).

For the assessment period 2009-2020, no assessment was possible for rock and biogenic circalittoral habitats. The greater proportion of circalittoral sand (100%) and circalittoral mud (83%) habitats were under low levels of disturbance. Bathyal and abyssal habitats were, logically, largely undisturbed, with percentages ranging from 73,8% to 99,5% of area under zero disturbance, depending on the habitat considered. Moderate disturbance in bathyal and abyssal habitats ranged from a maximum of approximately 23% in the lower bathyal sediments to a minimum of 0% in upper bathyal rock and biogenic reefs. High disturbance level was observed only in limited areas of circalittoral mud (~4%), upper bathyal sediment (2,7%) and lower bathyal sediment (1,5%)

For the assessment period 2016-2020, rock and biogenic circalittoral habitats were largely unassessed (87%). Circalittoral sand habitats were mostly undisturbed (82%) or under low levels of disturbance (18%). A contrasting picture was observed for circalittoral mud habitats, which showed low levels of disturbance in approximately 83% of their extent, with 17% undisturbed. Bathyal and abyssal habitats were, logically, largely undisturbed, with percentages ranging from 83,9% to 99,6% of area under zero disturbance depending on the habitat considered. Moderate disturbance in these habitats ranged from a maximum of 15,2% (lower bathyal sediments) to a minimum of 0% (upper and lower bathyal rock and biogenic reef). During 2016-2020, high disturbance levels were observed only in upper bathyal sediments (1,4%) and lower bathyal sediments (0,3%)

Assessment of the status of OSPAR listed threatened and /or declining habitats in the Wider Atlantic

The status assessments highlight a particular lack of information to describe change over time, with most of the available information coming from single mapping studies and surveys, rather than repeated monitoring efforts at the same location over a long period. To improve understanding of the status of deep-sea benthic habitats and changes to their status over time, there is a need to develop and implement dedicated monitoring programmes. Regional coordination would be beneficial, due to the relatively high costs and the difficulty in accessing deep-sea habitat sites. Several status assessments revealed the need to better understand how climate change can impact deep ocean circulation, and in turn to improve knowledge of how these changes could impact the larval dispersal of habitat-forming species.

Carbonate mounds occur as clusters of mounds formed by successive periods (> 10 000 years) of coral reef development, sedimentation and (bio)erosion. The Wider Atlantic Region in the OSPAR Maritime Area is believed to contain the greatest concentration and largest examples of coral carbonate mounds worldwide. Since the last assessment in 2010, new mounds have been discovered on the Iberian margin of the Galicia Bank. These are not being interpreted as increasing in extent but rather as an improvement on knowledge. A wider range of threatened and / or listed habitat types has been found to be associated with carbonate mounds than was recognised during the previous assessment. Habitats dominated by fragile and long-lived filter- and suspension-feeders, such as *Lophelia* reefs, deep-sea sponge aggregations and coral gardens, occur on carbonate mounds, as do a high diversity of shrimps, crabs, crinoids, ophiuroids, and fish species such as the orange roughy. While the carbonate mounds are not seen as directly threatened by human activities, unless new activities such as aggregate removal are initiated, the habitats that form on them are sensitive to disturbance.

A decrease in the density, biomass and body diameter of deep-sea sponges (*Phernoema carpenteri*) has been detected over the past decades at the Porcupine Sea bight, due to human activities. The deep-sea sponge aggregations are sensitive to pressures from fishing, and their documented decline is considered to be an indication of a downward trend in the condition of the habitat. Similarly, coral gardens are sensitive to bottom-contacting fisheries, and their condition has been assessed as increasingly unfavourable in previously trawled marine protected areas.

Lophelia reefs occur along the shelf edge and around seamounts and ridges in the Wider Atlantic. Fifty per cent of the Region's known *Lophelia* reefs occur within marine protected areas. The *Lophelia* reefs at Rockall have been found not to be in good status.

The oceanic ridges and hydrothermal vent habitat were assessed as being in good status, with an improvement in condition since the last assessment but with a low level of confidence. This is the only deep-sea habitat in the Wider Atlantic which has changed its overall status assessment since QSR 2010. Hydrothermal vents, which are rare, sensitive and island-like ecosystems, require protective measures to ensure that the habitat remains in good condition and is not exploited through extractive activities. Biodiversity and population densities at the small sites of active hydrothermal vents are high compared with densities in the surrounding areas, with higher degrees of endemism for species in deeper vent fields than in shallower vents. Time series information on population densities is only available from one vent field (Lucky Strike) and shows stable megafauna populations. Due to the limited monitoring and knowledge, it is not possible to assess overall trends for this Region.

Seamounts occur most abundantly in the Wider Atlantic Region. The distribution and extent of seamounts does not change over time, but the communities of species on them that represent their ecological condition, can change and have been assessed as declining. For example, the Anton Dohrn, Rosemary Bank and Hebrides Terrace seamounts are seen to be in a favourable state, but the communities associated with them have been impacted by fishing activities, although recent management strategies have reduced the fishing pressure that this northern area was experiencing. Seamounts with summits deeper than 1 500 m are believed to be in better condition, as they are not targeted by fishing activities.

Table S.7: Summary results of the assessment of the OSPAR threatened and / or declining habitats in the Wider Atlantic

Celtic Seas	Deep-sea sponge aggregations	Carbonate mound	Coral gardens	*Lophelia pertusa* reefs	Oceanic ridges and hydrothermal vents	Seamounts
Distribution	⇔	⇔	⇔	↑	⇔	⇔
Extent	?	⇔	?	⇔	⇔	⇔
Condition	↓	?	↓	⇔	↑	↓
Previous OSPAR status assessment	•	•	•	•	•	•
Status (overall assessment)	poor	poor	poor	poor	good	poor

Legend:

Previous status assessment:

Regions where species occurs (○) and has been recognised by OSPAR to be threatened and/or declining (●)

Trends in status (since the assessment in the background document):

↓ decreasing trend or deterioration of the criterion assessed
↑ increasing trend or improvement in the criterion assessed
⇔ no change observed in the criterion assessed
? trend unknown in the criterion assessed

Status of Criterion assessed:

good	not good	unknown

Progress made, remaining knowledge gaps, and way forward towards a more integrated assessment of benthic habitats

Even if the full integration method is not yet agreed or complete for the benthic thematic assessment, several "pieces of this puzzle" have already been developed and further progressed under the EcApRHA and NEA PANACEA projects, with contributions and review from the whole OSPAR Benthic Habitat Expert Group.

The indicators are being developed by the experts who lead the different work areas, using a complementary approach to ensure that indicators can be operationalised as a set and integrated in the future. There are **two main types of OSPAR benthic indicators**:

- **Station sample-based**, used to quantify specific state-pressure relationship curves at fine scale: Sentinels of the Seabed (BH1), Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment (BH2a), Condition of Benthic Habitat Communities: Margalef diversity in Region II (Greater North Sea) (BH2b);
- **Area and model-based**, used to estimate the impacts from pressures at wider scales, based on sensitivity values and state-pressure relationships, on broader habitat types and the OSPAR List of threatened and declining habitats: Extent of Physical Disturbance to Benthic Habitats: Fisheries with mobile bottom-contacting gears (BH3a), Extent of Physical Disturbance to Benthic Habitats: Aggregate Extraction (BH3b), Pilot Assessment of Area of Habitat Loss (BH4).

BH2a, is already **extrapolating the station results for each assessed coastal water body**, which is the relevant scale for benthic quality elements under the EU Water Framework Directive, the corresponding Norwegian water regulations (Vannforskriften) and the Water Environment Regulations and Water Environment Water and Services Act for United Kingdom waters.

The BH2 "**common conceptual approach**" a precursor of this thematic assessment, was developed as a separate "chapeau" concerning the use of several multi-metric indices to address different pressure types but involving common requirements in terms of sampling at similar biological and geographical scales, and data requirements in terms of parameters and taxonomical referencing. The more recent BH1 indicator, focusing on sensitivities at species biological scale and more pressure-specific sensitivities, is also included with these types of indicators.

More recently, BH3 was also applied to two different types of physical pressure, leading to two separate and specific assessments: BH3a considered physical disturbance by bottom-contacting fisheries, while BH3b looked at physical disturbance by aggregate extraction. Although this area- and model-based type of indicator is different from the previously mentioned BH1 and BH2, its approach and conceptual chapeau is similar, and it aims to use similar methods to assess different pressure types and thus **facilitate comparison and further methodological development** under the "common approach" (See: CEMP Guideline: Common Indicator - BH3 Extent of Physical damage to predominant and special habitats (Agreement 2017-09))

At a more advanced integration level, the **conceptual approach to link and combine (data and methods) these two types of indicators** has been published as a detailed deliverable of the EcApRHA project (Elliott *et al.,* 2017a) and summarised as an article in a peer-reviewed international scientific journal (Elliott *et al.,* 2018). Under the NEA PANACEA project, this common approach was successfully tested and published both as a CEMP appendix of BH1, also referred to in BH3 and in a pilot assessment in the Bay of Biscay and Iberian Coast. Even if there are still data and methodological limitations, this new recent step forward will help the progress **towards a more integrated method** which combines these two types of indicators to help improve methodologies and confidence in the overall assessment of benthic habitat quality status (**Figure S.9**).

Despite this recent significant progress, **more working and scientific policy interactions** are still needed, at both regional-sea and European levels. In line with the steps described above, the **coordination and additional resources shared through common projects** are key to enabling this work to proceed under commonly agreed and defined timelines and priorities.

In the near future, significant progress is urgently needed to greatly improve **the monitoring that supplies the required data**, and the **scientific policy process itself,** to enable sufficient technical, methodological and management progress towards a more integrated assessment, as well as provide information and evidence to **support evaluation of the efficiency of management measures**. This needs to happen both within and between benthic and biodiversity assessments (Elliott *et al.,* 2017b; Padegimas *et al.,* 2017), considering also the most recent progress made nationally and through the MSFD (Guérin and Lizińska, 2022), and in wider socio-economic areas (Révelard *et al.,* 2022).

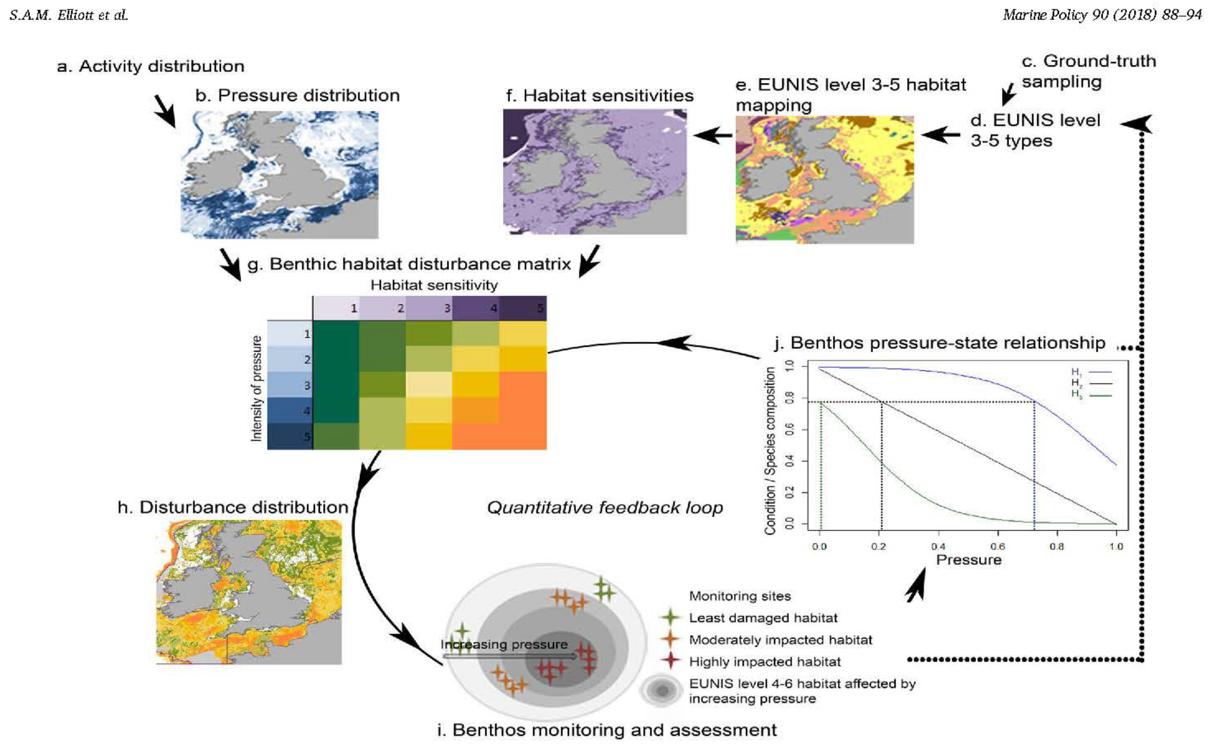

Figure S.9: Overarching conceptual approach for an integrated assessment of benthic habitat indicators at sub-regional scale, to highlight the feedback of information gathered across Indicator Assessments and provide increased confidence in benthic Indicator Assessment. (Elliott et al., 2018)

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The Wider Atlantic: Abyssal plains, seamounts and the Mid-Atlantic Ridge

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I – Impact (on ecosystem services)

Impacts on ecosystem services supported by benthic ecosystems

Eutrophication and nutrient enrichment in coastal benthic communities point to local problems, even in these sub-regional scale assessments, although they were measured as good in a large proportion of assessed areas. Owing to the relatively high proportion of areas still not assessed and the use of different indices (with various sensitivities to different pressure types), the status of coastal habitats is uncertain in most sub-regions. Benthic habitats are also generally not in good quality status due to widespread physical disturbance and a reduction in benthic diversity in the more offshore assessed areas. This is likely to cause strong negative impacts, notably on services for wild fish and other natural aquatic biomass and related raw materials, food web regulation, nursery populations and habitat maintenance, and water and sediment quality.

Method and result

The possible impacts of state (change) on marine ecosystem services in the North-East Atlantic was evaluated on the basis of expert judgement and is presented as **Figure I.1**. The nature (e.g., positive, negative or neutral) and magnitude (e.g., unknown, low, medium or high) of the impacts is indicated. The information in the state (change) boxes conveys the overall observed state (change) in benthic habitats across the whole OSPAR Maritime Area and focuses on the ecosystem services for which the scientific literature supports association with benthic habitats.

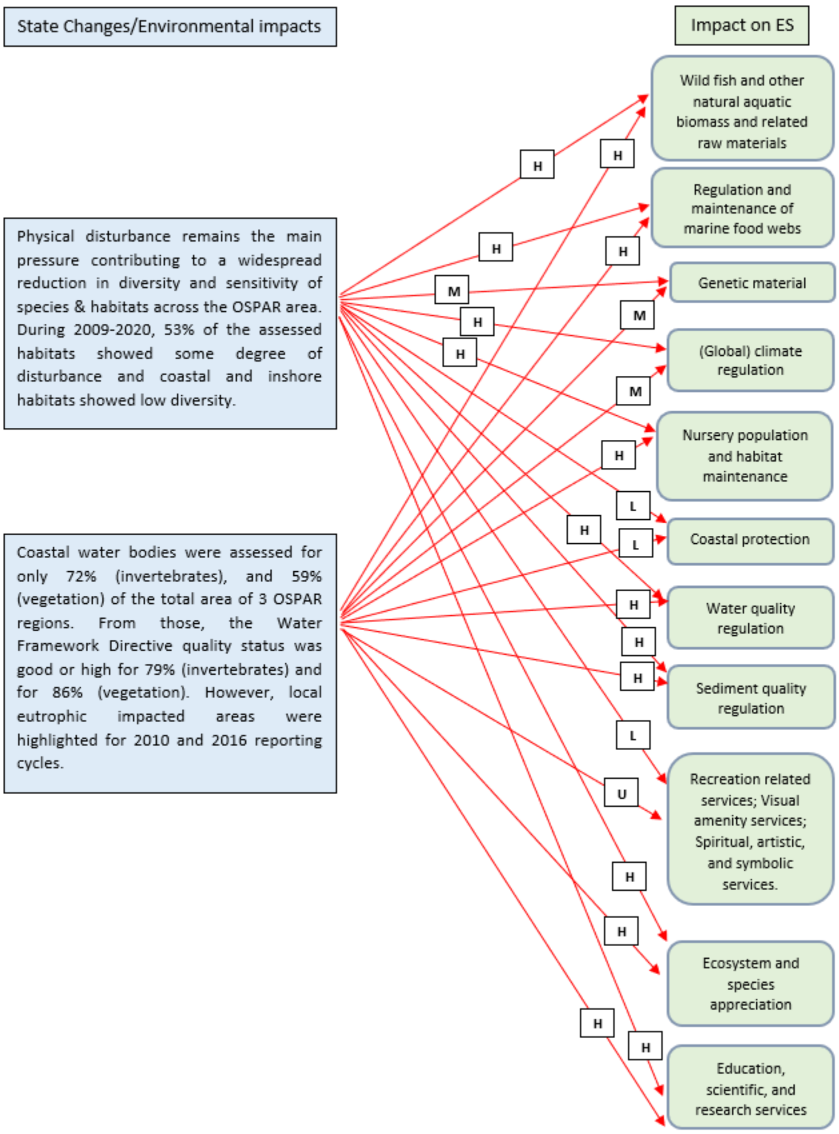

Figure I.1: Schematic depicting 'state (change)' / 'impacts on Ecosystem Services' linkages for the Benthic Habitats thematic assessment. The ecosystem services shown are those considered most relevant in relation to the Benthic Habitats thematic assessment. Each arrow also denotes an expert judgement estimate of the nature and magnitude of the impact (red arrow = negative impact; H = high impact, M = medium impact, L = low impact, U = unknown impact)

Detailed rationale on the role of benthic habitats (and their state) in relation to the provision of ecosystem services

Benthic habitats consist of marine organisms living on or within sediments and rocks. Benthic habitats perform essential ecological functions in supporting commercial aquatic species, providing food for predators and generally maintaining the balance of marine food webs. Thus, several marine species rely directly or indirectly on the seabed for food, shelter, rest or reproduction. Benthic habitats are essential to ecosystem services, for example by providing natural carbon storage when left undisturbed, which is very important for the mitigation of CO_2 emissions. The huge variety of benthic habitats includes communities that have different sensitivities to the physical disturbance associated with human pressure. Impacts on the seabed from human activities, such as bottom-contact fishing, nutrient and organic matter enrichment and contaminants, can adversely affect benthic habitats and the provision of the ecosystem services that depend on their good condition. In this respect, it is important to note that benthic habitats are characterised by both animal and plant communities, including macroalgae with either no mobility or less than that of other organisms (e.g., pelagic organisms). The whole community is therefore exposed to potential pressure on the seabed, and the status of benthic habitats thus reflects the cumulative effect of different pressures on them. Bottom trawling on the seabed is considered to have the most widespread physical impact in the parts of the OSPAR Maritime Area where it occurs.

As observed in the context of the 2017 OSPAR Intermediate Assessment (IA), the quality of benthic communities is generally lower in coastal areas than in offshore areas because human-induced pressures such as fishing (but also the introduction of nutrients and contaminants) are higher in coastal areas (OSPAR, 2017). At the same time, as reported in the work on the mapping of ecosystem services provided by benthic habitats in the North-East Atlantic Ocean conducted by Galparsoro *et al.,* (2014), benthic habitats generally provide more ecosystem services closer to shore, given the greater difficulty humans have in accessing more distant and deeper ocean areas and the lack of scientific knowledge about more distant and deeper benthic habitats. Consequently, due to the concomitance of higher human-induced pressure and higher ecosystem service provision, ecosystem services are likely to be more greatly impacted closer to the coast. With this in mind, it is worth considering which ecosystem services are underpinned and provided by benthic habitats. In addition, the same study observed how the levels of marine ecosystem service provision by benthic habitats vary across the North-East Atlantic Ocean sub-regions, with the North Sea providing the highest levels.

The ecosystem services 'wildfish and other natural aquatic biomass and raw materials' and 'nursery population and habitat', as found in **Figure I.1** and defined in the standard definition list, were found to be those most commonly provided by the different benthic habitats in the North-East Atlantic Ocean (Galparsoro *et al.,* 2014). Coastal protection, (global) climate regulation and cultural ecosystem services were found to be provided at a high level but by a limited number of benthic habitats (Galparsoro *et al.,* 2014). For example, (global) climate regulation and the regulation and maintenance of marine food web services (supported by the primary production of benthic habitats) were found to be more highly provided in coastal margin habitats than in deeper subtidal habitats. As a further example, the ecosystem services generally provided at a higher level by sandy and muddy habitats were found to be wild fish and other natural aquatic biomass and related raw materials, and nursery population and habitat maintenance (through the provision of important spawning, foraging and nursery sites). In summary, provisioning services were found to be provided at significantly higher levels than regulating and maintenance services and cultural services (Galparsoro *et al.,* 2014). Despite these differences in ecosystem services supply, the study conducted by

Galparsoro *et al.,* (2014) shows that benthic habitats in the North-East Atlantic provide a diverse set of ecosystem services. These benthic habitats are so numerous and diverse that, as also shown in Rife (2018), they provide ecosystem services belonging to all categories: provisioning, regulation and maintenance, and cultural.

The interaction of species and their biological traits determines the function of benthic communities and thus the resulting provision of ecosystem services. It follows that the disturbance of benthic communities by trawling, causing chronic changes in ecosystem functioning, may compromise the provision of ecosystem services that depend on the interrelationship of different benthic functions (Muntadas *et al.,* 2015). The ecosystem services provided by benthic habitats depend on functions such as the digging of deep-burrowing fauna, which increases the flow of oxygen in the sediment, extending the total denitrification zone and stimulating nutrient cycling. The results obtained by Muntadas *et al.,* (2015) confirm that epifaunal functional composition is highly influenced by bottom trawling activities, especially those characterised by higher intensity. Fishing activity was found to have a significant effect on both functional components and benthic ecosystem service providers (organisms that share particular biological traits related to certain ecosystem functions that ultimately underpin the provision of ecosystem services; Muntadas *et al.,* 2015). In addition, the impacts of bottom trawling, on benthos can, for example, alter. the ecosystem function of bentho-pelagic coupling, which is also important in supporting the provision of ecosystem services in the water column (for more details see the Pelagic Habitats Thematic Assessment; Muntadas *et al.,* 2015).

Intensively trawled areas experience a reduction in the biomass of attached and epiphytic organisms such as sponges and soft and hard corals, through the physical destruction of marine sediments and the associated negative effects on suspended organisms. These organisms are essential in providing habitat (reproductive, feeding, and nursery ground) for marine life forms, as they add a three-dimensional structure to the seabed. Consequently, trawling can negatively impact the ecosystem service for nursery populations and habitat maintenance (Howarth *et al.,* 2018). Since benthic habitats also host commercially important species, trawling may also indirectly impact the ecosystem service for wild fish and other natural aquatic biomass and related raw materials. In addition, bottom trawling removes biomass from benthic communities, potentially affecting all sizes of organisms and causing mortality in a wide range of non-target and target species ranging from nematodes to large sharks, given the non-selective nature of bottom trawling (Howarth *et al.,* 2018). For this reason, it could be assumed that this type of fishing can also negatively affect all cultural services that are based on the good status of benthic biodiversity, such as recreational diving and recreational fishing, but also the symbolic value attributed to charismatic species and people’s interest in conserving such biodiversity for future generations and themselves. Furthermore, it can be assumed that the loss of benthic biodiversity negatively impacts the ecosystem service identified here as genetic material.

In addition, the activities of filter-feeding organisms, in combination with the degradation processes carried out by microbial communities in the sediment, contribute to the regulation of sediment and water quality by immobilising and degrading pollutants (Ashley *et al.,* 2018).

As reported in the context of OSPAR IA 2017, physical disturbance of the seabed can induce changes in the composition of a benthic community, with small-bodied, fast-growing opportunistic species replacing large, long-lived organisms (OSPAR, 2017i). However, these opportunistic species have a reduced potential for bioturbation, which may result in a reduction in sediment quality regulation (Culhane *et al.,* 2019a; Morys *et al.,* 2021; Prather *et al.,* 2013). Sandy sediments cover 90% of the North Sea seabed, and every single grain of sand in them can be colonised by 10 000 to 150 000 micro-organisms (Berger, 2018; Probandt *et al.,* 2018).

The demanding conditions to which they are subjected, with variable inputs of oxidising and reducing agents, promote metabolic adaptations such as denitrification in the presence of oxygen. In this way, sandy sediments host microbial communities that are highly efficient at removing critical nitrogen inputs. It has been observed that high organic carbon inputs in the sediment, in combination with such microbial communities, trigger a nitrogen loss process that contributes to the removal of more than 30% of total nutrient inputs. This biocatalytic filtering role of sandy sediments contributes to the regulation of water quality and also oceanic sediment quality by filtering anthropogenic nutrient inputs (water quality regulation and sediment quality regulation). However, increased human-induced pressures on benthic habitats, such as trawling and nutrient loading, may negatively impact these ecological functions, and consequently the provision of ecosystem services that depend on them (Berger, 2018). In this regard, it has been observed that bottom trawling on muddy sediments disturbs the redox structure of the sediments, causing a reduction in denitrification processes. Consequently, the physical impact of bottom trawling, by negatively affecting denitrification and in turn the ecosystem services of water quality regulation and sediment quality regulation, can further contribute to eutrophication (Morys *et al.,* 2021; for more details on eutrophication see: Eutrophication Thematic Assessment).

Given that the assessments carried out in the context of QSR 2023 indicate that physical disturbance remains the main pressure contributing to a widespread reduction in diversity and sensitive species and habitats across the OSPAR area, with 36% of areas showing high / moderate levels of disturbance and coastal and inshore habitats showing low diversity, the impacts on ecosystem services have been represented as negative in nature (see red arrows in **Figure I.1**).

Eutrophication can also have negative effects on benthic habitats, leading to a reduction and / or absence of dissolved oxygen, a decline in benthic biodiversity and subsequent impacts on marine food webs and ecosystem services underpinned and provided by benthic habitats. Eutrophication together with deoxygenation due to organic enrichment can lead to a reduction in benthic species richness, degradation of benthic ecological functions (e.g., bioturbation and nutrient cycling) and, consequently, have a negative influence on the provision of ecosystem services (including sediment quality regulation, water quality regulation and (global) climate regulation). Changes in benthic invertebrate communities, such as the loss of larger species, can have knock-on impacts on the entire marine ecosystem as they are a key component of food webs (Culhane *et al.,* 2019b; for more details see the Eutrophication Thematic Assessment).

Given that the assessments carried out in the context of QSR 2023 indicate that coastal benthic habitat quality status, in relation to nutrient and / or organic enrichment, shows local eutrophication-impacted areas, the impacts on ecosystem services have been represented as negative in nature.

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R – Response

Management and policy responses to protect, improve and recover benthic ecosystem

The actions taken by OSPAR in relation to the management of specific human activities or pressures, including eutrophication, renewable energy development, near-shore and deep-sea mineral extraction, dredging, oil and gas extraction and cable placement, all contribute to addressing the impacts from pressures and should contribute to improving the status of benthic habitats. The Collective Arrangement provides a useful framework for working with other competent organisations on responses relevant to benthic habitats that are outside OSPAR's competence in selected areas outside national jurisdiction, for example in relation to fisheries.

OSPAR has identified eighteen habitats considered to be of concern in the North-East Atlantic in coastal, shelf and deep waters. Recommendations for actions to be taken by Contracting Parties nationally and collectively to protect and conserve these species have been adopted. At present, it is very challenging to evaluate whether these measures will be able to reduce the pressures and human activities that continue to undermine benthic habitats in the North-East Atlantic. In part this is because one response may address multiple activities and/or pressures. In addition, some response measures are not necessarily producing data that can be included in the current Indicator Assessments aimed at evaluating the effectiveness of those measures on the recovery of benthic ecosystems. Overall, the measures currently being implemented do not seem to have improved the status of benthic habitats.

The OSPAR network of Marine Protected Areas (MPAs) is an important response for improving the status of benthic habitats, including but not limited to those habitats identified in the OSPAR List of threatened and /or declining species and habitats. The development of the network is progressing in line with regional and global commitments. OSPAR listed habitats in the Arctic region are notably underrepresented in the OSPAR MPA network. Some habitats such as *Cymodocea* meadows are naturally region-specific, and others like carbonate mounds are not sufficiently known or included, which increases the challenge of understanding the ecological coherence of the MPA network.

Benthic Habitat R-section ANNEX: The section development has been supported by the collation of relevant measures: [measures of relevance to benthic habitats included in this section]

Overview

This section describes the responses taken to minimise the effect of human activities and their resulting pressures or impacts on ecosystem services, and the responses that aim to improve the state of benthic habitats in the North-East Atlantic. These can include the development of policy or legislation and measures to manage or regulate specific human activities or to mitigate impacts on ecosystem services.

The section considers the diversity of benthic habitats that occur across all regions of the OSPAR Maritime Area, including those in coastal and shelf seas as well as deep seas within and outside of national jurisdiction. The primary focus is on responses that have been adopted by the OSPAR Commission to implement Contracting Parties' commitments under the OSPAR Convention and the strategic objectives of the North-East Atlantic Environment Strategy (NEAES 2030). Article 22 of the OSPAR Convention requires that Contracting Parties report to the OSPAR Commission at regular intervals on the steps they have taken to implement OSPAR Decisions and Recommendations, the effectiveness of those measures and the problems encountered during their implementation. The section also aims to describe the progress made in implementing these measures and whether they are working in terms of achieving the ambitions set out in NEAES 2030. It attempts to set OSPAR's responses in the wider policy context, and the responses of other competent organisations are also considered where they are pertinent to improving the status of benthic habitats in the North-East Atlantic.

Benthic habitats are a clear focal point of three strategic objectives under NEAES 2030, namely those relating to protection and conservation, restoration, and the management of human activities:

Strategic Objective 5: Protect and conserve marine biodiversity, ecosystems and their services to achieve good status of species and habitats, and thereby maintain and strengthen ecosystem resilience.

S5.O1: By 2030 OSPAR will further develop its network of marine protected areas (MPAs) and other effective area-based conservation measures (OECMs) to cover at least 30% of the OSPAR Maritime Area to ensure it is representative, ecologically coherent and effectively managed to achieve its conservation objectives.

S5.O4: By 2025 at the latest OSPAR will take appropriate actions to prevent or reduce pressures to enable the recovery of marine species and benthic and pelagic habitats in order to reach and maintain good environmental status as reflected in relevant OSPAR status assessments, with action by 2023 to halt the decline of marine birds.

S5.O5: By 2025 OSPAR will have implemented all agreed measures to enable the recovery of OSPAR listed threatened and /or declining species and habitats and will take additional measures as needed.

Strategic Objective 6: Restore degraded benthic habitats in the North-East Atlantic when practicable to safeguard their ecosystem function and resilience to climate change and ocean acidification.

S6.O1: By 2023 OSPAR will identify habitats suitable for restoration and develop a common knowledge base on the most appropriate and effective methods for restoration of degraded habitats.

S6.02: By 2025 OSPAR will develop a regional approach, including relevant qualitative and / or quantitative targets for restoration of degraded habitats suitable for restoration, and will then implement actions to achieve the targets as appropriate.

Strategic Objective 9: Safeguard the structure and functions of the seabed / marine ecosystems by preventing significant habitat loss and physical disturbance due to human activities.

S9.O1: By 2023 OSPAR will deliver a quantitative evidence base on pressures from human activities causing physical loss and disturbance to seabed habitats. On this basis, OSPAR will address and, where possible, reduce these pressures from human activities within its competence and regularly engage with other competent authorities with a view to reducing these pressures within their respective areas of competence in order to help achieve or maintain good environmental status.

There are a number of linkages to other thematic assessments, including: Fish Thematic Assessment, Eutrophication Thematic Assessment, Food webs Thematic Assessment, Marine Litter Thematic Assessment

The reader is referred to the following feeder reports for additional information on some of the key human activities affecting benthic habitats: Fisheries, Shipping and Ports, Aquaculture, Assessment of Data on the Management of Wastes or Other Matter (Dredged Material) 2008 - 2020

Measures adopted by OSPAR

This section focuses on measures adopted by OSPAR and draws on the efforts to protect and conserve habitats of particular concern and to establish an ecologically coherent and well managed network of MPAs, as well as specific measures that OSPAR has adopted to address human activities and pressures of relevance to benthic habitats.

The implementation status of all OSPAR measures was reported in 2021: Implementation of OSPAR measures - A progress report.

Addressing benthic habitats in decline and under threat

The OSPAR Contracting Parties have identified eighteen habitats of particular concern in the North-East Atlantic. These have been included in the OSPAR List of Threatened and / or declining species and habitats (OSPAR Agreement 2008-06) (the OSPAR List). This list, which was first adopted in 2003 and updated in 2008 and 2021, guides OSPAR in setting priorities for its further work to conserve and protect marine biodiversity under Annex V to the OSPAR Convention. Recommendations for actions to protect and conserve 16 of these habitats were adopted by OSPAR between 2010 and 2016. The remaining two, kelp forests and *Haploops* habitats on muddy seabed, were added to the OSPAR List at the OSPAR Ministerial Meeting in 2021, and Recommendations for their protection and conservation were adopted in parallel.

The purpose of these Recommendations is to agree on national and collective actions to strengthen the protection of the listed habitats, recover their status and ensure that they are effectively conserved in the OSPAR Maritime Area. A common understanding of the Recommendations was adopted in 2013 (OSPAR Agreement 2013-13). The Recommendations are broad in nature and address a range of human activities and pressures. The actions to be taken nationally include steps to ensure appropriate national legislation for the protection of a given habitat, consideration of how to strengthen the knowledge base, monitoring and assessment, steps to manage key human activities, calls for the designation of MPAs within their jurisdiction, and awareness raising. The collective actions include coordination of monitoring and assessment, enhanced knowledge exchange, collaborating and maintaining cooperation with relevant competent organisations with regard to addressing key pressures (such as fishing and shipping), and research.

The most recent implementation reporting took place in 2019, with the next round due in 2025. A detailed overview of the scope and range of the actions implemented in this reporting round can be found in the OSPAR Overview assessment of implementation reporting. For the purpose of this overview, habitats are grouped into “coastal and shelf” or “deep-sea” habitats.

Coastal and shelf habitats: Reporting indicated relatively high engagement in the implementation of this set of Recommendations. These habitats are relatively accessible, with high proximity to human activities, and are also of concern in a number of other legislative frameworks, including the EU Habitats Directive (Council Directive 92/43/EEC), the Marine Strategy Framework Directive (2008/56/EC), and the Water Framework Directive (2000/60/EC) as well as The Trilateral Wadden Sea Agreement.

Most Contracting Parties reported progress in monitoring and mapping activities for coastal and shelf habitats, although there are still gaps as well as challenges relating to the comparability of data across habitats and countries. Progress has also been made in the designation of MPAs to protect these habitats. Actions to implement restoration have been reported by several Contracting Parties, for example Sweden, the United Kingdom, Denmark and the Netherlands with *Zostera* beds; the Republic of Ireland, Germany, Belgium with *Ostrea edulis* beds, Northern Ireland (UK) with *Modiolus* beds and the Netherlands with intertidal *Mytilus edulis* beds, indicating a possible basis for sharing experience and developing this area of work within OSPAR.

Deep-sea habitats: Some Contracting Parties reported that deep-sea habitats are remote and difficult to access. Monitoring and distribution data are expensive to acquire, less available and therefore part of the reason for lower engagement in reporting under this group of Recommendations. It may therefore be practical for OSPAR Contracting Parties to focus on collaborative actions for deep-sea habitats.

The implementation of legislation to protect deep-sea habitats was variable. For some habitats, such as seamounts, legislation is being considered but has not been established, whereas for others, such as *Lophelia* reefs, coral gardens and deep-sea sponge aggregations, it has been implemented. This principally concerns regulations to restrict fishing activities, in particular with bottom-contacting gear and is implemented as both EU legislation and national legislation. A number of reporting Contracting Parties that are also EU Member States noted their use of the EU Habitats Directive (Council Directive 92/43/EEC) and other EU legislation, and another reported using the environmental objectives of the MSFD to help implement action to introduce legislation to protect deep-sea habitats such as seamounts, deep-sea sponge aggregations and coral gardens.

There appears to be a good level of implementation of management actions to protect coral gardens, *Lophelia* reefs and deep-sea sponge aggregations at the national level, informed by a programme of work to understand the distribution of these habitats. Collaboration with the fisheries sector was identified as important for most of the deep-sea features (carbonate mounds, *Lophelia* reefs, coral gardens and deep-sea sponge aggregations), both as a key pressure and as an important collaborating partner for increasing the evidence base and ensuring protection. The United Kingdom and Sweden reported using information on location and extent of habitat provided by fishers to increase their information base on *Lophelia pertusa* reefs, and Iceland and Spain reported the use of observers on board fishing vessels to increase the same information base.

Where deep-sea habitats are also recognised as Vulnerable Marine Ecosystems (VME, as defined by the FAO in 2009), protection is also afforded under measures taken by other competent organisations and reported as part of collective actions, such as the ban on the use of bottom-contact fishing operations under the North-East Atlantic Fisheries Commission (NEAFC) Recommendation 19 2014: 'Protection of VMEs in NEAFC Regulatory Areas', as amended by Recommendation 09:2015 and 10:2018. The NEAFC started closing some VME areas from 2005 onwards, with most closures in place by 2010. EU Regulation 2016/2336, which bans the use of bottom trawls in depths below 800 m in the NE Atlantic, affords additional protection to carbonate mounds deeper than 800 m.

Are these measures working?:
Reporting by Contracting Parties demonstrates that the OSPAR Recommendations on protection and conservation have generated conservation action at the national level. Contracting Parties are increasing the protection of features that are threatened on a regional scale, through various awareness-raising activities, by introducing national measures and legislation to regulate human activities causing pressures on the features and by establishing monitoring programmes to assess the status of the features. Many of these actions are also being taken as part of national responses to EU legislation such as the EU Habitats Directive (Council Directive 92/43/EEC). It is difficult to differentiate between the effects of measures taken as part of different programmes and to evaluate the impact of the OSPAR measures compared with others. The measures to protect VMEs being implemented by fisheries organisations such as the NEAFC are regularly reviewed by the organisations and also by the UN General Assembly (most recently in 2022).

The habitat status assessments (see State) show that all but one of the threatened and / or declining habitats are still rated as poor (only oceanic ridges with hydrothermal vents have good status), implying that these measures cannot be considered effective at this stage. There have been some examples of Contracting Parties considering their level of response to be effective in addressing the protection of the habitat. Ireland reported that its current legislation for *S. spinulosa* is considered to be effective. Although no direct actions are in force in Iceland for seamounts, this was considered to be sufficient, as there is no fishery or other human activity conducted on known seamounts.

The reporting indicated growing experience of habitat restoration within Contracting Parties for *Zostera* and *Ostrea edulis* beds, with examples also noted for *Modiolus* beds and intertidal *Mytilus* beds. This growing experience supplemented the measures taken to support the natural recovery of habitats such as intertidal mudflats and intertidal *Mytilus edulis* beds. These experiences are potentially useful to build on in view of the NEAES 2030 objectives on ecosystem restoration (see "Gaps and Opportunities").

The adoption of a Roadmap for the implementation of collective actions within the Recommendations for the protection and conservation of OSPAR listed Species and Habitats (2017-2025) (The Roadmap) has supported the implementation of collaborative efforts across the thematic boundaries within OSPAR as well as informing or supporting actions implemented at the national level. However, it is not yet possible to report on the impact or effectiveness of the collective actions.

To improve the understanding of a measure's effectiveness, there is a need to be able to track whether a response is reducing the human activity or pressure of concern, and whether this in turn results in an improvement in the status of the habitat in question. There is progress in our understanding of the linkages between activities, pressures and status, but there are still a number of challenges that limit the OSPAR Commissions ability to determine whether or not the measures are effective. More spatial data are needed, as there are large evidence gaps, especially beyond the coastal zone. The OSPAR Recommendations address many actions, some specific, others more general, making it difficult to determine linkages and causality between action and effect for individual actions, and where more effort could have the biggest effect. Finally, there is a need to take into account the time lag between taking an action and seeing whether it is having the desired effect. This delay depends on a number of factors specific to each of the habitats; in the case of some deep-sea habitats, it could be decades.

Considering listed habitats within Environmental Impact Assessment

The approval of marine licences for certain activities and projects requires some kind of environmental impact assessment (EIA). In 2010 OSPAR adopted Recommendation 2010/05, with the aim of ensuring that the features included in the OSPAR List are specifically taken into consideration when EIAs of human activities are prepared.

The most recent reporting on the implementation of Recommendation 2010/05 took place in 2020. Contracting Parties that are also EU Member States reported that they work towards meeting this Recommendation through the national legislation adopted to implement the EU EIA Directive (2014/52/EU) and the Strategic Environmental Assessment (SEA) Directive (2001/42/EC). Some Contracting Parties also point to other relevant legislation that complements their EIA and SEA obligations. Examples are the EU Habitats Directive (Council Directive 92/43/EEC) including the Natura 2000 network and Habitats Directive assessments, which impose requirements on any plan or project likely to have an effect on a protected site, and the EU Marine Strategy Framework Directive (Directive 2008/56/EC). Also, Norway reported having used the OSPAR List and the background documents for assessments of environmental impacts and in connection with the mapping and monitoring of the seabed around oil and gas installations.

Is the measure working?:

Overall, the approach of using EIA and SEA legislation is an important mechanism for promoting the protection of OSPAR listed threatened and / or declining species and habitats. The fact that the OSPAR List

(OSPAR Agreement 2008-06) and Recommendation 2010/05 are non-binding can mean that the effectiveness of implementation is dependent on overlaps with national practice.

Current reporting on the application of Recommendation 2010-05 focuses on the extent to which species and habitats on the OSPAR List are expressly included within the scope of EIAs / SEAs. It is not possible to determine whether those assessments have resulted in effective mitigation measures or otherwise resulted in the reduction of impacts, and this could be a useful area for further sharing of good practice. Lack of knowledge on the distribution and status of habitats has been identified as a practical barrier.

Within NEAES 2030, OSPAR will establish a mechanism by 2024 to provide that, where Contracting Parties authorise human activities under their jurisdiction or control that may conflict with the conservation objectives of OSPAR MPAs in Areas Beyond National Jurisdiction (ABNJ), such activities are subjected to an EIA or SEA (S5.O3).

The OSPAR network of Marine Protected Areas

Within OSPAR, MPAs are understood as areas for which protective, conservation, restorative or precautionary measures have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment (as defined in Recommendation 2003/03, as amended by Recommendation 2010/02 implementing Annex V of the OSPAR Convention). In 2003, OSPAR adopted a Recommendation to establish an ecologically coherent and well managed network of MPAs, which was then amended in 2010. By 1 October 2021, the OSPAR Network of MPAs numbered 583, including eight that had been collectively designated in ABNJs. The network of MPAs has a total surface area of 1 468 053 km^2, covering 10,8% of the OSPAR Maritime Area and achieving the spatial coverage requirement in Aichi Biodiversity target 11 of the United Nations Convention on Biological Diversity (CBD) and in Sustainable Development Goal 14, target 14,5, to conserve at least 10 per cent of coastal and marine areas by 2020. See: Report and assessment of the status of the OSPAR network of Marine Protected Areas in 2021.

MPAs as a response to conserve benthic habitats:

MPAs form part of a suite of wider management measures which address the reduction or removal of activities and pressures in order to support the conservation and recovery of benthic habitats and the species they support. MPAs are a tool that is applied for the protection of all benthic habitats, not only those on the OSPAR List.

The OSPAR Recommendations for the conservation and protection of the eighteen benthic habitats that it lists as being of particular concern include action to consider whether there are sites that justify selection as MPAs for the protection of these habitats and the species they support. The 2019 reporting on the implementation of these Recommendations identified that many Contracting Parties were designating MPAs to protect coastal and shelf habitats, noting some cases where habitats were not included. For example, two Contracting Parties reported that sea-pen and burrowing megafauna habitats were currently not within their networks of MPAs. An example of alternative approaches to area-based management was reported by the Netherlands, which does not protect sea-pen and burrowing megafauna in the context of the Habitats Directive (Council Directive 92/43/EEC), but has submitted a proposal to the European Commission for the designation of a 2 000 km^2 'seafloor protection area' as a contribution to achieving the seafloor integrity targets under the MSFD.

In Scotland, a community marine biodiversity monitoring handbook has been created in order to build up citizens' scientific skills for the collection of data that can be used in the condition assessment and management of MPAs and the wider marine environment. An example of transboundary protection can be seen for *Lophelia pertusa* in the Tisler Reef, involving bilateral collaboration between MPAs in two Contracting Parties: The Kosterhavet National Park in Sweden and the Ytre Hvaler National Park in Norway. Other forms of area-based conservation actions have also been reported as responses to the habitat Recommendations. Since July 2019, Norway has closed 10 areas of coral gardens to fishing in the waters around Svalbard and, while these have not been reported as MPAs to OSPAR, the areas are fully protected.

The ecological coherence of the OSPAR MPA network for benthic habitats

One of the criteria for understanding whether the network is achieving the ambition of ecological coherence assesses how well represented the OSPAR listed habitats are within the network, and how many MPAs these habitats occur in. This can help identify where the network may need to be further strengthened.

The "one out, all out" principle applies, so if there is either insufficient representativity or replication within the network for one region where the species is under threat and / or decline, then the criteria for ecological coherence are not met. In the 2021 MPA Status Assessment, half of the eighteen habitats listed by OSPAR as threatened and / or declining are considered to be adequately represented and replicated by the OSPAR MPA network. OSPAR listed habitats in the Arctic Waters Region are notably underrepresented in OSPAR MPAs. *Cymodocea* meadows are not represented at all, and carbonate mounds not sufficiently replicated, representing a gap in the ecological coherence of the MPA network.

Table R.1: Overview of the ecological coherence (representation and replication) of threatened and declining benthic habitats within the OSPAR MPA network (Source: Table 2.7 of the 2021 MPA status assessment)

Key:

There is MPA protection in OSPAR Region(s) where the habitat is considered to be under threat/ subject to decline
The habitat is not protected in a Region where it is considered to be under threat and subject to decline
The habitat is not known to occur in that Region
The habitat is present in the Region and protected but not considered to be under threat or in decline

The number represents the number of MPAs designated for that feature in the given Region. The number is only bolded in Regions where the feature is of particular concern.

OSPAR T&D fish species	I - Arctic Waters	II - Greater North Sea	III - Celtic Seas	IV - Bay of Biscay and Iberian Coast	V - Wider Atlantic
Carbonate mounds	0			0	1
Coral gardens	2	2	0	4	12
Cymodocea meadows				0	
Deep-sea sponge aggregations	0	5	0	2	7
Haploops		3			
Intertidal mudflats	2	21	23	11	
Intertidal *Mytilus edulis* beds on mixed and sandy sediments		14	11	4	
Kelp forests	0	0	0	0	0
Littoral chalk communities		9	3		
Lophelia pertusa reefs	8	2	1	3	10
Maerl beds	0	12	25	5	0
Modiolus modiolus beds	0	11	11	1	0
Oceanic ridges with hydrothermal vents/fields	0				2
Ostrea edulis beds		2	2	3	
Sabellaria spinulosa reefs	0	10	3	5	0
Seamounts	0			1	12
Sea-pen and burrowing megafauna communities	1	16	17	1	4
Zostera beds	1	27	34	13	

Management status of the OSPAR MPA network

At the 2010 OSPAR Ministerial Meeting in Bergen, Norway, OSPAR ministers committed to ensuring that the OSPAR MPA network is well managed, namely that coherent management measures are set up and are being implemented to achieve the conservation objectives for the protected features of OSPAR MPAs. While there is no formal agreement on what constitutes 'well managed' in terms of an MPA, four questions have been posed to help understand progress in implementation: whether the MPA management has been documented, whether measures to achieve the conservation objectives of the MPA are being implemented, whether monitoring is in place to assess if the measures are working, and finally whether the MPA is moving towards its intended conservation objectives.

OSPAR has made progress on the management of the MPA network. The 2021 status assessment showed that 88% of OSPAR MPAs have either full or partial management information in place which is publicly documented. The report showed a rise in the implementation of measures considered to be required in order to achieve conservation objectives; they had increased by 17% since assessments began in 2016, to 83%. Another area of improvement was the increase in monitoring to be able to detect progress towards achieving conservation objectives. The assessment showed that 75% of OSPAR MPAs have either full or partial monitoring programmes, although these are largely based on the ability to monitor sea users' compliance with the rules and regulations associated with OSPAR MPAs, as opposed to direct site condition monitoring, which is costly. Nearly half of OSPAR MPAs are thought to be moving towards achieving their conservation objectives. It is important to note that the percentage of OSPAR MPAs achieving or moving towards their conservation objectives has increased over time, from 36% to 44% and then 49% for 2016, 2018 and 2021 respectively. Despite improvements in understanding the management status of the MPA network, it is still difficult to determine whether the protected features of OSPAR MPAs are moving towards their conservation objectives, owing to lack of site-specific information or long-term monitoring programmes, as noted above.

Future OSPAR work should focus on implementing the management measures considered necessary to achieve the conservation objectives of the protected features of the MPAs. In parallel, there is a need for long-term monitoring programmes to be established to evaluate the effectiveness of management measures to be able to conclude with greater confidence that the conservation objectives of the protected features of OSPAR MPAs are being achieved. In addition, work should progress on improving the methods for evaluating the degree to which the OSPAR MPA network is sufficiently well managed to support a more sophisticated assessment of whether it is delivering a genuine conservation benefit to targeted habitats, species and ecological processes as well as the wider marine environment.

There should be continued effort to further the Collective Arrangement (OSPAR Agreement 2014-09) and to cooperate through other mechanisms, such as Memoranda of Understanding, with the relevant competent management authorities, so that they can consider appropriate management actions to help deliver the conservation objectives for OSPAR MPAs in ABNJs.

Is this measure working?:
OSPAR is progressing towards key metrics in terms of area-based protection; however, there are still gaps in geographic coverage (particularly in the Arctic Waters Region), in ecological coherence and in understanding whether or not management is effective. Within the NEAES 2030, the Contracting Parties committed to further developing the OSPAR network of MPAs and other effective area-based conservation measures (OECMs) by 2030 to cover at least 30% of the OSPAR Maritime Area to ensure that it is representative, ecologically coherent and effectively managed to achieve its conservation objectives (Objective S5.O1). This ambition is in line with target three of the Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework adopted in December 2022.

The mandate of OSPAR is restricted when it comes to management of certain human activities, and effective implementation relies on action by the Contracting Parties in areas under national jurisdiction and with other competent organisations in ABNJs. However, the common ambition of a regionally coherent network is important and brings useful attention to the protection of threatened and / or declining habitats. Under NEAES 2030, OSPAR has committed to establishing a mechanism whereby, if Contracting Parties seek to authorise human activities under their jurisdiction or control that may conflict with the conservation objectives of OSPAR MPAs in ABNJs, those activities are subjected to an Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA).

The requirement within the measure for regular reporting provides a valuable mechanism for tracking progress and accountability. There is, however, a need to continue improving the availability of data relating to the OSPAR MPA network in order to better inform those responsible for managing different human activities in the marine environment. This includes information on the features that are protected, the management plans that are in place, and the development necessary in order to deliver on NEAES S11.O2 ("By 2023, and every six years thereafter, OSPAR will assess at a regional scale the OSPAR network of marine protected areas in respect of the resilience of marine biodiversity to climate change, with the aim of ensuring that the network provides a good representation of species and habitats and that its spatial design and management regime remains relevant").

Understanding the management effectiveness of MPAs within a network, and the network itself, remains an important gap to address. Under NEAES 2030, the OSPAR Contracting Parties have committed to identifying barriers to the effective management of MPAs and taking steps to address them appropriately, to enable all OSPAR MPAs to achieve their conservation objectives by 2024 (NEAES S5.O2).

Other OSPAR measures responding to relevant human activities and pressures

Fish and shellfish harvesting (professional and recreational) [Extraction of living resources]:
Article 4 of Annex V of the OSPAR Convention sets out that no programme or measure concerning a question relating to the management of fisheries must be adopted under that Annex. However, where the OSPAR Commission considers that action is desirable in relation to such a question, it must draw that question to the attention of the competent authority or international body. Where action within the competence of the OSPAR Commission is desirable to complement or support action by those authorities or bodies, the Commission must endeavor to cooperate with them.

One response to help facilitate this type of cooperation is the Collective Arrangement between competent international organisations on cooperation and coordination regarding selected areas in areas beyond national jurisdiction in the North-East Atlantic' (Collective Arrangement, OSPAR Agreement 2014-09). This is a formal agreement between the legally competent authorities responsible for managing human activities in the ABNJs in the North-East Atlantic. To date, the Arrangement has been adopted by OSPAR and the North-East Atlantic Fisheries Commission (NEAFC) and focuses on selected geographic areas. In the case of OSPAR, the arrangement applies to the MPAs designated outside of national jurisdiction, and in the case of NEAFC, to certain areas with fishery closures; these areas are maintained as a list in Annex 1 to the Arrangement by the respective organisations. There is a strong overlap in these geographic regions enabling each organisation to act within its own field of competence in a manner that is coherent and complementary.

The Collective Arrangement has successfully provided a framework for productive informal dialogue, not only between OSPAR and NEAFC, but also with other relevant competent organisations. In 2017, a joint commitment was submitted under target 4.c of SDG 14 through which both Secretariats undertook to further promote the Collective Arrangement and widen its collaborative scope with the secretariats of intergovernmental organisations and bodies in other regions and sectors.

Please refer to Important measures taken by other competent bodies for more information about measures implemented by other competent organisations relevant to OSPAR's work, and OSPAR Feeder Report 2021 - Fisheries.

Eutrophication *(including from* **Agriculture)**
Eutrophication Thematic Assessment
Eutrophication results from excess nutrient and / or other organic enrichment and can lead to nuisance and toxic algal blooms, loss of benthic habitats through shading, and modification of benthic fauna communities due to specific sensitivities. Action to address eutrophication is a longstanding aspect of OSPAR's work, triggered in response to serious eutrophication effects found in the 1970s and 1980s. Agreement was reached on a target reduction in nutrient inputs of the order of 50% between 1985 and 1995 (PARCOM Recommendation 88/2)

OSPAR measures and the subsequent implementation of measures adopted in the EU, the European Economic Area and other international forums have had some effect in improving the eutrophication status of the OSPAR Maritime Area (including the Urban Waste Water Treatment Directive (91/271/EEC); the

Nitrates Directive (91/676/EEC); the Water Framework Directive (2000/60/EC); the Marine Strategy Framework Directive (2008/56/EC)).

The eutrophication status of the OSPAR Maritime Area has improved, and in the assessed Regions (Greater North Sea, Celtic Seas and the Bay of Biscay and Iberian Coast), benthic habitat status in relation to nutrient and / or organic enrichment is considered good, based on data reported for the EU WFD (See: Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment). There are still regional variations and local problem areas, however, particularly in areas sensitive to nutrient inputs, such as estuaries, fjords and bights, and in areas affected by river plumes. Work to "Tackle eutrophication, through limiting inputs of nutrients and organic matter to levels that do not give rise to adverse effects on the marine environment" remains a strategic objective for OSPAR under NEAES 2030 (Strategic Objective 1). One of its operational objectives focuses on the application of nature-based solutions to safeguard the natural capacity of the ecosystem to sequester nutrients through the conservation and restoration of estuarine, coastal and marine habitats (S1.O6).

Renewable energy generation

OSPAR Feeder Report 2021 - Offshore Renewable Energy Generation

Commitments to increase renewable energy production are leading to the rapid and, in some areas, extensive development of marine renewable infrastructure. There are several measures of relevance to the conservation and protection of benthic habitats, including some relating to environmental impact assessment and marine spatial planning as well as others specifically for guidance relating to the need to take nature conservation into account in renewable developments.

OSPAR produced guidance on the environmental considerations for offshore wind farm development in 2008 (OSPAR Agreement 2008-03). This guidance is aimed at approval authorities, to help them identify issues that may be associated with the environmental impacts of development at the operational and decommissioning stages. It covers the potential impacts for benthic habitats of different phases and elements of the structures, including power cables. The guidance also refers to other measures relevant to managing the impacts from the development of renewable energy infrastructure, including the EU Habitats Directive (Council Directive 92/43/EEC) and the Environmental Impact Assessment Directive (2014/52/EU). A 2020 survey of OSPAR Contracting Parties showed that the offshore wind guidance was generally fully implemented or that implementation was in progress, although not all Contracting Parties provided information for the survey. OSPAR also maintains a database of individual marine renewable developments, including tidal and wave, as well as offshore wind, installations.

The development of offshore renewable energy infrastructure may also have unintended consequences for benthic habitats, on the one hand by increasing hard substrate and reducing fishing with bottom-contacting gears, which could have a positive impact on benthic habitats; and on the other hand, by increasing hard substrate and possibly creating stepping stones to facilitate the movement of non-indigenous species. For OSPAR Contracting Parties that are also EU Member States, the European Commission's offshore renewable energy strategy (Regulation 2020/741) refers to the Birds and Habitats Directives (Directive 2009/147/EC of the European Parliament and the Council and Council Directive 92/43/EEC, respectively) to ensure that developments do not have negative impacts on listed species or habitats, and that any potential impacts are reduced or minimised. Guidance has been developed under EU Commission notice C (2020) 7730 as well as in the Wildlife Sensitivity Mapping Manual, which provides practical guidance for renewable energy planning within the European Union. By 2023, OSPAR will develop common principles, and by 2024 develop guidance, for promoting and facilitating sustainable development and the scaling-up of offshore renewable energy in a way that minimises cumulative environmental impacts (S12.O4).

Extraction of minerals

Aggregate extraction: OSPAR Agreement 2003-15 on sand and gravel extraction requires Contracting Parties which are coastal states of the Maritime Area to take the ICES Guidelines for the Management of Marine Sediment Extraction into account within their procedures for licensing the extraction of marine sediments (including sand and gravel). The Agreement encourages (i) the adoption of an ecosystem-based approach to the management of human activities in general plans for sediment extraction that are subject to strategic environmental assessment; and (ii) the placement of controls on the extraction of sediments from any ecologically-sensitive site. Mitigation could include measures such as seasonal closures for specific areas; the rotation of dredging intensity to allow the recolonisation and recovery of benthic habitats; and exploratory restoration techniques. The ICES guidelines are subject to a forthcoming review. See: OSPAR Feeder Report 2021 – Extraction of non-living resources

Deep-sea mining

Restructuring of seabed morphology, including dredging and deposit of materials

The dredging and dumping of waste and other matter have been well regulated since the Oslo Convention came into force in 1974. OSPAR has adopted guidelines for the management of dredged material at sea (OSPAR Agreement 2014-06) designed to assist Contracting Parties in the management of dredged material in ways that will prevent and eliminate pollution in accordance with Annex II to the 1992 OSPAR Convention, and to protect marine species and habitats in the OSPAR Maritime Area in accordance with Annex V. These set out a Best Environmental Practice approach for minimising both the amount of material dredged and the impacts of dredging and disposal. The guidelines include specific information on appropriate placement of dredged material in relation to the OSPAR List of threatened and /or declining species and habitats (OSPAR Agreement 2008-06). National authorities use these guidelines to manage dredging and dumping and to minimise effects on the marine environment. They also serve as a tool that Contracting Parties which are also EU Member States can use in managing dredged material that is subject to current European Directives (such as the Water Framework Directive 2000/60/EC, the Marine Strategy Framework Directive 2008/56/EC, and the Natura 2000 areas under the Birds and Habitat Directives 2009/147/EC and 92/43/EEC). Directive 2008/98/EC of the Parliament and of the Council of 19 November 2008, concerning waste (the Waste Framework Directive) has also been identified by the Contracting Parties as having implications for the management of dredged material, in addition to relevant national legislation.

Since 2000, the assessment and licensing procedures for dredged materials in most OSPAR countries have included action levels for contaminant loads based on the OSPAR guidelines. Since 1998, OSPAR has also had guidelines in place on the dumping of fish wastes (OSPAR Agreement 1998-21). The management of dredged material should respect the natural processes of sediment balance. Selecting the appropriate location for a dumpsite is essential in order to minimise environmental impact. Several dumpsites have been relocated after application of the OSPAR guidelines: a planned site in the Weser estuary was relocated after a site survey detected a mussel bank. Dumpsites have also been relocated or closed to avoid impacts on MPAs, fisheries and shipping. The ban on dumping vessels or aircraft has been implemented successfully.

A report on the use of the OSPAR guidelines was presented to OSPAR's Environmental Impacts of Human Activities Committee (EIHA) in 2020. Reports from Contracting Parties have indicated that the 2014 dredging guidelines are being fully implemented in the greater part of the OSPAR Maritime Area (§6.46 Shipping and Ports Feeder report). Under NEAES 2030, OSPAR will assess, review and potentially revise the OSPAR criteria, guidelines and procedures relating to the dumping of wastes or other matter and to the placement of matter by 2023 (S7.O4).

Extraction of oil and gas including infrastructure [Extraction of non-living resources]:
Oil production activities have a localised impact on benthic habitats. While this activity is in decline, there are still more than 1 350 operational installations, with an increasing number reaching their end of life in the next two decades. A number of the OSPAR measures relating to the management of offshore oil and gas activities refer to the need to consider the impacts on habitats associated with construction, decommissioning or contamination during operation. Examples are OSPAR Decision 98/3 on the disposal of disused offshore installations and OSPAR Recommendation 2006/5 on a management regime for offshore cuttings piles. Measures taken under the offshore oil and gas strategy have had a high level of implementation, with reductions in the discharge of contaminants and fewer localised impacts recorded following the implementation of management regimes for offshore cuttings piles.

Marine litter

Marine Litter Thematic Assessment - Response
Marine litter can alter or degrade benthic habitats through physical disturbance, smothering or contamination (NOAA, 2016). Plastics and fishing gear account for most of the litter detected on the seafloor that is likely to cause harm to benthic habitats (see: Marine Litter Thematic Assessment – State). In 2021, OSPAR concluded delivery of its First Regional Action Plan for Marine Litter (OSPAR Agreement 2014-01). Despite high engagement and the successful delivery of the actions under this plan, the quantities of marine litter in the North-East Atlantic remain high.

In 2022 OSPAR adopted the Second Regional Action Plan for Marine Litter (OSPAR Agreement 2022-05), which continues the drive towards achieving the NEAES Strategic Objective of preventing inputs of and significantly reducing marine litter, including actions to address harm from marine litter and the identification and removal of ghost fishing gear.

Transmission of electricity and communications (cables) [Production of energy]:
To date, no common programmes or measures have been developed by OSPAR with respect to the placement of sub-sea cables. There are, however, examples of requirements for assessment under national permit application procedures, including in respect of physical disturbance of benthic habitats or changes in community composition as a result of temperature changes. In Germany, for example, the nature conservation authorities have agreed on a maximum tolerable temperature increase threshold of 2 K in 20 cm depth in the sediment in German offshore areas, which requires the burial of cables at depths of approximately one metre and more. This 2 K value was considered appropriate as applying the precautionary approach to protect benthic organisms and communities from cable-induced temperature rises. The effectiveness of this measure has not yet been reported.

Scientific research [Education and research]:
Generating further scientific information about deep-sea ecosystems protected by MPAs is listed as one of the actions in the relevant management recommendations. The OSPAR code of conduct for responsible marine research in the deep seas and high seas of the OSPAR Maritime Area (OSPAR Agreement 2008-01) was adopted to facilitate this work and to ensure that minimum damage is caused to ecosystems through research activities. It includes guidance to "avoid, in the course of scientific research, activities which could lead to substantial physical, chemical, biological or geological changes or damage to marine habitats" and calls for the utmost care to ensure that OSPAR listed features are not disturbed or damaged. No information is requested on the state of implementation of this measure.

Marine aquaculture

OSPAR Feeder Report 2021 - Aquaculture
The primary measure for addressing the environmental impacts of marine aquaculture on benthic habitats, including impacts from contaminants and nutrient enrichment, is to take site-specific decisions on the location and management of aquaculture on the basis of assessments made of projects conducted under individual countries' regulatory systems. OSPAR has taken few specific measures on aquaculture. OSPAR guidelines on the reporting of nutrient discharges / losses from marine and freshwater aquaculture plants were issued in 2004 and revised in 2018 (OSPAR, 2018). Under the Riverine Inputs and Direct Discharges (RID) programme there is some reporting of inputs from aquaculture (nutrients, heavy metals and certain organic pollutants). PARCOM Recommendation 94/6 covers the reduction of inputs from potentially toxic chemicals used in aquaculture, although reporting ceased in 2006. Since there are now significant developments in the aquaculture industry giving rise to concern about pollution, OSPAR decided in 2020 to initiate a new reporting round on Recommendation 94/6 in 2022.

Other relevant activities

Tourism and leisure infrastructure has been identified as an activity affecting benthic habitats, but no measures have been taken to address this. However, infrastructure development activities for tourism, transport or coastal defences will be subject to environmental impact assessment and covered by OSPAR Recommendation 2010/5.

Important measures taken by other competent bodies

This section highlights measures that have been taken by other competent bodies which complement OSPAR's response for improving the state of benthic habitats within the North-East Atlantic.

General conservation measures

There are a number of general measures at the European level that are important in addressing the state of benthic habitats of the North-East Atlantic in the coastal zone and beyond, in particular Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive), which includes the designation of a network of areas to protect habitats identified in its annex 1 and 2 (N2000); and the EU Water Framework Directive 2000/60/EC, which applies to coastal waters up to one nautical mile offshore and requires EU member states to take measures to prevent deterioration of the ecological and chemical status of waters, restore polluted waters, reduce pollution and cease or phase out inputs of hazardous substances. Directive 2014/89/EU establishing a framework for maritime spatial planning is seen as a tool to implement the ecosystem approach and is relevant to all human activities that could potentially affect benthic habitats; it is also intended to ensure that planning retains ecosystem benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention.

Benthic habitats are considered under Descriptor 1 (Biodiversity) of the Marine Strategy Framework Directive, which notes consistency with and connects to action under the Habitats Directive (including the Natura2000 network). EU member states are required to identify programmes of measures to be undertaken in order to achieve good environmental status in their waters, including for benthic habitats. Equivalent national frameworks, including programmes of measures, also exist in non-EU member states that are OSPAR Contracting Parties.

Another example within a sub-region of the Greater North Sea OSPAR Region is the Trilateral Wadden Sea Cooperation, an agreement between the Governments of Denmark, Germany and the Netherlands. This measure recognises the particular ecological value of this coastal area and the need to coordinate any responses to ensure conservation and sustainable management and maintain natural processes. The agreement aims to be consistent with the obligations under the EU Birds and Habitats Directives. The Dutch-German-Danish Wadden Sea has been placed on the UNESCO World Heritage List for its Outstanding Universal Value as the largest unbroken system of intertidal sand and mud flats in the world, with significance for biodiversity on a global scale, including *Sabellaria* reefs and seagrasses.

Fish and shellfish harvesting (professional and recreational) [Extraction of living resources]:

OSPAR Feeder Report 2021 - Fisheries
OSPAR does not itself have the competence to address questions relating to the management of fisheries. However, given that fisheries are a key human activity affecting the state of biodiversity, including in benthic habitats, OSPAR maintains a watching brief on responses taken to address fisheries management by the relevant competent organisations.

There is a global framework for fisheries management which establishes common principles, including conservation measures relating to vulnerable marine ecosystems (VME), a subset of which are included on the OSPAR List. These include United Nations General Assembly Resolution 64/72 on Sustainable fisheries and the UN Food and Agriculture Organization (FAO) International Guidelines for the management of deep-sea fisheries in the high seas, relating to deep-sea ecosystems.

Within the North-East Atlantic, the ICES has been advising relevant competent authorities, including the North-East Atlantic Fisheries Commission (NEAFC) and the EU, on the potential for damage to vulnerable habitats from fishing activity since the early 2000s. A number of measures have been taken, including some relating to gear restriction and to habitat protection through fishery closures.

In the context of the EU, a new regulation 2019/1241 on the conservation of fishery resources and the protection of marine ecosystems through technical measures was adopted to support the implementation of the EU Common Fisheries Policy. It addresses the reduction of ecosystem impacts (including on benthic habitats) through approaches such as closed areas and measures to regulate certain fishing gear. In addition, regulation EU 2016/2336 establishes specific conditions for fishing for deep-sea stocks in the North-East Atlantic and international waters, drawing on the best available scientific advice and setting out specific requirements to protect VMEs from fishing operations that use bottom-contacting gears between a depth of 400 and 800 m (ICES, 2021).

In areas beyond national jurisdiction, the NEAFC started to implement measures to address the possible adverse impacts of bottom fisheries in the early 2000s. In addition to the conservation of deep-sea fish species, these measures also aimed to address habitats or VMEs that are susceptible to lasting damage from bottom-contacting gear. A recommendation on the Protection of Vulnerable Marine Ecosystems in the NEAFC Regulatory Area is subject to periodic review, based on the latest scientific advice provided by the ICES, and the current amendment (Recommendation 10:2021) is in force until 31 December 2027. A 2019 review for the NEAFC concluded that implementation of its regulation on vulnerable marine environments had been largely effective; further action to improve monitoring and management advice has been agreed by the NEAFC (NEAFC, 2020). Continuing work by the ICES / NAFO (Northwest Atlantic Fisheries Organization) joint group on deep-water ecology is improving understanding of vulnerable ecosystems and the management tools needed to protect them (ICES, 2020).

Transport shipping [Physical damage / Pollution of oil and other noxious substances]:
The designation of Particularly Sensitive Sea Areas under Resolution A.982(24) on Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas (PSSAs) is a response developed by the International Maritime Organization (IMO) to address potential environmental hazards from shipping, in particular in ecologically sensitive areas. These hazards are identified as relating to operational discharges, accidental or intentional pollution and physical disturbance to habitats. The impacts may include the smothering of habitats and contamination by anti-fouling systems or by other substances through groundings. Within the OSPAR Maritime Area, PSSAs have been designated in the Wadden Sea (2002) and in the Western European Waters (2004). No reports on the effectiveness of PSSAs for benthic habitats were found.

Extraction of minerals [Extraction of non-living resources]:
Deep-sea mining: The development of exploitation technology and mitigation or restorative techniques for deep-sea mining is at an early stage, and there are substantial gaps in our understanding of their effects. (Aggregates Feeder report §6.6).

The International Seabed Authority (ISA) is the competent organisation for the management of mining activities in the Area. The ISA is established under the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and operationalised through the 1994 Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea. Through ISA, State Parties to UNCLOS shall organise and control all mineral-resources-related activities in the Area for the benefit of humankind as a whole. In doing so, ISA has the mandate to ensure the effective protection of the marine environment from harmful effects that may arise from such activities. The ISA uses i.a. Regional Environmental Management Plans as tools for the effective protection of the marine environment by establishing regional goals and objectives and providing a basis for decision making in a given geographic region. Regulations on prospecting and exploration for cobalt-rich ferromanganese crusts, polymetallic nodules and sulphides have been adopted by the ISA as of July 2012. The Council of the ISA is currently negotiating regulations for the potential exploitation of these minerals.

OSPAR and the ISA cooperate through an MoU (Agreement 2010-09).

Regional differences

Within the Greater North Sea (Region II), Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV) there are many measures in place aiming to reduce the pressures from human activities on the status of benthic habitats, especially where OSPAR Contracting Parties are also EU Member States. There are fewer such measures for Arctic Waters (Region I) and the Wider Atlantic (Region V), reflecting the lower pressures from human activities in these Regions. Actions to implement OSPAR measures at the national level are often also reported to fulfil other obligations, and vice versa (e.g., as collective actions under the MSFD), further complicating the task of understanding the added value of particular responses. In the Arctic Waters Region there are more national level responses.

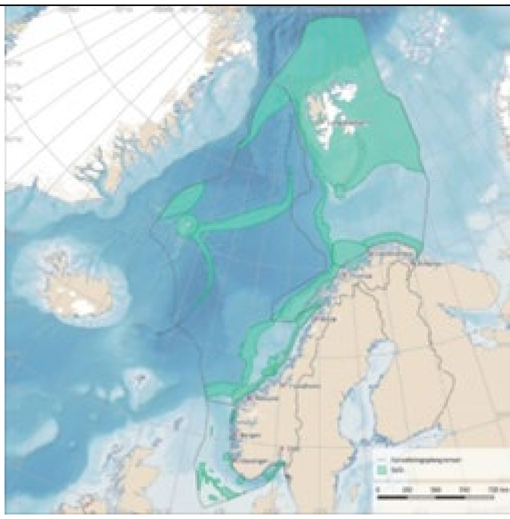
Case Study: Arctic Waters

Norwegian national measures for holistic management of open seas marine ecosystems, including benthic habitats

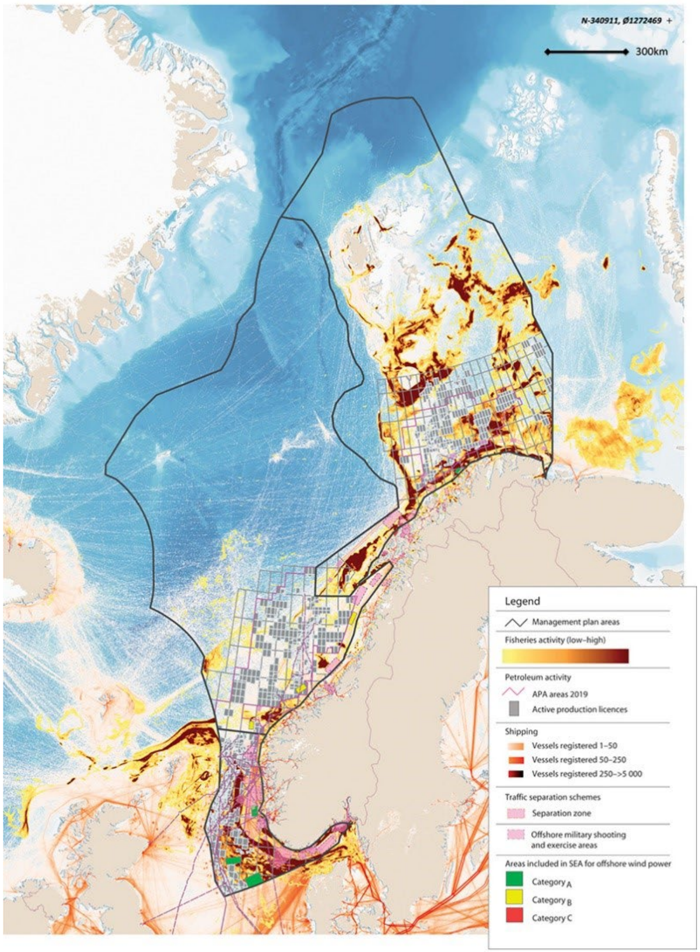
Norway is not a member of the European Union and is not implementing the Marine Strategy Framework Directive (MSFD). Norway has developed and is taking measures for managing open seas marine ecosystems through holistic ecosystem-based plans, for all marine areas under Norwegian jurisdiction **(Map 1).** The area covered by the management plans is approximately 2,4 million km^2 and constitutes a substantial part of OSPAR Region I. The area includes habitats ranging from near-coastal waters, open waters, deep sea plateaus, volcanic under-water mountain ridges, shelf seas and the polar ice region.

The management plans are tools for facilitating both value creation and food security, and for maintaining the high environmental value of Norway's marine areas through the sustainable use of marine natural resources and ecosystem services. Value creation from ocean-based activities **(Map 2),** such as fisheries and aquaculture, shipping, petroleum activities and emerging new ocean industries, depends on maintaining good environmental status and high biodiversity in the marine and coastal environment, safeguarding the oceans as a source of food, and using ocean resources sustainably.

A set of particularly valuable and vulnerable areas (SVOs) has been identified as being of great importance for biodiversity and biological production; they form an entire management plan area **(Map 1).** The SVOs are selected using predefined criteria similar to those used in identifying ecologically or biologically significant marine areas (EBSAs) under the Convention on Biodiversity (CBD)[4]. They provide key guidance on where anthropogenic activities must be managed with particular care in order to avoid damage to ecosystem components, guide maritime planning and activities to minimise destructive impacts on the marine ecosystems and secure ecosystem hotspots of key importance to so as to maintain the rich productivity and biodiversity inside and beyond the Norwegian EEZ. For instance, the management plan for the Norwegian Sea (2008-2009) stated that Norway would map known coral habitats so that they could be more effectively protected against damage from fishing operations. This led to an extensive national seabed mapping effort, with the result that Norway (2021) has now registered more reefs of the coldwater coral *Lophelia pertusa* than any other country, most of them in the Norwegian Sea[1].



Map 1: Outlines of the Norwegian EEZ, separated into North Sea, Norwegian Sea and Barents Sea areas, with green shading indicating current SVOs. Taken from [1]

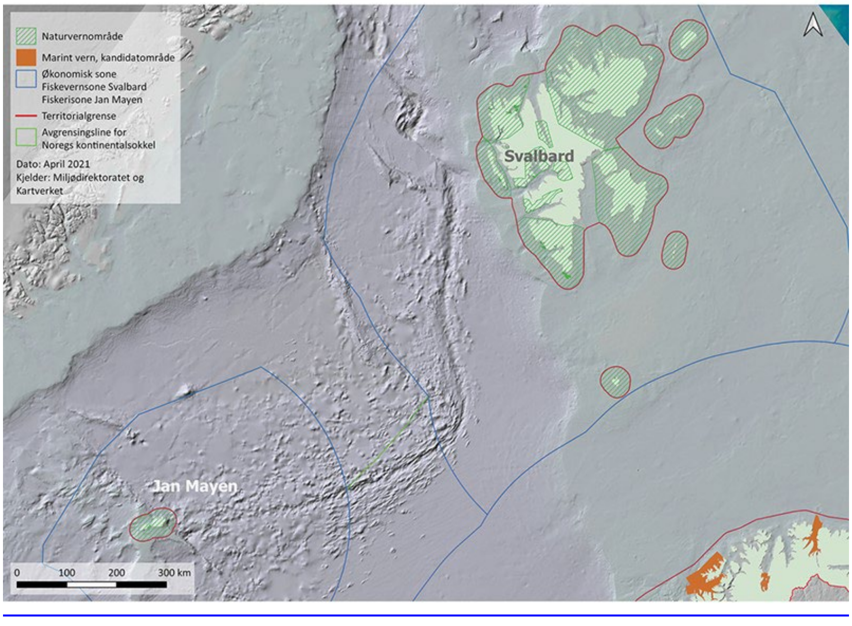


Map 2: Overview of ocean-based activities in the management plan areas. Taken from [1]

Marine Protected Areas

The management plans clarify an overall framework for ocean-based industries and set out measures for the conservation and sustainable use of marine ecosystems. They encourage closer coordination and clear priorities for the management of Norway's marine areas. The various sectoral authorities are responsible for implementing the measures set out in the management plans, under relevant legislation that they administer. In addition, a White Paper on the protection of marine nature was published in 2021 (**Maps 3a, b**).

Map 3a: Existing (blue/green), planned (dark/light orange) and suggested (grey) MPAs in Norway as well as selected MPAs for the protection of coral reefs (red crossbars). The red full line is the 12 nm territorial line. Taken from [2]



Map 3b: Marine national parks at Svalbard and in the open sea (green crossbars). The red full line is the 12 nm territorial lines. Taken from [2]

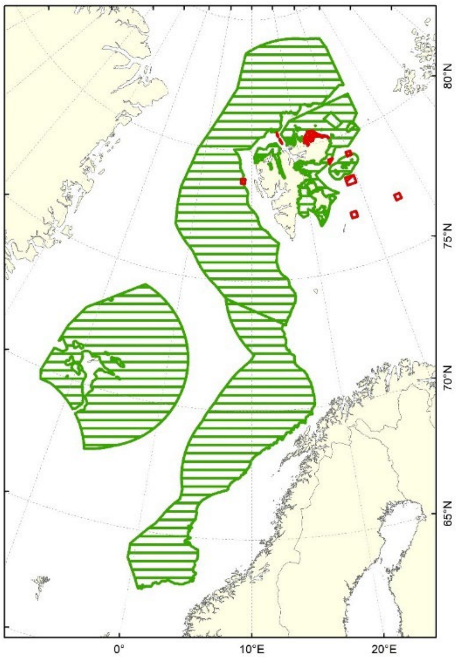
Habitat protected areas

The protection of cold-water coral reefs from smothering and other damage from fishing activities, has resulted in a series of small, local protection zones **(Map 4).** The protection of major cold-water coral reefs is in accordance with some of the measures under the OSPAR Recommendation on *Lophelia* reefs.

Map 4: Protective areas (red cross-barred boxes) and known and documented coral reefs (orange dots) along the Norwegian coastal shelf and the slope towards the deep-sea basins. The red full line is the 12 nm territorial lines. Taken from [2]

Fisheries restricted areas

Besides the protective areas in map 4, area closures are also in effect to protect vulnerable bottom habitats and vulnerable species in Norway's sea areas. **Map 5** shows the large areas closed to protect vulnerable bottom habitats (more information in [5]). Many areas are closed to bottom fisheries to protect juveniles of commercial species, and some of them are dynamic in space and time. Such areas are not included in this case study.



Map 5: Sea areas closed to bottom fisheries (green crossbars) and no-fishing boxes in fishing fields (red boxes). Source: The Norwegian Directorate of Fisheries database "Yggdrasil", January 2023

The areas closed in order to protect vulnerable species include the 56 areas closed to protect lobster along the southern coastline. The first lobster reserves were established in 2002, with a successful outcome [3]. Since then, more such reserves for lobster protection have been planned and established by coastal municipalities, building on the positive impact documented over the past 20 years.

References

[1] Norway's integrated ocean management plans — Barents Sea–Lofoten area; the Norwegian Sea; and the North Sea and Skagerrak — Report to the Storting (white paper): https://www.regjeringen.no/en/dokumenter/meld.-st.-20-20192020/id2699370/

[2] Norway's integrated plan for the conservation of areas of special importance for marine biodiversity: Meld. St. 29 (2020–2021) - regjeringen.no

[3] Knutsen *et al.*, 2022: https://www.sciencedirect.com/science/article/pii/S0308597X21005194

[4] EBSA-publication: Azores Scientific Criteria and Guidance for identifying ecologically or biologically significant marine areas and designing representative networks of marine protected areas in open ocean waters and deep sea habitats: https://www.cbd.int/doc/meetings/mar/ebsaws-2014-01/other/ebsaws-2014-01-azores-brochure-en.pdf. [See annex I, decision IX/20].

[5]Jørgensen *et al.*, 2020: Responding to global warming: New fisheries management measures in the Arctic - ScienceDirect. https://doi.org/10.1016/j.pocean.2020.102423

In the deep seas and areas outside of national jurisdiction, the main response from OSPAR has been to designate MPAs to protect particular benthic features. However, the competence to manage the main human activities of concern that may take place in those areas lies with other organisations, and initiatives such as the Collective Arrangement will need to be strengthened in order to ensure coordination and consistency in achieving conservation and management objectives.

Gaps and opportunities

Are we doing enough?:

On the whole, benthic habitats in the North-East Atlantic continue to be in a poor state, and so the short answer is that the current suite of measures being implemented does not seem to have improved the status of benthic habitats, in particular within EEZs.

It is not possible to answer the question whether these measures are able to reduce the pressures and human activities that continue to undermine benthic habitats in the North-East Atlantic. There are several reasons why this is the case, including how the measures have been designed and how they are reported upon. Many measures are developed to address multiple activities and pressures, and unless the reporting is very explicit, it is not easy, and in many cases impossible, to disaggregate which action addresses which activity or pressure; the same action may be reported as a response to multiple measures.

Are there other types of responses that could be undertaken by OSPAR to improve the status of benthic habitats?:

In 2010, OSPAR ministers committed to halting the decline of species and habitats, with the strategic objective of preventing further loss by 2020, in particular by restoring threatened and / or declining species and habitats through measures designed to protect them from the pressures of human activities (Bergen statement §24). Restoration has been included as a national action in three of the OSPAR Recommendations on actions to address habitats on the OSPAR List (*Ostrea edulis* beds, kelp forest, intertidal mudflats), and currently no collective actions have been taken. There is a need and opportunity for OSPAR to progress the development of responses relating to restoration of degraded habitats, as an integral part of a management approach to reduce pressures and restore vulnerable ecosystems. This need is recognised in the Cascais

Ministerial Declaration (2021), under which OSPAR (§23) commits to playing an ambitious role in the CBD Post-2020 Global Biodiversity Framework that establishes a target for the restoration of ecosystems, including marine ones, as well as in the context of the UN Decade for Ecosystem Restoration. The implementation of this ambition is articulated in NEAES 2030, through a specific strategic objective to restore degraded ecosystems and the operational objectives mentioned below:

Strategic Objective 6: Restore degraded habitats in the North-East Atlantic when practicable to safeguard their ecosystem function and resilience to climate change and ocean acidification.

> **S6.O1** By 2023 OSPAR will identify habitats suitable for restoration, and develop a common knowledge base on the most appropriate and effective methods for restoration of degraded habitats.
>
> **S6.O2** By 2025 OSPAR will develop a regional approach, including relevant qualitative and / or quantitative targets for restoration of degraded habitats suitable for restoration, and will then implement actions to achieve the targets as appropriate.

In addition, there are two other operational objectives that reference restoration of benthic habitats.

> **S1.O6** By 2030 OSPAR will develop and implement a regional approach to applying nature-based solutions to reinstate and safeguard the natural capacity of the ecosystem to sequester nutrients through conservation and restoration of estuarine, coastal and marine habitats, where this is practicable.
>
> **S12.O1** By 2025 OSPAR will develop a regional approach to applying nature-based solutions for carbon storage and implement specific measures to protect and restore relevant carbon sequestration and storage habitats, such as seagrass beds, kelp forests and saltmarshes.

Restoration will also support delivery of another operational objective by strengthening the blue carbon potential and the ambition for OSPAR to take nature-based carbon storage into account by 2025 when reviewing the criteria for the designation of marine protected areas and reviewing the OSPAR List of threatened and / or declining species and habitats (S12.O2).

References

FAO (2009). *International Guidelines for the Management of Deep-sea Fisheries in the High Seas*. Rome. 73pp. https://www.fao.org/docrep/011/i0816t/i0816t00.HTM

ICES (2020). ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 2:62. 171 pp. Available at: http://doi.org/10.17895/ices.pub.6095

ICES (2021) EU Request to advise on the list of areas where VMEs are known to occur or are likely to occur and on the existing deep-sea fishing areas (ref. (EU)2016/2336)

NOAA, National Oceanic and Atmospheric Administration Marine Debris Program. (2016). Report on Marine Debris Impacts on Coastal and Benthic Habitats. Silver Spring, MD: National Oceanic and Atmospheric Administration Marine Debris Program.

NEAFC (2020). Submission by NEAFC to a UN report on actions addressing the impacts of bottom fishing on vulnerable marine ecosystems and the long-term sustainability of the deep-sea fish stocks. Available at: https://www.neafc.org/other/31810

Cumulative Effects

Cumulative effects assessment for benthic habitats

It should be noted that the Sankey plots and associated narratives in this thematic assessment are an illustrative representation of a complex set of interactions between DAPSIR components at the coarse North-East Atlantic scale and should be considered and interpreted alongside the supporting full thematic assessment narrative. The Sankey plots should thus be applied with caution and not considered or used as the sole basis for management decisions.

A range of human activities contribute pressures which cumulatively have the potential to affect the state of benthic habitats and associated ecosystem services *(*which have consequences for societal drivers, e.g., food, energy, space, health, biodiversity*)*. Physical disturbance to the seabed, physical loss, climate change, ocean acidification, inputs of other substances, litter, nutrients, organic matter, other forms of energy, non-invasive species, and mortality and injury of species are the predominant pressures. Following a Driver-Activity-Pressure-State-Impact-Response (DAPSIR) framework and a weighting exercise, an indicative assessment of cumulative effects has been undertaken (see: CEMP Guideline for details) as a first step to describing potential pathways of cumulative causes and consequences of change in the ecosystem linking these to impacts on ecosystem services.

The Benthic Habitats thematic assessment describes the connectivity between the relevant DAPSIR components, and the sections on activities and pressures provide an overview of the evidence available on some of the interactions between these pressures and benthic ecosystems. Sankey diagrams provide a schematic of potential impact pathways describing cumulative causes and consequences of change in the ecosystem, demonstrating that multiple human activities are contributing to multiple pressures which can lead to multiple and cumulative impacts on the state of benthic habitats and the associated ecosystem services (see: CEMP Guideline for details). A better understanding of this complexity in the causes and consequences of cumulative effects from human activities on ecosystem state and ecosystem services is critical in order to apply the ecosystem approach explicitly and target management measures appropriately.

The evidence underpinning the analyses described in this section are drawn from the Driver, Activity, Pressure, State, Impact and Response sections of this thematic assessment, and should thus be read and interpreted alongside the extended narratives provided therein. The sections on Human Activities and Pressures in this thematic assessment provide detail on the threats that the left-hand side of the Sankey plot **(Figure CE.1a)** pose to benthic habitats. The State section of this thematic assessment provides detail on ecosystem state, shown in the centre of the Sankey plot **(Figure CE.1a)** illustrated for benthic habitats. The right-hand side of **Figure CE.1a** incorporates the impact on ecosystem service scores to present the Activity, Pressure, State and Impact components of the benthic habitat 'ecosystem' in a single plot. This is consistent with NEAES operational objective S7.O3 on "ecosystem services and natural capital […] to recognise, assess and consistently account for human activities and their consequences in the implementation of ecosystem-based management".

Figure CE.1a shows the complex combinations of humans and pressures on state changes (left-hand side) and state changes on ecosystem services (right-hand side); however, there is currently insufficient understanding and evidence to be able to directly track from left to right, hence the single bar in the centre. This should be a focus of study to inform future assessments.

Overall, the confidence in the evidence for the weighted bow-tie analysis outputs presented in this benthic habitat thematic assessment is described as **medium for evidence** and **medium / low for degree of agreement**. *The confidence assessment does not currently account for regional or biogeographical variability. The sensitivity of benthic ecosystem components to pressures will vary depending on exposure to ambient environmental variables such as depth, temperature and hydrodynamic conditions (e.g., localised tidal regimes).* Additionally, separate confidence assessments have been applied to each module.

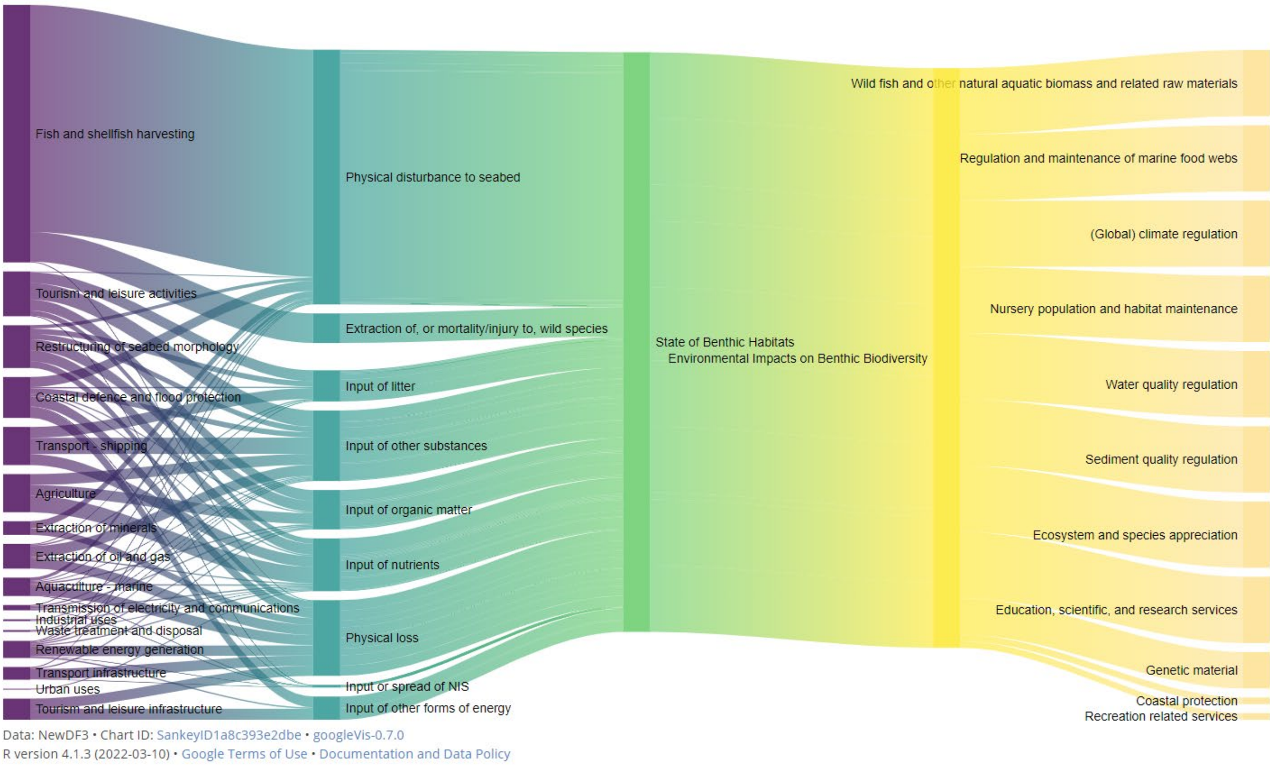


Figure CE.1a: Impact potential of benthic habitats to exposure to pressures from human activities in the North-East Atlantic. Columns left to right: Activity, Pressure, State, Environmental Impact, Ecosystem Service. Derived from Exposure score (Extent x Frequency of pressure) x Degree of Impact score (in terms of whether the impact is acute or chronic). Pressures with a low Degree of Impact score have been removed for clarity. ‘Impact’ in this context does not consider the persistence of the pressure or the resilience of the ecosystem associated with that pressure. Were these parameters to be included, the relative contribution for some pressures will most likely increase. For example, at the NEA scale, non-indigenous species have a small spatial footprint and thus score relatively low in this Figure, but if their persistence and the resilience of the ecosystem to their presence is considered, they score more highly in the relative ranking. Links are weighted to indicate relative contribution to impact. A wider link = greater potential for impact

NOTE: Confidence in Activity/Pressure impacts, apart from Fish and shellfish harvesting and Climate change, is Low. It should be noted that the Sankey plots and associated narratives in this thematic assessment are an illustrative representation of a complex set of interactions between DAPSIR components at the coarse North-East Atlantic scale and should be considered and interpreted alongside the supporting full thematic assessment narrative., The Sankey plots should thus be applied with caution and not considered or used as the sole basis for management decisions.

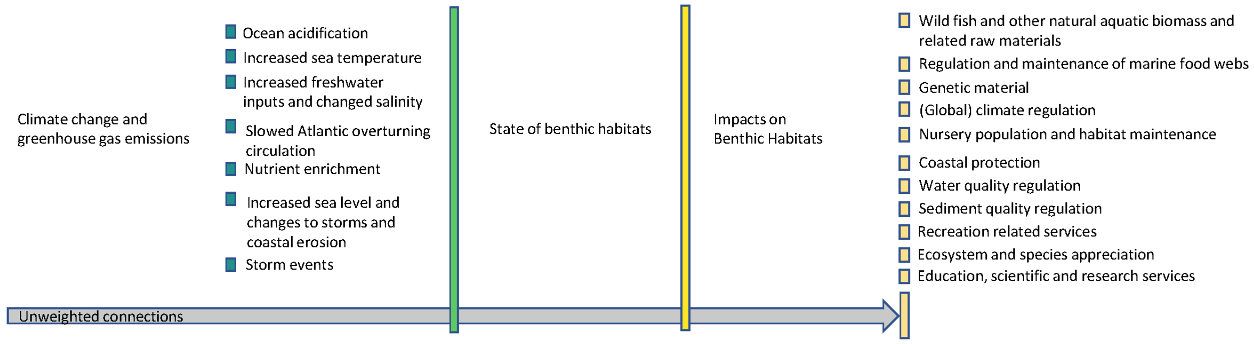


Figure CE.1b: Unweighted assessment of the contribution by climate change and greenhouse gas emissions to pressures affecting benthic habitats in the North-East Atlantic. Columns left to right: Activity, Pressure, State, Environmental Impact, Ecosystem Service

Figure CE.1a and b demonstrate the complex relationships which the collective pressures from human activities exert on the quality status of benthic habitats. This complexity suggests that, while single-issue responses may be effective, in order to fully apply ecosystem-based management OSPAR needs to consider the causes and consequences of changes in ecosystem state more holistically, namely:

- recognise that any measures to reduce impacts, while critical to ecosystem health, could have potential consequences for our ability to maintain ecosystem services to meet society's needs, which in turn has consequences for the viability of human activities in the North-East Atlantic;
- recognise that pressures may have additive, multiplicative, synergistic or antagonistic interactions when combined, with implications for the nature of the threats posed to benthic habitats and how best to manage those threats.

Methodology

See: [CEMP Guideline: Cumulative effects assessment for the QSR 2023 (Bow Tie Analysis)]

A modified bow-tie analysis (Cormier *et al.,* 2018; Cormier *et al.,* 2019) was developed to identify and connect all the DAPSIR components, integrating them into either a pressure (e.g., underwater sound, litter, hazardous substances, eutrophication) or a biodiversity receptor-focused analysis of the causes and consequences of change (e.g., pelagic habitats, benthic habitats, fish, marine birds, marine mammals). For the biodiversity assessments the APS connections are weighted to determine which are the most important, using an adaptation of the ODEMM pressure assessment (Robinson *et al.,* 2013; Knights *et al.,* 2015) focusing on:

1. **Exposure module:** spatial extent and frequency for all activity pressure combinations on state, to generate exposure weightings;
2. **Impact potential module:** spatial extent, frequency of occurrence and impact potential for all activity pressure combinations on state, to generate impact potential weightings;
3. **Risk module:** spatial extent, frequency of occurrence, impact potential for all activity pressure combinations on state, combined with pressure persistence and ecosystem resilience, to generate risk weightings.

The SI (ecosystem services) connections are weighted to determine which are the most important (Cornacchia, 2022).

The impact potential and ecosystem services outputs are combined and presented in Sankey diagrams **(Figure CE.1).**

Confidence in this weightings exercise for benthic habitats has been assessed in accordance with the QSR 2023 guidance. Confidence is based on two criteria to communicate degree of uncertainty in the key findings: (i) level of evidence (determined by considering the type, amount, quality, and consistency of evidence (i.e., Robust, Medium, or Limited)), and (ii) degree of agreement (i.e. High, Medium, or Low).

Exposure module:

Confidence Assessment: Evidence – Medium; Consensus – Medium

Pressures from human activities have been demonstrated in the assessments for this QSR to be widely distributed in the OSPAR Maritime Area. The presence of pressures does not automatically lead to impacts. However, in the first instance, consideration of the spatial and temporal extents of pressures provides a useful basis for our consideration of cumulative effects within a risk-based approach (in line with the North-East Atlantic ecosystem principle and strategic approach).

The exposure module describes how much pressure from human activities exists in the North-East Atlantic. It considers the spatial extent and frequency of human activity pressure combinations which have been identified as important for benthic habitats (derived from spatial extent score multiplied by frequency score). Exposure relates only to the pressure cell in the DAPSIR schema (**Figure CE.1**). Consideration of exposure in isolation provides a coarse cross-cutting assessment to provide an early identification which enables OSPAR to develop management strategies for pressures in order to prevent / minimise impacts.

The thematic assessments for Hazardous Substances, Eutrophication, Marine Litter, Offshore Industry, Human Activities, Climate Change and the Ocean Acidification Other Assessment describe pressures on benthic habitats. Radioactive Substances Committee Thematic Assessment identifies inputs of radionuclides from a range of human activities but has concluded that there are no significant radiological impacts on biodiversity from the current levels of radionuclides.
Climate Change and Ocean Acidification pressures have been identified as important for benthic habitats.

Input of other substances; input of nutrients and organic matter; input of litter; physical disturbance to the seabed; input of radioactive substances; input and spread of NIS; extraction of species; and input of other forms of energy are also identified as important and rank highly for exposure, demonstrating the ubiquitous nature of some of these pressures in the North-East Atlantic.

The exposure scores support the importance that OSPAR places on these pressures in the North-East Atlantic Environment Strategy:

- Strategic Objective 1 to tackle eutrophication by limiting inputs of nutrients and organic matter (and the work of the Hazardous Substances and Eutrophication Committee (Eutrophication Thematic Assessment).
- Strategic Objective 2 to prevent pollution by hazardous substances and the work of the Hazardous Substances and Eutrophication Committee (Hazardous Substances Thematic Assessment).
- Strategic Objective 3 to prevent pollution by radioactive substances and the work of the Radioactive Substances Committee (Radioactive Substances Committee Thematic Assessment)
- Strategic Objective 4 to prevent inputs and significantly reduce marine litter (Marine Litter Thematic Assessment) and the work of the Environmental Impacts of Human Activities Committee (Human Activities Thematic Assessment)
- Strategic Objective 5 to protect and conserve marine biodiversity and ecosystems (this Benthic Habitats thematic assessment, the work of the Biodiversity Committee, including the other biodiversity thematic assessments (Pelagic Habitats Thematic Assessment, Fish Thematic

Assessment, Marine Mammals Thematic Assessment, Marine Birds Thematic Assessment, Food webs Thematic Assessment).

- Strategic Objective S7.02 to develop a coordinated management approach to ensure the number of non-indigenous species introduced via human activity is minimised and where possible reduced to zero.
- Strategic Objective 9 to safeguard the structure and functions of the seabed / marine ecosystems by preventing significant habitat loss and physical disturbance (this Benthic Habitats thematic assessment and the work of the Biodiversity Committee).
- Strategic Objectives 10 to raise awareness of climate change and ocean acidification; 11 to facilitate adaptation to the impacts of climate change and ocean acidification; and 12 to mitigate climate change and ocean acidification.

Multiple human activities have been identified as exerting these pressures in the North-East Atlantic. Any actions to manage these pressures to prevent or reduce impacts on state either individually or cumulatively (collectively) will need to consider if and how these human activities might best be targeted (and the consequences for the associated drivers and ecosystem services) within an Ecosystem Approach.

Impact potential module

Confidence Assessment: Evidence – Medium; Consensus – Medium / Low

The impact potential is incorporated with the exposure module (spatial extent and frequency) of pressures from specified human activities. Impact potential here relates to the generic interaction in terms of a pressure's likely effects on the ecological component, categorised as low potential for significant impact, chronic impact or acute impact (Robinson *et al.,* 2013). **Figure CE.1** shows the combined weighted scores for exposure and impact potential.

Any activity-pressure combination with a low Degree of Impact score was filtered out, following discussion with the expert group. For example, the input of radionuclides has been filtered out based on the conclusions in the Radioactive Substances Committee Thematic Assessment, as the available evidence shows that these have a low potential for resulting in a significant impact. Other pressures filtered out as having low potential for significant impact are inputs of other forms of energy from marine aquaculture, oil and gas extraction and subsea cables.

The relative ranking of pressures changes when impact is considered **(Figure CE.1a).** Physical disturbance to the seabed from multiple activities ranks highest (as it is the most widespread and frequently occurring pressure), as does physical loss of habitats. Climate change and ocean acidification pressures are considered highly important for benthic habitats (see the Climate Change Thematic Assessment for details of contributing human activities and the Ocean Acidification – Other Assessment) and the climate change section, but there is low confidence in incorporating these pressures directly into weighted bow- tie analyses **(Figure CE.1a),** so they are shown separately in **Figure CE.1b**. The Pressures section of this thematic assessment describes the importance of pressures on benthic habitats and corroborates the importance of seabed disturbance and climate change pressures. Although the weighted bow-tie analysis has identified relative rankings for other pressures, the OSPAR Benthic Habitats Expert Group considers that limited evidence exists to confirm these relative rankings. It is thus concluded that the other pressures shown in **Figure CE.1a** should be considered of equal importance until further evidence can be provided (i.e., input of other substances, input of nutrients, input of organic matter, input of litter, mortality and injury of wild species, input of other forms of energy, input and spread of NIS, and others).

Impacts on the state of habitats across OSPAR will vary depending on the variability of activities and pressures across regional areas, as well as variations in their interactions with different habitat types, for example coastal habitats under highly hydrodynamic regimes against deeper habitats highly sensitive to changes in natural environmental conditions. Most of the data available on the status of habitats and impacts have been evaluated using results from the common and candidate benthic indicators for some of the main activities and predominant associated pressures, in particular physical disturbance caused by bottom trawling and aggregate extraction in benthic habitats, and impacts from nutrients on coastal waters. The evaluation of habitat loss is only available for some areas. Additional impacts from pressures to be included in the next round of assessments will help us to build a wider picture of the interactions and effects on benthic ecosystem status. Impacts from climate change and ocean acidification have not been evaluated with a set of indicators; however, there is a wide range of evidence on the sensitivity of these habitats to climatic drivers and acidification effects, which will be investigated further to improve benthic status assessments.

Risk module:

Confidence Assessment: Evidence – Low; Consensus – Low

Given the low confidence score, the outputs from the risk analyses have not been included in this thematic assessment for QSR 2023. Nevertheless, it is beneficial to consider the agreed outputs of the persistence weightings. Details of the criteria applied in the risk module are described in the CEMP Guideline.

Regional summary of likely cumulative effects:

Confidence Assessment: Evidence – High; Consensus – Medium

Although the weighted bow-tie analyses displayed in the Sankey diagrams have been produced at the North-East Atlantic scale, consideration can be given to where regional differences may arise through cross-referencing with other assessments in QSR 2023.

The Benthic Habitats Thematic Assessment identifies the cumulative pressures for benthic habitats in terms of both exposure and impact, but does not attempt a regional breakdown of pressures:

The list below summarises the main pressures on benthic habitats, with information on associated activities. Please note that activity-pressure combinations scored as low impact based on the current available evidence have been filtered out from the Sankey diagram in **Figure CE.1a**. The activity-pressure links listed below relate to the unfiltered outputs used in the Exposure assessment.

- Climate change and ocean acidification pressures;
- Habitat loss and physical disturbance from extraction of oil and gas; restructuring of seabed morphology; tourism and leisure infrastructure; transmission of electricity and communications; aquaculture – marine; coastal protection and flood defence; renewable energy generation; transport infrastructure; fish and shellfish harvesting and extraction of minerals;
- Extraction or mortality of wild species through extraction of oil and gas and fish and shellfish harvesting as well as from transport infrastructure, coastal defence and flood protection;
- Input of nutrients from urban uses, waste water treatment and disposal; industrial uses; transport – shipping; agriculture; extraction of oil and gas; restructuring of seabed morphology; tourism and leisure infrastructure; aquaculture; coastal defence and renewable energy generation;
- Input of other substances from urban uses; waste water treatment and disposal; industrial uses; transport – shipping; research, survey and educational activities; military operations; agriculture; extraction of oil and gas; restructuring of seabed morphology; tourism and leisure infrastructure; transmission of electricity and communications; aquaculture – marine; coastal

protection and flood defence; renewable energy generation and non-renewable energy (Nuclear);

- Input of litter from transport – shipping; extraction of oil and gas; restructuring of seabed morphology; tourism and leisure infrastructure; aquaculture – marine; coastal protection and flood defence and renewable energy generation;
- Input of organic matter from agriculture; extraction of oil and gas; restructuring of seabed morphology; tourism and leisure infrastructure; transmission of electricity and communications; aquaculture – marine; coastal protection and flood defence; renewable energy generation and transport infrastructure;
- Input of NIS from extraction of oil and gas; tourism and leisure infrastructure; transmission of electricity and communications; aquaculture – marine; coastal protection and flood defence; renewable energy generation and transport infrastructure;
- Input of other forms of energy from extraction of oil and gas; tourism and leisure infrastructure; transmission of electricity and communications; aquaculture – marine; coastal protection and flood defence and renewable energy generation;
- Disturbance of species from non-renewable energy generation (Nuclear); extraction of minerals (Aggregate extraction), fish and shellfish harvesting and extraction of minerals.

It should be noted that s*ome of the activities listed above, even if considered to be high intensity, are very localised, for example aggregate extraction, and proportionally only affect a small area of habitats within a region, whereas other activities have high intensity and are very localised but affect a large proportion of habitats (and have the potential to grow in the near future), for example offshore wind and associated infrastructure. Activities such as fisheries harvesting can generate widespread pressures across most habitat types.*

OSPAR does not have evidence on all human activities, but a regional breakdown of relative intensities for agriculture; aquaculture; extraction of minerals (aggregates); oil and gas; nuclear; renewable energy; fisheries and shipping has been drawn from the supporting evidence for QSR 2023 and is summarised below. The direct influences of the cumulative pressures on benthic habitats from these activities are likely to follow similar trends in intensity within these regions. Pressures spread beyond the spatial extents of the human activities, but insufficient evidence is currently available, so trends in indirect cumulative pressures have not been considered.

The Offshore Industry Thematic Assessment describes:

- low relative intensity of oil and gas sector activity in the Bay of Biscay and Iberian Coast (Region IV) and Wider Atlantic (Region V);
- moderate relative intensity of oil and gas sector activity in Arctic Waters (Region I) and Celtic Seas (Region III);
- high relative intensity of oil and gas sector activity in Greater North Sea (Region II).

The Human Activities Thematic Assessment describes:

- low relative intensity of aggregate extraction sector activity in Arctic Waters (Region I) and Wider Atlantic (Region V);
- moderate relative intensity of aggregate extraction sector activity in Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV);
- high relative intensity of aggregate extraction sector activity in Greater North Sea (Region II);
- moderate relative intensity of agriculture sector activity in Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV);

- high relative intensity of agriculture sector activity in Greater North Sea (Region II);
- moderate relative intensity of aquaculture sector activity in Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV);
- high relative intensity of aquaculture sector activity in Arctic Waters (Region I) and Greater North Sea (Region II);
- low relative intensity of fisheries sector activity in Wider Atlantic (Region V);
- moderate relative intensity of fisheries sector activity in Bay of Biscay and Iberian Coast (Region IV);
- high relative intensity of fisheries sector activity in Arctic Waters (Region I), Greater North Sea (Region II) and Celtic Seas (Region III);
- low relative intensity of offshore renewable energy sector activity in Bay of Biscay and Iberian Coast (Region IV);
- moderate relative intensity of offshore renewable energy sector activity in Celtic Seas (Region III);
- high relative intensity of offshore renewable energy sector activity in Greater North Sea (Region II);
- low relative intensity of tourism sector activity in Arctic Waters (Region I) and Wider Atlantic (Region V);
- moderate relative intensity of tourism sector activity in Celtic Seas (Region III);
- high relative intensity of tourism sector activity in Greater North Sea (Region II) and Bay of Biscay and Iberian Coast (Region IV);
- low relative intensity of transport and shipping sector activity in Wider Atlantic (Region V);
- moderate relative intensity of transport and shipping sector activity in Arctic Waters (Region I);
- high relative intensity of transport and shipping sector activity in Greater North Sea (Region II), Celtic Seas (Region III) and Bay of Biscay and Iberian Coast (Region IV).

The Radioactive Substances Committee Thematic Assessment describes:

- no nuclear sector activity in Wider Atlantic (Region V);
- low relative intensity of nuclear sector activity in Arctic Waters (Region I).
- moderate relative intensity of nuclear sector activity in Bay of Biscay and Iberian Coast (Region IV);
- high relative intensity of nuclear sector activity in Greater North Sea (Region II) and Celtic Seas (Region III).

Regional evidence for trends in the intensity of other human activities and Climate Change and Ocean Acidification was not available in sufficient detail to be used in this assessment.

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Climate Change

Climate change effects and impacts on benthic habitats

Direct and indirect pressures driven by climatic change and ocean acidification factors can significantly alter the environmental conditions (e.g., increase in sea surface temperature, decreases of pH) necessary for benthic ecosystem processes and functions, and therefore affect habitat suitability for sensitive benthic species, species distributions, community structures and diversity patterns (Harley *et al.,* 2006; Hoegh-Guldberg and Bruno 2010; Poloczanska *et al.,* 2013; Gattuso *et al.,* 2015; Nagelkerken and Connell 2015; Poloczanska *et al.,* 2016; Weinert *et al.,* 2016). Climate change could lead to increases in mean sea level rise and changes in storminess, leading to a greater need for flood and coastal erosion defences. There are some uncertainties in the predictions, which will require additional research in order to increase accuracy on the future impacts of benthic habitats, particularly along the coastline.

There is not always a wide range of datasets available to systematically measure the effects of climate change and ocean acidification on benthic habitats and species, due to the paucity of the monitoring programme. However, there is a large volume of evidence of the impacts across different Regions. There are variations in the level and type of impacts due to geography (e.g., Arctic Waters) and the physical characteristics of the seafloor (e.g., depth), and in the typology of benthic habitat composition (e.g., calcifying species).

Benthic habitats also provide solutions for the mitigation and adaption of climate change effects. For example, the natural carbon storage and sequestration capacity of some benthic habitats highlights their major role in the context of climate change and in mitigating the carbon inputs to the atmosphere from human activities. (https://www.equinor.com/energy/northern-lights; https://www.upstreamonline.com/energy-transition/uk-launches-first-ever-carbon-storage-licensing-round/2-1-1237194).

Specific effects of climate change in Region I – Arctic Waters:

Changes in sea-bottom temperature in the western and central Barents Sea have been well documented (e.g., ICES WGIBAR 2021, Skagseth *et al.,* 2020; Weslawski *et al.,* 2010a) (**Figure CC.1**).

A biogeographic boundary exists in the Barents Sea region, associated with the Polar Front where Atlantic and Arctic water masses meet. Indications of Atlantification (i.e. increased influence by Atlantic water masses) in the region suggest this transition zone will move northward with climate change, which may see Arctic-associated communities retreating north in response (Jørgensen *et al.,* 2014, Buhl-Mortensen *et al.,* 2020).

The most recent ecosystem state report for Arctic Waters (ICES 2021, annexes 4 and 6) describes large-scale stability in distribution, biomass, and abundance patterns in the Region. However, in 2020 the distribution and biomass / abundance of megabenthos were below the long-term mean, with fluctuations being positively correlated to increasing sea temperature.

Temperature preference and bottom depth were included in the baseline analyses of Jørgensen *et al.,* (2022a). While frequencies of cold-water and warm-water taxa were quite similar in Icelandic waters and in North-East Greenland, warm-water taxa were more common in the Barents Sea. Taxa groups found in areas with the coldest median temperature and a relatively narrow temperature range were termed 'cold-water taxa' (**Figure CC.2**). Taxa groups in regions with the warmest median temperature, along with the broadest temperature range, were termed 'warm-water taxa'.

Jørgensen *et al.,* (2022b) show that in a biogeographic transition zone on the slope north-east of Svalbard, surface deposit feeding crustacean assemblages encounter mobile Arctic echinoderm predators, and that, at a sharp transition some 500 m along the shelf of Svalbard, boreal filtrating deep-sea sponges meet a unique upraised large-bodied assemblage of bathyal species on the Yermak Plateau.

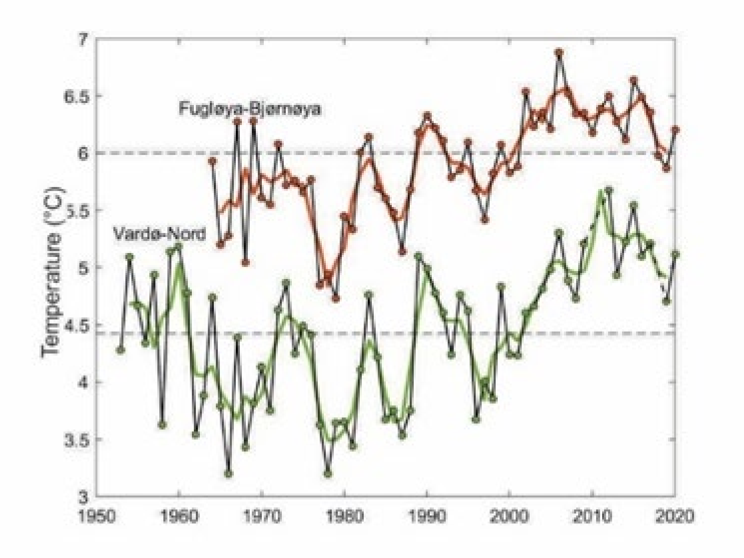

Figure CC.1: Average temperature at 50-200 m depth in the western Fugløya-Bear Island transect and the eastern Vardø-North section transect. Black lines show annual August-September values and thick lines show three-year running means. Horizontal lines show average temperature between 1981-2010. Graph from ICES WGIBAR, 2021

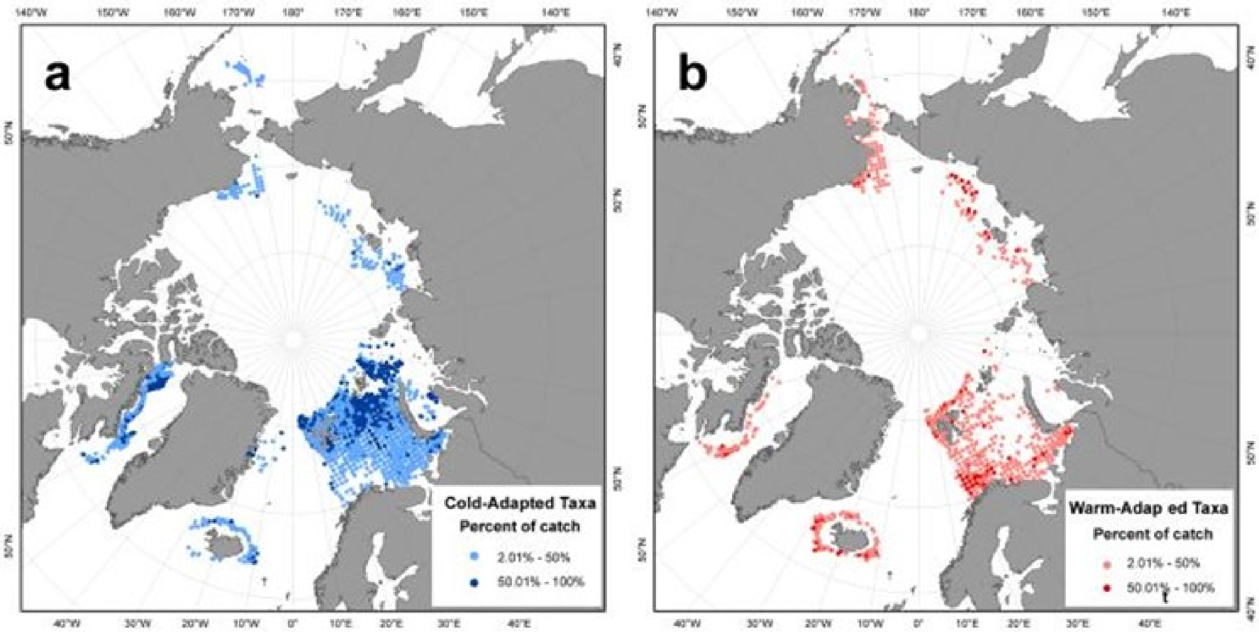

Figure CC.2. Distribution of (a) cold-water and (b) warm-water taxa, as percentage of catch (greater and less than 50% of catch) within each grid cell (50 km × 50 km). Note: Canadian taxa data from shrimp surveys were removed because species identification was limited until recently. From: Jørgensen et al., 2022a

Impacts on threatened and declining habitats and benthic species:

A rapid evaluation using the Marine Evidence-based Sensitivity Assessment (MarESA; https://www.marlin.ac.uk/habitats/biotopes) was undertaken to summarise the main sensitivities to climate change of the OSPAR threatened and / or declining habitats. This was done by considering the 'high' sensitivity classification in MarESA for the following climate change-related variables **(Table CC.1):**

The criteria and approach for the use of the different scenarios (high, middle, extreme, local) can be found here: https://www.marlin.ac.uk/sensitivity/SNCB-benchmarks

Table CC.1: Climate change pressure benchmarks derived from MarLIN MarESA, (please see for full detail: https://marlin.ac.uk/sensitivity/SNCB-benchmarks)

MarESA Pressure Assessment Benchmark	**Definition**
Global warming (high, middle)	**Middle emission scenario benchmark (by the end of this century (2081-2100):** A 3°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats). A 1°C rise in deep-sea habitats (>200 m) off the continental shelf. A 2°C rise in surface air temperature in intertidal habitats exclusive to Scotland. **High emission scenario benchmark by the end of this century (2081-2100):** A 4°C rise in SST, NBT (coastal to the shelf seas) and surface air temperature (in eulittoral and supralittoral habitats). A 1°C rise in deep-sea habitats (>200 m) off the continental shelf, and A 3°C rise in surface air temperature in intertidal habitats exclusive to Scotland.
Marine heatwaves (high, middle)	**Middle emission scenario benchmark:** A marine heatwave occurring every three years, with a mean duration of 80 days, with a maximum intensity of 2°C. **High emission scenario benchmark:** A marine heatwave occurring every two years, with a mean duration of 120 days, and a maximum intensity of 3.5°C.
Ocean acidification (high, middle)	**Middle emission scenario benchmark:** A further decrease in pH of 0.15 (annual mean) and corresponding 35% increase in H+ ions with no coastal aragonite undersaturation and the aragonite saturation horizon in the NE Atlantic, off the continental shelf, at a depth of 800 m by the end of this century (2081-2100). **High emission scenario benchmark**: A further decrease in pH of 0.35 (annual mean) and corresponding 120% increase in H+ ions, seasonal aragonite saturation of 20% of UK coastal waters and North Sea bottom waters, and the aragonite saturation horizon in the NE Atlantic, off the continental shelf, occurring at a depth of 400 m by the end of this century (2081-2100).
Sea level rise (extreme, high, middle)	**Middle emission scenario benchmark:** A 50 cm rise in average UK sea-level rise by the end of this century (2081-2100). **High emission scenario benchmark:** A 70 cm rise in average UK by the end of this century (2081-2100). **Extreme scenario benchmark**: A 107 cm rise in average UK by the end of this century (2081-2100).

Temperature increase (local)	An increase in 5°C for one month or 2°C for one year.
Temperature decrease (local)	A decrease in 5°C for one month or 2°C for one year.
Salinity increase (local)	An increase in one MNCR salinity category outside the usual range of the biotope/habitat for one year. Please see MarLIN MarESA for salinity category definitions: https://marlin.ac.uk/glossarydefinition/salinity
Salinity decrease (local)	A decrease in one MNCR salinity category outside the usual range of the biotope/habitat for one year. Please see MarLIN MarESA for salinity category definitions: https://marlin.ac.uk/glossarydefinition/salinity
Water flow (tidal current) changes (local)	A change in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than 1 year.
Emergence regime changes (A change in the time covered or not covered by the sea for a period of => 1 year	A change in the period covered or not covered by the sea for a period of ≥ 1 year. Or An increase in relative sea level or decrease in high water level for ≥ 1 year.
Wave exposure changes (local)	A change in nearshore significant wave height >3% but <5% for one year.

- Global warming (high, middle);
- Marine heatwaves (high, middle);
- Ocean acidification (high, middle);
- Sea level rise (extreme, high and middle);
- Temperature increase (local)
- Temperature decrease (local);
- Salinity increase (local);
- Salinity decrease (local);
- Water flow (tidal current) changes (local);
- Emergence regime changes (A change in the period covered or not covered by the sea for a period of ≥ 1 year);
- Wave exposure changes (local).

Carbonate mounds, *Haploops* habitat and *Cymodocea* meadows were excluded due to the lack of information available within the MarESA sources. (https://www.marlin.ac.uk/sensitivity/sensitivity_rationale).

Global warming and marine heatwave pressures were assessed to be causing the largest impacts on the majority of communities comprising kelp forest, maerl bed and *Modiolus modiolus* bed habitats. Sea-level rise was also listed as highly impactful for kelp forest. Ocean acidification was assessed as likely to represent a serious threat to coral gardens, *Lophelia pertusa* reefs, and maerl beds.

Climate change can have a compounding effect on threats already impacting habitats. For example, for *Zostera* beds, existing threats such as increased water turbidity / reduced light penetration and sediment re-suspension may be exacerbated by climate change in the future, and climate change may also increase the need to further reduce other stressors in order to facilitate expansion of *Zostera* beds to deeper, cooler waters (Krause-Jensen *et al.,* 2021).

Changes in coastal development due to increased needs for coastal protection as a result of climate change impacts could lead to increased risks for habitat loss and increased risks of coastal squeeze, i.e. the coastal zone in built-up areas becoming narrower due to a rising sea level. This may also need to be taken into consideration to ensure that future management becomes "climate ready" to protect, for example, *Zostera* beds.

Local salinity changes (i.e., increase or decrease) were found to have a significant impact on coral gardens, deep-sea sponge aggregations, kelp forests, littoral chalk communities, *Lophelia pertusa* reefs, *Modiolus modiolus* beds and sea-pen and burrowing megafauna communities. Water flow (tidal current) changes were likely to impact maerl beds and sea-pen and burrowing megafauna communities. Littoral chalk communities were also found to be highly affected by emerging regime changes.

Intertidal mudflats can be affected by climate-change induced sea-level rise and increased storm frequency, affecting the sedimentation patterns of mudflats and estuaries, coastal squeeze (e.g., in the United Kingdom) and changes in exposure time. Climate change also leads to temperature increase resulting in changing ecological interactions between species.

The predictions of future trends (2020-2030) for the condition of deep-sea sponge aggregations are quite challenging. Modelling predicts shifts in temperature, pH, oxygen, and particulate organic carbon (i.e., food supply) in the bathyal zone (i.e. the zone where several deep-sea sponge aggregations have been found) for OSPAR Regions by 2100 under Representative Concentration Pathway (RCP)8.5. By combining (i) the model predictions for abiotic / biotic conditions in bathyal habitats (see above) and (ii) the scientific knowledge about the impacts of temperature, acidification and diet / feeding metabolism, it is possible to suggest that future environmental conditions in the OSPAR Maritime Area may contribute to deterioration in the condition of deep-sea sponge aggregations. However, further research is needed to advance scientific knowledge on this front. The northernmost regions of the North Atlantic are predicted to experience the greatest impacts under worst-case scenario predictions. Increased temperature and lower pH will drastically reduce the suitable habitat for ecosystem-engineer species and lead to declines in population densities, loss of biodiversity and reduced biogeographic distribution that might compromise large-scale connectivity and long-term survival. The reductions in carbon fluxes in oligotrophic areas may be even more serious. The predicted effects of climate change on deep-sea sponge aggregations by 2100 are changes in distribution, extent and condition. Changes in circulation due to the slowdown of the Atlantic Meridional Overturning Circulation (which affects all OSPAR Regions) will influence regional and local circulation patterns, which will also alter patterns of population connectivity.

Climate change threatens to induce significant shifts in the biological communities on carbonate mounds in the Wider Atlantic and the impact processes that support these features, through altered hydrodynamic regimes, a re-distribution of primary productivity and the availability of organic matter on the seafloor, and ocean acidification. Regarding the latter, the ICES Report on Ocean Climate Change, 2014 (Larsen, *et al*., 2016) has predicted that under RCP4.5, the waters surrounding the Hatton and Porcupine Banks will be approaching aragonite undersaturation by 2100. Climate change and ocean acidification impacts on carbonate mounds remain unknown, even after the last assessment, and either may not yet have occurred or may not have been measured *in situ* on these listed features. However, expert judgement suggests that these impacts could have started to take place, as even short-term exposure to decreased pH can impact cold-water corals, and these pressures are likely to increase over the next 6 to 12 years.

There was no explicit implementation reporting in 2019 on climate change under paragraph 3.1b of OSPAR Recommendation 2014/10: "assessing whether existing management measures for the protection of carbonate mounds are effective, and determine whether further measures are needed to address the key threats, including the potential impacts from climate change and ocean acidification".

Although ocean acidification is clearly continuing, the current and immediate future impacts on coral gardens are difficult to quantify.

Deep-sea corals, especially those with aragonite rather than calcite skeletons, are vulnerable to the effects of ocean acidification, with impacts predicted by the end of this century. The ICES Report on Ocean Climate Change, 2014 (Larsen, *et al*., 2016) predicts that, under RCP4.5, the waters surrounding the Reykjanes Ridge, the southern Iceland shelf and the edge of the Hatton and Porcupine Banks will be approaching aragonite undersaturation by 2100. Under RCP8.5 most of the North Atlantic will be undersaturated except for the Celtic margin and the Bay of Biscay. Other models of aragonite saturation states under RCP8.5 have predicted similar results (e.g., Puerta *et al.,* 2020), including for specific coral garden taxa such as *Acanella* and *Paragorgia* (Morato *et al.,* 2020). Predictions tend not to take into account the potential increased vulnerability of early life stages to ocean acidification.

Other effects of climate change likely to impact coral gardens by the end of the century include increases in temperature affecting distribution, decreased particulate organic carbon inputs, and the slowing of the Atlantic Meridional Overturning Circulation, which could have broad-scale impacts on the whole of the North Atlantic.

It has been shown that meridional overturning circulation has the potential to increase acidification in the deep Atlantic Ocean, with rapid shoaling of the aragonite saturation horizon, particularly in the subpolar North Atlantic, possible within the next three decades (Perez *et al.,* 2018). Acidification can impact the integrity of coral reefs and cause ecosystem-scale habitat loss (Hennige *et al.,* 2020). Some recent studies, however, suggest that *Lophelia* may contain sufficient genetic variability to adapt to future ocean acidification (Kurman *et al.,* 2017), at least in some regions (Georgian *et al.,* 2016).

Morato *et al.,* (2020) used habitat suitability modelling to compare present-day (1951–2000) and projected *Lophelia* distributions under future (2081–2100; RCP8.5) environmental conditions. The models predict a decrease of approximately 80% in suitable habitat for *Lophelia pertusa* by 2100 due to a combination of factors. The authors stress the importance of identifying and preserving species climate refugia when planning conservation measures, to improve resilience against climate change.

Although adult vent organisms are adapted to oscillations and variable low pH, high temperature and low oxygen in vent fluids, it is not known whether species are adapted to permanent change in environmental variables. To what degree, and whether, vent larvae that disperse via ocean currents are adapted to changes in pH, temperature and oxygen in the ocean, is unknown. Changes induced by climate stressors, such as altered circulation due to the slowdown of the Atlantic Meridional Overturning Circulation (AMOC), can impact connectivity at regional scales and may even increase the risk of species extinction, especially given the fragmented nature of these environments and the planktonic nature of many vent species.

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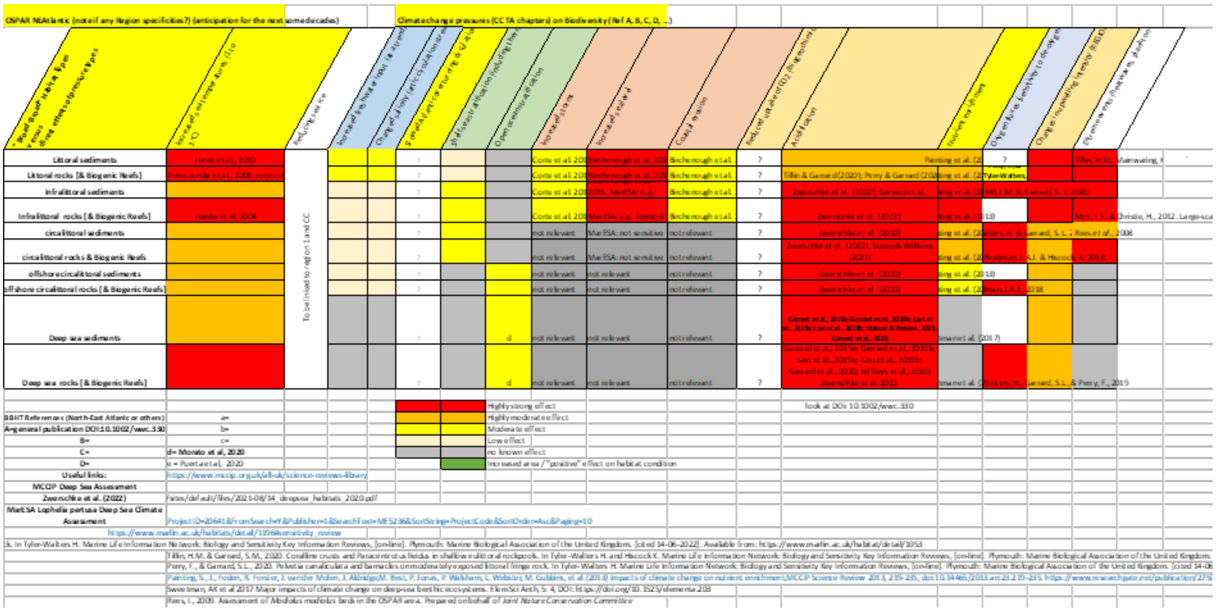
Overarching impacts on benthic habitats from climatic drivers and ocean acidification:

Table CC.2 is a high-level evaluation of the evidence available on the impacts of climatic drivers and ocean acidification on broad-scale habitats.

Table CC.2: Overarching foreseen impacts (experts' judgement) on North-East Atlantic benthic habitats, from climatic drivers and ocean acidification [full table]



An overview of climate change-related impacts on the marine benthos in the North Atlantic is published in Birchenough *et al.,* (2015), which tackles the relationship between different physical aspects of climate change and the marine benthos and covers: (a) the responses to changes in seawater temperature (biogeographic shifts and phenology); (b) altered Hydrodynamics; (c) ocean acidification (OA); and (d) sea-level rise coastal squeeze.

Ocean acidification

Ocean acidification is the reduction in the pH of the ocean caused by uptake of excess carbon dioxide (CO_2) from the atmosphere. This is a natural process, but the accelerated release of anthropogenically produced CO_2 into the atmosphere is happening too fast for the natural system to keep pace. The effects of ocean acidification on marine benthic species and habitats are not well understood. Marine species with calcium carbonate shells and skeletons, such as corals and mussels, are particularly vulnerable. Often species are exposed and affected by ocean acidification across their life cycle, including their early development and larval stages. Thus, ocean acidification may not only impact established populations, but also reduce the likelihood of successful reproduction to maintain these populations. Understanding the extent and magnitude of these impacts is important because they could result in reductions in sensitive habitats and species and continued declines in biodiversity. This can have knock-on effects on the food web (e.g., prey availability) and the ecosystem services provided (e.g., commercial fishing, carbon storage). An initial study was undertaken to evaluate and identify seabed species and habitats and their associated larval stages most sensitive to ocean acidification, and to identify the areas most likely to experience the largest changes in pH. The results showed that, regardless of the emissions scenario, significant changes in ocean pH and carbonate chemistry alongside changes in benthic communities can be expected within the next three decades. These changes are likely to be more pronounced in certain areas such as the northern North Sea, the eastern Channel and the Irish Sea (Zwerschke *et al.,* 2022).

Increased sea temperature

Species can adapt to increases in temperature by changing their depth and / or latitude distribution ranges. Species able to change both ranges (depth and latitude) will be less sensitive than species which cannot modify their depth range. Because of this it is considered that algae communities (restricted to depth ranges with enough light availability) will be more threatened by the increase of temperatures than invertebrate communities living in sediment habitats. In the same way, cold-water corals living near the aragonite saturation horizon will also be more threatened than species living far from this horizon.

Increased freshwater inputs and changed salinity

The impacts of changes in salinity are very region-dependent. For example, in the Baltic Sea, salinity is a major driver of diversity, which is not the case for open-water regions such as the Bay of Biscay and Iberian Coast (OSPAR Region IV).

Climate change can result in changes to the timing and extent (relative importance) of freshwater inputs, with (sub)regional differences in precipitation resulting in either increased or decreased freshwater inputs.

In general, it is thought that both changed salinity and changed freshwater inputs will have low direct impact on benthic communities, although they can be locally important in littoral communities, especially near river mouths.

Slowed Atlantic Meridional Overturning Circulation (AMOC)

The slowing of the AMOC will have strong impacts on the climate of Europe. Although it is not possible to forecast the exact impacts on specific benthic communities, the expected change is likely to be considerable. Currents influence sediment types, which have a major impact on benthic communities and are also key for filter feeding organisms such as corals and sponges. However, without an understanding of how these changes will occur specifically, it is not possible to forecast their impacts on the benthos, which need not necessarily be exclusively negative.

Nutrient enrichment

The potential impacts of climate change include changes in the magnitude of nutrient enrichment in estuarine, coastal and offshore waters, in physical and chemical oceanography (e.g., circulation patterns, acidification and light) and in the rates of biogeochemical cycling in these waters. Nutrient enrichment leads to a number of negative impacts on benthic habitats, such as community changes (see: Condition of Benthic Habitat Communities: Assessment of some Coastal Habitats in Relation to Nutrient and/or Organic Enrichment (BH2a), Drivers, Activities, Pressures). Climate effects are typically related to changes in precipitation and peaks / extremes in run-off, including nutrient loads. It is difficult to distinguish between anthropogenic and climate change-driven nutrient effects (related processes). Typically, the largest effects have been observed in river plumes and shallow areas, due to the increase in algal blooms there which change light conditions and species compositions, potentially also leading to oxygen depletion (Painting *et* al., 2013). It is also expected that increased temperatures may decrease denitrification. Higher concentrations of nitrate may lead to a switch to phosphate as the limiting nutrient. Increased storminess would increase nutrient concentrations at the ocean surface and may increase supply to shelf seas like the

North Sea. Modelling of ocean productivity in a warmer climate suggests that increased stratification in summer will limit nutrient supply to surface waters during the productive seasons and inhibit mixing due to storms in winter. The most likely effects on shelf seas are largely unclear at the moment (Mills and Hydes, 2006). With regard to deep-sea habitats, increased stratification and therefore limited transport to the seafloor might counteract or even overrule increased nutrient input and, more likely, lead to nutrient decreases in deep-sea benthic habitats. The resulting impact on benthic community levels is largely unclear (Sweetman et al., 2017).

Increased sea level and changes to storms and coastal erosion

Sea-level rise increases water depth at the shore and results in changes in wave and tidal energy along the coast (Wolf *et al.,* 2020). Benthic habitats such as subtidal bedforms, intertidal flats, saltmarshes and sand dunes migrate along and parallel to the shore to maintain their position in the coastal energy gradient (Garrard and Tyler-Walters, 2020). Sedimentary habitats are liable to adapt to a gradual sea level rise and compensate for alterations by extra sedimentation. However, coastal habitats and particularly tidal flats may suffer substantial losses if sea level increases too rapidly and where coastal defence structures prevent their natural movement (coastal squeeze) (Birchenough *et al.,* 2015; Garrard and Tyler-Walters, 2020). Infralittoral and intertidal rock and biogenic reef habitats (e.g., blue mussel beds, honeycomb worm reefs) that are unable to migrate landwards are particularly threatened by increasing water depths (Stamp and Williams, 2021; Tillin *et al.,* 2020). Large areas of macrophyte-dominated habitats such as seagrass beds and kelp forests may also be lost, as an increase in depth reduces the light available to the plants (d'Avack *et al.,* 2022a; d'Avack *et al.,* 2022b; Stamp *et al.,* 2020).

Human interventions to mitigate **coastal erosion** may add to the ecological impact of sea-level rise (Birchenough *et al.,* 2015). In particular, 'hard' coastal protection structures such as dykes can alter hydrological and sediment dynamics along the shoreline and thereby also affect benthic biodiversity and productivity (Spreybroeck *et al.,* 2006). The effects of sea-level rise may be further increased by storms and storm surges, which in turn will raise the need for coastal protection measures. Higher wave energy during storms may translocate and disperse large sediment volumes, thus altering sediment properties and reducing habitat heterogeneity. While the majority of the species occurring in coastal habitats are adapted to high-energy environments and may recover within a short time frame, the impact on benthic habitats will increase with the magnitude, frequency, and spatial scale of storm events (Corte *et al.,* 2017).

Extreme events (heatwaves)

Marine heatwaves are increasingly becoming a global concern, with impacts from warm-water events predicted to increase in frequency in the coming years. These are defined as occurring when the surface temperature exceeds a threshold greater than five consecutive days (Brauko *et al.,* 2020). These prolonged events are associated with coral bleaching, reductions in kelp forests and seagrass meadows (Holbrook *et al.,* 2020), reduced surface chlorophyll (Bond *et al.,* 2015), loss of invertebrates (Caputi *et al.,* 2016), species range shifts coupled with community restructuring (Cavole *et al.,* 2016; Wernberg *et al.,* 2016), alteration of fishery quota and closures (Cavole *et al.,* 2016) and tensions between nations. Warm-water events can vary with extent and depth and are dependent on the geometry of regions and the mechanisms that cause and maintain them (Reed *et al.,* 2016). In addition to a long-lasting global increase in marine temperatures, discrete extreme warm-water events are projected to become more frequent, intense, and longer lasting in the 21st century (Meehl and Tebaldi, 2004). The 2012 event in the North-West Atlantic saw significant shifts in geographical and seasonal shifts in several marine species, leading to altered fishing activities and harvesting patterns and substantial political and economic complications for the region (Mills *et al.,* 2013). Further study is needed to improve knowledge of the impacts from marine heatwaves on benthic habitats in the North-East Atlantic.

Further work to improve assessment of climate change effects on benthic habitats

Benthic indicators have been developed to measure the pressures caused by human impacts (e.g., trawling disturbance, eutrophication) on benthic habitats across regions. They take into account relevant environmental parameters such as depth in order to calculate the different degrees of impact. However, the current design is not sufficiently sensitive to measure changes driven by climatic factors and / or ocean acidification. To fill the gaps, new or adapted indicators that include additional environmental parameters might be needed to measure the impact of climate change on benthic habitats. Although currently no specific indicators have been developed for this task in the framework of OSPAR's Benthic Habitats Expert Group (OBHEG), the scientific literature contains good examples that could be adapted. For instance, it will be possible to predict the impact of climate change in the habitat of different relevant species by OSPAR Region, measuring the loss or reduction of suitable habitat as a consequence of climate change (Morato *et al.,* 2020). On the other hand, use can be made of metrics such as Preferred Temperature of the Community (PTC), which is calculated by weighting species' preferred temperature by their annual abundance (Collie *et al.,* 2008). This has already been used in the Bay of Biscay and the Iberian Coast Region to measure the impact of climate change on fish communities (Punzón *et al.,* 2021). Another example is the Intertidal Community Temperature Index, which measures the status of a benthic community in terms of the composition of cold- and warm-water species. It is quantitative, easily applied, and gives a direct measurement of the response to climate and climate change across all the species in a community. This information is essential for understanding how anthropogenic pressure exacerbates the effects of climate change (Burrows *et al.,* 2018).

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Thematic Metadata

Field	Explanation
Linkage	[EcApRHA project – Applying an Ecosystem Approach to (sub) Regional Habitat Assessment] [NEA PANACEA project - North East Atlantic project on biodiversity and eutrophication assessment integration and creation of effective measures] Elliott, S.A.M., Arroyo, A.L., Safi, G., Ostle, C., Guérin, L., McQuatters-Gollop, A., Aubert, A., Artigas, F., Pesch, R., Schmitt, P., Vina-Herbon, C., Meakins, B., González-Irusta, J.M., Preciado, I., López-López, L., Punzón, A., de la Torriente, A., Serrano, A., Haraldsson, M., Capuzzo, E., Claquin, P., Kromkamp, J., Niquil, N., Judd, A., Padegimas, B. and Corcoran, E. 2017b. Proposed approaches for indicator integration. EcApRHA deliverable WP4.1, ISBN: 978-1-911458-29-6. http://dx.doi.org/10.13140/RG.2.2.11217.61287 Elliott, S.A.M., Guérin, L., Pesch, R., Schmitt, P., Meakins, B., Vina-Herbon, C., González-Irusta, J.M., de la Torriente, A. and Serrano, A. 2018. Integrating benthic habitat indicators: Working towards an ecosystem approach. Marine Policy 90, 88-94. https://doi.org/10.1016/j.marpol.2018.01.003 Elliott, S.A.M., Guérin, L., Pesch, R., Schmitt, P., Meakins, B., Vina-Herbon, C., González-Irusta, J.M., de la Torriente, A. and Serrano, A. 2017a. Applying a risk-based approach towards an integrated assessment of benthic habitat communities at a regional sea scale. EcApRHA deliverable WP4.1, ISBN: 978-1-911458-25-8. http://dx.doi.org/10.13140/RG.2.2.32189.13289 González-Irusta, J.M., De la Torriente, A., Punzón, A., Blanco, M. and Serrano, A. 2018. Determining and mapping species sensitivity to trawling impacts: the BEnthos Sensitivity Index to Trawling Operations (BESITO). ICES Journal of Marine Science 75, 1710-1721. https://doi.org/10.1093/icesjms/fsy030 Guérin L. and Lizińska A. 2022. Analysis of the main elements of the "Good Environmental Status" from the 1st and 2nd MSFD cycles, reported by the European Member States for Descriptor 6 (sea floor integrity) - links with Regional Seas' Conventions and D4 (food webs integrity) and D5 (eutrophication). NEA PANACEA European project deliverable 3.1. PatriNat joint unit (OFB, MNHN, CNRS). Station marine de Dinard. http://dx.doi.org/10.13140/RG.2.2.16732.46728 McQuatters-Gollop A., L. Guérin, N.L. Arroyo, A. Aubert, L.F. Artigas, J. Bedford, E. Corcoran, V. Dierschke, S.A.M. Elliott, S.C.V. Geelhoed, A. Gilles, J.M. González-Irusta, J. Haelters, M. Johansen, F. Le Loc'h, C.P. Lynam, N. Niquil, B. Meakins, I. Mitchell, B. Padegimas, R. Pesch, I. Preciado, I. Rombouts, G. Safi, P. Schmitt, U. Schückel, A. Serrano, P. Stebbing, A. De la Torriente and C. Vina-Herbon. 2022. Assessing the state of marine biodiversity in the North-east Atlantic, Ecological Indicators, Volume 141, 109148, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2022.109148 (https://www.sciencedirect.com/science/article/pii/S1470160X22006203) OSPAR, 2017. BH2: Condition of Benthic Habitat Communities: the Common Conceptual Approach, in: OSPAR (Ed.), OSPAR Intermediate Assessment 2017. OSPAR, London, UK. Available at: https://oap.ospar.org/en/ospar-

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OSPAR's Quality Status Report 2023

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Our vision is a clean, healthy and biologically diverse North-East Atlantic Ocean, which is productive, used sustainably and resilient to climate change and ocean acidification.

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