OSPAR COMMISSION

Standardised lists of terms and definitions of DAPSIR elements (Drivers, Activities, Pressures, and Impact on Ecosystem Services) to be used in OSPAR Quality Status Report 2023 thematic assessments

OSPAR

QUALITY STATUS REPORT 2023

2022

OSPAR's Quality Status Report 2023

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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

The OSPAR Commission applies the ecosystem approach to work coherently towards a holistic approach to the problems addressed by the different OSPAR Strategies. To apply all aspects of the ecosystem approach in the OSPAR Quality Status Report 2023 requires a high-level understanding and integration of the interactions between the human and natural systems.

The DAPSIR framework is an established approach for ecosystem assessments. Drivers of basic human needs require Activities which lead to Pressures which can lead to changes in the State (environmental impact) of the natural system, which lead to Impacts on Ecosystem Services which in turn influence the Drivers. These interrelationships require management Responses.

Using standard terms and definitions of the DAPSIR components in all Thematic Assessments delivered in the framework of the QSR 2023 provides for coherence, clarity in the narratives and easier understanding for the reader. The “Standardised lists of terms and definitions of DAPSIR elements (Drivers, Activities, Pressures, and Impact on Ecosystem Services) to be used in OSPAR QSR 2023 thematic assessments”, or “DAPI list” presented here provides standard terms and definitions for drivers, activities, pressures and impact on ecosystem services. It is also here to support and guide assessment leads and contributors in the application of the DAPSIR framework and towards the completion of their respective Thematic Assessments.

Récapitulatif

La Commission OSPAR applique l’approche écosystémique pour mettre en œuvre une démarche cohérente qui permette de répondre de manière holistique aux problèmes abordés dans les différentes stratégies adoptées par OSPAR. Pour appliquer toutes les dimensions de l’approche écosystémique dans le cadre du Bilan de santé 2023 d’OSPAR (QSR 2023), il faut néanmoins bien comprendre et mettre en relation les interactions qui existent entre les systèmes naturel et humain.

Le cadre « DAPSIR » est une approche reconnue d’évaluation écosystémique. Pour satisfaire les besoins humains de base (« Drivers »), il faut mettre en œuvre des activités (« Activities ») qui engendrent des pressions (« Pressures ») pouvant avoir un impact sur l’état du milieu naturel (« State »). Cet impact va alors influer sur la fourniture de services écosystémiques (« Impact on Ecosystem Services »), qui va, à son tour, influer sur les besoins humains de base. Ces interconnexions nécessitent d’être gérées et encadrées (« Responses »).

Normaliser les termes et définitions des différentes « lettres » du DAPSIR lors de leur utilisation dans le cadre des évaluations thématiques du QSR 2023 permet une meilleure cohérence, rend le texte plus clair et en facilite la compréhension par le lecteur. La liste normalisée des termes et définitions des éléments du DAPSIR à utiliser dans les évaluations thématiques du QSR 2023 (« liste DAPI »), telle que présentée ci-dessous, contient des termes et définitions normalisés des lettres « D », « A », « P » et « I ». Ce document vise également à aider et à orienter les auteurs des évaluations thématiques, ainsi que les contributeurs, dans l’application du système DAPSIR, en vue de l’achèvement de leurs travaux.

1 Introduction

The OSPAR Commission applies the ecosystem approach to work coherently towards a holistic approach to the problems addressed by the different OSPAR Strategies. For the OSPAR Convention, the ecosystem approach is defined as *"the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity".*

To apply all aspects of the ecosystem approach in the OSPAR Quality Status Report 2023 requires an understanding and integration of:

- The **Drivers** of change [D]
- How human **Activities** and **Pressures** affect ecosystems [AP]
- The health, integrity and dynamics describing marine ecosystem **State** [S]
- **Impact** of changes on ecosystem goods and services [I]
- Integrated management measures (**Responses**) [R]

The DAPSIR framework is an established approach for ecosystem assessments (e.g. EC, 1999; Patrício *et al.*, 2016; Elliott *et al.*, 2017). Adapted from Elliott *et al.*, (2017), **Drivers** of basic human needs require **Activities** which lead to **Pressures** which can lead to changes in the **State** (environmental impact) of the natural system, which lead to **Impacts** on Ecosystem Services which in turn influence the Drivers. These interrelationships require management **Responses** (as Measures).

Using standard terms and definitions of the DAPSIR components in all thematic assessments provides for integration, clarity in the narratives and compliance with regulatory requirements. Here we provide standard terms and definitions for drivers, activities, pressures and ecosystem services. We also provide an overview of how ecosystem services connect with the drivers to close the loop in the DAPSIR cycle (noting that the ecosystem services work is being progressed under a separate project).

2 Drivers

The North-East Atlantic provides basic needs to society including biodiversity, food, energy, materials, prosperity, health and well-being. Elliott *et al.*, (2017) describe that the main societal Drivers are related to basic human needs such as the need for food, energy, space, movement of goods, security or recreation. Policies on the provision of these needs are captured within the seventeen UN Sustainable Development Goals (SDG) to end poverty, ensure prosperity and protect the planet. OSPAR policies, in line with the UN SDGs, directly relate to the provision of these basic human needs to achieve a clean, healthy and biologically diverse North-East Atlantic Ocean, used sustainably.

Derived from Maslow, 1943 & 1970, Elliott *et al.*, (2017) propose that Drivers are considered within a hierarchy of needs which set individual and societal motivations for action. We have mapped the societal need described by Maslow to the UN SDGs (Table 1):

Table 1. Maslow hierarchy of basic human needs mapped to the UN SDGs.

Maslow hierarchy	UN SDG
Deficiency needs (motivation decreases as needs are met)	
1. basic human needs relating to the biological requirements for human survival and include both physiological requirements (e.g. food, air, shelter) and safety (e.g. protection from elements and hazards) in order to maintain our physiological requirements.	[1] No Poverty [2] Zero Hunger [3] Good Health and Well-being [4] Quality Education [5] Gender Equality

	[6] Clean Water and Sanitation
2. psychological needs include belonging (e.g. sense of place, community, well-being) and esteem (e.g. prestige, achievement, self-respect, job security).	[7] Affordable and Clean Energy [13] Climate Action [14] Life Below Water [15] Life on Land
Growth needs (motivation for change increases as needs are met)	
3. cognitive needs (e.g. knowledge and understanding, curiosity, exploration, need for meaning and predictability)	[8] Decent Work and Economic Growth [9] Industry, Innovation and Infrastructure
4. aesthetic needs (e.g. appreciation and search for beauty, balance, form)	[10] Reduced Inequalities [11] Sustainable Cities and Communities
5. self-fulfilment needs (e.g. realising personal potential, seeking personal growth and peak experiences).	[12] Responsible Consumption and Production [16] Peace, Justice and Strong Institutions
6. transcendence needs (e.g. helping others to achieve self-fulfilment)	[17] Partnerships for the Goals

These needs are served by the goods and benefits[1] provided to society by the North-East Atlantic which set the context and motivation for the Drivers. Table 2 provides a standard list and definitions for the drivers used in the Quality Status Report 2023 (QSR2023) which influence how society uses, values and manages the North-East Atlantic. This list of drivers draws on discussions within the OSPAR Intersessional Correspondence Groups on Economic & Social Analysis (ICG-ESA) and Cumulative Effects Assessment (ICG-EcoC), and review of the Human Activity Thematic Assessment and Feeder Reports (produced by the EIHA Committee) and the future scenarios assessed in Bekhuis, 2021.

Table 2. Summary of Drivers used in OSPAR QSR2023 Thematic Assessments.

Driver	Description
Deficiency needs (motivation decreases as needs are met)	
Society's need for food	Growing global populations increase the demand for food. There is inequity in food availability at national and international levels. Supply and demand issues for society include cultural diet preferences / shifts; global food market chains and international trade; regulation of production and processing; innovation; political stability; food prices.
Society's need for energy	Growing global population increases the demand for energy. Shifts in policies towards low carbon economies, will require significant expansion of renewable energy development (including marine). Oil and gas part of energy mix (albeit declining) for many countries, continuing need to manage emissions.

[1] Goods and benefits include e.g. provisioning services (biodiversity; food; fertiliser and biofuels; medicines and blue biotechnology; energy; materials), regulating services (healthy climate; prevention of coastal erosion; sea defence; waste burial, removal, neutralisation), cultural (tourism and nature watching; spiritual and cultural well-being; aesthetic benefits; education, research; health).

Driver	Description
	Nuclear energy is a source for some countries. Market forces drive energy prices.
Society's need for health and well-being	Associated with the cost of living; environmental awareness; sense of place; health of population; demands for goods and services; accessibility of goods and services (convenience); communications; socio-economic status (regional / national / international differences); culture; historic environment; tourism and recreation; consequences of pandemics. Medical: treatments, pharmaceuticals, radiotherapy. Personal protective equipment (PPE).
Society's needs and appreciation of nature and biodiversity	UN SDG 14 "Life below water" to conserve and sustainably use the oceans, seas, and marine resources for sustainable development. Public pressure to drive political debate and action, e.g. climate change, litter, underwater noise, water quality, protection of species and habitats.
Society's need to mitigate the effects of Climate Change	Reductions in fossil fuel consumption (and extraction); reductions in greenhouse gas emissions; increased reliance on and expansion of renewable energy technologies.
Society's need to adapt to the effects of climate change	Threats to society require coast and flood protection; sea defences; levees; dikes; relocation of at-risk communities; shifts to catching and propagating warmer water species for human consumption. Shift to low-carbon heating, transport and power for homes, businesses, and industry.
Society's need to become more resilient to the effects of climate change	Building climate proof economic and social systems to be resilient to extremes, including floods, storms, winds, temperature changes. Constructions designed to withstand extreme weather events. Sustainable consumption of natural resources. Assessment of biodiversity changes to allow management responses for sustainable ecosystems.
Society's need for national security	Reliant on national (and international) military defence policies and programmes. Policies evolve to address changing geo-political threats.
Growth needs (motivation for change increases as needs are met)	
Society's need for trade and movement of goods	Associated with domestic and international trade, including imports and exports of goods and services critical to the economies of most countries. Supply and demand of goods and services; national and international targets and tourism affected by market forces. Maritime ports and shipping important for

Driver	Description
	coastal states, including the need to keep waterways navigable.
Society's need for global communications	Globalised, modern society wholly reliant of digital communications network.
Society's need for education	Inclusive and equitable quality education promoting lifelong learning opportunities for all of society to help understanding of the need to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
Society's need for materials	Growing population increasing demand for materials (marine aggregates) for housing; hospitals; roads; retail and business premises; utilities (e.g. sewerage, power networks); ports and harbours; airports; sea defences; coast protection. Digital Society's demand for rare earth elements.
Society's need for stable economies	Associated with political and economic autonomy; foreign aid contributions and distributions; tariffs and grants; international agreements; stocks and market prices; tourism; competition for spaces and resources; shift to circular economies. UN SDGs: people, planet, prosperity, peace, partnerships.
Society's need for industrial processes	Associated with the manufacturing and processing of materials (raw, synthetic, and recycled) to provide marketable goods, including - domestic appliances; business and office equipment; telecommunications equipment; agricultural equipment; clothes; vehicles; machinery; home entertainment; leisure equipment; toys.

3 Activities

The human **activities** that operate in the marine environment of the North-East Atlantic, where they are undertaken and how is a direct consequence of the **drivers** (to meet society's needs). Table 3 shows the standard list of human activities to be used in the QSR 2023. This is a consolidated list derived from the 2017 update of the Marine Strategy Framework Directive Annex III EUR-Lex - 32017L0845 - EN - EUR-Lex (europa.eu) and the OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014-2023 Theme B: Biodiversity and Ecosystems, Table 1 https://www.ospar.org/documents?d=32988. Table 3 also presents a standard set of definitions for each human activity. Unless stated otherwise these are derived from the JNCC, (2019) "Standardised list of human activities in the marine environment" (nationalarchives.gov.uk).

Table 3. Summary of human Activities used in OSPAR QSR2023 Thematic Assessments.

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
Physical restructuring of rivers, coastline or seabed (water management)	Land claim	Land reclamation	Reclamation of land from below the high water mark to create new land potentially for new quaysides, coastal defences, port estates. Often involves creation of new wall or hard coastal defence and infilling behind to raise height. Includes consideration of vessels/machinery/vehicles and materials associated with activity (JNCC, 2019).	N/A
	Canalisation and other water course modifications	Dredging for navigational purposes	Includes canalisation, culverting and trenching to alter the course of waterways. Also, includes causeways and dams. (Working Group on Good Environmental Status (WG GES), 2015).	Feeder report on Shipping
	Coastal defence and flood protection	Coastal defence	Construction of new coastal defence structures/schemes including seawalls, bunds, revetments, dykes, ditches, beach recharge, groynes, breakwaters etc. Includes consideration of construction works, plant and materials, plus vessels/machinery/vehicles associated with activity (JNCC, 2019).	N/A

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
	Offshore structures (other than for oil/gas/renewables)	Installations and structures - other than for oil and gas and offshore wind farms but including artificial islands	Construction and operation of offshore or detached coastal defence structures (intertidal or subtidal) including wave-screens, breakwaters as well as artificial islands. Includes consideration of vessels/machinery/vehicles and materials associated with activity. (JNCC, 2019).	N/A
	Restructuring of seabed morphology, including dredging and depositing of materials	Dredging for navigational purposes & Dumping of wastes or other matter (as well as deposits of dredged materials)	The extraction of materials from the seabed for the purpose of aiding navigation. This includes both capital and maintenance dredging (JNCC, 2019). Deposits of dredge materials - disposal of materials originating from the seabed (JNCC, 2019).	Feeder report on Shipping
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)	Sand and gravel extraction & Exploration and exploitation of deep-sea mineral resources, including deep sea mining	The extraction of aggregate materials (sand, gravel and crushed rock) from the seabed for economic profit i.e. use in the construction industry (JNCC, 2019). Activities associated with the exploration and extraction of deep sea marine minerals, such as Polymetallic nodules, Polymetallic sulphides, and Cobalt crusts. Adapted from source on The International Seabed Authority and Deep Seabed Mining | United Nations	Feeder report on extraction of aggregates Feeder report on extraction of aggregates

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
	Extraction of oil and gas, including infrastructure	Exploration for and exploitation of oil and gas and placement and decommissioning of structures for the exploitation of oil and gas	Activities associated with the extraction of marine hydrocarbons including exploration, construction, operation and decommissioning (JNCC, 2019).	OIC thematic assessment
	Extraction of salt	NA	The temporary or permanent removal of salts from the marine environment through varied techniques, such as sea water concentration and crystallisation, sea salt production and sea saltworks. Adapted from EC Expert Group for Technical Advice on Organic Production, 2021. EGTOP Annex II Draft/Final Report (europa.eu)	N/A
	Extraction of water	NA	The temporary or permanent removal of water from the marine environment (JNCC, 2019).	N/A
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure	Installations and structures – offshore wind farms and other marine energy developments	The construction and operation of offshore wind farms, and other renewable energy developments designed to harness wave energy and tidal energy, including associated infrastructure (JNCC, 2019).	Feeder report on offshore renewable energy generation
	Non-renewable energy generation		The construction and operation of infrastructure for the generation of non-renewable energy from nuclear energy sources (JNCC, 2019).	OIC thematic assessment, RSC thematic assessment

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
	Transmission of electricity and communications (cables)	Placement of cables and pipelines (Any assessment of this activity will include an assessment of the scope for action under other international law)	The construction and operation of cables (telecommunications & power) and pipelines laid on the sea floor (JNCC, 2019).	Feeder report on offshore renewable energy generation & thematic assessment of human activities
Extraction of living resources	Fish and shellfish harvesting (professional, recreational)	Fisheries	The targeted removal of marine fish and shellfish species for professional and recreational purposes. (JNCC, 2019).	Feeder report on fisheries
	Fish and shellfish processing		Onshore processing of marine fish and shellfish (and by-products) from wild capture fisheries, or from aquaculture sources (JNCC, 2019)	
	Marine plant harvesting		The gathering and removal of marine plants (wild seaweed) (JNCC, 2019).	Feeder report on fisheries
	Hunting and collecting for other purposes		Hunting and gathering/ collecting of living resources for other purposes (subsistence use), such as subsistence hunting of marine mammals (JNCC, 2019). Could also include ornamental fish collection, bait digging (for fishing), medicinal/cosmetics.	N/A
Cultivation of living resources	Aquaculture - marine, including infrastructure	Mariculture	Growing of finfish in cages/nets suspended from surface structures or lines, which may be anchored to the seabed. Seaweed grown on	Feeder report on aquaculture

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
			ropes/nets suspended from surface structures or lines, which may be anchored to the seabed. Relaying and harvesting of shellfish (e.g. mussels, oysters, scallops) on suitable areas of intertidal and subtidal substrate, including dredging for seed. Shellfish (mussels, oysters) grown on ropes/nets suspended from surface structures or lines. These structures may be anchored to the seabed. Shellfish (e.g. oysters) grown on racks or trestles in the intertidal zone. JNCC (2019)	
	Aquaculture - freshwater		Cultivation of aquatic organisms where the end product is raised in freshwater, such as reservoirs, rivers, lakes, canals and groundwater. Earlier stages of the life cycle of these aquatic organisms may be spent in brackish or marine waters. (FAO, 2021) Aquaculture statistics | Coordinating Working Party on Fishery Statistics (CWP) | Food and Agriculture Organization of the United Nations (fao.org)).	
	Agriculture	Agriculture	Farming on land of both animals (animal husbandry) and plants (agronomy, horticulture and forestry in part) (FAO, 2021) 1. Definitions (fao.org).	Feeder report on agriculture
	Forestry	NA	Forest classification covers plantations, natural forest and other types of wooded land. A broad range of forestry processes are captured in the description, including deforestation i.e. long-term/permanent removal of forest cover; afforestation i.e. transforming non forests land to forest; and re-forestation i.e. establishing forest plantations. (Adapted from FAO, 2020) i8661en.pdf (fao.org)	N/A

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
Transport	Transport infrastructure	Maritime transportation	Infrastructure supporting transport at sea, such as ports, navigational channels, anchorages etc. JNCC (2019)	Feeder report on shipping
	Transport - shipping		The passage or transport of vessels at sea, including people, goods and freight in the marine environment. JNCC (2019)	
	Transport - air		The passage or transport of aircraft in the air. JNCC (2019)	N/A
	Transport - land		The passage or transport of vehicles on land. JNCC (2019)	N/A
Urban and industrial uses	Urban uses	Urban and industrial uses [new]	Activities and associated infrastructure on land for urban uses, including retail, residences, roads etc. JNCC (2019)	N/A
	Industrial uses		Activities and associated infrastructure on land for industrial uses, including manufacturing, processing and storage of raw materials. JNCC (2019)	N/A
	Waste treatment and disposal		Treatment of discharges of wastewater from domestic and commercial foul water and sewage and industrial sources. Adapted from OSPAR 2021: Quality status Report 2023: Feeder report on Wastewater [EIHA draft]	Feeder report on Wastewater
Tourism and leisure	Tourism and leisure infrastructure	Tourism and Recreational activities (these activities will be examined with the aim of identifying whether specific activities within this	Infrastructure to support maritime activities (coastal based and at sea based), which are undertaken for the purpose of enjoyment, amusement or pleasure. Examples of infrastructure include moorings, coastal footpaths, buildings e.g. hotels, restaurants, leisure centre. JNCC (2019)	Feeder report on Recreation and Tourism in the

MSFD Theme (Annex III Table 2b)	Activity (MSFD Annex III Table 2b)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description	Applicable OSPAR feeder report 2021/22
	Tourism and leisure activities	group would require a further assessment)	Any maritime activity (coastal or at sea) that is expressly undertaken for the purpose of enjoyment, amusement or pleasure. Examples include boating, yachting, diving etc. (JNCC, 2019).	Northeast Atlantic Ocean
Security/defence	Military operations (subject to Article 2(2))	Dumped past chemical and conventional munitions	Disposal at sea of munitions e.g. bombs, grenades, torpedoes and mines as well as phosphorus incendiary devices and chemical munitions. Adapted from Dumped Chemical & Conventional Munitions | OSPAR Commission	N/A
Education and research	Research, survey and educational activities	Marine scientific research	Research activities carried out for the purpose of furthering understanding of the marine environment. (JNCC, 2019).	N/A
Carbon Capture	Carbon Capture and Storage in sub-seabed geological structures	Carbon Capture and Storage in sub-seabed geological structures	The deposition/ injection of natural gases or carbon into identified submarine storage sites/structures. (JNCC, 2019).	N/A

4 Pressures

Human **activities** might exert **pressures** on the marine ecosystem of the North-East Atlantic. Table 4 shows the standard list of pressures to be used in the QSR 2023. This is a consolidated list derived from the 2017 update of the Marine Strategy Framework Directive Annex III EUR-Lex - 32017L0845 - EN - EUR-Lex (europa.eu) and the OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014-2023 Theme B: Biodiversity and Ecosystems, Table II https://www.ospar.org/documents?d=32988. Table 4 also presents a standard set of definitions for pressures adapted from the list produced by OSPAR Intersessional Correspondence Group on Cumulative Effects and agreed by the EIHA Committee in 2011.

Table 4. Summary of pressures used in OSPAR QSR2023 Thematic Assessments.

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
Biological	Input or spread of non-indigenous species	Introduction or spread of nonindigenous species	The direct or indirect introduction of non-indigenous species, e.g. Chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spreading and out-competing of native species. Ballast water, hull fouling, stepping-stone effects (e.g. offshore wind farms) may facilitate the spread of such species. This pressure could be associated with aquaculture mussel or shellfishery activities due to imported seed stock or from accidental releases
	Input of microbial pathogens	Introduction of microbial pathogens	Untreated or insufficiently treated effluent discharges & run-off from terrestrial sources & aquatic vessels. It may also be a consequence of ballast water releases. In mussel or shellfisheries where seed stock is imported, 'infected' seed could be introduced, or it could be from accidental releases of effluvia. Escapees, e.g. farmed salmon could be infected and spread pathogens in the indigenous populations. Aquaculture could release contaminated faecal matter, from which pathogens could enter the food chain.

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
	Input of genetically modified species and translocation of native species	Genetic modification and translocation of indigenous species	Genetic modification can be either deliberate (e.g. introduction of farmed individuals to the wild, GM food production) or a by-product of other activities (e.g. mutations associated with radionuclide contamination). Former related to escapees or deliberate releases e.g. cultivated species such as farmed salmon, oysters, scallops if GM practices employed. Scale of pressure compounded if GM species "captured" and translocated in ballast water. Mutated organisms from the latter could be transferred on ships hulls, in ballast water, with imports for aquaculture, aquaria, live bait, species traded as live seafood or 'natural' migration. Movement of native species to new regions can also introduce different genetic stock.
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species	N/A	Pressure associated with aquaculture activities (either marine or freshwater) to cultivate animals or plants. Changes to natural biological communities could include the provision of habitat (e.g. the holdfasts and fronds of cultured algae) or the escape and naturalisation of farmed species. Note, effects may be closely linked to other pressures, such as the input of nutrients, other substances and the spread of non-indigenous species, which combine to affect the trophic cascade.
	Selective extraction of species, including non-target catches	Removal of non-target species	By-catch associated with all fishing activities. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type (D2) so this addresses the direct removal of individuals associated with fishing/ harvesting. Ecological consequences include food web dependencies, population dynamics of fish, marine mammals, turtles and sea birds (including survival threats in extreme cases, e.g. Harbour Porpoise in Central and Eastern Baltic).
		Removal of target species	The commercial exploitation of fish & shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
			fishing gear on seabed communities are addressed by the "abrasion" pressure type D2, so B5 addresses the direct removal / harvesting of biota. Ecological consequences include the sustainability of stocks, impacting energy flows through food webs and the size and age composition within fish stocks. Note, overlap with Extraction of, or mortality/injury to, wild species.
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	Removal of target species	The commercial exploitation of fish & shellfish stocks, including smaller scale harvesting, angling and scientific sampling. The physical effects of fishing gear on seabed communities are addressed by the "abrasion" pressure type D2, so B5 addresses the direct removal / harvesting of biota. Ecological consequences include the sustainability of stocks, impacting energy flows through food webs and the size and age composition within fish stocks. Note overlap with Selective extraction of species.
		Death or injury by collision	Injury or mortality from collisions of biota with both static &/or moving structures. Examples include: • Static - collision with rigs (e.g. birds) or screens in intake pipes (e.g. fish at power stations) • moving - bird collisions with wind turbine blades, fish & mammal collisions with tidal devices and shipping. The scale and intensity of this pressure will be influenced by the number of vessels transiting areas (e.g. new port development or construction works), rate of development, e.g. expansion of offshore renewable energy.
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence	Visual disturbance	The disturbance of biota by anthropogenic activities, e.g. increased vessel movements, such as during construction phases for new infrastructure (bridges, cranes, port buildings etc), increased personnel movements, increased tourism, increased vehicular movements on shore etc disturbing bird roosting areas, seal haul out areas etc

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
		Barrier to species movement	The physical obstruction of species movements, including local movements (within & between roosting, breeding, feeding areas) and regional/global migrations (e.g. birds, eels, salmon, whales). Both include up-river movements (where tidal barrages & devices or dams could obstruct movements) or movements across open waters (offshore wind farm, wave or tidal device arrays, mariculture infrastructure or fixed fishing gears). Species affected are mostly birds, fish, mammals.
Physical	Physical disturbance to seabed (temporary or reversible)	Physical loss (to another seabed type) &	The permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including to artificial (e.g. concrete). This therefore involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substrate habitats, removal of coarse substrate (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture i.e. mussel beds. Protection of pipes and cables using rock dumping and mattressing techniques. Placement of cuttings piles from oil & gas activities could fit this pressure type, however, there may be additional pressures, e.g. "pollution and other chemical changes" theme. This pressure excludes navigation dredging where the depth of sediment is changes locally but the sediment typology is not changed.
		Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	The disturbance of sediments where there is limited or no loss of substrate from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g. scallop dredging, beam trawling. Agitation dredging,

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			where sediments are deliberately disturbed by and moved by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g. from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50cm depth) Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bioprospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonisation remain suitable or relatively localised activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrate would adversely affect herring spawning grounds.
		Changes in suspended solids (water clarity)	Changes in water clarity from sediment & organic particulate matter concentrations. It is related to activities disturbing sediment and/or organic particulate matter and mobilising it into the water column. Could be 'natural' land run-off and riverine discharges or from anthropogenic activities such as all forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed & direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. This pressure also relates to changes in turbidity from suspended solids of organic origin (as such it excludes sediments - see the "changes in suspended sediment" pressure type). Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter. Anthropogenic sources mostly short lived and over relatively small spatial extents.
		Siltation rate changes, including smothering	When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
			type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. This accumulation of sediments is synonymous with "light" smothering, which relates to the depth of vertical overburden. “Light” smothering relates to the deposition of layers of sediment on the seabed. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. For “light” smothering most benthic biota may be able to adapt, i.e. vertically migrate through the deposited sediment. “Heavy” smothering also relates to the deposition of layers of sediment on the seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. This accumulation of sediments relates to the depth of vertical overburden where the sediment type of the existing and deposited sediment has similar physical characteristics because, although most species of marine biota are unable to adapt, e.g. sessile organisms unable to make their way to the surface, a similar biota could, with time, re-establish. If the sediments were physically different this would fall under L2. Eleftheriou and McIntyre, 2005 describe that the majority of animals will inhabit the top 5-10 cm in open waters and the top 15 cm in intertidal areas. The depth of sediment overburden that benthic biota can tolerate is both trophic group and particle size/sediment type dependant (Bolam, 2010). Recovery from burial can occur from: - planktonic recruitment of larvae - lateral migration of juveniles/adults - vertical migration (see Chandrasekara and Frid, 1998; Bolam et al, 2003, Bolam & Whomersley, 2005). Spatial scale, timing, rate and depth of placement all contribute the relative importance of these three recovery mechanisms (Bolam et al, 2006). As such the terms “light” and “heavy” smothering are relative and therefore difficult to define in general terms. Bolam, 2010 cites various examples: - H. ulvae maximum overburden of 5 cm

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			(Chandrasekara & Frid, 1998) - H. ulvae maximum overburden of 20 cm mud or 9 cm sand (Bijerk, 1988) - S. shrubsolii maximum overburden 6 cm (Saila et al, 1972, cited by Hall 1994) - N. succinea maximum overburden 90 cm (Maurer et al 1982) - gastropod molluscs maximum overburden 15 cm (Roberts et al, 1998). Bolam, 2010 also reported when organic content was low: - H. ulvae maximum overburden 16 cm - T, benedii maximum overburden 6 cm
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	Physical loss (to land or freshwater habitat) & Habitat structure changes – removal of substratum (extraction) &	The permanent loss of marine habitats. Associated activities are land claim, new coastal defences that encroach on and move the Mean High Water Springs mark seawards, the footprint of a wind turbine on the seabed, dredging if it alters the position of the halocline. This excludes changes from one marine habitat type to another marine habitat type
		Physical loss (to another seabed type	Unlike the "physical change" pressure type where there is a permanent change in sea bed type (e.g. sand to gravel, sediment to a hard artificial substrate) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonise; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed.
	Changes to hydrological conditions	Water flow (tidal current) changes – local, including sediment transport considerations &	Water flow changes in water movement associated with tidal streams (the rise and fall of the tide, riverine flows), prevailing winds and ocean currents. The pressure is therefore associated with activities that have the potential to modify hydrological energy flows, e.g. Tidal energy generation devices remove (convert) energy, and such pressures could be manifested leeward of the device, capital dredging may deepen and widen a channel and therefore decrease the water flow, canalisation &/or

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			structures may alter flow speed and direction; managed realignment (e.g. Wallasea, England). The pressure will be spatially delineated. The pressure extremes are a shift from a high to a low energy environment (or vice versa). The biota associated with these extremes will be markedly different as will the substrate, sediment supply/transport and associated seabed elevation changes. The potential exists for profound changes (e.g. coastal erosion/deposition) to occur at long distances from the construction itself if an important sediment transport pathway was disrupted. As such these pressures could have multiple and complex impacts associated with them.
		Emergence regime changes – local, including tidal level change considerations	Emergence regime changes in water levels reducing the intertidal zone (and the associated/dependant habitats). The pressure relates to changes in both the spatial area and duration that intertidal species are immersed and exposed during tidal cycles (the percentage of immersion is dependent on the position or height on the shore relative to the tide). The spatial and temporal extent of the pressure will be dependent on the causal activities but can be delineated. This relates to anthropogenic causes that may directly influence the temporal and spatial extent of tidal immersion, e.g. upstream and downstream of a tidal barrage the emergence would be respectively reduced and increased, beach re-profiling could change gradients and therefore exposure times, capital dredging may change the natural tidal range, managed realignment, saltmarsh creation. Such alteration may be of importance in estuaries because of their influence on tidal flushing and potential wave propagation. Changes in tidal flushing can change the sediment dynamics and may lead to changing patterns of deposition and erosion. Changes in tidal levels will only affect the emergence regime in areas that are inundated for only part of the time. The effects that tidal level changes may have on sediment transport are not restricted to these areas, so a very large construction could significantly affect the tidal level at a deep site without changing the emergence regime. Such a change could still

MSFD Theme (Annex III Table 2a	Pressure (MSFD Annex III Table 2a)	OSPAR Joint Assessment and Monitoring Programme (JAMP) 2014 – 2023	Description
			have a serious impact. This excludes pressure from sea level rise which is considered under the climate change pressures.
		Wave exposure changes – local	Wave exposure local changes in wavelength, height and frequency. Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages, wrecks that can directly influence wave action or activities that may locally affect the incidence of winds, e.g. a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline.
Substances, litter and energy	Input of nutrients - diffuse sources, point sources, atmospheric deposition	Deoxygenation	Any deoxygenation that is not directly associated with nutrient or organic enrichment. The lowering, temporarily or more permanently, of oxygen levels in the water or substrate due to anthropogenic causes (some areas may naturally be deoxygenated due to stagnation of water masses, e.g. inner basins of fjords). This is typically associated with nutrient and organic enrichment, but it can also derive from the release of ballast water or other stagnant waters (where organic or nutrient enrichment may be absent). Ballast waters may be deliberately deoxygenated via treatment with inert gases to kill non-indigenous species.
		Nutrient enrichment	Increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct and atmospheric inputs) or anthropogenic sources (e.g. wastewater runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, atmospheric deposition). Nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication (see also organic enrichment).

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			Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
	Input of organic matter - diffuse sources and point sources	Organic enrichment	Resulting from the degraded remains of dead biota & microbiota (land & sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural runoff. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication (see also nutrient enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) - diffuse sources, point sources, atmospheric deposition, acute events	Transition elements and organo-metal *e.g. &	The increase in transition elements levels compared with background concentrations, due to their input from land/riverine sources, by air or directly at sea. For marine sediments the main elements of concern are Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead and Zinc Organo-metallic compounds such as the butyl tins (Tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, e.g. Imposex in molluscs.
		Hydrocarbon and PAH contamination &	Increases in the levels of these compounds compared with background concentrations. Naturally occurring compounds, complex mixtures of two basic molecular structures: - straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation) - multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation) These fall into three categories based on source (includes both aliphatics and polyaromatic hydrocarbons): - petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off) - pyrogenic hydrocarbons (from combustion of coal, woods and petroleum)

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			- biogenic hydrocarbons (from plants & animals) Ecological consequences include tainting, some are acutely toxic, carcinomas, growth defects.
		Synthetic compound contamination (inc. pesticides, antifoulant, pharmaceuticals) TBT contamination) &	Increases in the levels of these compounds compared with background concentrations. Synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds include polychlorinated biphenols (PCBs), dichlor-diphenyltrichloroethane (DDT) & 2,3,7,8- tetrachlorodibenzo(p)dioxin (2,3,7,8- TCDD) are persistent and often very toxic. Pesticides vary greatly in structure, composition, environmental persistence and toxicity to non-target organisms. Includes: insecticides, herbicides, rodenticides & fungicides. Pharmaceuticals and Personal Care Products originate from veterinary and human applications compiling a variety of products including, Over the counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones. Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments they have become an emerging concern. Ecological consequences include physiological changes (e.g. growth defects, carcinomas)
		Radionuclide contamination	Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea -based operations (e.g. oil platforms, medical sources). The disposal of radioactive material at sea is prohibited unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA), namely that both the following radiological criteria are satisfied: (i) the effective dose expected to be incurred by any member of the public or a ship's crew is 10 µSv or less in a year; (ii) the collective effective dose to the public or ship's crew is not more than 1 man Sv per annum, then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea (pursuant to it fulfilling all the other disposal at sea provisions under the OSPAR Convention). The individual dose criteria are

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			placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 µSv/a. Ports and coastal sediments can be affected by the authorised discharge of both current and historical low-level radioactive wastes from coastal nuclear establishments.
	Input of litter (solid waste matter, including micro-sized litter)	Litter	Marine litter is any manufactured or processed solid material from anthropogenic activities discarded, disposed, or abandoned (excluding legitimate disposal) once it enters the marine and coastal environment. It includes plastics, metals, timber, rope, fishing gear etc. and their degraded components, e.g. microplastic particles. Ecological effects can be physical (smothering), biological (ingestion, including uptake of microplastics; entangling; physical damage; accumulation of chemicals) and/or chemical (leaching, contamination).
	Input of anthropogenic sound (impulsive, continuous)	Underwater noise changes	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental manmade/anthropogenic noise (apparent)) at a particular location. Species known to be affected are marine mammals and fish. The theoretical zones of noise influence (Richardson et al 1995) are temporary or permanent hearing loss, discomfort & injury; response; masking and detection. In extreme cases noise pressures may lead to death. The physical or behavioural effects are dependent on a number of variables, including the sound pressure, loudness, sound exposure level and frequency. High amplitude low and mid-frequency impulsive sounds and low frequency continuous sound are of greatest concern for effects on marine mammals and fish. Some species may be responsive to the associated particle motion rather than the usual concept of noise. Noise propagation can be over large distances (tens of kilometres), but transmission losses can be attributable to factors such as water depth and seabed topography. Noise levels associated with construction activities, such as pile-driving, are typically significantly greater than operational phases (i.e. shipping, operation of a wind farm).

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	Input of other forms of energy (including electromagnetic fields, light and heat)	Electromagnetic changes &	Localised electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). Such cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (e.g. sharks and rays).
		Introduction of light &	Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24 hours working; new tourist facilities, e.g. promenade or pier lighting, lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth.
		Temperature changes – local	Events or activities increasing or decreasing local water temperature. This is most likely from thermal discharges, e.g. the release of cooling waters from power stations. This could also relate to temperature changes in the vicinity of operational subsea power cables. This pressure only applies within the thermal plume generated by the pressure source. It excludes temperature changes from global warming which will be at a regional scale (and as such are addressed under the climate change pressures).
	Input of water - point sources (e.g. brine)	Salinity changes – local	Events or activities increasing or decreasing local salinity. This relates to anthropogenic sources/causes that have the potential to be controlled, e.g. freshwater discharges from pipelines that reduce salinity, or brine discharges from salt caverns washings that may increase salinity. This could also include hydromorphological modification, e.g. capital navigation dredging if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow/exchange rates. The pressure may be temporally and spatially delineated derived from the causal event/activity and local environment.

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5 Impacts on Ecosystem Services

Human activities and pressures, and changes in state can impact the ecosystem services of the North-East Atlantic. The project "Impacts on ecosystem services due to changes in the state of the environment in the North-East Atlantic Ocean" being undertaken by ICG-ESA is progressing this component of the DAPSIR framework for the QSR 2023. Table 5 shows the standard list of ecosystem services and definitions to be used in the QSR 2023.

Table 5. Summary of ecosystem services used in OSPAR QSR2023 Thematic Assessments.

Ecosystem Service Category	Ecosystem Service Name	Ecosystem Service Definition
Biotic Provisioning Services	Biomass and raw materials from in-situ aquaculture	The ecosystem contributes to the growth of animals and plants (e.g., fish, shellfish, seaweed) in aquaculture facilities that are harvested by economic units for various uses. Biomass from in-situ marine aquaculture (or mariculture) is included among the provisioning ecosystem service as the aquaculture practice exploits the contribution of the surrounding marine ecosystem to the growth of aquatic animal and plants for the farming of fish, bivalves, crustaceans, and seaweeds (Weitzman, 2019). These products are then harvested by economic units for various uses. The related seafood production is mainly destined for ex-situ consumption. Animals and plants from aquaculture facilities are what holds the capacity to provide the service. The rationale is that these organisms act as mediators of the biomass that is used or eaten by people but, at the same time, they represent the service as they constitute the output in terms of the ecosystem good that is harvested for different uses. These organisms therefore represent the same biomass that people value and to which they attribute a nutritional (or other raw material) benefit, linked to its consumption as food, or an economic benefit, linked to its sale as a result of various processes. The underlying ecosystem functions that enable biomass production are represented by the interactions of the reared organisms with the surrounding environment, as well as ecosystem processes such as feeding (e.g., filter-feeding bivalves). The organism, even in a semi-controlled context such as mariculture, performs the action of feeding on other marine biota, such as bacteria, plankton, and smaller fish, and uses the nutrition for growth (Culhane et al., 2019).
	Wild fish and other natural aquatic biomass and related raw materials	Wild fish and other natural aquatic biomass and raw materials represent a provisioning service as the functioning of the marine ecosystem with its ecological dynamics contributes to the growth of such biomass

		sources that are benefited as a service by people and their socio-economic activities (EEA, 2015). Unlike the biomass obtained from aquaculture, this ecosystem service includes biomass harvested in non-cultivated production contexts, i.e., the catching and harvesting of wild marine living resources for nutrition or material use or processing (EEA, 2015; Haines-Young & Potschin, 2018). This ecosystem service includes both wild plants such as macroalgae, macrophytes and wild animal biomass from vertebrates and invertebrates that are harvested or captured to serve as seafood or raw materials. Specifically, this ecosystem service can range from microalgae interesting for bioprospecting activities, fish, shellfish, and crustaceans for fisheries activities to marine mammals such as seals sometimes subject to illegal hunting (OSPAR, 2017; Steinrücken, 2017).
	Genetic material	This ecosystem service represents the ecosystem contributions from all biota (in this specific case marine biota), including seed, spore or gamete production, that are used by economic units for example to develop new animal and plant breeds; in gene synthesis; in product development directly using genetic material (Haines-Young & Potschin, 2018). The provisioning of genes, gametes, and/or spores is the basis for the provisioning of biomass, which is then benefited by humans as an ecosystem service (see 'Biomass and raw materials from in-situ aquaculture' and 'Wild fish and other natural aquatic biomass and related raw materials'; Turner et al., 2014). However, genetic diversity (the diversity of the gene pool) of marine organisms can also be directly used and benefited by humans (Turner et al., 2014). This role refers to those cases where cells, tissues, and/or whole organisms are taken from their natural environment or aquaculture settings and then cultured in an artificial environment for biotechnology, bioengineering, bioprospecting, etc. e.g., in the food industry, pharmaceutical industry, and/or for other non-purely scientific research purposes (Culhane et al., 2019; EEA, 2015;). Regarding purely scientific research, this pertains to the different ecosystem service 'Education, scientific, and research services'. Consequently, the final goods and benefits provided to humans by this ecosystem service are represented by goods and benefits such as medicines and blue biotechnology (term used to describe the application of technology, including biotechnology, to living

		aquatic organisms for the production of knowledge, goods, and services; OECD, 2016; Turner et al., 2014). Genetic material (genes) represents a resource for humans as they offer the potential to meet possible future needs. Intra-species genetic variation provides a number of building blocks that can be used to improve desirable traits and characteristics of species that already provide goods to humans, for example aquatic species raised in aquaculture activities. Wild species that are closely related to reared species, through breeding or laboratory molecular techniques, can provide desirable genes that can lead to enhancements in the benefits provided by their domesticated conspecifics. For example, brown sea trout and wild salmon are also wild relatives of food animals found in aquaculture contexts (UK NEA, 2011b). At another level, chemicals within marine animal, plant, and microbial organisms may be useful to humans for pharmaceutical purposes. Thus, it is possible to argue that since it is uncertain what humanity's future needs will be, all species are potentially useful for this purpose and that it would be appropriate to aim for their survival. For example, the species and varieties used were selected for their productivity in current aquaculture systems. However, in view of environmental state changes associated with climate change, the use of new varieties better suited to certain environmental conditions may be essential in the near future. This highlights the importance of the provision of the ecosystem service of genetic material by marine organisms to support the current and future human welfare (UK NEA, 2011b).
Biotic Regulation and Maintenance Services	Regulation and maintenance of marine food webs	The ecosystem contributes to the growth of wild animals, plants, and other biomass. Biomass is transferred in the ecosystem through trophic levels: primary producers, consumers, predator - prey relationships, scavengers, decomposers. Healthy marine ecosystems are dependent on maintaining these food webs supporting biodiversity and nature conservation (and providing a service to people, see 'Wild fish and other natural aquatic biomass and related raw materials'). This ecosystem service has been intended to represent the supporting service from the contribution that ecological processes such as primary biomass production, the role primary production plays in supporting biomass production at higher trophic levels, and marine biomass interactions across trophic levels have in regulating and maintaining the balance of marine food webs. Therefore, this ecosystem service represents the role

		that biomass of all wild plants such as macroalgae, macrophytes and wild animal from vertebrates and invertebrates (fish, birds, marine mammals) have in the maintenance and functioning of marine food webs and ecosystems, also contributing to the provision of several other ecosystem services (Scott et al., 2014). Given these features, this service is not directly benefited by people.
	(Global) climate regulation	The marine ecosystem contributes to the regulation of the chemical composition of the atmosphere and the ocean affecting local and global climate through the accumulation and retention of carbon dioxide and other GHGs (e.g., methane, nitrous oxide), and the control of the transfer of heat and moisture (UK NEA, 2011a). These processes affect climate parameters such as temperature, rainfall patterns, wind etc., contributing to the provision of a healthy and habitable ambient environment (climate and microclimate) to humans (EEA, 2019a; Turner et al., 2014). The climate regulation by the marine ecosystem comprises the following physical and biological processes: - Photosynthesis carried out by aquatic plant organisms and phytoplankton, representing the fundamental process that influences the levels of carbon dioxide in the atmosphere (UK NEA, 2011a). Photosynthetic organisms remove CO2 through its sequestration in terms of primary production but also through consumption (Culhane et al., 2019). - Marine organisms acting as a carbon sink in the ocean and facilitating carbon burial in seabed sediments (UK NEA, 2011a). Marine calcifying organisms are able to lock away calcium carbonate contributing to the removal of CO2 from the ocean and in turn of the atmospheric CO2. Bacteria also play a role, being able to reduce the levels of methane that originates from the ocean floor and then released into the atmosphere (Culhane et al., 2019). Moreover, marine organisms such as zooplankton through processes such as the export of particles by grazing, the fractioning of sinking particles, and the transport of particulate organic carbon at depth through its diel vertical migration, plays a crucial role in the functioning of the oceanic biological carbon pump that contributes to regulating atmospheric CO2 levels (Lomartire et al., 2021). - Evaporation of water vapor from the ocean to the atmosphere (Gimeno et al., 2012). - Ocean water surface albedo (proportion of incoming solar radiation that is reflected from the water surface)

		affecting the Earth's radiation balance, with the low albedo of the ocean causing it to absorb most of the incoming solar radiation (warming the water) and the high albedo of sea ice reflecting about 50-70 % of it (Perkins, 2019; UK NEA, 2011a). Thus, it is clear how essentially all marine organisms store carbon, albeit in different ways and forms and that at the same time also abiotic components of the marine ecosystem contribute to the provision of this ecosystem service. Biogeochemical effects operate more on a regional or global scale, while biophysical effects have more local or regional effects (Turner et al., 2014). Furthermore, it should be noted that human demand for this ecosystem service is passive, as there is no active human effort to benefit from a habitable environmental climate (Culhane et al., 2019).
	Coastal protection	The ecosystem contributions of linear elements in the seascape such as sand banks, dunes, coral reefs, saltmarshes, or mangrove ecosystems along the shore, in protecting the shore and the hinterland, thus mitigating the impacts of tidal surges or storms on local communities (UK NEA, 2011a). This service includes flooding prevention and erosion control. Underlying the latter are the processes of sediment stabilization, sediment accumulation, buffering, and wave energy attenuation by macroalgae beds, microphytobenthos, macrophytes, epifauna and infauna are the processes underlying this ecosystem service (Culhane et al., 2019; Hu et al., 2014; Spalding et al., 2014; UK NEA, 2011a). Biological structures such as macrophyte roots found in coastal saltmarsh ecosystems or other types of seafloor and coastal vegetation exhibit sediment stabilization capabilities. Biogenic reefs may exhibit the ability to retain and accumulate sediment, important for avoiding erosion processes associated with currents or wave motion. Kelp forest fronds can lower the risk or prevent flooding by breaking up wave energy prior to the impact on the coastline (Culhane et al., 2019; Hasler, 2016). This ecosystem service is predominantly limited to littoral and (shallow) sub-littoral habitats, as it provides security for people and human-built structures in coastal areas (Culhane et al., 2019). Usually, this service is passively benefited by people thanks to natural elements already present in the marine ecosystem. However, this service can also be actively benefited as a result of ecological restoration

		measures as done, for example, with sea grass meadows (Culhane et al., 2019; Hasler, 2016).
	Water quality regulation	Regulation, restoration, and maintenance of the chemical condition of marine water through the breakdown or removal of nutrients and other pollutants by marine ecosystem living processes that mitigate the harmful effects of the pollutants on human use or health (Haines-Young & Potschin, 2018). Waste and toxicant treatment, removal and/or storage and regulation of chemical condition of seawater via biota are included (Culhane et al., 2019; Haines-Young & Potschin, 2018). This service is therefore mainly determined by ecosystem capture processes such as nutrient uptake by aquatic plant and microbial organisms (contributing to eutrophication mitigation), breakdown of organic pollutants, control and buffering of water acidification by marine life forms, and denitrification processes by microorganisms (Silbiger & Sorte, 2018; UK NEA, 2011a). To provide some examples, coastal vegetation and mangroves have a role in purifying inland water flows to the ocean, the growth of algae has an influence on the dynamics of nutrients in seawater, zooplankton and mussels contribute via filtration and ingestion, oyster reefs and seagrass ecosystems provide water filtration processes, and different benthic populations have the ability to regulate water quality (Alarcon Blazquez, n.d.; Hasler, 2016; Veretennikov, n.d.). This ecosystem service can positively contribute to the provision of other final ecosystem services such as biomass and raw materials from in-situ aquaculture, wild fish and other natural aquatic biomass and related raw materials, and recreation related services (e.g., water quality and clarity for bathing waters; UK NEA, 2011a).
	Sediment quality regulation	Regulation, restoration, and maintenance of the chemical condition of marine sediments through the breakdown or removal of nutrients and other pollutants by marine ecosystem living processes that mitigate the harmful effects of the pollutants on human use or health. This ecosystem service is also passively used by humans because it positively contributes to the delivery of other ecosystem services such as climate regulation, the provision of aquatic wild or aquaculture biomass, and via cultural services (UK NEA, 2011a).

		The very definition of (marine) sediment quality describes the ability of the sediment to function in a purely natural or human managed context, and thus be able to support all those processes that are part of the functioning of the marine ecosystem such as the productivity of aquatic organisms, improvement of water quality etc. Consequently, this ecosystem service includes all those processes on the part of the marine biota that underlie the maintenance of sediment quality (Haines-Young & Potschin, 2018). Among these processes are the storage and degradation of organic matter, the mediation of gases exchange between sediment, ocean water and atmosphere, the storage, degradation and transformation of nutrients and contaminants by organisms ecologically connected to the marine sediment (UK NEA, 2011a). Biota living within soft sediments have the capacity for anthropogenic waste treatment. Aquatic vegetation, benthic infauna, epifauna and bacteria, through their activities including filtration and nutrition contribute to marine sediment decomposition and fixing processes, breakdown of pollutants, mineralization of hazardous and toxic substances, and ensure a balance of the nutrient cycle of the sediment that underlies the quality and functions of the sediment itself (Culhane et al., 2019; EEA 2015; Hasler, 2016).
	Pest control	In-situ control of pests in the marine environment, including invasive non-native species, proliferating native species, nuisance algae and any species that may become a nuisance to humans. As an ecosystem service, when natural pest control mechanisms fail, there may be a cost to people to maintain desired environmental conditions or to prevent or minimise any damage to biomass stocks (wild or aquaculture) or other benefits that may be affected by pests. For example, invasions of jellyfish small enough to enter cages can damage salmon stocks reared through aquaculture processes. Another example is the excessive numbers of jellyfish that sometimes occur along beaches and can cause damage to bathing and, consequently, to the economic activities around it (Culhane et al., 2019). So, the provision of this ecosystem service allows society to avoid economic costs thanks to the natural pest control function. This service can also positively contribute to the provision of other ecosystem services such as recreation related services or services such as

		wild animals, plants, and other biomass useful for the functioning of a healthy marine ecosystem. The service is mainly used passively in the marine environment (in situ), but an example of active use would be if a 'biological control' species were intentionally released as pest control. For example, wild perch are used to control sea lice in farmed salmon pens (Culhane et al., 2019). Furthermore, it should be noted that this ecosystem service is in turn dependent on the ecosystem service wild animals, plants, and other biomass and the ecological balance of all components of the marine ecosystem as it is underpinned by a stable marine food web (Culhane et al., 2019).
	Nursery population and habitat maintenance	The ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (e.g., for nurseries or migration) or the protection of natural gene pools (UK NEA, 2011d). More specifically, the service of nursery population and habitat maintenance describes the role of marine ecosystem components in providing suitable habitat, refuge from predation, and food resources for juveniles (of migratory or non-migratory species) and/or commercially important species (Culhane et al., 2019; Tuya et al., 2014). Nursery habitats are the most ecologically important habitats for juveniles, which are essential for growth. It should also be noted that nursery grounds, which may be represented simply by floating seaweeds or soft sediments, may lack significant physical structures such as rocky barriers but, nevertheless, play an essential role in the growth phase of the species (Culhane et al., 2019; Seitz et al., 2013). The contribution of marine habitats to the maintenance of gene pools and inter- and intra-specific genetic diversity through ecological and evolutionary processes are also included in this service (Ivarsson et al., 2017). Therefore, this is service may input to a number of different ecosystem services including biomass provision and recreation related services by sustaining juvenile populations of biotic groups that underpin such services (UK NEA, 2011d). Known nursery grounds include seagrass beds, biogenic reefs such as oyster and maerl beds, kelp forests but also nursery habitats mediated by abiotic elements such as soft sediments and hard bottoms (Seitz et al., 2013). This ecosystem service also includes

		links with biotic elements (marine animals or plants etc.) that are known to contribute through their activities such as feeding to the ecological maintenance of nursery grounds. Some examples of nursery grounds and biotic elements that contribute to their maintenance are as follows (Culhane et al., 2019): - Macrophytes such as seagrass beds and macroalgae such as kelp forests in shallow sublittoral and littoral habitats. - Deeper nursery habitats, such as deep-water corals, biogenic reefs etc. - Floating seaweed clumps (macroalgae) form rafts under which juvenile fish aggregate. - Sea turtles can maintain distinct seagrass beds in shallow sublittoral habitats through their feeding activities. - Infauna and epifauna maintain benthic habitats of commercially important species of demersal fish in soft sediment habitats. Thus, all soft sediment benthic habitats are included from littoral to lower bathyal (down to deepest fishing depth). - Some marine organisms, acting as prey, contribute to the maintenance of nursery populations. This includes phytoplankton and zooplankton (in pelagic habitats); fish and cephalopods may also contribute (in pelagic and benthic habitats); epifauna, infauna and microphytobenthos (in benthic habitats).
Cultural Services	Recreation related services	These are the contributions of marine ecosystems that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This is a final ecosystem service (Culhane et al., 2019; UK NEA, 2011c). For this ecosystem service, it is difficult to distinguish between physical and experiential interactions. For example, although swimming in the marine environment may be a simple physical activity not mediated by marine ecological components, it is still influenced by local features of the marine environment such as water quality, the presence of attractive and/or dangerous aquatic species, etc. (Culhane et al., 2019). This ecosystem service is provided by both marine biotic and abiotic elements of the seascape. These elements together contribute to the provision of recreational services for both locals and non-locals (i.e., tourists; UK NEA, 2011c). Most marine biotic groups contribute through their role in enhancing and sustaining in-situ physical and

		experiential activities such as diving, swimming, recreational fishing, boating, and wildlife-watching. However, not all marine biotic components are relevant to the provision of this service. For example, benthic organisms in areas not visited or reached by divers are unlikely to provide this service. Organisms such as bacteria and microphytobenthos are not considered to contribute to the provision of this service (Culhane et al., 2019). Thus, the provision of this ecosystem service depends both on the presence and state of the ecosystem components but also on the very human presence. Indeed, even if the marine ecosystem in a given area has a greater capacity to provide this service than a second area, this service will not be provided by the former if this area is not accessible to the people who are its beneficiaries (Culhane et al., 2019; O'Higgins et al., 2010).
	Visual amenity services	These are the contributions of marine ecosystems to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. This service combines with other ecosystem services, including recreation related services to underpin amenity values (UK NEA, 2011c). The provision of this ecosystem service by the seascape and its ecological components is based on the direct transmission of the feeling of "sense of place" resulting from their vision but also indirectly through the observation of artistic representations depicting marine ecosystems and landscapes. Consequently, people can use this service passively in-situ (unlike recreation related services that involve an active search for the experience) and actively or passively through viewing an artistic representation, picture, etc. in-situ or ex-situ (e.g., on the web). All components of the marine ecosystem have the potential to contribute to the provision of this service. It should be noted that in case of provision of this service ex-situ through images, artwork, books, etc., the provision does not necessarily reflect the current state of the ecological components that constitute marine ecosystems but potentially depicting a past and/or ideal condition of an environmental component. This characteristic differentiates this type of service from services such as provisioning or regulation and maintenance. This service may overlap

		with recreation related services since sensory benefits may also be experienced during recreational activities. To avoid this overlap, the context of the provision of this service needs to be specified, as recreation related services are in-situ and active (Culhane et al., 2019).
	Education, scientific, and research services	These are the contributions of marine ecosystems in enabling people to use the environment through intellectual interactions with it (UK NEA, 2011c). Scientific: Marine ecosystems and their components provide this service when they are used as the subject of both in-situ and ex-situ scientific research activities. However, the provision of this ecosystem service does not necessarily reflect the current state of the marine environment and its components. All components of the marine ecosystem can contribute to the provision of this service (Culhane et al., 2019). Educational: marine ecosystems and their components provide this service when they are used as the subject of both in-situ and ex-situ educational activities. These educational activities may include lectures held in schools and universities, museums, and coastal information centres where people are informed about local marine life forms and habitats and their characteristics. However, the provision of this ecosystem service does not necessarily reflect the current state of the marine environment and its components (Culhane et al., 2019).
	Spiritual, artistic, and symbolic services	These are the contributions of marine ecosystems recognised by people for their cultural, historical, aesthetic, sacred or religious meaning. These services may underpin people's cultural linkage with the surrounding environment, spiritually inspire people to express themselves in various form such as art and religion and bring to the surface memories born of the seascape that derive from cultural connections (UK NEA, 2011c). Heritage: marine ecosystems and their components provide this service when they are part of cultural heritage and are used ex-situ (e.g., historical records) or in-situ (e.g., old cultural practices that continue today). Numerous groups of marine organisms contribute to this service. Thus, there is an example of provision of this ecosystem service wherever there is a historical cultural record, e.g., traditional whaling and seal hunting. However, this use is ex-situ and does not necessarily reflect the current state of the marine

		environment and its components, reflecting the past condition of the marine organism populations under consideration. In contrast, activities such as seal hunting are an example of heritage service provision that takes place nowadays and is dependent on the state of the marine environment and its components. Since this activity is also linked to a provision of biomass, this type of activity is considered both in the 'wild fish and other natural aquatic biomass and related raw materials' service and in the heritage component of this ecosystem service. This does not lead to 'double counting' in an eventual economic assessment because the benefit is different depending on the ecosystem service considered (Culhane et al., 2019). Symbolic: Marine ecosystems and their components provide this service through marine biota having a symbolic role, and its use can occur either actively ex-situ (intentional symbolic representation) or ex-situ passively (e.g., welfare enhancement occurring unintentionally and as a result of symbolic use of a marine ecosystem component). Reference can be made to marine megafauna or other charismatic marine components (e.g., whales, turtles, birds, fish) that are often used as symbols of conservation societies, NGOs etc. Occurring ex-situ, the provision of this service does not necessarily reflect the current state of the marine environment and its components, possibly reflecting the past condition of the marine organism populations under consideration (Culhane et al., 2019). Sacred and/or Spiritual: Marine ecosystems and their components provide this service when they contribute to spiritual and ritual experiences and/or identity (e.g., marine organisms that are considered sacred), and the use of this service can be active or passive. Organized religious, sacred, or spiritual practices can occur in-situ or ex-situ, for example in Europe the Spanish marine religious festival for the 'Virgen del Carmen', the patron saint of fishermen and divers or the religious practices carried out by the Sami of Finland and Sweden through which they venerate elements of the marine biota. As also noted for previous services, the provision of this service also occurs ex-situ and does not necessarily reflect the current state of the marine environment and its components (Culhane et al., 2019).

	Ecosystem and species appreciation	This ecosystem service represents the well-being that people derive from the mere existence and conservation of the marine environment and its components for themselves and future generations, regardless of their direct or indirect use (UK NEA, 2011c). Marine ecosystems and their components provide this service intrinsically to their existence. People benefit from this service simply by knowing that marine ecosystems and their components exist and are in good condition, regardless of whether or not they have the opportunity to see them directly or use them. Consequently, all components of marine ecosystems contribute to the provision of this service. This service is therefore actively used ex-situ as people do not need to be in-situ to realise that they benefit from the existence of marine ecosystems. By occurring ex-situ, the provision of this service does not necessarily reflect the current state of the marine environment and its components. Furthermore, since such a thinking mechanism about the existence of marine ecosystem components by humans can also be triggered by viewing artistic or other representations, this service may overlap with some of the cultural services outlined above. However, if an economic assessment were to be conducted, there would be no risk of "double counting" as the benefits derived by humans from these cultural ecosystem services are different (Culhane et al., 2019).
Abiotic Provisioning Services	Mineral substances used for material purposes	Marine mineral resources include marine aggregates such as sand and gravel, minerals and metals such as manganese, tin, copper, zinc and cobalt, and dissolved chemicals such as salt and potassium. The extraction of marine aggregates, especially sand and gravel, is a long-established activity and an important economic activity in the OSPAR area. The supply of marine minerals, including rare earths and cobalt, can make a key contribution to meeting the rapidly growing demand for raw materials. Marine mineral resources have been extracted for centuries. In addition, mineral substances such as calcium and magnesium are extracted for example from maerl beds and used in fertiliser production by several countries, including France, at rates of up to 500,000 t/year (European Commission 2020; Haines-Young & Potschin, 2018).

Abiotic Regulation and Maintenance Services	Mediation of waste, toxics, and other nuisances by non-living processes	The contribution of the ecosystem in transforming biochemical or physical inputs to ecosystems via diluting wastes and toxic substances in marine water bodies or mediating wastes and toxic substances by other chemical or physical means such as sequestration, adsorption, accumulation, storage in marine sediments (EEA, 2015; Haines-Young & Potschin, 2018). This service includes the waste remediation processes provided by abiotic components and that are not included in the water quality regulation and sediment quality regulation services by marine biotic components. Abiotic processes such as fluid advection and photochemical transformations play an important role in the provision of waste remediation both in terms of the introduction of wastes into the marine environment but also in their dilution, degradation, and dispersal, allowing wastes to remain in the system but at harmless levels (Watson et al., 2016). For example, leaching or dissociation of toxic contaminants from plastics can degrade under the influence of many abiotic processes including photothermal, oxidative and hydrolytic degradation pathways (Watson et al., 2016). Also, wastes and toxics can be subjected to abiotic transport processes such as mixing, tidal currents, water residence, dilution etc. (Watson et al., 2016).

Table 6 presents some suggested connections between these selected ecosystem services and the Drivers of change (described in Table 2).

Table 6. Connecting ecosystem services with drivers of change.

Ecosystem Service	**Suggested connections to Drivers**
Biomass and raw materials from in-situ aquaculture	Society's need for food
Wild fish and other natural aquatic biomass and raw materials	Society's need for food
Wild animals, plants, and other biomass	Society's need for food Society's needs and appreciation of nature and biodiversity
Genetic material	Society's need for materials Society's needs and appreciation of nature and biodiversity

(Global) climate regulation	Society's need to become more resilient to the effects of climate change
Coastal protection	Society's need to adapt to the effects of climate change
Water quality regulation	Society's need for industrial processes
Sediment quality regulation	Society's need for industrial processes
Pest control	Society's need for food Society's needs and appreciation of nature and biodiversity
Nursery population and habitat maintenance	Society's needs and appreciation of nature and biodiversity
Recreation related services	Society's need for health and well-being
Visual amenity services	Society's need for health and well-being
Education, scientific and research services	Society's need for education
Spiritual, artistic and symbolic services	Society's need for health and well-being
Ecosystem and species appreciation	Society's needs and appreciation of nature and biodiversity
Mineral substances used for material purposes	Society's need for materials
Mediation of waste, toxics and other nuisances by non-living processes	Society's need for industrial processes

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OSPAR Secretariat
The Aspect
12 Finsbury Square
London
EC2A 1AS
United Kingdom

t: +44 (0)20 7430 5200
f: +44 (0)20 7242 3737
e: secretariat@ospar.org
www.ospar.org

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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