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Meeting of the Ecosystem Approach Correspondence Group on Monitoring (CORMON), Biodiversity and Fisheries

Athens, Greece, 9-10 March 2023

Agenda Item 4: **Development of IMAP EOs**

4.2. Development of EO6

Development of the IMAP Ecological Objective 6 on sea-floor integrity under the Barcelona Convention

SPA/RAC
Tunis, 2023

Note by the Secretariat

The Contracting Parties (CP) to the Barcelona Convention adopted (CoP 19, Athens 2016) the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP) (Decision IG.22/7) within the Ecosystem Approach (EcAp) process. The IMAP requirements focus on agreed Ecological Objectives (EOs) and their related common indicators.

The current IMAP covers with agreed common indicators the ecological objectives related to biodiversity (EO1), non-indigenous species (EO2), eutrophication (EO5), hydrography (EO7), coast (EO8), contaminants (EO9), and marine litter (EO10).

Ecological objectives for marine food webs (EO4) and sea-floor integrity (EO6) are not yet included in the IMAP. They were discussed in the early stages of the EcAp implementation process, with initial proposals made in 2013 for a description of Good Environmental Status (GES), associated indicators and related targets (UNEP/MAP, 2013b). However, it was agreed at the time that EO4 and EO6 needed further development, considering the lack of data and the knowledge gaps on these two topics in the Mediterranean Sea region.

This document is aimed at providing a working basis for the meeting of the Ecosystem Approach Correspondence Group on monitoring (CORMON) on biodiversity and fisheries. It includes proposals of GES descriptions, related targets and indicators for the EO6 (Sea-floor integrity). It includes also proposals regarding the broad benthic habitats, the sources of pressures to be considered in the determination of the GES regarding this EO and the linkages with the other EOs.

The meeting will be invited to review the provisional GES descriptions, related targets, indicators and to examine the proposals of the broad benthic habitats and the sources of pressures to be considered.

Also, the meeting will be invited to consider the proposal of rendering the implementation of the IMAP for EO1 and EO6 more closely aligned by merging the two EOs (only as regards seabed habitats for EO1), through use of a common set of habitats types, aligning the scales and areas for assessment between EO1 and EO6, reusing indicators, or the underlying data, from EO1 (CI-1 and CI-2) for EO6 purposes and aligning their related GES definition and targets.

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List of abbreviations and acronyms

ABIOMMED	Project "*Support coherent and coordinated assessment of biodiversity and measures across the Mediterranean for the next 6-year cycle of the MSFD implementation"* (funded by EC DG Environment)
AIS	Automatic Identification System (of vessels)
BC	Barcelona Convention
BDS2030	Biodiversity Strategy to 2030 (of EC)
BHT	Broad Habitat Type(s) (used and defined in MSFD)
CBD	Convention on Biological Diversity
CFP	Common Fishery Policy (of EU)
CI	Common Indicator (of IMAP)
CoP	Conference of the Parties (of BC)
COR-GEST	Correspondence Group on GES and targets (of EcAp process)
CORMON	Correspondence Group on Monitoring (of EcAp process)
CP	Contracting Party (to BC)
D1-D11	MSFD Descriptors 1 to 11
D6C1-C5	MSFD Descriptor 6 "Sea-floor integrity" Criteria 1 to 5
DG	Directorate General [for Environment – DG ENV] (of EC)
EC	European Commission
EcAp	Ecosystem Approach [process] (of UNEP/MAP)
EcAp CG	Ecosystem Approach Coordination Group (of EcAp process)
EEA	European Environment Agency
EMODnet	European Marine Observation and Data Network (of EC)
EO	Ecological Objective (of IMAP)
EQR	Ecological Quality Ratio
EU	European Union
EUNIS	European Nature Information System (habitat classification/typology of EEA)
FCS	Favourable Conservation Status (of HD)
FDI	Fisheries Dependent Information (from CFP's Data Collection Framework)
FRA	Fisheries Restricted Area (of GFCM)
GES	Good Environmental Status (of IMAP, MSFD)
GES Decision	Commission Decision on criteria and methods for GES (2010; 2017)
GFCM	General Fisheries Commission for the Mediterranean
HD	Habitats Directive (92/43/EEC)
HELCOM	Helsinki Commission (for the Convention on the Protection of the Marine Environment of the Baltic Sea Area, also known as the Helsinki Convention)
ICES	International Council for the Exploration of the Sea

IMAP	Integrated Monitoring and Assessment Programme (of UNEP/MAP)
INFO/RAC	Information and Communication Regional Activity Centre (of UNEP/MAP)
IUCN	International Union for the Conservation of Nature
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean (of UNEP/MAP)
MED QSR	Mediterranean Quality Status Report
MRU	Marine Reporting Unit (of MSFD)
MPA	Marine Protected Area
MS	Member State (of EU)
MSCG	Marine Strategy Coordination Group (of MSFD's Common Implementation Strategy)
MSFD	Marine Strategy Framework Directive (2008/56/EC)
MTF	Mediterranean Trust Fund
NIS	Non-indigenous species
NRL	Nature Restoration Law (2022 proposal by EC)
OHT	Other Habitat Type(s) (used in MSFD)
OSPAR	OSPAR Commission (for the Protection of the Marine Environment of the North-East Atlantic, also known as the Oslo-Paris Convention)
OWG	Online Working Group (of EcAp)
POPs	Persistent Organic Pollutants
QE	Quality Element (of WFD)
RCE	Risk if Cumulative Effects
SAC	Specially Protected Area (in Natura 2000 network of HD/BD)
SPA	Special Protection Areas (in Natura 2000 network of HD/BD)
SPA/RAC	Special Protected Areas Regional Activity Centre (of UNEP/MAP)
STECF	Scientific, Technical and Economic Committee for Fisheries (of CFP)
TG Seabed	Technical Group on seabed habitats and sea-floor integrity (of MSFD Common Implementation Strategy)
UNEP/MAP	United Nations Environment Programme/Mediterranean Action Plan
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System (of fishing vessels)
WFD	Water Framework Directive (2000/60/EC)

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1 Background

1. The Contracting Parties (CPs) to the Barcelona Convention adopted the *Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria* (IMAP; UNEP/MAP, 2016) within the Ecosystem Approach (EcAp) process. The IMAP requirements focus on agreed Ecological Objectives (EOs) and their related Common Indicators and have been developed in coherence with the European Union's (EU) Marine Strategy Framework Directive (MSFD[1]).

2. The current IMAP covers the ecological objectives related to biodiversity (EO1), non-indigenous species (EO2), eutrophication (EO5), hydrography (EO7), coast (EO8), contaminants (EO9), and marine litter (EO10). Each has one or more agreed Common Indicators (CI).

3. Ecological objectives for marine food webs (EO4) and sea-floor integrity (EO6) are not yet included in the IMAP. They were discussed in the early stages of the EcAp implementation process, with initial proposals made in 2013 for a description of Good Environmental Status (GES), associated common indicators and related targets (UNEP/MAP, 2013b). However, it was agreed at the time that EO4 and EO6 needed further development, considering the lack of data and the knowledge gaps on these two topics in the Mediterranean Sea region.

4. This present report focuses on the further development of **EO6 on sea-floor integrity**, which has been undertaken through contract No. 01_2022_SPA/RAC for the Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP) and its Regional Activity Centre on Specially Protected Areas (SPA/RAC). The work has been supported by the EU-funded ABIOMMED project "*Support coherent and coordinated assessment of biodiversity and measures across the Mediterranean for the next 6-year cycle of the MSFD implementation*" and by the Mediterranean Trust Fund (MTF).

5. Development of EO6 has been undertaken in coherence with the EU MSFD Descriptor 6 and, in particular, the recent work of the Technical Group on seabed habitats and sea-floor integrity (TG Seabed). It also takes account of recent policy developments, with a view to ensuring EO6 is relevant in the context of Mediterranean, European and global policies on environmental protection and climate change.

2 Objectives, scope and tasks

6. The aim of this report is to develop, within the framework of the Ecosystem Approach process of the Barcelona Convention, the IMAP Ecological Objective 6 on sea-floor integrity:

   a. GES definitions;
   b. related environmental targets, and
   c. list of the common indicators.

7. It has the following tasks:

   a. Examine the proposal of the EO6 (GES description, related Targets and indicators) elaborated in 2013, as set out in the document UNEP(DEPI)/MED WG.382/15: "Proposed GES and Targets regarding Ecological Objectives on biodiversity and fisheries (Joint session of the Eleventh Meeting of Focal Points for SPAs and COR-GEST on Biodiversity & Fisheries)";

1 Directive 2008/56/EC

b. Provide a revised and further developed proposal of the IMAP EO6 on sea-floor integrity (i.e., GES description, related environment targets and the list of the common candidate indicators), that should include also:

   i. the broad benthic habitats to be considered based on the Updated Reference List of Marine Habitat Types for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest in the Mediterranean;

   ii. the human activities (sources of pressures) to be considered;

   iii. information about the existence (or not) of baseline data in relation to each indicator;

   iv. the linkages (direct or indirect) with the other EO.

3 Policy context

3.1 Mediterranean Sea regional policies

8. The Mediterranean Action Plan (MAP), the first Regional Sea Programme under the auspices of UNEP, with the Barcelona Convention for the protection of the Marine Environment and the Coastal Region of the Mediterranean, focuses on conservation, management and sustainable practices, actions and strategies to be endorsed and implemented at national level by the 22 Contracting Parties (21 countries surrounding the Mediterranean Sea plus the EU). It is a unique legal framework in the region which aims to ensure coherence and regional cooperation. UNEP/MAP and its Regional Activity Centres (RACs) also assists countries in implementing national environmental policies and enhances the acquisition and exchange of scientific knowledge and data. The overall objective is to achieve sustainable development, at present and in the future, in a healthy Mediterranean.

9. **Seven protocols** are associated to the Barcelona Convention, each with a specific focus:

a. Dumping Protocol from ships and aircrafts;
b. Prevention and Emergency Protocol (concerning oil and other harmful substances);
c. Land-Based Sources Protocol;
d. Specially Protected Areas and Biological Diversity Protocol;
e. Offshore Protocol (pollution from exploration and exploitation);
f. Hazardous Wastes Protocol and
g. Protocol on Integrated Coastal Zone Management.

All seven have relevance, to varying degrees, to the protection and conservation of the Mediterranean sea-floor.

10. Following the recommendations of the Convention on Biological Diversity (CBD) on principals for implementing the **Ecosystem Approach (EcAp)** (CBD, 2000), the Contracting Parties of the Barcelona Convention adopted the **Ecosystem Approach Strategy and Roadmap** (UNEP/MAP, 2008), with the objective of achieving and maintaining Good Environmental Status (GES) for the Mediterranean Sea and coasts[2]. Implementation of this integrative approach was further detailed in subsequent years (UNEP/MAP, 2012, 2013a).

11. The **Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP)** was adopted by CPs in 2016 (UNEP/MAP, 2016a). It results from implementation of the Ecosystem Approach and defines strategies, Ecological Objectives (EO) and Common Indicators (CI) to assess and monitor the Mediterranean Sea and coasts.

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2 https://www.unep.org/unepmap/what-we-do/ecosystem-approach and https://www.rac-spa.org/ecap

12. The 2017 **Quality Status Report for the Mediterranean** (UNEP/MAP, 2017) is the first assessment for the Mediterranean Sea which is based on the Ecosystem Approach, and the Ecological Objectives and Common Indicators defined within the IMAP framework. National data reporting was not yet sufficient, so the report was based on best available information (UNEP/MAP, 2017). At the time, Ecological Objective EO6 on sea-floor integrity had not been developed and was therefore not specifically assessed in the 2017 MED QSR.

13. More recently UNEP/MAP-SPA/RAC strengthened its commitment towards seabed protection through the **Post-2020 Strategic Action Programme for the Conservation of Biological Diversity and Sustainable Management of Natural Resources in the Mediterranean Region** (UNEP/MAP 2021a) and the **Post-2020 Regional Strategy for marine and coastal protected areas and other effective area based conservation measures in the Mediterranean** (UNEP/MAP 2021b).

14. Alongside UNEP/MAP's goals to protect Mediterranean sea-floor biodiversity lie those of the General Fisheries Commission for the Mediterranean (GFCM). Key amongst GFCM actions to protect the seabed are its ban on bottom fishing below 1000m depth throughout the Mediterranean (GFCM, 2005) and protection of certain sensitive seabed habitats through establishment of Fisheries Restricted Areas (FRAs) (e.g., GFCM 2005, 2006, 2013, 2019, 2021a, b, c). GFCM has published a new strategy covering the period up to 2030, in which Target 1 focuses on healthy seas and productive fisheries (FAO, 2021).

3.2 European Union policies and initiatives

15. The **Marine Strategy Framework Directive** (MSFD) is applied by the 8 Mediterranean countries who are EU Member States (Croatia, Cyprus, France, Greece, Italy, Malta, Slovenia and Spain).

16. The directive aims to achieve "Good Environmental Status" (GES) of the EU marine waters. It requires the EU Member States to manage human activities which have an impact on the marine environment by implementing national marine strategies for their waters in cooperation with neighbouring countries in the Mediterranean Sea region. Five steps are included in the strategy[3]:

a. Assess the environmental status of the sea and the impacts upon it from human activities;
b. Determine the characteristics of good environmental status (GES);
c. Establish a series of environmental targets and associated indicators;
d. Establish and implement a monitoring programme for ongoing assessment and updating of targets;
e. Develop a programme of measures to achieve or maintain GES.

17. These steps are implemented within 6-year cycles and are reviewed and updated for the following cycle. The Member States report their marine strategies to the European Commission, who has the responsibility to assess their adequacy and provide guidance on how they should be improved. Implementation of the MSFD is currently being evaluated, with the possibility that the European Commission will propose, by 2023[4], that it is amended.

3 https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/reports_en.htm

4 MSFD Article 23 states that the Commission shall review the directive by 15 July 2023; however, the evaluation phase (2022) has concluded that the review should await the outcomes of other key policy developments and so is likely to be announced later.

18. The MSFD is supplemented by **Commission Decision (EU) 2017/848** (hereafter as 'GES Decision') which provides the criteria and methodological standards for determining GES and assessing the extent to which it has been achieved. The 2017 Decision provides a major update of the initial Commission Decision (2010/477/EU) including a much clearer framework for MSFD implementation. It is accompanied by a **revised MSFD Annex III**[5].

19. The **Water Framework Directive** (WFD[6]) establishes a framework for the protection of waters with the objective of achieving and maintaining good water status for all European waters. The directive applies to transitional and coastal waters and the sea-floor up to 1 nautical mile from the coastline. For assessment of good status, a number of Quality Elements (QE) are defined in WFD Annex V.1.2, some of which are particularly relevant for IMAP EO1 (biodiversity) and EO6 (sea-floor integrity).

20. The **Habitats Directive** (HD[7]) aims to ensure the EU's biodiversity, including in the marine environment, is restored and conserved. Specified species and habitats of Community interest should reach favourable conservation status (FCS) such that their long-term survival in their natural range within Europe is secured. Special Areas of Conservation (SACs) are designated by MS for this purpose. SACs, together with the Special Protection Areas (SPAs) of the Birds Directive (BD[8]), form the Natura 2000 network. The habitats to be protected are listed in HD Annex I and include 8 marine habitats of which one (Posidonia beds *Posidonia oceanica*) is treated as a priority habitat (European Commission, 2013).

21. The EU **Common Fisheries Policy** (CFP[9]) aims to ensure the negative impacts of fishing activities on the marine ecosystem are minimised (CFP Article 2(3)). This is supported, amongst others, by the Mediterranean Regulation[10], and reinforced through the Technical Measures Regulation[11] which requires EU fisheries to reduce their environmental impacts to levels compatible with 'good environmental status' under MSFD and 'favourable conservation status' under the Habitats Directive goals.

22. The **EU Biodiversity Strategy for 2030** (BDS2030[12]) is a plan to protect nature and reverse the degradation of ecosystems. It contains specific commitments and targets including:

Target 1 *Legally protect a minimum of 30% of the EU's land area and a minimum of 30% of the EU's sea area, and integrate ecological corridors, as part of a true Trans-European Nature Network.*

Sub-target A1.2 Legally protect a minimum of 30% of the EU sea area:

Indicator A1.2.1 Marine protected area coverage. Percentage of marine waters, per each European Country and at European level (EU 27), covered by protected areas. The indicator is calculated by the sum of nationally designated protected areas and the areas of Natura 2000 sites.

23. The BDS2030 has led to two initiatives of particular relevance to the sea-floor:

5 Commission Directive (EU) 2017/845

6 Directive 2000/60/EC

7 Directive 92/43/EEC

8 Directive 92/43/EEC

9 Regulation (EU) No 1380/2013

10 Council Regulation (EC) No 1967/2006

11 Regulation (EU) 2019/1241

12 Commission Communication COM/2020/380

a. Proposal for a **Nature Restoration Law**

24. The Nature Restoration Law (NRL, European Commission, 2022b) proposes that Member States adopt nature restoration plans, with a 2030-2050 timeline for the restoration of particular ecosystems, including marine ecosystems. The 2022 proposal includes in its Annex II a specified list of marine habitat types to be restored, based on the EUNIS typology; this includes seagrass beds, coastal saltmarsh, kelp and macroalgal communities, all of which are habitats with very high rates of carbon sequestration, and sediment habitats which, due to their very large extent[13], would provide the largest store of carbon if restored to their natural state. Restoration targets are proposed to be achieved by 2030 and 2040, ultimately achieving 90% restoration of each habitat by 2050.

b. Action Plan for the conservation of fisheries resources and protect marine ecosystems

25. The Action Plan [update when published] aims to build bridges between environmental and fisheries policy and will specifically address protection of the seabed from damage by bottom fishing, given that the BDS2030 acknowledges bottom fishing to be the most damaging activity affecting the seabed in the seas around Europe.

The Action Plan is expected to seek limitations to bottom fishing within marine protected areas (MPAs) to protect these designated areas, as well as beyond MPAs to achieve GES for MSFD[14].

3.3 Global policies

26. The Mediterranean and EU policies described in sections 3.1 and 3.2 are complimented and strengthened by a variety of global policies which aim to protect biodiversity and address impacts of climate change. These include UNCLOS, which requires protection of all seabed resources of Contracting Parties and in the high seas, and the Convention on Biological Diversity which adopted new global targets for marine biodiversity protection at its COP-15 meeting in December 2022.

3.4 Synergies between policies

27. The array of environmental policies described above provide a complex set of objectives and implementation requirements relating to the Mediterranean sea-floor. Their implementation by UNEP/MAP and its Contracting Parties, and in particular by those Contracting Parties who are also EU Member States, will be most effective and efficient if considered together in a holistic manner, thereby avoiding redundancy and reducing costs. As these policies are ultimately aiming to achieve a good status for the marine environment, through sustainable management of human activities, harmonised approaches to assessment of environment status, environmental monitoring, and setting of targets and measures, can help to ensure single underlying actions will deliver to multiple policies and objectives.

4 Anthropogenic pressures affecting the Mediterranean sea-floor

28. Anthropogenic pressures, stemming from activities in both the marine and terrestrial environments, can adversely affect[15] the marine environment. In addition, anthropogenic climate change may lead to a number of effects on the marine environment which can be broadly categorised as a) ocean acidification, b) carbon sequestration changes and c) hydrological changes. These

13 It is estimated that marine sediment habitats between 0-1000m depth cover an area of EU marine waters equivalent to about 44% of the EU land territory.

14 In order to achieve the threshold values currently being developed by TG Seabed for MSFD Descriptor 6.

15 ‘adverse effect’ is the term used in the MSFD; alternatively, it can be referred to as ‘environmental impact’.

pressures have been reviewed as to their possible relevance to the Mediterranean sea-floor and its habitats, using the list of pressures provided in MSFD Annex III Table 2a[16] (**Table 1**).

***Table 1**. Anthropogenic pressures, including from climate change, which can adversely affect the marine environment, with an indication of their relevance to the Mediterranean sea-floor and its habitats.*

Yes = widespread relevance, known impacts; Possible = limited relevance due to restricted nature of pressure (and associated human activities) or potential for impacts but limited knowledge. List of pressures derived from MSFD Annex III Table 2a (Commission Directive (EU) 2017/845), with climate change added.

Theme	Pressure	Possibility to affect sea-floor
Biological	Input or spread of non-indigenous species	Yes; non-indigenous species (NIS) are widespread and may be abundant enough to impact seabed habitats (through disturbances to habitat characteristics or loss when habitat structure or community switches to another one).
	Input of microbial pathogens	Possible; effects on sea-floor not often studied as monitoring is primarily focused on coastal water quality (e.g., bathing waters).
	Input of genetically modified species and translocation of native species	Possible; unlikely to be a significant pressure on the seabed except if there is a risk of spreading by some species (e.g., from marine culture or coastal translocations by vectors like fishing or extraction discards); not often monitored.
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species	Possible; seabed cultivation activities are limited in extent in the Mediterranean[17].
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence	Possible; pressure mainly affects mobile species (e.g., birds, seals, cetaceans, turtles, shark and rays), but could have very localised effects on some coastal habitats, and indirect effects due to changes in the functional use (e.g. trophic) of habitats by disturbed mobile species[18].
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)	Yes; widespread and extensive effects where bottom fishing using benthic-impacting fishing gears occurs, including Illegal, Unreported and Unregulated (IUU) fishing.
Physical	Physical disturbance to seabed (temporary or reversible)	Yes; widespread and extensive effects where bottom fishing and other activities such as sand extraction offshore energy farms, offshore oil/gas platforms, underwater pipelines and cables, physically affect the sea-floor, particularly during construction phase.
	Physical loss (due to permanent[19] change of seabed substrate or morphology and to extraction of seabed substrate)	Yes; widespread pressure, particularly in coastal and nearshore areas; habitat loss typically has limited extent, excepting for coastal (littoral) habitats but can also target specific habitat (sub)types.
	Changes to hydrological conditions	Yes; widespread pressure, particularly in coastal and nearshore areas; changes typically have limited extent, excepting when associated with loss of coastal (littoral) habitats and some

16 MSFD Annex III was updated in 2017 (Directive (EU) 2017/845), following a thorough review of the pressure types used in other fora. It aims to provide a comprehensive set of pressure types relevant to the marine environment, excepting for those related to climate change. The climate change pressures are introduced here for EO6 in recognition of the growing awareness of their importance in adversely affecting the marine (and terrestrial) environment.

17 Includes cultivation of benthic species, e.g., *Magelana gigas* which has spread from mariculture.

18 For example, Price (2008) in Lunney, Munn & Meikle Ed., 2008 http://dx.doi.org/10.7882/FS.2008.023.

19 Commission Decision (EU) 2017/848 defines ‘permanent change’ as a change which has lasted or is expected to last for 12 years or more.

Theme	Pressure	Possibility to affect sea-floor
		specific habitat types which have particularly extensive exposure to the pressure (e.g. seagrass beds, mudflats, beaches).
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition	Yes; eutrophication effects are restricted to certain coastal/nearshore areas, due to oligotrophic nature of Mediterranean. Nutrient enrichment may lead to anoxia or hypoxia at or near the seabed leading to significant effects on the seabed communities.
	Input of organic matter — diffuse sources and point sources	Yes; localised effects in some nearshore habitats (e.g., from fish farms, fish processing or urban and industrial waste-water discharges).
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events	Possible; diffuse pollution is widespread[20], but monitoring is focused on water quality or at species level; point-source pollution has potential to cause localised effects at 'community level'.
	Input of litter (solid waste matter, including micro-sized litter)[21]	Possible; widespread with possible effects, but monitoring is focused on quantification of litter and effects on mobile species.
	Input of anthropogenic sound (impulsive, continuous)	Possible[22]; but monitoring is focused on quantification of noise and effects on mobile species.
	Input of other forms of energy (including electromagnetic fields, light and heat)	Possible; any effects likely to be localised, as indicated by some studies related to offshore renewable energy activities.
	Input of water — point sources (e.g. brine)	Possible; any effects likely to be localised.
Climate change	Ocean acidification	Yes; widespread and extensive, particularly for calcareous species (e.g., hard corals, molluscs, echinoderms and sd).
	Changes to carbon sequestration processes	Yes; widespread and extensive, particularly for physically-disturbed and vegetated habitats.
	Hydrological changes (water temperature and heat waves, salinity, sea-level, wave action/storms, currents, freshwater inputs)	Yes; widespread and extensive[23], particularly for coastal and nearshore habitats.

29. From **Table 1**, it can be seen that the anthropogenic pressures causing most widespread and extensive adverse effects to the sea-floor and its habitats in the Mediterranean are:

a. Non-indigenous species

b. Extraction of wild species

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20 Contamination by pollutants may occur far from riverine inputs, even extending into deep-sea canyons, for example in French waters out from the River Rhône (Bonifacio et al, 2014, https://doi.org/10.1016/j.ecss.2014.10.011).

21 Includes lost and abandoned fishing gear.

22 For example, effects linked to generation of offshore renewable energy (http://dx.doi.org/10.35690/978-2-7592-3545-2 [in French].

23 Possible wide-ranging effects on marine species, their productivity and life cycles, occurrence of NIS, changes in food webs and plankton.

c. Physical disturbance to the seabed
d. Physical loss of seabed
e. Changes to hydrological conditions
f. Input of nutrients and organic matter
g. Input of litter (including lost and abandoned fished gear)
h. Climate change (acidification, carbon sequestration, hydrological changes)

Contracting Parties are invited to agree:

The IMAP process for Ecological Objective 6 on sea-floor integrity should focus on the main pressures (a-h) which are widespread and have potential to cause extensive adverse effects to seabed habitats and sea-floor integrity in the Mediterranean.

Contracting Parties may wish to additionally consider other pressures, as noted in Table 1, in cases where these pressures are considered particularly relevant to specific areas and/or habitats in a national context.

5 Human activities affecting the Mediterranean sea-floor

30. UNEP/MAP-SPA/RAC (2022) [UNEP/MED WG. 547/Inf.4] provides a review of the main human activities affecting the Mediterranean sea-floor (provided in Annex I for convenience). **Table 2** provides a relationship between these human activities and the main sea-floor pressures (a-h), as identified in section 4. It also provides a review of land-based pollution, non-indigenous species, litter, climate change and cumulative impacts (see Annex I). Annex II provides a review of 'blue carbon', particularly in relation to activities causing physical disturbance of the seabed, such as bottom fishing.

***Table 2**. Human activities in the Mediterranean (based on UNEP/MAP-SPA/RAC (2022) [UNEP/MED WG. 547/Inf.4])) and their main effects (pressures) on the sea-floor. Organised according to the activity and pressure themes of MSFD Annex III. Note that only the main activity/pressure interactions are indicated (orange cells).*

	Pressure theme	**Biological**		**Physical**			**Substances, litter & energy**		**Climate change**		
Activity theme	**Pressure** **Activity**	NIS	Extraction of species	Physical disturbance	Physical loss	Hydrological changes (localised)	Inputs of nutrients and organic matter	Inputs of litter (including fished gear)	Acidif-ication	Carbon sequest -ration	Hydrological changes (widespread)
Physical restructuring of rivers, coastline or seabed	Coastal artificialisation										
	Dredging and dumping										
Extraction of non-living resources	Gas and oil exploration and exploitation										
	Mining										
Production of energy	Offshore wind farms & other renewable energy generators										
Extraction of living resources	Commercial bottom fishing (including trawls & dredges)										
	Small-scale and recreational fishing										
Cultivation of living resources	Aquaculture activities										
Transport (marine)	Shipping, including anchoring, lost containers, oil spills and wreckage										
Urban and industrial uses	Urban uses; industrial uses; waste treatment & disposal										

6. Relationship between EO6 and the other EOs

31. EO6 on sea-floor integrity is closely linked to several EOs which directly deal with seabed habitats and with other EOs that address pressures that may affect the sea-floor and its habitats. These are presented in

32. **Table 3**, together with comments on how these synergies could be exploited.

Table 3*. Links between EO6 and other EOs and their Common and Candidate Indicators (UNEP/MAP, 2016). Links are to 2017 MED QSR indicator assessments.*

Ecological Objective	Common and Candidate Indicators	Relevance to EO6
EO1 Biodiversity	CI-1: Habitat distributional range CI-2: Condition of the habitat's typical species and communities CI-3, CI-4 and CI-5 address marine birds, mammals and reptiles (Species distributional range, Population abundance and Population demographic characteristics)	Relevant. EO1 addresses seabed habitats (as well as species of marine birds, mammals and reptiles), thereby providing a direct overlap with EO6 in cases where the seabed addressed under each EO overlaps (see section 10.2). CI-1 and CI-2 could be reused for EO6.
EO2 Non-indigenous species	CI-6: Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species	Potentially relevant. Benthic NIS, when occurring in high abundance or when multiple NIS are present in a community, can cause adverse effects to the seabed habitat. CI-6 provides an assessment of the extent and abundance of NIS. Assessments of adverse effects of NIS per habitat type, based on CI6, could be used to contribute to the assessment of EO1 and EO6.
EO3 Harvest of commercially exploited fish and shellfish	CI-7: Spawning stock biomass CI-8: Total landings CI-9: Fishing mortality CI-10: Fishing effort CI-11: Catch per unit of effort (CPUE) or Landing per unit of effort (LPUE) as a proxy CI-12: Bycatch of vulnerable and non-target species (EO1 and EO3)	Potentially relevant. The status of demersal/benthic commercially exploited fish and shellfish (derived from CI-7, CI-9 and other CIs) could be used to contribute to the assessment of EO1 and EO6, as the species status may partially reflect the status of the seabed habitat occupied by the species. CI-12 may be used to assess bycatch of macrobenthic species, including so-called 'VME species'.
EO4 Marine food webs	To be developed	Potentially relevant. Food webs include interactions between the seabed, water column and marine species living in and above the sea. When CIs are being developed for EO4, it would be sensible to consider whether the data and CIs available under EO1 and EO6 could be reused for EO4 purposes, and how future CIs for EO4 could address specific functional aspects of food webs that also contribute to EO1 and EO6.
EO5 Eutrophication	CI-13: Concentration of key nutrients in water column CI-14: Chlorophyll-a concentration in water column	Limited relevance at present. Eutrophication can affect the seabed as well as the water column and in the Mediterranean is mostly confined to coastal waters; CI-13 and CI-14 relate to the water column; in cases where their assessment indicates high pressure levels it may indirectly indicate there may be eutrophication problems on the seabed.

Ecological Objective	Common and Candidate Indicators	Relevance to EO6
EO7 Hydrography	CI-15: Location and extent of habitats impacted directly by hydrographic alterations	Relevant. Hydrographical alterations to seabed habitats are directly relevant to EO6 (and EO1). Assessments of CI-15 need to provide the extent of adverse effect per habitat so results can feed into assessments of EO-6 and EO-1.
EO8 Coastal ecosystems and landscapes	CI-16: Length of coastline subject to physical disturbance due to the influence of man-made structures Candidate Indicator-25: Land use change	Relevant. If assessment of CI-16 provides results on the extent of effects to littoral rock and sediment habitats, the results can be directly used under EO6. In addition to the direct loss of littoral habitats by construction on the coast (CI-16), artificialisation of coastline can lead to dispersal of material in the near-shore zone, thereby causing smothering and loss of near-shore habitats.
EO9 Pollution	CI-17: Concentration of key harmful contaminants measured in the relevant matrix CI-18: Level of pollution effects of key contaminants where a cause-and-effect relationship has been established CI-19: Occurrence, origin (where possible), extent of acute pollution events (e.g. slicks from oil, oil products and hazardous substances), and their impact on biota affected by this pollution CI-20: Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood CI-21: Percentage of intestinal enterococci concentration measurements within established standards	Potentially relevant. CI-17 assesses contamination in seabed sediment, while CI-18 and CI-20 assess contamination in species, some of which may be benthic. The quality thresholds for these CIs are typically not set to detect 'community-level' changes in habitat condition; however, chronic pollution (e.g., from point source discharges) can adversely affect habitat condition. CI-21 tends to address water quality issues and is generally not suitable to indicate pollution problems for benthic habitats. CI-19 could potentially be used for EO6 and EO1 assessments, if results are oriented towards specified seabed habitat types.
EO10 Marine litter	CI-22: Trends in the amount of litter washed ashore and/or deposited on coastlines (including analysis of its composition, spatial distribution and, where possible, source) CI-23: Trends in the amount of litter in the water column including microplastics and on the seafloor Candidate Indicator-24: Trends in the amount of litter ingested by or entangling marine organisms focusing on selected mammals, marine birds and marine turtles	Limited relevance at present. CI-22 and CI-23 can yield results on the amount of litter on the shore (coast) and seabed; this quantification is of only limited use in assessing whether the litter is adversely affecting the seabed habitats because litter/habitat interactions are not well understood. Areas where litter accumulates (litter sinks) offer more possibilities to assess the impacts of litter at the habitat/community level.
EO11 Energy including underwater noise	Candidate indicator-26: Proportion of days and geographical distribution where loud, low, and mid-frequency impulsive sounds exceed levels that are	Not currently relevant. The CIs for EO11 are focused on quantifying the distribution and intensity of underwater noise, calibrated to their effects on certain marine species (e.g., cetaceans, fish). Effects of underwater noise on

Ecological Objective	Common and Candidate Indicators	Relevance to EO6
	likely to entail significant impact on marine animals Candidate Indicator-27: Levels of continuous low frequency sounds with the use of models as appropriate	benthic species are reported in scientific literature, but the CIs are not currently of direct use to assess effects to seabed habitats.

From the analysis in

33. **Table 3**, it can be concluded that there is a direct overlap in the areas of seabed addressed by EO6 (as sea-floor integrity) with EO1 (as seabed habitats) and EO8 (as coastal habitats), which all focus on the state of biodiversity and ecosystems. There are also links to EO4 through the broader consideration of food webs and to EO3 through demersal/benthic commercially exploited fish and shellfish.

34. There are strong links to EOs which address specific pressures that can yield a measurable footprint of impact on the sea-floor and its habitats: EO2 (non-indigenous species), EO5 (eutrophication) and EO7 (hydrography). EO9 (pollution), EO10 (litter) and EO11 (underwater noise) can all have effects on seabed habitats or species, but their direct use (at least at present) for EO6 is limited.

35. These inter-relationships provide an opportunity to reuse indicators, data and assessments from other EOs for EO6 purposes. This is especially valid when their outputs are made with direct use for EO6 in mind (e.g., producing footprints of impact per habitat type for a given pressure). However, the CIs for some EOs are not currently fully adapted for use under EO6 but could be useful if further developed.

Contracting Parties are invited to agree:

Ecological Objective 6 on sea-floor integrity should be implemented in close association with other state-based EOs (EO1, EO3, EO8) by making use of their Common Indicators, data and assessments when suitable.

EO6 should also make use of the pressure-based EOs (EO2, EO5, EO7) by using their Common Indicators, data and assessments when suitable (or further developing these to make them more suitable, such as to provide 'footprints' of impact). It is important to provide such results per seabed habitat to enable their reuse for EO6 assessments.

7. Relationship between EO6 and MSFD descriptors and criteria

36. UNEP/MAP has sought to maintain close relationships between the IMAP and the MSFD to help ensure IMAP implementation can be of direct relevance to those Contracting Parties who are also EU Member States. Implementation of IMAP and the MSFD started about the same time (2008) and has progressed in parallel since then. There is, consequently, a close relationship between the IMAP Ecological Objectives and the MSFD Descriptors, and also between the IMAP Common/Candidate Indicators and the criteria and indicators provided in Commission Decision 2010/477/EU which aims to allow assessment of the extent to which GES has been achieved under the MSFD. This 2010 'GES Decision' was replaced in 2017 by Commission Decision (EU) 2017/848 which provides a more structured and detailed set of criteria, benefitting from the increased understanding and scientific developments that took place in the early years of the MSFD implementation process. The correspondence between the criteria/indicators of the 2010 GES Decision and the criteria of the 2017 GES Decision is given in Annex I of the MSFD 2018 reporting guidance (EC, 2018[2019]).

Building upon the analysis in

37. **Table 3**, **Table 4** shows the correspondence between the EOs and their Common/Candidate Indicators and the MSFD Descriptors and their criteria.

Table 4*. Correspondence between the EOs and their Indicators (UNEP/MAP, 2016) and the MSFD Descriptors and their criteria (Commission Decision (EU) 2017/848).*

IMAP Ecological Objectives	Common and Candidate Indicators	MSFD criteria Primary criteria (in bold); secondary criteria (not in bold)	MSFD Descriptors
EO1 Biodiversity	CI-1: Habitat distributional range		D1 Biodiversity
	CI-2: Condition of the habitat's typical species and communities	**D1C6 Pelagic habitat condition**	
	CI-3: Species distributional range (birds, mammals, turtles)	**D1C4 Population distributional range and pattern (Mammals, turtles, HD[24] fish)** (Birds, non-HD fish, cephalopods)	
	CI-4L Population abundance of selected species (birds, mammals, turtles)	**D1C2 Population abundance**	
	CI-5: Population demographic characteristics (birds, mammals, turtles)	**D1C3 Population demographic characteristics (Mammals, turtles, commercial fish & cephalopods, HD fish)** (Birds, non-commercial fish & cephalopods)	
		D1C5 Habitat for the species (Mammals, turtles, HD fish) (Birds, non-HD fish, cephalopods)	
EO2 Non-indigenous species	CI-6 (in part)	**D2C1 Newly-introduced NIS**	D2 Non-indigenous species
	CI-6: Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species	D2C2 Established NIS	
		D2C3 Adverse effects of NIS on species and habitats	
EO3 Harvest of commercially exploited fish and shellfish	CI-7: Spawning stock biomass	**D3C2 Spawning stock biomass (SSB)**	D3 Commercial fish and shellfish
	CI-8: Total landings		
	CI-9: Fishing mortality	**D3C1 Fishing mortality rate (F)**	
		D3C3 Population age and size distribution	
	CI-10: Fishing effort		
	CI-11: Catch per unit of effort (CPUE) or Landing per unit of effort (LPUE) as a proxy		

24 HD refers to species listed under the Habitats Directive.

IMAP Ecological Objectives	Common and Candidate Indicators	MSFD criteria **Primary criteria (in bold);** secondary criteria (not in bold)	MSFD Descriptors
	CI-12: Bycatch of vulnerable and non-target species	**D1C1 Mortality rate from incidental by-catch**	D1 Biodiversity
EO4 Marine food webs	Indicators to be developed.	**D4C1 Trophic guild species diversity**	D4 Food webs
		D4C2 Abundance across trophic guilds	
		D4C3 Trophic guild size distribution	
		D4C4 Trophic guild productivity	
EO5 Eutrophication	CI-13: Concentration of key nutrients in water column	**D5C1 Nutrient concentrations**	D5 Eutrophication
	CI-14: Chlorophyll-a concentration in water column	**D5C2 Chlorophyll a concentration**	
		D5C3 Harmful algal blooms	
		D5C4 Photic limit	
		D5C5 Dissolved oxygen concentration	
		D5C6 Opportunistic macroalgae of benthic habitats	
		D5C7 Macrophyte communities of benthic habitats	
		D5C8 Macrofaunal communities of benthic habitats	
EO6 Sea-floor integrity	For possible indicators refer to section 10.3 of this paper.	**D6C1 Physical loss of the seabed**	D6 Sea-floor integrity
		D6C2 Physical disturbance to the seabed	
		D6C3 Adverse effects from physical disturbance on benthic habitats	
		D6C4 Benthic habitat extent	
		D6C5 Benthic habitat condition	
EO7 Hydrography		D7C1 Permanent alteration of hydrographical conditions	D7 Hydrographical conditions
	CI-15: Location and extent of habitats impacted directly by hydrographic alterations	D7C2 Adverse effects from permanent alteration of hydrographical conditions on benthic habitats	
EO8 Coastal ecosystems and landscapes	CI-16: Length of coastline subject to physical disturbance due to the influence of man-made structures		
	Candidate Indicator-25: Land use change		
EO9 Pollution	CI-17: Concentration of key harmful contaminants measured in the relevant matrix	**D8C1 Contaminants in environment**	D8 Contaminants

IMAP Ecological Objectives	Common and Candidate Indicators	MSFD criteria **Primary criteria (in bold);** secondary criteria (not in bold)	MSFD Descriptors
	CI-18: Level of pollution effects of key contaminants where a cause-and-effect relationship has been established	D8C2 Adverse effects of contaminants on species and habitats	
	CI-19: Occurrence, origin (where possible), extent of acute pollution events (e.g. slicks from oil, oil products and hazardous substances), and their impact on biota affected by this pollution	**D8C3 Significant acute pollution events (in part)** D8C4 Adverse effects of significant pollution events on species and habitats (in part)	
	CI-20: Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood	**D9C1 Contaminants in seafood**	D9 Contaminants in seafood
	CI-21: Percentage of intestinal enterococci concentration measurements within established standards		
EO10 Marine litter	CI-22: Trends in the amount of litter washed ashore and/or deposited on coastlines (including analysis of its composition, spatial distribution and, where possible, source)	**D10C1 Litter (in part)**	D10 Litter
	CI-23: Trends in the amount of litter in the water column including microplastics and on the seafloor	**D10C1 Litter (in part)** **D10C2 Micro-litter (in part)**	
	Candidate Indicator-24: Trends in the amount of litter ingested by or entangling marine organisms focusing on selected mammals, marine birds and marine turtles	D10C3 Litter ingested (in part) D10C4 Adverse effects of litter on species (in part)	
EO11 Energy including underwater noise	Candidate indicator-26: Proportion of days and geographical distribution where loud, low, and mid-frequency impulsive sounds exceed levels that are likely to entail significant impact on marine animals	**D11C1 Anthropogenic impulsive sound**	D11 Energy, including underwater noise
	Candidate Indicator-27: Levels of continuous low frequency sounds with the use of models as appropriate	**D11C2 Anthropogenic continuous low-frequency sound**	

38. From **Table 4**, it can be seen there is a high degree of correspondence between IMAP EOs and indicators and the MSFD Descriptors and criteria of the 2017 GES Decision (bearing in mind that the IMAP indicators were developed considering the 2010 GES Decision). There are some notable differences:

a. EO1 Biodiversity addresses habitats via indicators CI-1 and CI-2, while the 2017 GES Decision has merged the seabed habitat aspect of Descriptor 1 with sea-floor integrity under Descriptor 6, placing all criteria under Descriptor 6, to reduce redundancy;

b. EO3 Commercial fish and shellfish includes CI-12 on bycatch, while the equivalent criterion is placed under Descriptor 1 for MSFD (criterion D1C1 on species mortality from bycatch mirrors criterion D3C1 on fish and shellfish mortality under Descriptor 3);
c. EO8 Coastal ecosystems and landscapes has no equivalent descriptor under MSFD. The Barcelona Convention includes the coastal (land) zone of the Mediterranean within its scope and consequently this zone is included in the IMAP, thereby supporting integration objectives across the land-sea boundary. The MSFD scope extends to the top of the shore where the sea has influence but not onto the coastal land above this;
d. EO9 Pollution includes indicators CI17-CI19 which are addressed under MSFD Descriptor 8 (contaminants in the environment) and CI-20 which is addressed under Descriptor 9 (contaminants in seafood), effectively treating contaminants under a single pollution EO. EO9 also includes CI-21 on microbial pathogens for which there is no equivalent criterion under MSFD. Microbial pathogens are included in the list of pressures in Table 2 of MSFD Annex III and so may be considered in environmental assessments;
e. At the indicator/criteria level, there is a high degree of correspondence between IMAP and MSFD, but both systems cover topics that are not addressed by the other. Indicators are not yet developed for EO4 (food webs) and EO6 (sea-floor integrity) – the latter are considered in this paper (see section 10.3). As noted in section 4 (pressures on seabed) and section 6 (relationship of EOs and indicators to EO6), there is a need and possibility to use indicators from other EOs to contribute to assessments for EO6, particularly to assess the extent of impacts from specific pressures.

Contracting Parties are invited to note:

The close relationships between the IMAP Ecological Objectives and Common/Candidate Indicators and the MSFD Descriptors and criteria, and that these synergies support use of IMAP in implementation of the MSFD for those Contracting Parties who are also EU Member States.

For the MSFD, the 2017 GES Decision brought together the criteria relevant for seabed habitats under Descriptor 1 Biodiversity and those for sea-floor integrity under Descriptor 6, to reduce redundancy in implementation processes by requiring a single set of assessments of seabed habitat types to cover both descriptors.

39. As noted above, treatment of seabed habitats under MSFD Descriptor 1 and sea-floor integrity under Descriptor 6 has been brought together in the 2017 GES Decision via a single set of criteria (D6C1 to D6C5). This recognises the close relationship between the two descriptors which essentially address the same part of the marine environment (seabed) and have similar aims (to achieve good condition for benthic species and communities and ecosystem functioning). It is also the intension of the 2017 GES Decision that treating seabed habitats and sea-floor integrity together will remove redundancies by having single processes for defining GES, undertaking monitoring and assessments, setting targets and introducing measures.

Contracting Parties are invited to consider:

Whether implementation of the IMAP for EO1 and EO6 should become more closely aligned, as has been done under the MSFD through the 2017 GES Decision.

This could, for example, be achieved through:

a. Merging the two EOs (only as regards seabed habitats for EO1), through use of a common set of habitat types (see section 8);
b. Aligning the scales and areas for assessment between EO1 and EO6 (see section 9);
c. Reusing indicators, or the underlying data, from EO1 (CI-1 and CI-2) for EO6 purposes (see section 10);
d. Aligning GES and targets (see section 11).

8. Scope of the sea-floor and seabed habitats to be addressed

40. The sea-floor and its marine habitats extend from the littoral zone, periodically uncovered by the tides each day[25], down to the abyss at depths of 5000 m or more. This entire area falls within the scope of EO6. The scope of the Barcelona Convention extends to the coastal zone above the high-water mark; this lies outside the scope of EO6 but is addressed under EO8.

41. In the context of MSFD Descriptor 6 on sea-floor integrity, ICES (2014) gives the following definition for the sea-floor: "*a key compartment for marine life. It includes both the physical and chemical parameters of seabed (e.g., bathymetry, roughness (rugosity), substratum type, oxygen supply, etc.) as well as the biotic composition of the benthic community. Different kinds of habitats for sedentary and mobile marine species are formed inside and above the seabed".*

42. The biotic and abiotic characteristics of the sea-floor vary according to depth, substrate type and hydrological conditions, including temperature and salinity regimes, wave action, currents and other factors. TG Seabed provides further details on habitat characteristics in a background paper on assessing adverse effects on the seabed for MSFD Descriptor 6 (TG Seabed, 2021a). Particular combinations of abiotic characteristics support recognisable communities of benthic species, such as *Posidonia* seagrass meadows and maerl beds. These are referred to as habitats (or more technically as biotopes or bioceonoses). The Barcelona Convention has defined a typology (classification) of the marine habitats present in the Mediterranean (SPA/RAC–UN Environment/MAP, 2019; Montefalcone et al. 2021); this typology is also included in the European EUNIS habitat classification (European Environment Agency, 2022).

8.1 Habitat to be assessed – broad and specific types

43. Protection of seabed habitats by the Barcelona Convention has mostly focused on specific types which are considered to be under particular threat, such as *Posidonia* meadows, maerl beds and coralligenous beds. For IMAP and application of EO1, monitoring methods have been defined for these three habitat types (UNEP/MAP, 2019, 2021c) and data flows into the INFO/RAC system were initiated in 2020. Discussions within the Biodiversity Online Working Group (OWG) have considered a longer list of habitat types for application under EO1, but a final list has not yet been agreed. A review of possible EO1 habitats is underway (SPA/RAC, 2022).

44. The scope of EO6 is broad, referring more generally to 'sea-floor integrity'. Under MSFD, the equivalent Descriptor 6 it is being applied to a set of 22 'broad habitat types' (BHT) as listed in Table 2 of Commission Decision (EU) 2017/848. Together these cover the entire seabed from the littoral zone down to abyssal depths with the aim of achieving GES across a full range of seabed habitats. **Figure 1** shows the level-2 structure of the marine habitat typology of the Barcelona Convention and EUNIS typologies (note, for BC habitats add '.5' to the EUNIS code, e.g., 'MB1.5' for Infralittoral rock). The MSFD 'broad habitat types' equate directly to these BC/EUNIS level-2 types, although some are aggregations of these types, as indicated by the thick red boxes. This reduces the number of habitat types to be assessed from 42 to 22.

25 And by wave action and changes in atmospheric pressure.

		Hard/firm		Soft			
	Level 2	Rock*	Biogenic habitat (flora/ fauna)	Coarse	Mixed	Sand	Mud
Phytal gradient/ hydrodynamic gradient	Littoral	MA1	MA2	MA3	MA4	MA5	MA6
	Infralittoral	MB1	MB2	MB3	MB4	MB5	MB6
	Circalittoral	MC1	MC2	MC3	MC4	MC5	MC6
Aphytal/ hydodynamic gradient	Offshore circalittoral	MD1	MD2	MD3	MD4	MD5	MD6
	Upper bathyal	ME1	ME2	ME3	ME4	ME5	ME6
	Lower bathyal	MF1	MF2	MF3	MF4	MF5	MF6
	Abyssal	MG1	MG2	MG3	MG4	MG5	MG6

MSFD Broad Habitat Types

Figure 1*. Level 2 structure of the Barcelona Convention/EUNIS marine habitats classification, showing the MSFD broad habitat types as directly relating to a BC/EUNIS level 2 class or aggregations of classes (bold red borders) (from MSCG_29-2021-05). For BC codes add '.5' to the EUNIS code (e.g., 'MB1.5' for Infralittoral rock).*

45. In addition to the BHTs, EU Member States may choose to protect more specific habitats, referred to as 'other habitat types' (OHTs), such as those listed under Regional Sea Conventions and the Habitats Directive. This allows Member States to focus more specific attention under the MSFD on certain habitats which are under threat. This approach is similar to that being considered for EO1.

46. The proposal for a Nature Restoration Law (NRL) (EC, 2022b) includes a specified list of marine habitat types in its Annex II; these are a mixture of specific habitats with high carbon storage capacity (macroalgal forests, shellfish beds, seagrass beds, sponge, coral and coralligenous beds and maerl beds) and soft sediments down to 1000m depth as their carbon sequestration processes are disrupted by bottom fishing and other activities which physically disturb the seabed.

47. **Table 5** provides a list of the BHTs to be addressed for MSFD Descriptor 6 and a correlation with the Barcelona Convention and EUNIS habitat classes. It also includes the habitats which are being considered under EO1 (provisional list from ABIOMMED project, July 2022) and the proposed NRL and lists these against the relevant BHT (i.e., they lie within a BHT in the hierarchical Barcelona Convention/EUNIS classifications).

Table 5*. Benthic Broad Habitat Types relevant for MSFD D6 and their correspondence with benthic habitats in the Barcelona Convention habitat classification (SPA/RAC – UN Environment, 2019; Montefalcone et al. 2021) and EUNIS classification, plus specific habitats within these broad types that are proposed for use under EO1 and the EU Nature Restoration Law.*

MSFD broad habitat type (BHT) (Table 2 in (EU) 2017/848)	**Barcelona Convention habitat** (SPA/RAC – UN Environment; Montefalcone et al., 2021)	**EUNIS habitat** (EUNIS habitat classification, 2022)	**IMAP EO1 habitats** (SPA/RAC, 2022)	**Mediterranean marine habitats in** Nature Restoration Law (EC, 2022b Annex II)
Littoral rock and biogenic reef	MA1.5 Littoral rock; MA2.5 Littoral biogenic habitat	MA1, MA2	MA2.5 Littoral biogenic habitat	Macroalgal forests: MA1548

MSFD broad habitat type (BHT) (Table 2 in (EU) 2017/848)	**Barcelona Convention habitat** (SPA/RAC – UN Environment; Montefalcone et al., 2021)	**EUNIS habitat** (EUNIS habitat classification, 2022)	**IMAP EO1 habitats** (SPA/RAC, 2022)	**Mediterranean marine habitats in** Nature Restoration Law (EC, 2022b Annex II)
				Shellfish beds: MA1544
Littoral sediment	MA3.5 Littoral coarse sediment; MA4.5 Littoral mixed sediment; MA5.5 Littoral sand; MA6.5 Littoral mud	MA3, MA4, MA5, MA6		Soft sediments (<1000m depth): MA35, MA45, MA55, MA65
Infralittoral rock and biogenic reef	MB1.5 Infralittoral rock; MB2.5 Infralittoral biogenic habitat	MB1, MB2	MB1.51 Algal-dominated infralittoral rock MB1.51a Well-illuminated infralittoral rock, exposed MB2.53 Reefs of *Cladocera caespitosa* MB2.54 *Posidonia oceanica* meadow	Seagrass beds: MB252, MB2521, MB2522, MB2523, MB2524 Macroalgal forests: MB1512, MB1513, MB151F, MB151G, MB151H, MB151J, MB151K, MB151L, MB151M, MB151W, MB1524 Shellfish beds: MB1514 Sponge, coral & coralligenous beds: MB151E, MB151Q, MB151α
Infralittoral coarse sediment	MB3.5 Infralittoral coarse sediment	MB3	MB3.511 Association with maerl or rhodoliths	Maerl beds: MB3511, MB3521, MB3522 Soft sediments (<1000m depth): MB35
Infralittoral mixed sediment	MB4.5 Infralittoral mixed sediment	MB4		Soft sediments (<1000m depth): MB45
Infralittoral sand	MB5.5 Infralittoral sand	MB5	MB5.521 Association with indigenous marine angiosperms	Seagrass beds: MB5521, MB5534, MB5535, MB5541, MB5544, MB5545 Soft sediments (<1000m depth): MB55
Infralittoral mud	MB6.5 Infralittoral mud	MB6		Soft sediments (<1000m depth): MB65
Circalittoral rock and biogenic reef	MC1.5 Circalittoral rock; MC2.5 Circalittoral biogenic habitat	MC1, MC2	MC1.5 Circalittoral rock MC2.51 Coralligenous platforms	Macroalgal forests: MC1511, MV1512, MC1513, MC1514, MC1515, MC1518 Sponge, coral & coralligenous beds: MC1519, MC151A, MC151B, MC151E, MC151F, MC151G, MC1522, MC1523, MC251

MSFD broad habitat type (BHT) (Table 2 in (EU) 2017/848)	**Barcelona Convention habitat** (SPA/RAC – UN Environment; Montefalcone et al., 2021)	**EUNIS habitat** (EUNIS habitat classification, 2022)	**IMAP EO1 habitats** (SPA/RAC, 2022)	**Mediterranean marine habitats in** Nature Restoration Law (EC, 2022b Annex II)
Circalittoral coarse sediment	MC3.5 Circalittoral coarse sediment	MC3	MC3.52 Coastal detritic bottoms with rhodoliths	Macroalgal forests: MC3517 Maerl beds: MC3521, MC3523 Soft sediments (<1000m depth): MC35
Circalittoral mixed sediment	MC4.5 Circalittoral mixed sediment	MC4		Soft sediments (<1000m depth): MC45
Circalittoral sand	MC5.5 Circalittoral sand	MC5		Soft sediments (<1000m depth): MC55
Circalittoral mud	MC6.5 Circalittoral mud	MC6		Sponge, coral & coralligenous beds: MC6514 Soft sediments (<1000m depth): MC65
Offshore circalittoral rock and biogenic reef	MD1.5 Offshore circalittoral rock; MD2.5 Offshore circalittoral biogenic habitat	MD1, MD2		Sponge, coral & coralligenous beds: MD151, MD25
Offshore circalittoral coarse sediment	MD3.5 Offshore circalittoral coarse sediment	MD3		Soft sediments (<1000m depth): MD35
Offshore circalittoral mixed sediment	MD4.5 Offshore circalittoral mixed sediment	MD4		Soft sediments (<1000m depth): MD45
Offshore circalittoral sand	MD5.5 Offshore circalittoral sand	MD5		Soft sediments (<1000m depth): MD55
Offshore circalittoral mud	MD6.5 Offshore circalittoral mud	MD6		Sponge, coral & coralligenous beds: MD6512 Soft sediments (<1000m depth): MD65
Upper bathyal rock and biogenic reef	ME1.5 Upper bathyal rock; ME2.5 Upper bathyal biogenic habitat	ME1, ME2	Bathyal	Sponge, coral & coralligenous beds: ME1511, ME1512, ME1513
Upper bathyal sediment	ME3.5 Upper bathyal coarse sediment; ME4.5 Upper bathyal mixed sediment; ME5.5 Upper bathyal sand; ME6.5 Upper bathyal mud	ME3, ME4, ME5, ME6	Bathyal	Sponge, coral & coralligenous beds: ME6514 Soft sediments (<1000m depth): ME35, ME45, ME55, ME65
Lower bathyal rock and biogenic reef	MF1.5 Lower bathyal rock; MF2.5 Lower bathyal biogenic habitat	MF1, MF2	Bathyal	Sponge, coral & coralligenous beds: MF1512, MF1513

MSFD broad habitat type (BHT) (Table 2 in (EU) 2017/848)	**Barcelona Convention habitat** (SPA/RAC – UN Environment; Montefalcone et al., 2021)	**EUNIS habitat** (EUNIS habitat classification, 2022)	**IMAP EO1 habitats** (SPA/RAC, 2022)	**Mediterranean marine habitats in** Nature Restoration Law (EC, 2022b Annex II)
Lower bathyal sediment	MF3.5 Lower bathyal coarse sediment; MF4.5 Lower bathyal mixed sediment; MF5.5 Lower bathyal sand; MF6.5 Lower bathyal mud	MF3, MF4, MF5, MF6	Bathyal	Sponge, coral & coralligenous beds: MF6511, MF6513 Soft sediments (<1000m depth): MF35, MF45, MF55, MF65
Abyssal	MG1.5 Abyssal rock; MG2.5 Abyssal biogenic habitat; MG3.5 Abyssal coarse sediment; MG4.5 Abyssal mixed sediment; MG5.5 Abyssal sand; MG6.5 Abyssal mud	MG1, MG2, MG3, MG4. MG5, MG6		

Contracting Parties are invited to agree:

EO6 should have a broad scope, addressing all seabed habitats in the Mediterranean from the littoral zone down to the abyss.

EO6 should be assessed for 22 broad habitat types, aligned with those used under MSFD Descriptor 6.

Contracting Parties are invited to consider:

The relationship between habitats under EO6 and the more specific habitats being addressed under EO1 (see section 6 on the overall links between EO1 and EO6).

9 Assessment scales and areas

48. Assessments of whether GES and targets have been achieved, as needed for the periodic Mediterranean Quality Status Reports, for national purposes and to inform management actions, need to be made for specified areas within the Mediterranean Sea region. The scale used for assessment has a direct and marked influence on assessment outcomes (i.e., whether a habitat has achieved GES or not), due to the distribution and extent of impacts, which vary according to the situation in different parts of the Mediterranean. For example, a habitat may be deemed to be below GES in one (part of a) country, as it is subject to extensive pressures and impacts in this area but is in GES in another country where the impacts are less extensive. Also, if the habitat is assessed at the whole Mediterranean Sea scale its GES status could differ to that at national scale because of the overall extent of pressures and impacts across the region.

49. To date, assessment scales and areas for the Mediterranean region have not been formally agreed for either EO6 or EO1.

50. Assessments could be undertaken at a variety of scales, such as at the whole region scale or one of its four subregions. However, these are too large to be meaningful for management purposes, as actions needed to achieve GES and targets typically need to be taken at finer scales, such as at national or subnational level.

51. According to the GES Decision, assessments of broad habitat types for MSFD Descriptor 6 are to be undertaken at the scale of 'subdivision or region or subregion, reflecting biogeographic differences in species composition of the broad habitat type'. TG Seabed provides guidance on defining assessment scales and areas in its MSFD Article 8 assessment guidance (EC, 2022a[26]). Further consideration of the issue of assessment scales and their effects on the outcomes of assessments and for management[27] indicates the importance, within this biogeographic approach, of national (or sub-national)-level assessments (reporting) because responsibilities for taking management actions (if GES has not been achieved) would lie at national level[28].

52. Under the MSFD, the assessment areas for D6 assessments have been defined by each Member State for the purposes of Article 8 reporting[29]; however, a harmonised set of scales/areas for application by the Member States in the Mediterranean has not yet been developed.

53. TG Seabed proposed possible subdivisions of the Mediterranean Sea region (and other regions), based only on biogeographic considerations[30]. These proposals were further developed by DG Environment for the purposes of a study on the distribution and intensity of bottom fishing (STECF, 2022; **Figure 2**), undertaken to support preparation of an Action plan to conserve fisheries resources and protect marine ecosystems for the EU Biodiversity Strategy 2030.

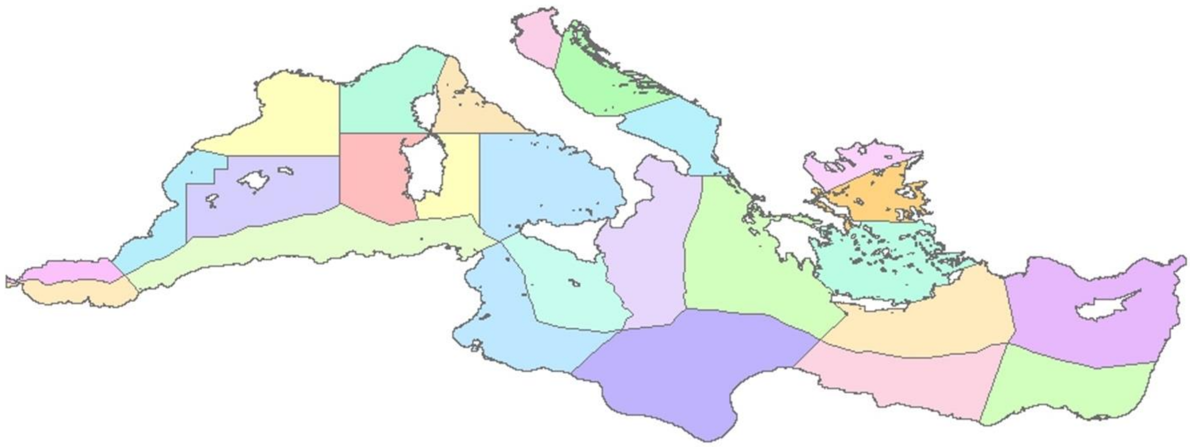

***Figure 2**. Subdivisions of the Mediterranean Sea region and subregions (from STECF, 2022).*

54. While the subdivisions shown in **Figure 2** were developed specifically for the STECF study, they are also of relevance to implementation of MSFD D6 and IMAP EO6 as they are based on:

a. The four subregions of the Mediterranean Sea region, as adopted by UNEP/MAP and MSFD;

26 MSFD GD19, 2022; further elaborated in TG Seabed's extended guidance (latest draft: SEABED_11-2022-02).

27 SEABED_12-2022-02

28 This should not preclude countries taking collective action, through regional or subregional cooperation, on activities which are transnational in character (e.g., some types of bottom fishing).

29 The MSFD reporting in done according to nationally-defined Marine Reporting Units (MRUs); for Article 8 assessments these were last updated for the 2018 reports.

30 TG Seabed (2021b) SEABED_8-2021-04

b. Biogeographic considerations, primarily temperature and salinity regimes (at the sea bottom and sea surface, in summer and in winter)[31];

c. National borders of marine waters;

d. Management considerations, such as the management of the bottom fishing sector, including use of some GFCM geographical sub-area boundaries.

55. Annex III provides more specific information on the subdivisions shown in Figure 2. In particular, it indicates the long-term average sea temperature and salinity in each subdivision (surface and bottom; summer and winter) which influence the biological characteristics water column and seabed communities. The annex indicates the 'origin' of the boundaries of each subdivision, indicating whether they have an ecological basis (based on temperature and salinity regimes) or a 'management' basis (i.e. the coastline, a national marine border, a GFCM area boundary).

56. It should be noted that these subdivisions currently have no formal status.

Contracting Parties are invited to consider:

whether the subdivisions shown in **Figure 2** could be used as the assessment areas for application of EO6 [and EO1] [and MSFD], and specifically whether:

a. the overall scale/size of the areas is appropriate for assessment and management purposes;

b. any specific boundaries need adjustment (e.g., to better suit national needs or reflect ecological characteristics);

c. further actions needed to develop an agreed set of assessment areas (e.g., for use in future QSRs).

10 Assessment of sea-floor integrity for EO6

10.1 Assessing a sea-floor affected by multiple pressures and impacts

57. Section 4 highlights that the sea-floor may be subject to a variety of anthropogenic pressures, some widespread throughout the Mediterranean Sea region, others more localised. Section 5 provides an overview of the main human activities that may lead to such pressures. Any given area of seabed may consequently be subject to multiple pressures and their impacts on seabed habitats, but because the range of activities and pressures varies across the region, so too varies the possible extent of pressures and their impacts. The approach to assessing the state of the sea-floor for EO6 needs to accommodate this variation across the region. **Figure 3** illustrates a possible scenario for an assessment area which contains multiple broad habitat types and is subject to a variety of activities and pressures. The intensity, frequency and duration of each pressure will determine the extent to which the seabed is adversely affected (impacted) by each pressure.

58. To make an assessment of each assessment area requires:

a. A map of the distribution of seabed habitats;
b. Maps of the distribution, extent and intensity of each pressure, based on the relevant human activities;
c. Interfacing the habitat maps with the pressure maps to give the extent of pressure per habitat type;
d. Assessment of the extent of impacts (adverse effects) to the seabed from each pressure, derived from assessment of a Common Indicator(s) and the threshold value which distinguishes whether the habitat is in good condition or impacted;

31 Mapping data used to define the subdivisions are given in TG Seabed (2021b; SEABED_8-2021-04) and presented in Annex III.

e. Aggregation of assessment results to determine the extent of impact per habitat type in the assessment area, taking account of data on the state of the habitat in areas considered to be in a good or reference state.

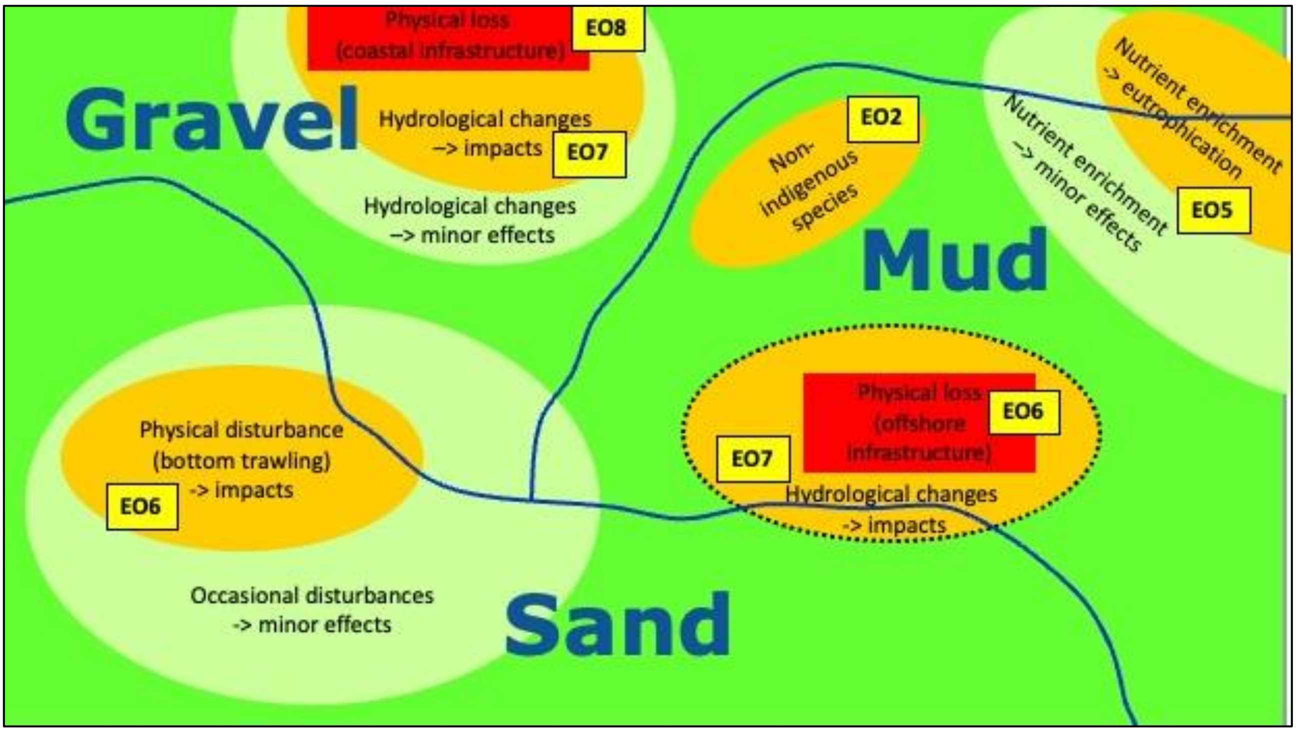

Figure 3. *Scenario for an assessment area with several habitat types and subject to multiple activities and pressures.*

Red = lost habitat (due to infrastructure); orange = impacted areas (due to pressures – physical disturbance, hydrological change, NIS, nutrient enrichment); light green = areas only slightly affected by pressures, but still in good condition; dark green = areas in reference state (largely without effects of pressures). Yellow boxes show the related Ecological Objective. (Modified from Connor & Canals, 2021, SEABED_7-2021-16).

59. This process focuses on assessing the activities and their pressures considered to be most affecting the seabed. Data from mapping the distribution of human activities and modelling their pressures provides a cost-effective approach to enable assessment across the very large areas of the Mediterranean seabed in a systematic data-driven way. Gridded mapping data of activities and pressures suitable for such assessments have been compiled for the Mediterranean by the European Environment Agency (Korpinen et al., 2019). However, for EO6 purposes (for a MED QSR) it would be necessary to interface such data with the broad habitat types (to derive the extent of pressure per habitat) and to assess impacts using suitable indicators. Impact assessment can be undertaken through a mixture of modelling and ground-truth data, such as from grab samples or direct observations.

10.2 Availability of IMAP indicators to assess sea-floor integrity

60. As described in section 6, some impacts to the seabed are, or potentially could be, assessed using CIs from other EOs. There are however certain pressures, notably physical loss and physical disturbance, which are not addressed by other EOs and would need new indicators for application under EO6. In addition, climate change effects, particularly carbon sequestration rates, should be assessed. **Table 6** summarises the main pressures affecting the sea-floor (see section 4) and the indicators currently available (CIs, see section 6) or needing to be developed for EO6 purposes.

***Table 6**. Main pressures affecting sea-floor integrity and the availability of IMAP Common Indicators or identification of need to develop new indicators.*

Theme	Pressure	Ecological Objective	Common Indicators	Application for EO6
Biological	Non-indigenous species	EO2 Non-indigenous species	CI-6: Trends in abundance, temporal occurrence, and spatial distribution of non-indigenous species, particularly invasive, non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species	CI-6 needs to provide an assessment of the distribution and extent of NIS. For use under EO6, it should focus particularly on benthic NIS which occur in high density and thus likely to be impacting natural communities (invasives). The output from CI-6 could then be used to assess the extent of adverse effects per habitat type (= MSFD criterion D2C3). Due to potentially high costs for more generalised NIS monitoring, assessment of NIS impacts for EO6 should be highly focused on specific NIS in selected vulnerable areas.
	Extraction of wild species	EO3 Harvest of commercially exploited fish and shellfish	CI-7: Spawning stock biomass CI-9: Fishing mortality CI-10 Fishing effort	If demersal/benthic commercially exploited fish and shellfish species are in poor status (derived from CI-7, CI-9 and other CIs) this species-level assessment could be used to contribute to the assessment of EO6, reflecting partially the status of the seabed habitat occupied by the species. May be particularly useful for demersal/benthic species fished using bottom-contacting gears such as trawls and dredges. CI-10 could provide information on the distribution and extent of bottom fishing (if this type of fishing is distinguished in the data) and thereby give data on the extent of physical disturbance to the seabed for use under EO6.
Physical	Physical disturbance to the seabed	EO6 Sea-floor integrity	Not yet developed	Physical disturbance to the seabed is the most widespread and extensive pressure affecting the sea-floor. It is caused by a range of human activities (e.g., bottom fishing, aggregate dredging, ship anchoring) and affects the seabed from the coast down to 1000m depth (below 1000m, bottom fishing is banned by GFCM and other relevant activities are rare). An indicator is needed for physical disturbance, possibly assessed according to the different contributing activities.
	Physical loss of the seabed	EO8 Coastal ecosystems and landscapes	CI-16: Length of coastline subject to physical disturbance due to the influence of man-made structures	Assessment of CI-16 provides results on the extent of human-made structures along the coastline. The results could be directly used under EO6 to represent the amount of habitat loss for littoral rock and littoral sediment combined. Data on the substrate type (rock or sediment) in front of the coastal structure could provide a proxy for loss of littoral rock and littoral sediment separately.

Theme	Pressure	Ecological Objective	Common Indicators	Application for EO6
				Application of CI-16 is currently restricted to the coastal (littoral) zone under EO8. The CI needs to be extended to subtidal areas (under EO6) where the placement of infrastructures or removal of natural habitat (such as by aggregate extraction) has led to habitat loss.
	Hydrographical changes	EO7 Hydrography	CI-15: Location and extent of habitats impacted directly by hydrographic alterations	Hydrographical alterations to seabed habitats are directly relevant to EO6 (and EO1). Assessments of CI-15 need to provide the extent of adverse effect per habitat so that results can feed into assessments of EO-6 (and EO-1). Hydrographical changes are often directly associated with infrastructures (on the coast or in the subtidal zone). The assessment of CI-15 therefore is closely linked to CI-16.
Substances, litter and energy	Inputs of nutrients (and organics)	EO5 Eutrophication	CI-13 and CI-14 address the water column	Eutrophication can affect the seabed as well as the water column; eutrophication problems in the Mediterranean are confined to certain areas (e.g., mouth of River Po). The assessment of CI-13 and CI-14, which assess the water column, may indirectly indicate there may be eutrophication problems on the seabed. However, there are currently no IMAP indicators focused on eutrophication effects on the seabed. The following MSFD criteria cover seabed eutrophication: D5C4 (photic limit), D5C5 (oxygen levels near seabed), D5C6 (opportunistic macroalgae), D5C7 (macrophyte communities) and D5C8 (macrobenthic communities).
	Inputs of litter (including lost or abandoned fishing gear)	EO10 Marine litter	CI-22: Litter on coastline CI-23: Litter in water column and on sea-floor	CI-22 and CI-23 are currently focused on quantifying the amount of litter on the coastline and on the sea-floor. Further development of the indicators would be needed to relate litter quantities to impacts on seabed habitats; this could be focused, in the first instance, on areas where litter accumulates in high quantities on the seabed leading to smothering effects.
Climate change	Acidification		Not yet developed	Ocean acidification is a widespread pressure on the marine environment, and potentially affects benthic species, particularly those with calcareous skeletons. OSPAR is undertaking an assessment of ocean acidification[32]; its suitability for application under EO6 needs consideration.
	Carbon sequestration		Not yet developed	Disruption of carbon sequestration processes are widespread due to losses of seagrass beds and other macrophyte communities (high carbon stores) and widespread physical disturbance, especially from bottom fishing.

32 OSPAR ICG-OA(1) 2019

Theme	Pressure	Ecological Objective	Common Indicators	Application for EO6
				An indicator needs to be developed to quantify the carbon stored per unit area per habitat, and how this is affected by physical disturbance.
	Hydrological changes (widespread)		Not yet developed	Hydrological changes, resulting from climate change effects, may include changes to sea temperature, sea level rise, increased storminess, and alterations to freshwater inflows (both from droughts and increased flooding). All these have the potential to significantly affect seabed habitats but are not currently assessed with dedicated indicators. This should be considered as part of a wider strategy to monitor the effects of climate change.
State (habitat condition)	All	EO1 Biodiversity	CI-1: Habitat distributional range CI-2: Condition of the habitat's typical species and communities	EO1 addresses seabed habitats, thereby providing a direct overlap with EO6 in cases where the seabed addressed under each EO overlaps. CI-1 and CI-2 provide useful indicators for application under EO1 in relation to specified habitat types (list under consideration by Biodiversity OWG). Note that there are, as yet, no agreed metrics or threshold values for use with the data collected for CI-2; therefore, some additional development and testing is required under EO1. CI-2 could be applied in the broader context of EO6 to provide information about the state/condition of seabed habitats. If sampled in areas of little or no pressures, the data could provide valuable information on reference state, and so help benchmark the indicators focused on specific pressures.

61. From **Table 6**, it can be concluded that there is a need to use CIs from other EOs to contribute to the assessment of EO6. While some may be directly usable in their current form (e.g., CI-15 hydrography, CI-16 coastal loss), others would need to be further developed to give outputs of direct use for EO6 (e.g., CI-6 NIS) or extended in their application to EO6 habitats (CI-1, CI-2, CI-16). There remain gaps in indicator coverage related to eutrophication, physical disturbance and climate change (particularly carbon sequestration) (see section 10.3).

10.3 Possible new indicators

10.3.1 Impacts from non-indigenous species

62. The importance of NIS in the Mediterranean is widely acknowledged and has been extensively studied. There is a large body of data relating to the occurrence and distribution of NIS, and to identifying the source and pathways of their introduction to the Mediterranean region. CI-6 is focussed on further developing this approach, with particular attention on invasive species and hotspots for their occurrence and introduction. CI-6 thus aims to provide an assessment of the scale of the NIS pressure and its source, with a view to reducing further introductions of NIS, and preventing their spread across the region.

63. For the purposes of EO6, data on the occurrence of NIS (from CI-6) needs to be used to assess the impacts of NIS on seabed habitats. This would require a new indicator under EO2 which would be equivalent to MSFD criterion D2C3.

64. Operational indicators focused on NIS impacts are generally less advanced than monitoring introductions and spread of NIS. However, a ‘bio-pollution index’ has been developed (Olenin et al., 2007) and applied in Germany (Wittfoth & Zettler, 2013) and other areas of the Baltic Sea region. The index is based on quantification of NIS and their effects on seabed habitats and could, in principle, be applied to the Mediterranean. The biotic index ALEX (Çinar & Bakir, 2014) could also be considered for this purpose.

65. As previously indicated, due to the potential costs of monitoring, such an indicator is best considered for high-risk areas where NIS occur in high densities and are likely to be an important pressure on the seabed.

10.3.2 Physical disturbance and its impacts

66. For sea-floor integrity, this is the most important pressure to assess, given the range of human activities causing the pressure, how widespread and extensive it is in the Mediterranean, and how damaging it can be to seabed habitats and the carbon cycle.

67. Due to the importance of the pressure, it has received considerable attention for MSFD implementation purposes (to assess criteria D6C2 and D6C3), including by HELCOM, OSPAR and ICES. A number of operational indicators have been developed, focused particularly on physical disturbance from bottom-fishing gears (e.g., OSPAR’s BH3, ICES’ PD and L1), but extended to include a number of other relevant activities (e.g., HELCOM’s CUMI). These indicators have been applied at regional scale and to MSFD broad habitat types, making them potentially very suitable to consider for IMAP EO6 purposes. ICES undertook a review of these, and other seabed habitat indicators (ICES, 2022b), leading to technical advice to DG Environment (ICES, 2022a eu.2022.11). ICES evaluated the performance of a selection of these reviewed indicators (WKBENTH3 workshop, October 2022), and provided advice to DG Environment in December 2022 on the suitability and shortcomings of the tested indicators for MSFD Descriptor 6 purposes. It is recommended to consider the ICES advice and the possible need for further evaluation of indicators, ongoing studies (e.g. ABIOMMED project, ICES’ WG-FBIT 2022 report), and the data requirements and data availability, in order to identify the most suitable indicator(s) for IMAP EO6.

10.3.3 Physical loss

68. Under EO8 (Coast), IMAP has adopted CI-16 which assesses the length of coastline which has been artificially modified and expresses this as a proportion of the total length of coastline per country. Results from application of the indicator are presented in the Med QSR 2017 for Italy, France and Montenegro and are being prepared for other countries for the Med QSR 2023.

69. CI-16 provides an estimate of the length of natural coastline which has been lost due to the building of infrastructures and other coastal developments and modifications. For EO6 purposes, it could act as a proxy for the extent of loss of littoral habitat (rock and sediment habitats combined).

70. The principals of CI-16, centred on measurement of the extent of artificialisation of natural habitat, could be extended to other broad habitat types to assess physical loss for EO6 although the results should be expressed by area (km^2 and % of each habitat) rather than by length of coast (km) as currently used for CI-16. The ABIOMMED project (2021-2023) is developing guidance for such assessments. This would provide outputs suitable for MSFD criteria D6C1 and D6C4.

71. A similar indicator has been developed for the North-East Atlantic (OSPAR's BH4 indicator in ICES, 2022a) with a pilot assessment under preparation for the North Sea as part of OSPAR's QSR 2023. ICES reviewed the main causes of physical loss and disturbance in the Mediterranean (ICES, 2019b, c, d) leading to ICES Advice for MSFD criteria D6C1 and D6C4 (ICES, 2019a, sr.2019.25).

10.3.4 Eutrophication

72. Nutrient enrichment and its eutrophication effects are mostly generated from land-based sources which affect the sea via riverine inputs and coastal run-off. WFD assessments of transitional and coastal waters are oriented towards these issues, with indicators developed to assess eutrophication status for several quality elements (macrophytes, macrobenthos) relevant to the seabed. The WFD indicators are defined at national level with threshold values provided in the WFD Commission Decision (EU) 2018/229 (EC, 2018). The indicators and assessment processes are generally well established in EU Member States and could be applied to non-EU states in areas where eutrophication may be a problem (such as river mouths). In some areas, it may be necessary to extend the assessments beyond the 1nm zone of coastal waters.

73. In the north-east Atlantic, OSPAR has demonstrated reuse of the WFD assessments for the purpose of assessing eutrophication of the seabed (indicator BH2a). This reuse of WFD results is a cost-effective approach to seabed eutrophication assessment. TG Seabed explored how WFD benthic assessment results can be integrated with other assessments at the habitat level (TG Seabed, 2021c).

74. Nutrient enrichment can lead to areas of hypoxia and anoxia at or near the seabed, which can have marked effects on seabed habitats. Indicators to assess oxygen levels in the water column near the seabed are available under WFD, OSPAR and HELCOM.

10.3.5 Habitat condition

75. As noted in section 10.3.2, ICES reviewed a range of available indicators for sea-floor integrity, relevant both for MSFD criteria D6C3 (physical disturbance) and D6C5 (habitat condition). The resulting ICES advice (ICES, 2022b; eu.2022.18) should be taken into account when selecting the most suitable indicator(s) for IMAP EO6.

76. EO1 includes CI-2 on habitat condition; this indicator is in principle suitable for use under EO6 and could be applied to other habitat types than currently considered under EO1. It should be noted that implementation of CI-2 is currently focused on data collection for three specific habitat types (*Posidonia* meadows, maerl beds, coralligenous habitats); as yet there is no agreed method for analysing the data or threshold values that would allow an assessment of whether the habitat is in GES.

10.3.6 Carbon sequestration capacity and rates

77. Annex 2 provides a review of blue carbon and the importance of seabed habitats in storing vast stocks of carbon through natural sequestration processes, acting as a sink for carbon absorbed into the ocean from the atmosphere. Oceanic carbon sequestration is increasingly important to help mitigate the rising levels of atmospheric carbon stemming from greenhouse gas emissions. Annex 2 also indicates how physical disturbance to the seabed can significantly affect the carbon stocks and sequestration rates. While the highest concentrations of carbon are held in coastal macrophyte-dominated habitats (e.g., seagrass beds, saltmarshes), such habitats only cover a small fraction of the seabed. In contrast, seabed sediment habitats cover the vast majority of the seabed[33], and their widespread disturbance, by bottom trawling and other activities, can have a major effect on carbon

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33 It is estimated that marine sediment habitats between 0-1000m depth cover an area of EU marine waters equivalent to about 44% of the EU land territory.

sequestration rates; the disturbance causes carbon to be released back into the water column, adding to ocean acidification and potentially reducing the ocean's capacity to absorb atmospheric carbon.

78. Given that climate change is such a widespread global problem, and that the seabed plays such an important role in carbon sequestration, it is important to monitor and assess seabed carbon stocks and, in particular, how physical disturbance is affecting the natural carbon processes. This issue is attracting increasing attention of research scientists, as demonstrated in Annex 2, but is less well known for environmental status perspectives. However, assessment of carbon stocks and sequestration rates, linked to the extent and intensity of physical disturbance pressures, would provide valuable information on climate change effects in the marine environment. Such efforts would also contribute to the proposed EU Nature Restoration Law (EC, 2022b).

79. Further work would be needed to develop an indicator on seabed carbon stocks and sequestration rates, to provide a quantified assessment per habitat type. DG Environment may undertake a study, to support implementation of the BDS2030 Action Plan, to develop suitable approaches to seabed quantification of carbon, linked to disturbance rates.

Contracting Parties are invited to consider:

a. Whether the CIs from other EOs should be further developed, as described, to enable their use under EO6.
b. The priorities for development of new indicators, including the possibility to adopt indicators already developed elsewhere but which may need data and testing/calibration in a Mediterranean context.
c. The ICES review of seabed indicators, including comparative analyses of their performance and advice on possible threshold values (ICES, 2022b; eu.2022.18) and take this into account in prioritising which indicators to use for EO6.

10.4 Assessing adverse effects

80. The pressure/impact indicators in **Table 6**, together with CI-2 on habitat condition and others considered in section 10.3 aim to provide an assessment of whether a seabed habitat is adversely affected (either by a specific pressure, or more generally by multiple pressures). This is done by:

a. defining the parameters used in the indicator to assess habitat condition, such as species composition, species diversity, carbon content;
b. specifying the degree of change in habitat condition from natural conditions (reference state) through defining a threshold value, that distinguishes a habitat area in good condition from an area that is adversely affected.

81. TG Seabed reviewed the topic and provides a paper which sets out the basis for defining change in habitat condition (TG Seabed, 2021a), including:

a. characteristics of natural habitats;
b. influence of biogeography on natural habitats;
c. how different pressures affect habitats in different ways;
d. use of models and empirical data to assess change;
e. defining reference condition/state as the basis from which to assess change;
f. considerations on how to set a quality threshold, below which the habitat is considered to be adversely affected.

82. TG Seabed is in the process of defining a quality threshold for habitat condition for MSFD criterion D6C5. In December 2022 TG Seabed proposed the following qualitative description: A benthic broad habitat type is adversely affected in an assessment area if it shows an unacceptable deviation from the reference state in its biotic and abiotic structure and functions (e.g., typical species composition, relative abundance and size structure, sensitive species or species providing key

functions, recoverability and functioning of habitats and ecosystem processes)34. This description has been further elaborated (SEABED_14-2022-03) to guide the development of a more quantitative threshold, linked to use of specific indicators. TG Seabed expects the boundaries between ‘good’ and ‘not good’ state for different indicators to be between 60% and 90% of reference state.

83. The assessment of quality, through various indicators, is scientifically complex, partly because of the wide variation in habitat characteristics (shallow to deep, across the four regional seas around Europe) and partly because of the complex relationship between pressures and their impacts, which vary according to pressure intensity, duration and frequency and by habitat type, due to varying sensitivities of the habitats. To overcome this complexity, TG Seabed has proposed to develop a benchmarking framework to which the different indicators are calibrated. A framework is being developed by ICES and was tested using a number of sample datasets and currently available indicators at the WKBENTH3 workshop in October 2022. Datasets tested include pressure gradients across the seabed for physical disturbance from bottom fishing, eutrophication and pollution. From this ICES published its Advice to DG Environment in December 2022 (ICES, 2022b; eu.2022.18).

84. The indicators to be used under EO6 require similar considerations, including the definition of reference state, the setting of quality threshold(s) to define what is adverse effect, and how various indicators can be used (e.g., depending on the pressure) whilst ensuring they each give equivalent results on habitat condition (i.e., the threshold values used are not markedly different between pressures, habitats and areas).

Contracting Parties are invited to note:

a. The ongoing work by TG Seabed to agree a quality threshold value (as a percentage change from reference state) for application in MSFD criterion D6C5;
b. The ongoing work by ICES to develop a framework for assessment of results from habitat impact and condition indicators, benchmarked against reference state;
c. The possible application of this work (TG Seabed, ICES) for EO6 purposes.

11 GES and targets for EO6

11.1 Overall goals of IMAP’s Ecological Objectives

85. Under the IMAP, each EO has a stated objective (Table 7), and the EOs collectively contribute to the overall goal of achieving GES for the Mediterranean Sea region. The EOs and their objectives are closely aligned with the MSFD Descriptors, but with some differences: EO8 has no MSFD equivalent, and the wording of the objectives/descriptors differ to varying extents, excepting for EO2/D2.

***Table 7**. Goals expressed in the Ecological Objectives of IMAP (UNEP/MAP, 2016).*

Ecological Objective	Definition
EO1 Biodiversity and ecosystem (birds, mammals and turtles)	Biological diversity is maintained or enhanced. The distribution and abundance of coastal and marine species are in line with prevailing physiographic, hydrographic, geographic and climatic conditions.
EO1 Biodiversity and ecosystem (habitats)	Biological diversity is maintained or enhanced. The quality and occurrence of coastal and marine habitats are in line with prevailing physiographic, hydrographic, geographic and climatic conditions.
EO2 Non-indigenous species	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

34 MSCG_31-2022_WP-Seabed threshold values proposal (12/12/2022).

Ecological Objective	Definition
EO3 Harvest of commercially exploited fish and shellfish	Populations of selected commercially exploited fish and shellfish are within biologically safe limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
EO4 Marine food webs	Alterations to components of marine food webs caused by resource extraction or human-induced environmental changes do not have long-term adverse effects on food web dynamics and related viability.
EO5 Eutrophication	Human-induced eutrophication is prevented, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.
EO6 Sea-floor integrity	Sea-floor integrity is maintained, especially in priority benthic habitats.
EO7 Hydrography	Alteration of hydrographic conditions does not adversely affect coastal and marine ecosystems.
EO8 Coastal ecosystems and landscapes	The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved.
EO9 Pollution	Contaminants cause no significant impact on coastal and marine ecosystems and human health
EO10 Marine litter	Marine and coastal litter do not adversely affect coastal and marine environment
EO11 Energy, including underwater noise	Noise from human activities cause no significant impact on marine and coastal ecosystems.

86. The goals of the EOs can be broadly categorized as follows:
   a. Maintain ecosystem structure and functions (EO1, EO4, EO6, EO8)
   b. Achieve healthy and sustainable populations of species (EO1, EO3)
   c. Ensure anthropogenic pressures are at levels that do not cause impacts (adverse effects) to marine ecosystems (EO2, EO5, EO7, EO9, EO10, EO11).

11.2 Achieving GES whilst accommodating 'sustainable' uses of the sea-floor

87. As already outlined in section 5, the sea-floor is subject to a wide range of activities, many of which by their very nature are damaging the seabed – such as through physical abrasion (e.g., bottom fishing, anchoring) or placement of infrastructures on coastal and marine habitats (e.g., coastal defences, ports and offshore installations). The approach adopted under the MSFD is to manage such human activities so as to minimise their impacts such that a balance is struck between protection of the marine environment and the use of its resources. For Descriptor 6, the 2017 GES Decision provides for this objective by specifying the need to set maximum extents for habitat loss (D6C4) and adverse effects (D6C5), thereby enabling certain human activities which, by their very nature cause impacts to the seabed, to continue but within specified limits. This approach is described and visualised in the MSFD horizontal issues document SWD(2020) 62 (EC, 2020), and further developed by TG Seabed in a paper, adopted by MSCG in May 2022[35], which sets out the basis for defining thresholds (**Figure 4**).

35 TG Seabed (2022a) MSCG_30-2022-06rev

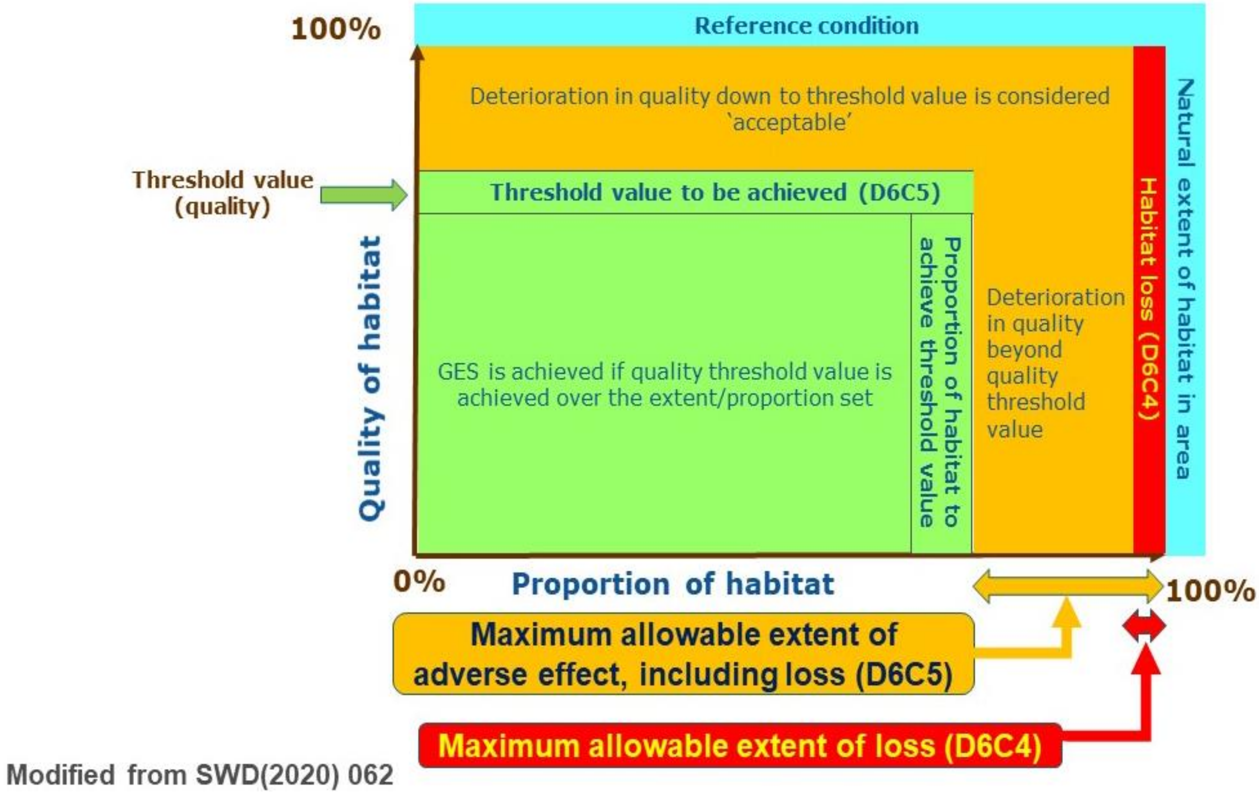

Figure 4. *Generic quality and proportion framework for determining GES (from MSCG_30-2022-06rev).*

Modified from Figure 12 in SWD (2020) 62 according to the needs of the GES Decision for D6. The threshold and proportion values shown are purely for illustrative purposes only. These values are to be set by Member States through Union, regional or subregional cooperation, as set out in the GES Decision (see boxed text for explanation).

Explanation of **Figure 4** (from TG Seabed, 2022a):

The GES Decision requires threshold values for the 'quality' to be achieved for each habitat, which must be set in relation to reference condition (GES Decision Art. 4(1)(c)). The threshold value typically accommodates an 'acceptable deviation' from reference condition, i.e., allowing for some degree of perturbation/change from an unimpacted/fully natural state (orange area across top of figure). The Y axis represents this quality aspect of a habitat, with 100% representing reference condition and the quality threshold for D6C5 set as a reduced level of habitat quality compared to the reference condition.

The extent of the habitat in an assessment area is represented on the X axis, with 100% representing the total natural extent of the habitat in the area. The GES Decision then requires two extent values to be set: the 'maximum allowable extent of habitat loss' (D6C4) (vertical red bar in the figure) and the 'maximum allowable extent of adverse effects' (vertical orange bar in the figure), both being set as a proportion of the total natural extent of the habitat type. If the quality threshold is achieved over the defined proportion of the habitat (i.e., 100% less the value set for adverse effects, including loss) (green area in the figure), then the habitat is considered to be in a GES in this assessment area. By setting values for the maximum allowable extent of adverse effect and loss, the GES Decision is indicating that specified proportions of the habitat can be impacted or lost and still the habitat can be in GES. The MSFD and GES Decision is therefore not requiring the habitat to be in good quality throughout its distribution (100%) in each assessment area, which allows for activities which cause damage to the habitat to continue, but within specified limits.

Contracting Parties are invited to agree:

a. That GES for an EO6 habitat should be defined as a quality threshold for habitat condition with limits set on the extent of habitat loss and adverse effects, thereby allowing human activities which cause damage to the habitat to continue, but within specified limits;
b. GES should be achieved for each habitat in each assessment area in order to achieve the overall goal of EO6 Sea-floor integrity;
c. Actions and measures to achieve GES could be prioritised towards certain habitats, areas or pressures/activities within an overall programme to achieve GES for EO6, to reflect the EO6 wording 'especially in priority benthic habitats'.

11.3 Proposal for GES and targets for EO6

88. A proposal for GES and targets for EO6, following the structure adopted for presenting proposed GES and targets for other EOs in 2013 (UNEP/MAP, 2013), is given in **Table 8**. The proposed GES description follows closely that for criteria D6C4 and D6C5 of the MSFD GES Decision. However, instead of encompassing the maximum extent of loss and adverse effect per habitat type as part of the GES definition, it is proposed to treat these values as IMAP targets which, if already exceeded, could be achieved in steps through management actions to reduce the causative pressures.

89. Note also that MSFD criteria D6C1 and D6C2 relate to assessing the extent of physical pressures (loss and disturbance, respectively) and criterion D6C3 relates to assessing the extent of impacts from physical disturbance. For IMAP EO6 it is proposed that these aspects of assessing sea-floor integrity can be incorporated into the overall assessment process (i.e., extent of pressures, section 10.1) and as a specific indicator on physical disturbance under the general 'habitat structure and function' objective (**Table 8**).

90. The proposed GES and targets for EO6 (for broad habitat types) (Table 8) need to be considered in relation to those already agreed for EO1 (for other habitat types).

***Table 8**. Proposed GES and targets for EO6 sea-floor integrity.*

Operational objective	Indicator	Proposed GES description	Proposed targets
All benthic broad habitat types maintain their natural extent, with limited loss due to anthropogenic pressures	Extent of physical loss of natural habitat	The extent of loss of each habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.	Extent of physical loss per habitat type does not exceed [X%] of each habitat's natural extent.
All benthic broad habitat types maintain their natural structure, functions and biodiversity	Extent of adverse effects on benthic habitat (this may comprise several indicators which address specific pressures)	The extent of adverse effects from anthropogenic pressures on the condition of each habitat type, including alteration to its biotic and abiotic structure and its functions (e.g., its typical species composition, absence of particularly sensitive or fragile species or species providing a key function, size structure of species; carbon sequestration capacity), does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.	Extent of adverse effects from anthropogenic pressures[36] per habitat type does not exceed [Y%] of each habitat's natural extent.

36 Value Y% for adverse effects includes value X% for physical habitat loss. Value Y% encompasses any loss of biogenic habitat and changes to habitats at EUNIS level 2 that are defined as habitat loss under MSFD (MSFD GD19, 2022) because such losses can be more much extensive than losses due to physical structures.

91. Under the MSFD, TG Seabed submitted a proposal to MSCG in December 2022 seeking adoption of values proposed for X (maximum extent of habitat loss) and Y (maximum extent of adverse effects). The scientific basis for these values was discussed at length by TG Seabed. It is widely recognised that these values cannot currently be defined based strictly on scientific data but are more a policy decision. In contrast, it is considered that the quality threshold value, set to distinguish a habitat in good condition from one that is adversely affected, can and should be more clearly based on scientific data, as represented through various suitable indicators.

Contracting Parties are invited to agree:

a. The proposed operational objectives, indicators and GES descriptions for EO6, noting that the 'extent of adverse effects' indicator is a broad indicator which should comprise several more specific operational indicators;
b. Agree the proposed targets and discuss possible values (noting that the target values are incorporated as part of the GES determination under MSFD Descriptor 6).

11.4 Reporting on status of habitats per assessment area

92. Assessment of sea-floor integrity for EO6 should identify the extent to which each broad habitat type is in good condition in each assessment area. Such assessments should be undertaken through a structured methodology which integrates results from the available CIs on the extent of impacts from certain (most important) pressures, the extent of any habitat loss and any more general assessment of habitat condition. The methodology could follow a similar approach to that used under MSFD Descriptor 6 for the integration of criteria (Figure 5.7-1 in MSFD Guidance Document 19). An outline table of results is given in **Table 9**. The overall results per assessment area could be expressed as the proportion of habitats, by number and by area, in GES (compared to total number of habitats present in the area and the total extent of habitats in the area).

***Table 9**. Outline table of assessment results for EO6 (for a single assessment area – see **Figure 2** - and selected habitats), showing how assessments of main pressures contribute to an overall assessment of status. Mock results for illustration purposes only.*

Assessment area	**East Sardinia**				
Habitat (only (circalittoral types shown)	Circalittoral rock & biogenic reef	Circalittoral coarse sediment	Circalittoral mixed sediment	Circalittoral sand	Circalittoral mud
Extent of habitat in assessment area (%)	2	12	10	15	10
Physical disturbance	0	15%	20%	60%	65%
Physical loss	<0.05%	<0.05%	<0.05%	<0.05%	<0.05%
Hydrological changes	<0.05%	<0.05%	<0.05%	<0.05%	<0.05%
Total extent of impacts*	<0.1%	15%	20%	60%	65%
Habitat status**	GES	GES	GES	Not in GES	Not in GES
Overall status – proportion of habitats	60% of habitats (3 out of 5) in GES [circalittoral zone only]				
Overall status – proportion of area	24% of area (out of 49%) in GES [circalittoral zone only]				

* Following pressures not considered significant for circalittoral habitats in this assessment area: NIS, inputs of nutrients; following pressures may be significant, but not assessed (no common indicator available): extraction of wild species, climate change (carbon sequestration).

** Based on extent of habitat impacted or lost in relation to target values (if target value for extent of impact is [25%] and extent of loss is [2%]).

12 Data sources for EO6 assessment

93. Assessment of EO6 for a MED QSR needs a number of data sets covering the following:
   a. Map of the distribution of habitat types;
   b. Map of the assessment areas;
   c. Maps of the distribution and extent of key human activities;
   d. Maps of the key pressures from those human activities;
   e. Data or models on the quality (condition) of seabed habitats either related to specific pressures or more generally.

94. **Table 10** provides an initial list of data sets that could support an EO6 assessment at the Mediterranean Sea region scale. This gives an initial indication of the feasibility of undertaking assessments for EO6 purposes; however further consideration of the suitability of each dataset is needed once the selection of indicators is more advanced, recognising that indicator selection and data availability are intricately linked.

95. Further data sets may be available at subregional, national or subnational scales that could be used to supplement the regional datasets. These may be particularly valuable in providing data of higher quality (e.g., more accurate, more recent, higher density) or not available as region-wide datasets and thus complement the regional datasets and help improve the overall confidence in the assessments.

***Table 10**. Datasets for the Mediterranean Sea region for potential use to assess EO6 sea-floor integrity.*

Topic	Data set	Source
Habitat classification and maps	Barcelona Convention typology of Mediterranean seabed habitats EUNIS typology of European marine habitats EUNIS, Barcelona Convention and MSFD habitat maps (EUSeaMap, 2021); selected local maps; maps of *Posidonia*, maerl and coralligenous habitats (MEDISEH)	SPA/RAC – UN Environment (2019); Montefalcone et al. (2021) European Environment Agency (2022) EMODnet seabed habitats
Assessment areas	GIS data set for Mediterranean Sea region, subregions and possible subdivisions	D. Connor/DG Environment
Human activities	Bottom fishing: a. distribution per month (2014) – AIS data b. distribution/intensity (FDI database on landings per grid call) c. distribution/intensity (VMS & other data) Distribution of: a. Aggregate extraction b. Algae production c. Aquaculture d. Cables e. Cultural heritage (shipwrecks) f. Desalination g. Dredging h. Ocean energy/wind farms i. Oil & gas j. Pipelines	IDEM WebGIS (cnr.it) STECF (2022) ICES request from DG Environment (ongoing) EMODnet human activities and EMODnet geoviewer

Topic	Data set	Source
	k. Vessel density (all ships, fishing, etc)	
Pressures	Physical disturbance: a. Anchoring (VesselFinder) b. EU MSFD reports for D6C2/D6C3 (WISE Marine) c. Bycatch from bottom fishing d. Physical disturbance (demersal fishing, dredging, sand and gravel extraction, anchorage sites, windfarms, oil platforms, aquaculture, Shipping in shallow water) Physical loss: a. EU MSFD reports for D6C1/D6C4 (WISE Marine) b. Physical loss of seabed (dredging, dumping, oil and gas rigs, ports, sand and gravel extraction, windfarms). Hydrographical pressure (WFD data)	VESSELFINDER (see Fourt 2022) WISE Marine (MSFD) ETC/ICM Technical Report 4/2019 ETC/ICM Technical Report 4/2019 WISE Marine (MSFD) ETC/ICM Technical Report 4/2019 ETC/ICM Technical Report 4/2019
Habitat condition and impacts from pressures	Eutrophication: a. EU WFD reports on benthic quality elements for coastal and transitional waters b. Blue2 models for Mediterranean Physical disturbance: a. MEDITS surveys for fish stock assessment include benthic invertebrate sampling – possible use as condition indicator (cf similar use of Atlantic fisheries survey data by IEO, Spain) General condition: a. Benthic data for *Posidonia*, maerl and coralligenous habitats under EO1	WISE Freshwater (WFD) JRC Blue2, Macias Moy et al., 2018 MEDITS INFO/RAC and SPA/RAC

13 Conclusions

96. This paper provides an initial outline for IMAP's Ecological Objective 6 on sea-floor integrity, giving details of the human activities and associated pressures that most likely affect sea-floor integrity, on the possible links to other EOs and the potential to use assessments from their Common Indicators, and on the key gaps in indicator coverage that need to be addressed. Finally, some potential indicators and data sets are identified, noting that advice on the performance and suitability of seabed indicators was published by ICES in December 2022.

97. The framework for EO6 proposed here benefits from the recent work undertaken for MSFD Descriptor 6 purposes by TG Seabed; following this framework would help ensure that implementation of EO6 would be in line with MSFD needs and thereby support Contracting Parties who are also EU Member States.

98. Agreement on the overall scope and framework for EO6, including GES definitions, targets and common indicators, through the IMAP and EcAp processes, will help identify the next steps needed to operationalise the indicators for assessment (MED QSR) purposes.

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Annex I. Activities and pressures affecting the Mediterranean sea-floor

The following review is reproduced from Fourt (2022[37]) and provides an overview of the main activities affecting the sea-floor in the Mediterranean Sea region, together with a review of selected pressures.

A1 Introduction

The Mediterranean maritime economy has been growing and is expected to grow during the upcoming years. Sectors such as tourism, shipping, aquaculture and offshore oil and gas but also new sectors such as renewable energy, seabed mining and biotechnology are expected to develop in the Mediterranean Sea (Piante & Ody, 2015). A downward trend may only be envisaged for the professional fisheries (Piante & Ody, 2015).

The ranking of the activities causing habitat loss and/or disturbance proposed for the Mediterranean Sea by ICES (2019a) was used as a starting point and a reference document concerning the impact of anthropogenic activities on Mediterranean sea-floor.

A2 Main human activities

A2.1 Bottom trawling fishing activities

Bottom trawling fisheries have gear of different nature depending on the target species, the fishing depth and area. All bottom trawlers (otter trawlers, beam trawlers and dredges) drag or pull heavy gear on the seabed to collect target species but each type leaves different footprints on the sea-floor (Eigaard et al., 2016, 2017).

(Özalp, 2022)[38]

37 Draft version of 1 July 2022 used.

38 Photograph shows the gold coral *Savalia savaglia* which is considered to be near to a risk of extinction (NT – Near Threatened, IUCN). The coral is very vulnerable to fishing impacts. In the mesophotic zone of the Sea of Marmara, trawlers, seine and beam trawls and associated underwater tools have impacted them severely. Although this species and its facies in the Sea of Marmara and the Çanakkale Strait are highly important, and at some locations form a hotspot of

In the Mediterranean Sea, bottom trawling fishing is recognised as being the major activity creating disturbance to sea-floor (ICES, 2019a) with large areas physically disturbed by this fishing practice (PERSEUS, 2013). Korpinen et al. (2019) estimate that bottom trawling is impacting 35% of the European continental shelf area and is the most extensive anthropogenic activity impacting sea-floor. IUCN (2016) reports that more than 25% of marine benthic habitat types are under threat from benthic trawling. The degree of damage caused on sea-floor is dependant of the type of gear, of the frequency at which an area is submitted to trawling, the substrate and the benthic habitats and ecosystems of the area.

Benthic biogenic habitats and species are particularly vulnerable to bottom trawling such as macrophyte dominated habitats such as *Posidonia oceanica* (González-Correa et al., 2005), *Laminaria rodriguezii* (Žuljević et al., 2016), maerl beds (Bordehore et al., 2000), coralligenous habitats, cold-water corals (e.g. D'Onghia et al., 2017) especially *Isidella elongata* (e.g. Maynou & Cartes, 2011), and other benthic assemblages. They are either threatened directly by the mechanical abrasion or by the plume of sediment that is suspended in the water column by the gear.

Of the total Mediterranean fishing fleet, 7.9% are bottom trawlers mainly concentrated in the Adriatic Sea and the Western Mediterranean (FAO, 2020). At the Mediterranean scale, the bottom trawlers represent 27% of the landings but the highest revenue per year (39.4% of the fisheries), while only the third place relatively to employment (15.9%) (FAO, 2020).

GFCM has defined Fisheries Restricted Areas (FRAs) where towed dredges and net are regulated. The largest concerns all depths over [below] 1000m depth in the Mediterranean where such practices are banned. Three other areas have been delimited where trawling and dredging is banned to protect Vulnerable Marine Ecosystems (VMEs). Still, the majority of the soft bottom benthic habitats of the continental shelf and slope are threatened by bottom trawling activities.

Some Mediterranean areas, such as the Aegean Sea, are under multiregulated fishing framework with important spatial, temporal and gear variability. This makes monitoring and control very challenging (Petza et al., 2017).

A2.2 Bottom otter trawling fishing activities

Bottom otter trawling is generally used on sediment sea-floor (sandy and muddy). It consists of a large conical net maintained open on the sea-floor by two large panels (doors) and dragged by a boat (see Eigaard et al., 2016). The boats and gear are of different sizes giving them the ability to fish at depths from 10 to 2500 m depth (Eigaard et al., 2016). In practice, in the Mediterranean, trawlers concentrate mainly on depths between 200 to 500 meters depth (Eigaard et al., 2017), as in the Gulf du Lion where trawling traces were observed between 150 and 600 meters depth mainly on sandy-muddy substrate (Fourt et al., 2014). But Eigaard et al. (2017) estimate that in the Mediterranean, around 40% of macrophyte-dominated sediments and biogenic habitats have been trawled. Hiddink et al. (2017) consider that 6% of the biota per pass are removed.

The continental shelf and the top continental slope are the most impacted by trawling fisheries. In the Mediterranean Sea available information concerns mainly European countries where bottom trawling activities (otter trawling, beam trawling and dredges) are concentrated along the north-eastern coast of Spain, south of Sicily, along the Italian coast in the Tyrrhenian Sea and with the highest effort concentrated in the western Adriatic Sea (Korpinen et al., 2019).

Depending on the depth and the area, by-catch and discards from trawling fisheries in the Mediterranean are important, amounting from over 35% to 70% by weight (European Parliament,

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biodiversity for other animals, they are under a huge risk of mortality in these regions (Barış Özalp, pers. comm., December 2022).

2014; Damalas et al., 2018; Tiralongo et al., 2021). Targeted species can constitute much less than the discard in weight, highlighting the low selectivity of this fishery. Amidst the species constituting the discards, they are many benthic invertebrates (e.g., corals, sponges, echinoderms) and algae (Sacchi, 2008).

Otter trawlers smoothen the sea-floor surface, modify consistently the first centimetres disrupting benthic fauna habitats complexity, ecosystems and species (PERSEUS, 2013). Some parts of the gear (doors) can penetrate the seabed to depths up to 30cm or more while other parts cause abrasion (Lucchetti and Sala, 2012). The physical impact of otter trawlers, which can be of variable sizes and gear, depends on the penetration of some elements, the collision and abrasion and the sediment mobilisation (Rijnsdorp et al., 2016).

The high frequency of the activity on the same grounds causes:

- harsh physical damage on large surfaces of the sea-floor, on sessile fauna and on the associated benthic ecosystems (Lucchetti and Sala, 2012; PERSEUS, 2013);
- persistent reduction of available organic matter even after two months of closure (Paradis et al., 2021a);
- sediment resuspension and increase which in the configuration of submarine canyons affects also deeper benthic habitats (Martin et al., 2014; Arjona-Camas et al., 2021; Paradis et al., 2021b).

In different parts of the Mediterranean Sea as in Crete (Greece, SE Mediterranean) and Palamos canyon (Spain, NW Mediterranean), management strategies with periodic closures of trawling activities are insufficient to allow the recovery of the benthic fauna and the restoration of the sea-floor (Smith et al., 2000; Paradis et al., 2021a).

A2.3 Beam trawlers and dredges

Generally, beam trawlers and fishing dredges are used in shallow waters, less than 100m depth (Eiggard et al., 2017). Also, the boats and the gear are of smaller size than otter bottom trawlers. The targets and gear of the beam trawling fisheries varies between Mediterranean areas and the fisheries named differently.

Gangui were used in France but have now been banned since 2002 because of the damage they caused mainly on *Posidonia* meadows (RAC/SPA, 2003)[39].

The use of benthic ***Kiss*** in Tunisia has been banned but in practice over 400 boats using this gear practice around the Kerkennah Islands and the Gulf of Gabes, often at a few meters' depth contributing largely to the depletion of the *Posidonia* meadows and the surrounding ecosystems (Zaouali, 1993; Zerelli, 2018; Mosbahi et al., 2022). The boats and gear are rather small but the mesh size of the nets used is also much smaller (18mm compared to 28mm and other trawlers) (Mosbahi et al., 2022).

In the Adriatic Sea, fisheries using ***Rapido*** beam trawlers target scallops in sandy areas and flatfish in muddy inshore areas. The use of *Rapido* is forbidden within 3-miles limit [from coast] (Pravoni et al., 2000).

Dredges and especially **hydraulic dredges** for shellfish cause great sea-floor surface disturbance by higher penetration of the gear in the sea-floor (Pitcher et al., 2022). Penetration is comparable for gravel and mud sea-floors but is less in sand bottoms (Pitcher et al., 2022). It is estimated that

39 17 fishing vessels in France currently have derogations to the ban on using gangui; some Croatian vessels use similar gear (DG Environment, pers. comm., September 2022).

hydraulic dredges cause the depletion of 41% of the biota on each pass (Hiddink et al., 2017). In shallow sandy bottoms in the northern and central Adriatic (3 to 12m depth), about 380 boats operate dredges that plough up to 15-16cm in the sea-floor to collect the shells (Lucchetti & Sala, 2012; Hiddink et al., 2017). Many studies show that in the Adriatic Sea where the number of dredges is important, sea-floor and macrobenthos suffer important changes and alteration especially in shallow coastal areas (e.g., Morello et al., 2005; Lucchetti and Sala, 2012).

Discard from beam trawling and dredging is important as underlined by many authors. For non-target species, mortality is high and many species such as fragile echinoderms are severely damaged (Pravoni et al., 2001; Morello et al., 2005; Urra et al., 2019; Ezgeta-Balić et al., 2021). By causing more damage and mortality to certain species compared to others, beam trawlers and dredges most probably contribute to important shifts in soft bottom community compositions (Pravoni et al., 2001).

A2.4 Non-trawling small-scale fisheries and recreation fishing

Non-trawling small-scale fisheries and recreational fishing (mainly gillnets, trammel nets, long lines and various bottom traps) may locally have an impact on habitats in particular from bycatch and mechanical damage by entanglement creating derelict fishing gear. Cold-water corals may constitute bycatches by gillnets and longlines on depths between 200 and 700m as reported by Mytilineou et al., (2012) for the Ionian Sea where *Isidella elongate* and *Leiopathes glaberrima* appeared as the most often reported cold-water coral bycatch. Observations by remotely operated vehicles (ROV) of mechanical damage caused to gorgonians, maerl beds and corals by entanglement with derelict fishing gear have often been reported (e.g. Bo et al., 2014; Giusti et al., 2019; Betti et al., 2020; Rendina et al., 2020, Özalp, 2022).

The damage caused by non-trawling small-scale fisheries and recreational fisheries may be important locally on sessile benthic communities, but the physical impact on sea-floor substrate is negligible.

A2.5 Coastal artificialisation

Coastal artificialisation or urbanisation affects mainly the littoral and upper infralittoral sea-floor and habitats. Littoral constructions such as ports, keys and dams, beach management imply sea-floor sealing and disturbance, dredging (see Annex section 1.1.4) but also changes in hydrological conditions that change substrate and disturb habitats. The result is a physical loss of sea-floor and habitats and a fragmentation of the habitats that loose connectivity despite the existence of marine protected areas (MPAs) (Santiago-Ramos & Feria-Toribio, 2021). The increasing urbanisation and touristic development of the coastal Mediterranean is bound to lead to an increase of coastal development of artificial infrastructures. Coastal artificialisation is especially consequent along Spanish and French coasts where in many areas, more than 15% of the coast has been artificialized (Piante & Ody, 2015).

There is no general view of the coast artificialisation at the Mediterranean scale. Some Mediterranean countries though have assessed the length of coastal artificialisation such as Italy where in 2006 almost 16% of the coastline was identified as built, Montenegro where in 2013, 32% of the coastline was built (see UNEP/MAP, 2017) and French Mediterranean where MEDAM[40] has assessed in detail the artificialisation of the coast in time and space. The French Mediterranean coastline shows a global rate of artificialisation of 12% (see MEDAM), but as for other countries, they are wide spatial differences.

40 French MEDiterranean Coasts. Inventory and Impact of Reclamations from the Sea (MEDAM)

Coastal artificialisation implies direct physical loss of sea-floor but also indirect disturbance in the surroundings by changing hydrological conditions or increasing turbidity during construction for example.

A2.6 Dredging and dumping

Dredging generally concerns littoral and infralittoral sea-floor but dumping may occur on circalittoral habitats.

Dredging can be carried out for the following reasons[41]:

(i) to create or extend littoral infrastructure (e.g., a port). This dredging of seabed that has never been dredged is ***capital dredging;***

(ii) to remove sea-floor substrate that has gathered and is an obstruction to navigation such as in ports, canals and river mouth. In these areas dredging is recurrent; it is ***maintenance dredging;***

(iii) to extract minerals such as sand, then we talk about **mineral dredging;**

(iv) to remove material purely for environmental reasons as for an old industrial site (***remedial dredging***).

Capital and maintenance dredging concerns mainly soft sediments (but not only) that are removed and dumped some other place in the sea from a barge. Capital dredging impacts sea-floor that has never been dredged and often precedes coastal constructions. The main threat of maintenance dredging resides in the degree of pollution of the material dredged and the area where it will be dumped.

Capital and maintenance dredging with associated dumping is affecting most of the Mediterranean countries and has been increasing during the last decade (Depe et al., 2018). The growing tourism pressure in the Mediterranean region will most probably intensify such activities. Concerns are therefore arising as for efficient management. Depe et al. (2018) underline the threats of dredging and dumping activities in a context of poor relevant regulatory framework in the Mediterranean and lack of unified framework at a regional or sub-regional scale. UNEP/MAP's MED POL published a Guide on Management of Dredged Materials to help Mediterranean countries in the decision making, characterisation of materials, assessment, sampling and monitoring (see Decision IG. 23/12). Mikac et al. (2022) have studied the impacts of the innovative ejectors plant technology that seems to reduce damage from maintenance dredging.

Mineral dredging, which in the Mediterranean generally concerns extraction of sand (also called sand mining), is collected in more or less deep areas to nourish depleted beaches or seashores (e.g. Sardà et al., 2000).

Distant impacts of mineral dredging on the seabed are not well known. It nevertheless consists of a physical removal (therefore loss) of sea-floor, meaning an initial loss of abundance of benthic community and a modification of the sea-floor topography and hydrological conditions (Van Dalfsen et al., 2000; Trop, 2017). After sand extraction activities, recovery of the impacted sea-floor and associated fauna depends amongst other, on the local hydrology, the frequency and on the depth (Van Dalfsen et al., 2000).

Some national guidance documents exist such as in Italy (ICRAM & APAT, revised version 2007).

41 European Dredging Association

Capital dredging disturbs the dredged surroundings by an increase of turbidity and represents a physical loss of sea-floor especially since it is done to construct and therefore seal the area concerned. Mineral dredging consists generally in the Mediterranean of sand extraction and is therefore strictly speaking a physical loss of sea-floor but depending on the frequency in an area, it may be considered as a physical disturbance since recovery seems possible. Dumping areas of dredged materials should be managed with more attention.

A2.7 Anchoring

Anchors mechanically damage habitats by digging in the sea-floor, uprooting benthic species and creating depressions resulting in a patchiness of the habitat. The damage can be a disturbance but locally also a physical loss. In the Mediterranean Sea, damage caused by anchoring on sea-floor have deteriorated habitats such as *Posidonia oceanica* meadows where depressions become week points for the entire meadow. Furthermore, the chains by turning around the anchor on the sea-floor, cause abrasion. To better manage anchorage damage, modelling tools have been developed and applied such as the accounting model applied on *Posidonia oceanica* meadows in Portofino, Italian MPA to assess the quantitative net impact of anchoring on this sensitive habitat (see Dapueto et al., 2022).

The damage caused by anchors has been mainly studied on fragile, long-to-recover habitats where the impact is long lasting. Nevertheless, along the French coast between 0 and 80m depth, almost a third of the seabed habitats were subject to anchoring pressure between 2010 and 2015 (Deter et al., 2017). The most important in descending order were: circalittoral soft bottom, infralittoral soft bottom and *Posidonia oceanica* meadows (Deter et al., 2017).

Deter et al. (2017) based their study on Automatic Identification System (AIS) data and show the seasonality of the touristic anchoring pressure (mainly concentrated between May and September) but also the geographic distribution of this pressure that also concerns commercial vessels (Deter et al., 2017).

Regarding commercial vessels, an interesting tool to easily identify anchoring locations of commercial vessels and obtain details is the website VESSELFINDER that tracks vessels with AIS. In a given area it is possible to count all boats at anchor and obtain easily details on each boat (length, tonnage, draft) in particular the status that indicates if the boat is at anchor (see **Figure 5**). By crossing with bathymetric data and habitat information, pressure by anchoring of commercial vessels or large motorboats (see **Figure 6**) can be estimated for a given area and a given habitat. A certain number of data is free of access, though historical data going back to 2009 are not free.

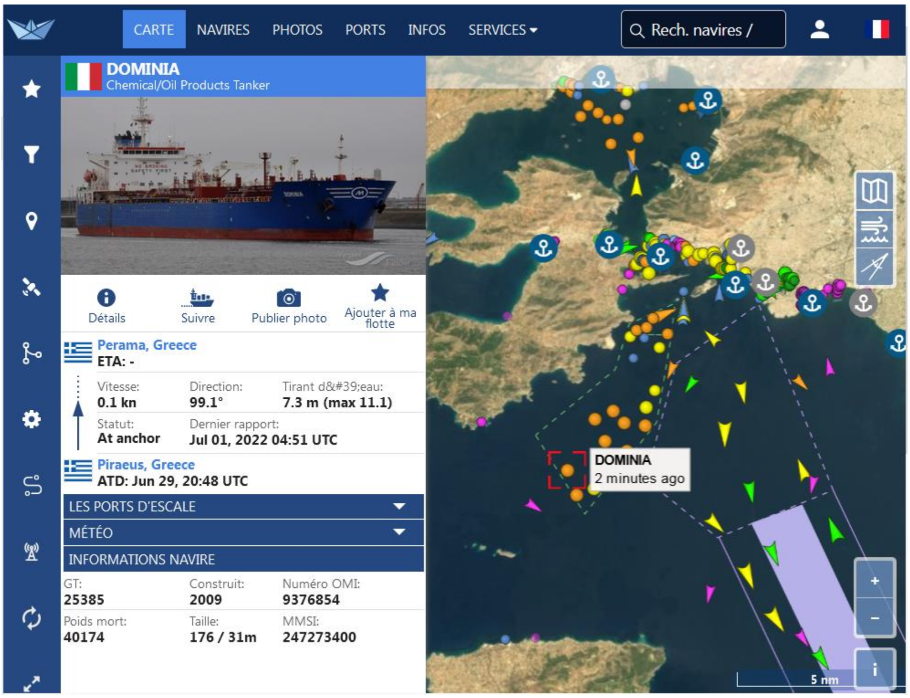

Figure 5. *Snapshot of the internet site VESSELFINDER following boats with AIS captured 31/06/2022. It shows the boats at anchor (circles) and those underway (arrows) in front of the Greek port of Piraeus and associated information on length, draft, tonnage and status of the selected vessel. Entry of channel and anchoring area are delimited.*

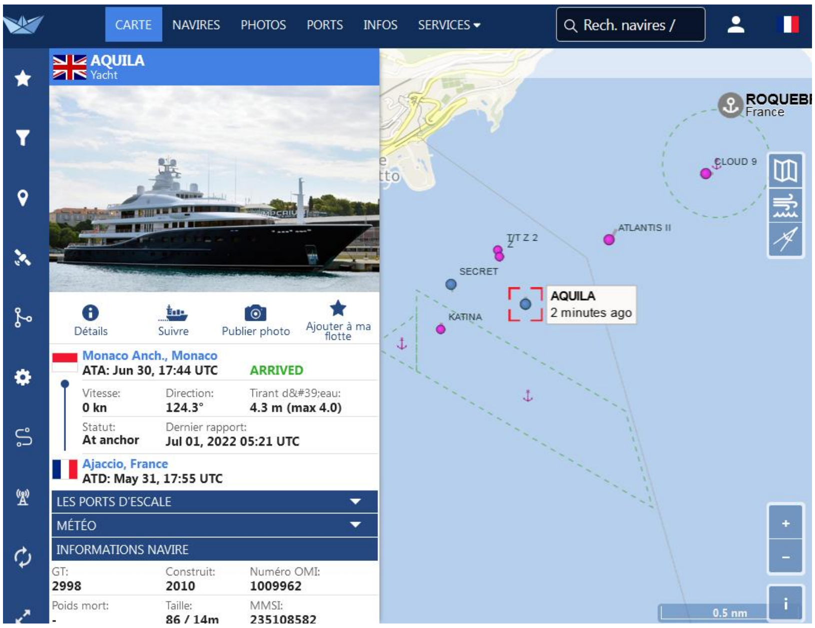

Figure 6. *Snapshot of the internet site VESSELFINDER following boats with AIS captured 31/06/2022. It shows the boats at anchor in front of Monaco and associated information on length, draft, tonnage and status of the select vessel. Also, anchoring areas are delimited but here little respected.*

Efforts have been done along French Mediterranean coast to protect especially *Posidonia oceanica* meadows from anchor damage. The recent [French] decree N°123/2019 that has been declined in regional decrees bans anchoring on *Posidonia* meadows.

For French coasts a freely accessible application DONIA can be downloaded to mobile phones (MEDTRIX, 2019). It gives access to bathymetrical maps with very detailed information on habitat's geographic distribution down to 50 m depth, especially vulnerable habitats such as *Posidonia* meadows. Through this application, the navigation and anchoring regulations are mapped as well as other facilities and information.

Anchoring causes physical sea-floor damage in specific areas that can represent a large percentage of infralittoral sea-floor. It can lead to localised physical loss of biogenic habitat (e.g., seagrass) but mainly it provokes physical disturbance of the sea-floor. It represents an already important source of damage on Mediterranean sea-floor and a threat that will be increasing in the Mediterranean Sea.

A2.8 Aquaculture activities

Aquaculture (brackish and marine) in the Mediterranean Sea has rapidly grown since the 1970's (Piante & Ody, 2015). The development is expected to steadily grow up to 100% by 2030 in terms of production and value (Piante & Ody, 2015). Aquaculture releases organic matter creating bacterial mats and inorganic wastes that deposit on the sea-floor (Knight et al., 2021). The impacts on the sea-floor are localised under and in the close vicinity of the cages and are mainly: sediment anoxia and chemical changes, macrofaunal changes as well as severe effects on *Posidonia* meadows (Plan Bleu, 2015).

Physical loss due to aquaculture activities are limited to the anchoring gear of the structure. Increased turbidity under and in the close vicinity of the cages disturbs biogenic habitats especially macrophytes, the disturbance may result in a loss of habitat.

A2.9 Gas and oil exploration and exploitation

The oil and gas production in the Mediterranean Sea is relatively limited compared to other areas (Piante & Ody, 2015). Nevertheless, the demand in oil and gas is increasing especially in the actual geopolitical context (war in Ukraine and European sanctions on Russia). Therefore, exploration is taking place in large areas of the Mediterranean Sea (PERSEUS, 2013; Piante & Ody, 2015; Kostianoy & Carpenter, 2018).

Offshore platforms exist in various countries around the Mediterranean Sea where in 2005 over 350 offshore wells were drilled (Kostianoy & Carpenter, 2018). Exploitation, development and/or exploration for oil and gas occurs today in Italian, Egyptian, Greek, Libyan, Lebanese, Tunisian, Spanish Algerian, Maltese, Cypriote and Turkish waters (Kostianoy & Carpenter, 2018). A large concentration of gas platforms are in operation in the North-Eastern part of the Adriatic and Ionian Sea with over 100 installations (Piante & Ody, 2015).

For the Mediterranean Sea, experts consider that once platforms are installed, the actual physical damage of sea-floor (physical loss in this case) is relatively limited in terms of surface (ICES, 2019a) compared to other threats. Moreover, the platform structure offers new hard substrate that is often colonised by various benthic species, including NIS (Manoukian et al., 2010; Harry, 2020). Gas and oil extraction has been ranked 15 on a scale that classifies 31 activities, rank 1 considered to be causing the greatest amount of physical disturbance to sea-floor in the region (ICES, 2019a). Oil offshore production discharge are considered to be limited compared to other sources of inputs (Harris, 2020) and it is estimated that less than 1% of total oil pollution in the Mediterranean Sea originates from platforms (Kostianoy & Carpenter, 2018). Nevertheless, in the context of expanding oil and gas exploration and future exploitation in the Mediterranean Sea, notably in the Eastern Mediterranean, drilling activities during exploration (such as anchorage of platform and drilling) represent potential increasing sources of damage to sea-floor and its geological structure. The increase in platforms will also increase the risk of accidental oil spills and the problem represented by decommissioning of offshore platforms.

The implementation of platforms disturbs sea-floor in the close vicinity but for a short time. Platforms though represent also a localised loss of sea-floor by sealing, even though the new artificial hard substrate (the immerged structure) represents a new substrate for sessile species. At the Mediterranean scale the UNEP/MAP offshore protocol gives recommendation for these installations so as to limit impact on the environment.

A2.10Offshore wind farms

Installation of offshore wind farms impacts directly the sea-floor by loss of sea-floor and benthic habitats where the foundations are set and disturbance during the implementation of the wind farms. But the impact is limited in surface and damage can be reduced if properly planned in areas without vulnerable benthic habitats. Boero et al. (2016) even consider that the foundations of the wind farms could increase connectivity between ecosystems since benthic species will develop on the foundations. Prevention of fishing activities within the wind farm could even create refuge habitats for many species including fish and increase connectivity (Boero et al., 2016).

Marine renewable energy is at the first stages of development in the Mediterranean Sea (Piante and Ody, 2015). Wind energy is developing with projects mainly in the EU states (Piante and Ody, 2015). The high costs of the installation in deep seas and the low mean wind speed pose technical limits in the development of such energies (see the EU-funded COCONET project; Boero et al., 2016), but coupling wind energy with environmental features appears to have a potential for increasing connectivity between ecosystems and therefore having positive impacts (Boero et al., 2016). Possibilities to associate sustainable aquaculture, for example bivalves, on the foundations could also be considered (Boero et al., 2016). Röckmann et al., (2018) indicates that many Mediterranean countries intend to develop offshore wind farms such as Albania, Algeria, Bosnia and Herzegovinia, France. Spain, Greece and Malta intend to develop offshore renewable energy without specification.

The Coconet project has studied wind-farm installation potentialities in the Mediterranean Sea taking in account many factors and proposes a smart wind chart for pilot areas (Boero et al., 2016). The impact of effects such as potential vibrations on sea-floor and benthic habitats and seabirds is still not clear and would need to be further studied in pilot areas.

The implementation of offshore wind farms (OWF) disturbs sea-floor in the close vicinity but for a limited time. Offshore wind farms represent also a localised loss of sea-floor by sealing, even though the new artificial hard substrate (the immerged structure) represents a new substrate for sessile species. Spatially well-planned OWF could possibly increase connectivity between benthic communities and therefore favour biodiversity.

A2.11Mining

Deep-sea mining for the extraction of metals and minerals (other than sand) is not yet developed in the Mediterranean Sea. However, mining could grow in the near future to meet the increasing global need in metals and minerals. In France and Spain, potential areas for seabed mining have been identified (Piante & Ody, 2015). Potential space conflicts with other offshore activities could occur if sea-floor mining develops in the Mediterranean (Piante & Ody, 2015). Furthermore, other than the loss of sea-floor extracted by mining, the impacts of sea-floor mining on Mediterranean deep ecosystems are unknown.

A3 Review of selected pressures

A3.1 Non-indigenous species

The presence of non-indigenous species (NIS) in the Mediterranean has clearly increased these last years (Zenetos et al., 2022). The phenomenon is rapidly growing given that increase of sea temperature due to climate change that favours the establishment of lesseptian species. Some benthic NIS can develop rapidly and impact native habitats by increasing competition for space (Pergent et al., 2008). Others impact coralligenous habitats by growing in epibiosis on sessile species (e.g., Sempere-Valverde et al., 2021). In the Mediterranean, NIS impact marine ecosystems including benthic habitats in multiple ways (Katsanevakis et al., 2016). To mitigate impact of NIS on Mediterranean ecosystems and societies, UNEP/MAP and contracting parties have adopted the *Action Plan concerning species introductions and invasive species in the Mediterranean Sea*[42].

NIS can disturb sea-floor biogenic habitats but up to date, no loss of habitats has been recorded in the western Mediterranean, whilst changes are documented for the eastern (Levant) Mediterranean (Bitar, 2008; SPA/RAC, 2018).

A3.2 Land-based pollution

It is estimated that 80% of the marine pollution comes from land-based human activities (Piante & Ody, 2015). Here we consider only the pollution by nutrients, heavy metals and Persistent Organic Pollutants (POPs), litter being developed farther in section 1.2.3. In the Mediterranean, the main sources are: industries, untreated urban and domestic wastewaters, surface run-off, dumping grounds, river discharges to the sea. Assessment of land-based pollution and its different components has become a common approach in marine waters and sediments, although littoral sands are less considered (Galgani et al., 2011). Impact on sea-floor concerns mainly coastal areas, such as for chemical contamination that decrease in the sediment when moving offshore (Gómez-Gutiérrez et al., 2007). Nutrients can change benthic community compositions in shallow rocky habitats especially macroalgae communities (Arévalo et al., 2007) and benthic communities of soft sediments seem strongly affected by heavy metals in sediments (Chatzinikolaou et al., 2018). Furthermore, sediments integrate heavy metal pollution on several years and represents therefore an archive of the changes (Chatzinikolaou et al., 2018).

The development of Waste-Water Treatment Plants (WWTPs) and their increasing efficiency in treating waste-waters, has considerably improved the quality of the treated water released in the sea.

Land based pollution will mainly cause chemical damage on algal, macrophyte and other benthic communities. Physical damage to sea-floor is limited to eventual increase of turbidity. It may lead though to a loss of biogenic habitats. Moreover land-based pollution is covered by EO9 (CI-17).

A3.3 Litter

The Mediterranean Sea by its configuration of semi-enclosed sea surrounded by a highly populated coast and being one of the first touristic destination, is highly threatened by litter and more specifically by plastic litter. Litter has been confirmed in all compartments of marine environment and more than 50% of the seabed marine litter in the Mediterranean is plastic litter (UNEP/MAP & Plan Bleu, 2020) and can count up to 62% in weight in some areas (e.g., Adriatic see Pasquini et al., 2016).

On sea-floor, plastic litter concentrate in specific areas and although coastal areas show higher concentration in litter (e.g., Strafella et al., 2015), in deeper areas hotspots of plastic litter concentrations have been identified (Pasquini et al., 2016; Angiolilo & Fortibuoni, 2020). Deep-sea canyons are also impacted by litter especially when they are near the coast (Gerigny et al., 2019).

Recent concerns focus further on pollution by microplastics which by their size are hardly visible but can penetrate easier habitats and sediments and their impact on macrofauna are not yet known. Tsiaras et al., 2021 have modelled the distribution of microplastics on the Mediterranean continental shelf depending on the size. With this model, eastern Spain, the Gulf of Lion and the Tyrrhenian Sea appear as the most impacted by microplastics.

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Litter on sea-floor can physically damage erect sessile key species of some habitats but the damage is relatively restricted to certain areas and does not affect the sea-floor substrate.

Micro-plastics though by their small size can penetrate in biogenic habitats and soft substrates and the impact there is still unknown. The impact of litter is covered by EO10 (CI-22 and CI-23).

A3.4 Climate change

Impact of climate change on Mediterranean benthic species has been widely studied since the 1980's, although effects in eastern Mediterranean are known from the decades before 1980. Since then, frequent and drastic mortality events have been recurrent (e.g., Pérez et al., 2000; Garrabou et al., 2001, 2003; Lejeusne et al., 2010; Galassi & Spada, 2014; Pairaud et al., 2014; Bianchi et al., 2019; Moraitis et al., 2019). The damage caused by climate change has mainly been studied on infralittoral and circalittoral hard substrate communities but impacts on deep-sea benthic ecosystems have recently also been considered (e.g., Levin & Le Bris, 2015; Danovaro, 2018).

Damage from climate change impacts sea-floor benthic habitats, although changes in Mediterranean hydrodynamic circulation due to climate change could induce changes in sea-floor substrate topography. Furthermore, the littoral fringe of the Mediterranean coast is expected to undergo drastic changes due to climate change with a rise of the sea-level and erosion of the coastline and beaches. It is difficult to assess damage on sea-floor from climate change since the climate change effects cumulate with other effects.

A3.5 Cumulative effects

Sea-floor damage is often the result of multiple threats that add but may also interact and create more damage than the sum of impacts, increasing the risk of damage on sea-floor and its vulnerability. It is difficult to assess the cumulative impacts due to scattered data (Bevilacque et al., 2020). Although little is known about the cumulative impact threat, littoral Mediterranean habitats are more subject to an accumulation of threats than others. More generally, it is estimated that 20% of the entire Mediterranean basin are heavily impacted by cumulative impacts (Micheli et al., 2013a).

A methodology and model for mapping the Risk of Cumulative Effects (RCE) on benthic habitats has been developed based on previous works (e.g., Halpern et al., 2008) and applied to the French coastal region (0-200m depth) by Quemmerais-Amice et al. (2020). In this work, the contribution of bottom trawling to RCE is from far the most important.

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Annex II. Blue carbon and bottom fishing

A5 Review of blue carbon and the effects of bottom fishing

Marine sediments are one of the most expansive and critical carbon (C) reservoirs on the planet; shallow seas (<1000m depth) [i.e. where bottom fishing is still permitted] store 15.5% of global marine carbon (360 Pg); continental shelves store more carbon per unit area (<19,000 Mg km^{-2}) than the rest of the ocean provinces including the deep ocean abyssal plains and basins (~6000 Mg km^{-2}) due to the higher productivity in the waters above the shelves (Atwood et al. 2020). Shelf sea sediments are the dominant component (~93%) of coastal and shelf sea carbon stores; saltmarshes and seagrass store more carbon per unit area, but their areas are small relative to shelf sediments. This emphasises that shelf sediments are an important carbon store both locally and indeed globally (Bauer et al., 2013, Liusetti et al. 2019). The amount of carbon sequestered into shelf seas is comparable to that in tropical forests (Luisetti et al. 2020).

Disturbance of these carbon stores can re-mineralize sedimentary carbon to CO_2, which is likely to increase ocean acidification, reduce the buffering capacity of the ocean and potentially add to the build-up of atmospheric CO_2 (Sala et al. 2021). Disturbance to the seafloor by bottom trawling results in an estimated 1.47 Pg of aqueous CO_2 emissions, owing to increased carbon metabolism in the sediment in the first year after trawling, equivalent to 15–20% of the atmospheric CO_2 absorbed by the ocean each year (Sala et al. 2021). Ground-fish fisheries could have the greatest impacts on the carbon sink through trophic cascades as described in the Baltic Sea (Casini et al., 2008 in Cavan & Hill, 2021) and physical disturbance of the seabed (Duarte et al., 2020 in Cavan & Hill, 2021; Luisetti et al., 2019; Pusceddu et al., 2014). Trawling impacts up to 75% of continental shelf sediments globally, with almost 20 million km2 of sediments subject to trawling once or more per annum (Kaiser et al., 2002). Bottom trawling affects sedimentary carbon storage through remineralisation of the resuspended sedimentary organic carbon, altering the depth and rate of organic carbon burial and by changing the seabed communities involved in bioturbation and bio-irrigation (Duplisea et al., 2001) (Liusetti et al. 2019). Overall, the dominant control on net release of carbon to the atmosphere was found to be the intensity of trawling (a function of the depth to which carbon was disturbed, the POC content of the sediment, and the fraction redeposited without mineralisation) (Liusetti et al. 2019). Effectively all organic carbon oxidised will be released to the atmosphere as CO2 (Liusetti et al. 2019).

Trawling affects sediments to a depth of 10 cm with a 52% reduction in organic carbon storage, slower carbon turnover and reduced meiofauna abundance and biodiversity (Pusceddu et al., 2014). A recent study found 30% less organic carbon in deep-sea (500m) sediment continuously trawled for shrimp compared to sediment where trawling had been banned for 2 months (Paradis et al., 2021). However, the slow rate of sediment accumulation means a longer ban (decades) on trawling than 2 months is required to restore sediment organic carbon (Paradis et al., 2021).

Fishery disturbance is not yet factored into forecasts of future changes to the global carbon cycle (Laufkötter et al., 2016 in Cavan & Hill, 2021) and carbon sequestration in shelf sea sediments should be considered within the scope of both IPCC inventory and environmental–economic accounting methodologies (Luisetti et al. 2020). In a scenario of increased human and climate pressures over a 25-year period, the present value of damage costs from carbon release ranging are estimated between US$1.7 billion using the social cost of carbon approach (Tol, 2005) and US$12.5 billion using the UK's abatement cost approach (BEIS, 2017 in Liusetti et al. 2019), with an intermediate US$5.2 billion using Nordhaus' mixed approach of social cost of carbon and abatement cost (Nordhaus, 2017). Protecting the carbon-rich seabed is a potentially important nature-based solution to climate change (Sala et al. 2021).

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Annex III. Basis for assessment areas proposed for EO6 [New Annex since v 1.0)

A7 Introduction

A proposal for a set of assessment areas for EO6 application was introduced in Section 9 and **Figure 2**. In **Figure 7**, the subregions and subdivisions are labelled/numbered to link to the data provided in **Table 11** on the characteristics of each assessment area (subdivision of the marine region).

It should be noted that these subdivisions currently have no formal status.

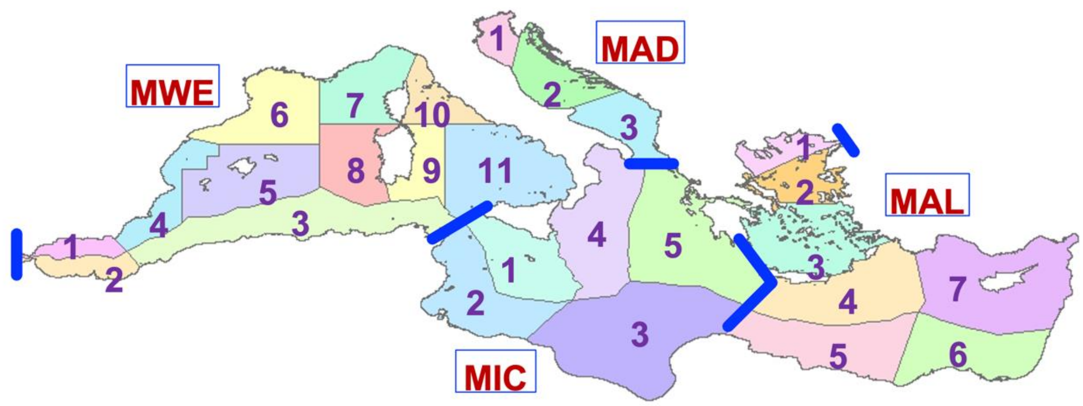


***Figure 7**. Subdivisions proposed for EO6 application (used in STECF, 2022). Subdivisions are numbered within each subregion (blue lines) with codes: MWE-Western Mediterranean Sea; MAD-Adriatic Sea; MIC-Ionian Sea and the Central Mediterranean Sea; MAL-Aegean-Levantine Sea.*

These 'subdivisions' of the Mediterranean Sea are based on:

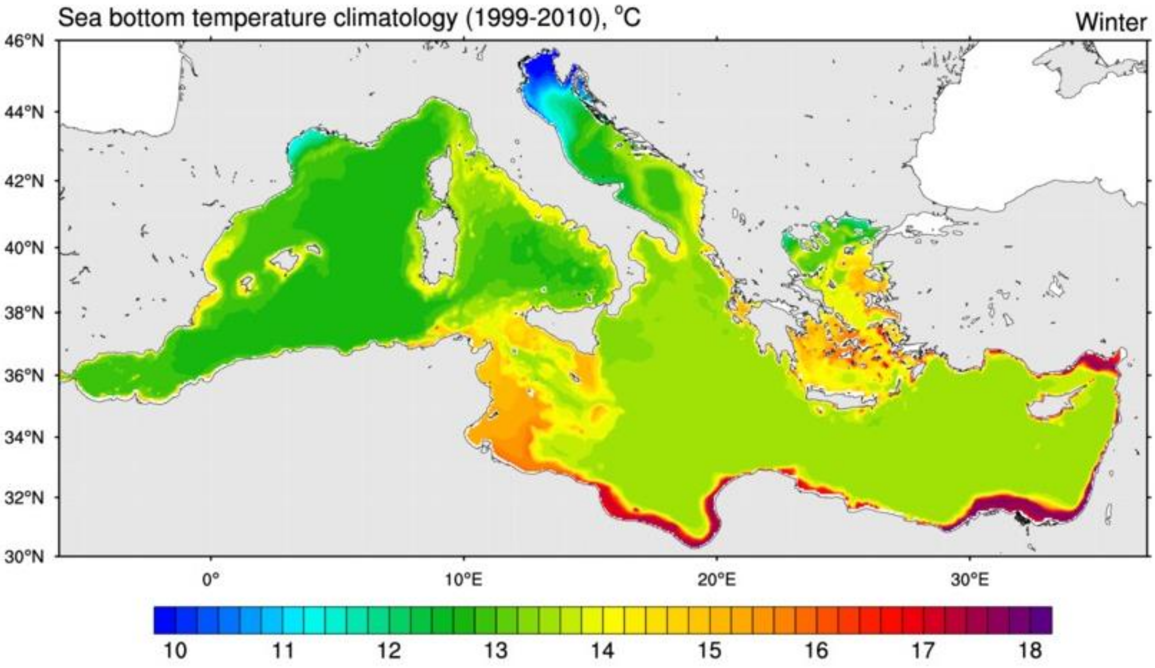
a. The four subregions of the Mediterranean Sea region, as adopted by UNEP/MAP and MSFD;
b. Biogeographic considerations, primarily temperature and salinity regimes (at the sea bottom and sea surface, in summer and in winter);
c. National borders of marine waters;
d. Management considerations, such as the management of the bottom fishing sector, including use of some GFCM geographical sub-area boundaries.

A8 Temperature and salinity data used

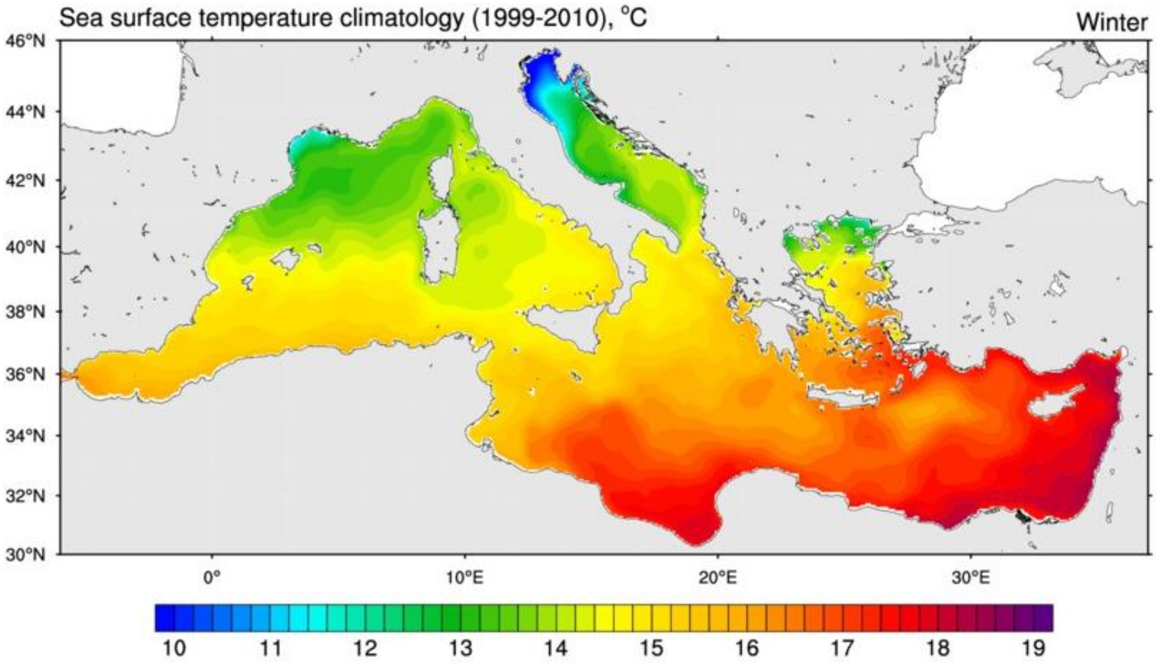
Long-term average sea temperature and salinity (climatology) play a key role in determining biogeographic characteristics of marine communities. The species become accustomed to the long-term characteristics of the sea in which they live, and this is reflected in the biological communities of both the water column and the seabed (TG Seabed, SEABED_2-2019-08).

Long-term data on sea temperature and salinity reveals broad patterns in the characteristics of the sea and can help identify biogeographic variation across the Mediterranean Sea. Data on sea temperature and salinity at the surface and at the bottom and in summer and winter seasons was considered. The most distinct changes in temperature and/or salinity are likely to give more marked variations in biological communities, particularly for bottom temperature and salinity conditions. Date from MyOcean (accessed via Eye-on-Earth November 2013) for the period 1999-2010 was used to define the subdivisions used in STECF (2022) and proposed here (see figures below, from TG Seabed 2021b; SEABED_8-2021-04).

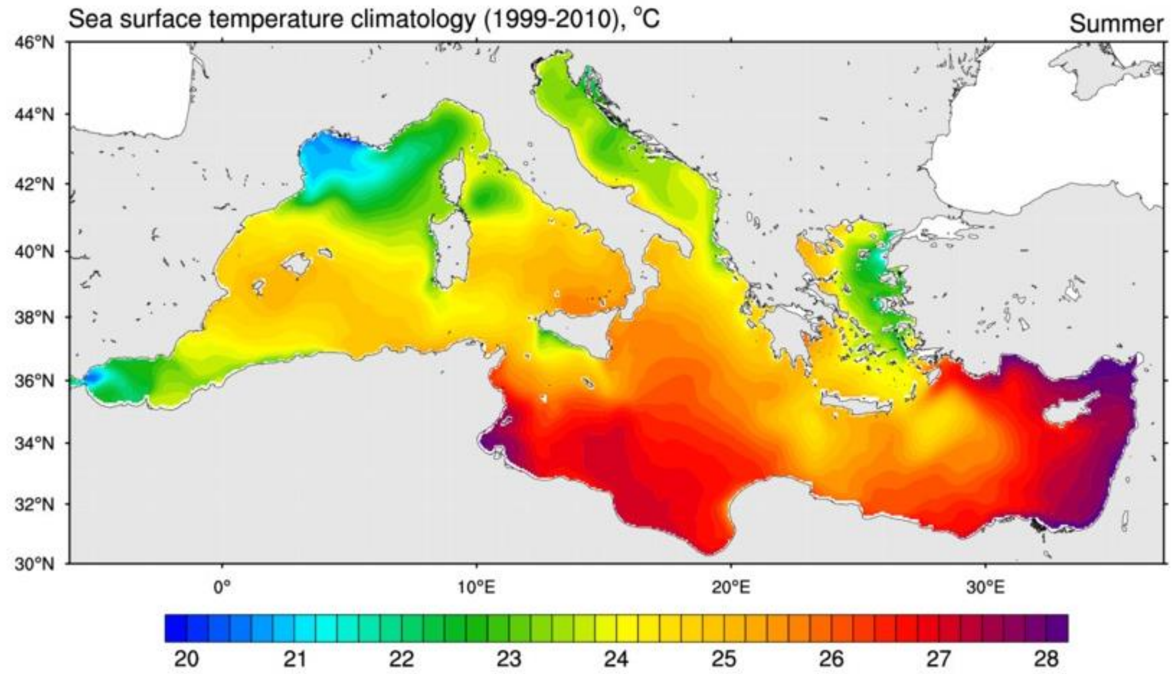
A8.1 Mediterranean Sea bottom temperature - winter (average 1999-2010)



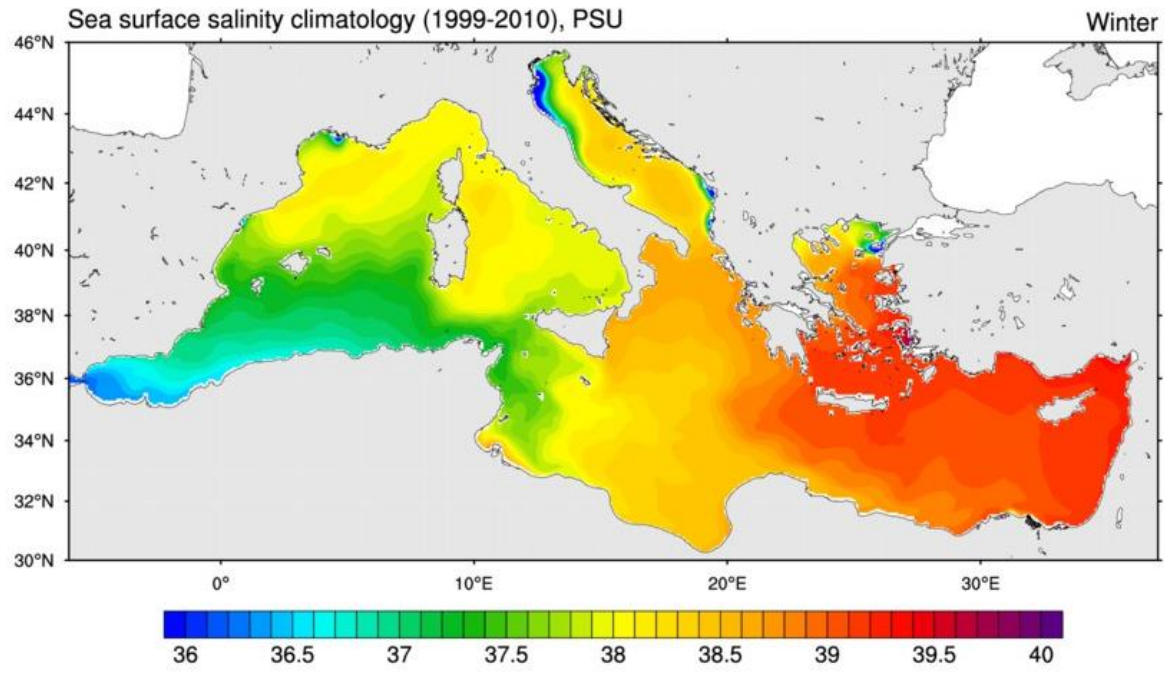
A8.2 Mediterranean Sea surface temperature – winter (average 1999-20)



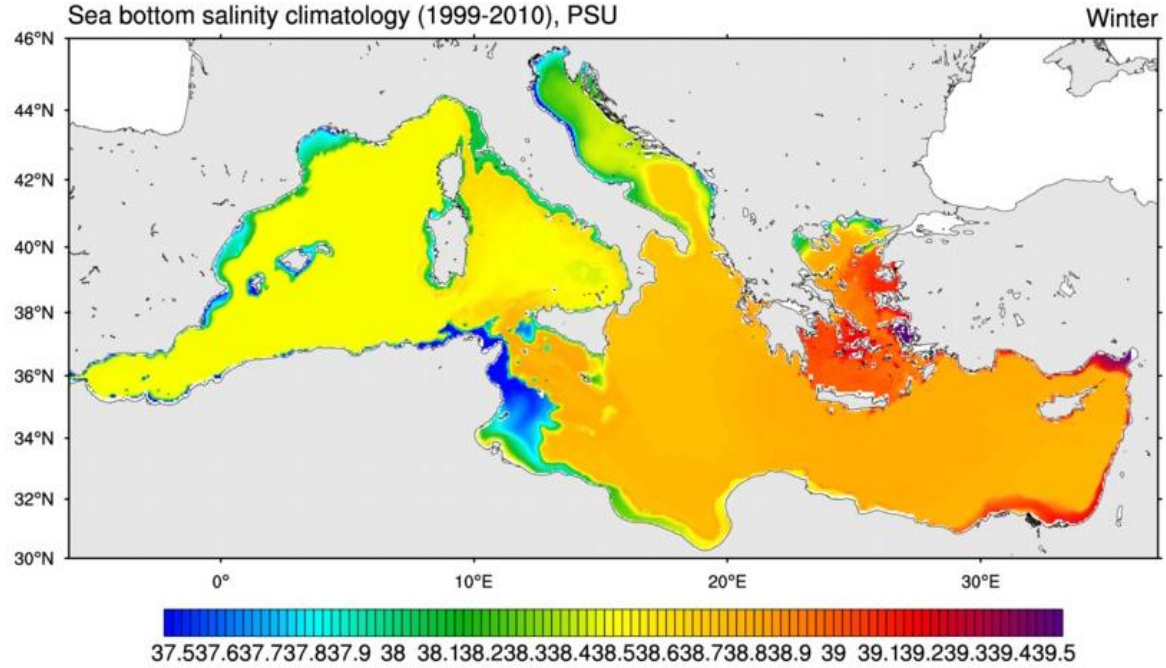
A8.3 Mediterranean Sea surface temperature – summer (average 1999-2010)



A8.4 Mediterranean Sea surface salinity – winter (average 1999-2010)



A8.5 Mediterranean Sea bottom salinity – winter (average 1999-2010)



A8.6 Characteristics of each subdivision

More specific information on the subdivisions shown in **Figure 7** is provided in **Table 11**. In particular, it indicates:

a. the long-term average sea temperature and salinity in each subdivision (surface and bottom; summer and winter), and
b. the 'origin' of the boundaries of each subdivision, indicating whether they have an ecological basis (based on temperature and salinity regimes) or a 'management' basis (i.e., the coastline, a national marine border, a GFCM area boundary).

***Table 11**: Characteristics of subdivisions proposed for EO6.*

Subregions: MWE - Western Mediterranean Sea; MAD – Adriatic; MIC – Ionian Sea and the Central Mediterranean Sea; MAL – Aegean-Levantine Sea. Temperature and salinity values are 1999-2010 climatology averages from MyOcean ('coast' here mainly refers to the shelf zone above 200m depth); the main basis for boundaries is indicated as ecological (green) or management (beige).

Assessment area		Countries	Temperature (C)			Salinity (ppt)		Basis for boundary of subdivision			
Sub-region	Sub-division	Codes	Surface Summer	Surface Winter	Bottom Winter	Surface Winter	Bottom Winter	North	East	South	West
MWE	1	ES	20-23	14.5-15.5	12-13	36.2-36.5	38.5	Coast ES	Ecological	Marine border ES	BC limit (subregion)
MWE	2	MA, DZ	20-23	15.5-16	12-13	36.2-36.5	38.5	Marine border ES	Ecological	Coast MA, DZ	BC limit (subregion)
MWE	3	DZ, TN	23-24.5	14.5-15.5	12-13	36.5-37.3	38.5	Marine border ES, IT	Ecological (subregion)	Coast DZ, TN	Ecological
MWE	4	ES	24-25	14.5-15	12-13 (coast14-15)	37.3-37.8	38.5 (coast 37.8-38.2)	Coast ES	GFCM	Marine border ES	Ecological
MWE	5	ES	24-25	14.5-15	12-13	37.3-37.5	38.5 (coast 38-38.2)	GFCM, ecological	GFCM, ecological	Marine border ES	GFCM
MWE	6	ES, FR	20-23	12.5-13.5 (coast 11-11.5)	12-13 (coast 11)	38 (Gulf of Lion 37)	38.5 (coast 38-38.2)	Coast FR	GFCM, ecological	GFCM, ecological	Coast ES
MWE	7	FR, IT	22-23	13-14 (coast 14-14.5)	12-13	37.5-38	38.5	Coast FR, IT	Ecological, coast Corsica	Ecological (GFCM)	GFCM, ecological
MWE	8	IT	24.25	14-14.5	12-13 (coast14-15)	37 (coast 38)	38.5 (coast 37.8-38.2)	Ecological (GFCM)	Coast Sardinia	Marine border IT	GFCM
MWE	9	IT	24-25	14	12-13 (coast14-15)	38	38.5 (coast 37.8-38.2)	GFCM (ecological)	GFCM	Marine border IT	Coast Sardinia
MWE	10	IT	22-24	14-15	13-15	38	38.5 (coast 37.8-38.2)	Coast IT	Coast IT	GFCM (ecological)	Ecological, coast Corsica
MWE	11	IT	24.5-25.5	14.5-15	12.5-13.5 (coast14-15)	37.6-37.8	38.5 (coast 37.8-38.2)	GFCM (ecological)	Coast IT	Subregion, coast IT	GFCM
MAD	1	IT, SI, HR	23-24	10-11.5	10-11	36-38	37.5-38.1	Coast IT	Coast SI, HR	Ecological	Coast IT
MAD	2	IT, HR	22-24.5	12-13	12-13	37.5-38.5	38.1-38.5	Ecological	Coast HR	Ecological	Coast IT

Assessment area		Countries	Temperature (C)			Salinity (ppt)		Basis for boundary of subdivision			
Sub-region	Sub-division	Codes	Surface Summer	Surface Winter	Bottom Winter	Surface Winter	Bottom Winter	North	East	South	West
MAD	3	IT, HR, BA, ME, AL, EL	23-24.5	13.5-14.5	12-14.5	38-38.5	38.6-38.7 (coast 38)	Ecological	Coast HR, BA, ME, AL, EL	Subregion (ecological)	Coast IT
MIC	1	IT, MT	23-25	14.5-15.5	14-15	37.5-38	37.5-38.8	Subregion, coast IT	Ecological	Marine border IT, MT	Ecological (subregion)
MIC	2	TN, LY	25.5-28	15-16.5	14.5-15.5	37.2-38.2	38.8 (shelf 37.5-38.2)	Marine border IT, MT	Ecological	Coast TN, LY	Ecological (subregion)
MIC	3	LY	26.5-27	17-18	13.5 (coast 16-17)	38-38.5	38.8 (shelf 38.2-38.5)	Marine border IT, EL	Subregion (ecological)	Coast LY	Ecological
MIC	4	IT	25-26	14.5-15	13-13.5	38.5-38.8	38.7	Coast IT, subregion	Marine border IT/EL	Marine border IT	Ecological, coast IT
MIC	5	EL, AL	24-25	15.5-16	13-13.5 (coast 14-14.5)	38.7-39	38.7-38.8	Subregion (ecological)	Coast AL, EL, subregion	Marine border EL	Marine border IT/EL
MAL	1	EL, TR	23.5-25.5	12.5-14.5	12.5-13.5	36-38.5	38.1-38.8	Coast EL	Coast TR	Ecological	Coast EL
MAL	2	EL, TR	22-24.5	14.5-15.5	13.5-14.5	38.7-39	38.8-39.1	Ecological	Coast TR	Ecological	Coast EL
MAL	3	EL, TR	24-25.5	15.5-16.5	13.5-15	39.2-39.4	39.1-39.2	Ecological	Coast TR	Coast EL, ecological	Ecological (subregion, coast EL)
MAL	4	EL, TR	24-26.5	16.5-17	13-13.5	39-39.3	38.8	Coast EL, ecological	Ecological	Marine border EL, TR	Subregion (ecological)
MAL	5	LY, EG	25.5-26.5	16.5-17.5	13.5 (coast 16-17)	38.5-39	38.8 (coast 38.5)	Marine border EL, TR	Ecological	Coast LY	Subregion (ecological)
MAL	6	EG, IL	27-28	17.5-18	13.5 (coast 17-18)	39-39.4	38.8 (coast 39.2)	Marine border, TR, CY, LB	Coast IL	Coast EG	Ecological
MAL	7	TR, CY, SY, LB	27-28	16.5-18	13.5 (coast 16-17)	39-39.4	38.8 (coast 39.3-39.5)	Coast TR	Coast SY, LB	Marine border TR, CY, LB	Ecological