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

Athens, 7-8 April 2025

Agenda Item 3: Development of EcAp Ecological Objectives

3.1. EO6: Sea-floor integrity

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

SPA/RAC
Tunis, 2025

Disclaimer:

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.

The initial proposal for the further development of EO6 regarding sea-floor integrity was drafted during the biennium 2022-2023. 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 document was presented to the Biodiversity Online Working Group (OWG) on benthic habitats (9 December 2022), to the meeting of the Ecosystem Approach Correspondence Group on monitoring (CORMON) on biodiversity and fisheries (Athens, 9-10 March 2023), to the SPA/BD Focal Points meeting (Malta, 22-24 May 2023), to the Ecosystem Approach Coordination Group meeting (Istanbul, 11 September 2023) and to the meeting of the Ecosystem Approach Correspondence Group on monitoring (CORMON) on biodiversity and fisheries (Videoconference, 6-7 June 2024). Comments received from these meetings were incorporated into the revised version presented here.

To assist Contracting Parties with reviewing the present version of this document, substantive changes to the version that was presented to CORMON in June 2024 (UNEP/MED WG.592/03) are presented in **RED** text.

The Meeting is expected to review the document and agree on its submission to the SPA/RAC Focal Points Meeting (scheduled for May 2025) and the EcAp Coordination Group Meeting (scheduled for September 2025).

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Acknowledgment:

This report was prepared with the participation and voluntary contribution of the Biodiversity Online Working Group (OWG) on benthic habitats and updated for the present CORMON meeting.

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
BD	Birds Directive (2009/147/EC)
BDS2030	Biodiversity Strategy for 2030 (of EC)
BHT	Broad Habitat Type(s) (defined and used in MSFD)
CBD	Convention on Biological Diversity
CCI	Candidate Common Indicator (of IMAP)
CFP	Common Fisheries 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)
CPUE	Catch per unit of effort (EO3 indicator)
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
EIA	Environmental Impact Assessment
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, of 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
IUU	Illegal, unreported and unregulated (fishing)
LPUE	Landing per unit of effort (EO3 indicator)
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean (of UNEP/MAP)
MedQSR	Mediterranean Quality Status Report (of UNEP/MAP)
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
NRR	Nature Restoration Regulation ((EU) 2024/1991)
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 on benthic habitats (of CORMON)
POPs	Persistent Organic Pollutants
QE	Quality Element (of WFD)
RAC	Regional Activity Centre (of UNEP/MAP)
RCE	Risk of Cumulative Effects
RSC	Regional sea Convention
SAC	Special Areas of Conservation (in Natura 2000 network of HD/BD)
SPA	Special Protection Areas (in Natura 2000 network of HD/BD)
SPA/BD FPs	Specially Protected Areas and Biological Diversity Focal Points (of UNEP/MAP)
SPA/RAC	Specially 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
UNCLOS	United Nations Convention on the Law of the Sea
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 (BC) 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**. It was prepared during 2022-2023 under 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), with the support of 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 the Mediterranean Trust Fund (MTF).

5. The report was presented to the Biodiversity Online Working Group (OWG) on benthic habitats on 9 December 2022, to the CORMON Biodiversity and Fisheries meeting on 9-10 March 2023, Athens (UNEP/MED WG.547/10), to the SPA/BD Focal Points meeting on 22-24 May 2023, Malta (UNEP/MED WG.548/inf.12), and to the Ecosystem Approach Coordination Group (EcAp CG) meeting on 11 September 2023, Istanbul (UNEP/MED WG.567/Inf.17). Comments received from these meetings were incorporated into the latest version (UNEP/MAP SPA/RAC, 2023a). The report was also presented to the final meeting of the ABIOMMED project on 11-12 December 2023, Athens.

6. The report was updated for presentation to the CORMON Biodiversity and Fisheries meeting on 6-7 June 2024 (UNEP/MAP SPA/RAC, 2024) and has been further updated for the CORMON Biodiversity and Fisheries meeting on 7-8 April 2025. The present version takes account of comments received from the 2024 CORMON meeting and presents the conclusions of that meeting on the EO6 proposal (Section 14).

7. Development of EO6 has been undertaken in coherence with the EU MSFD Descriptor 6 and, in particular, the 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.

1 Directive 2008/56/EC

2 Objectives, scope and tasks

8. 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.

9. 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)”;
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

10. 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.

11. **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.

12. 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).

13. 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, 2016). 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.

14. The 2017 **Quality Status Report for the Mediterranean** (MedQSR) (UNEP/MAP, 2017) was the first assessment for the Mediterranean Sea 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 MedQSR.

15. The 2023 **Quality Status Report for the Mediterranean** (UNEP/MED WG.567/Inf.3, UNEP/MED IG.26/Inf.10) was undertaken with a more data-driven approach and included an assessment of three seabed habitat types (Coralligenous habitat, Maerl and rhodoliths habitat, *Posidonia oceanica* meadows) for EO1 (https://medqsr2023.info-rac.org/mediterranean-quality-status-report/). To provide a broader perspective on the state of the Mediterranean seabed, a complementary initial assessment was provided for EO6, together with a pilot assessment of EO6 for the Adriatic Sea (UNEP/MAP, 2023).

16. UNEP/MAP SPA/RAC strengthened its commitment towards sea-floor 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).

17. 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

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

19. 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

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

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.

20. 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 (EC), 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 EC will propose[4] that it is amended.

21. 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]. For the assessment of GES threshold values which are defined at EU level are now available for some descriptors and criteria, including for seabed habitats (EC, 2024, **C/2024/2078**).

22. 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).

23. 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 (EC, 2013).

24. 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

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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 than 2023.

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

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.

25. 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.

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

a. Regulation on Nature Restoration

The Nature Restoration Regulation (NRR[13]) requires Member States to adopt nature restoration plans, with a 2030-2050 timeline for the restoration of particular ecosystems, including marine ecosystems. The NRR includes in its Annex II a specified list of marine habitat types to be restored: seagrass beds, macroalgal forests, shellfish beds, maerl beds, sponge, coral and coralligenous beds, vents and seeps, and soft sediments (not deeper than 1,000 metres of depth), based on the EUNIS typology (European Environment Agency, 2022). This list includes seagrass beds, coastal saltmarsh, and macroalgal forests, all of which are habitats with very high rates of carbon sequestration, and soft sediment habitats which, due to their very large extent[14], 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 restoring all ecosystems in need of restoration by 2050. The Regulation came into force in 2024.

b. Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries

The Action Plan (EC, 2023b) aims to build bridges between environmental and fisheries policy and will specifically address protection of the sea-floor 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 seeks to eliminate bottom fishing within all marine protected areas (MPAs) by 2030, and to implement MSFD Descriptor 6 (sea-floor integrity) threshold values for the maximum allowable extent of seabed that can be lost or adversely effected[15].

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10 Council Regulation (EC) No 1967/2006

11 Regulation (EU) 2019/1241

12 Commission Communication COM/2020/380

13 Regulation (EU) 2024/1991

14 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.

15 The threshold values were developed by TG Seabed for MSFD Descriptor 6 in 2022 and adopted by the Marine Strategy Coordination Group (MSCG_31_2022_WP-Seabed threshold values proposal). They were published as a Communication from the Commission in March 2024 (EC, 2024, C/2024/2078).

3.3 Global policies

27. 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 (CBD) which adopted new global targets for marine biodiversity protection at its COP-15 meeting in December 2022.

3.4 Synergies between policies

28. 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 environmental 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

29. Anthropogenic pressures, stemming from activities in both the marine and terrestrial environments, can adversely affect[16] 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 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[17] (**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 habitat type).
	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).

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

17 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.

Theme	Pressure	Possibility to affect sea-floor
	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[18].
	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[19].
	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[20] 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 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 the 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[21], but monitoring is focused on water quality or at species level; point-source pollution has potential to cause localised effects at ‘community level’.

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

19 For example, Price (2008) in Lunney, Munn & Meikle (2008).

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

21 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).

Theme	Pressure	Possibility to affect sea-floor
	Input of litter (solid waste matter, including micro-sized litter)[22]	Possible; widespread with possible effects, but monitoring is currently focused on quantification of litter and effects on mobile species.
	Input of anthropogenic sound (impulsive, continuous)	Possible[23]; but monitoring is currently 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 and echinoderms).
	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[24], particularly for coastal and nearshore habitats.

30. 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
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)

5 Human activities affecting the Mediterranean sea-floor

31. A review of the main human activities affecting the Mediterranean sea-floor, derived from the chapter on benthic habitats prepared for the 2023 MedQSR (Connor et al., 2023) and UNEP/MAP SPA/RAC (2022), is provided in **Annex I**. **Table 2** provides a relationship between these human activities and the main sea-floor pressures (a-h), as identified in section 4. UNEP/MAP SPA/RAC (2022) also provides a review of land-based pollution, non-indigenous species, litter, climate change and cumulative impacts (see Annex I).

22 Includes lost and abandoned fishing gear.

23 For example, effects linked to generation of offshore renewable energy (Bonnel et al, 2022 [in French].

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

***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**	Non-indigenous	Extraction of species	Physical disturbance	Physical loss	Hydrological changes (localised)	Inputs of nutrients and organic matter	Inputs of litter (including fished gear)	Acidification	Carbon sequestration	Hydrological changes (widespread)
Physical restructuring of rivers, coastline or seabed	Coastal artificialisation										
	Dredging and dumping										
Extraction of non-living resources	Gas and oil 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

32. 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

33.

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

Table 3. Links between EO6 and other EOs and their Common Indicators (CI) and Candidate Common Indicators (CCI) (UNEP/MAP, 2016a).

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) CI-1 and CI-2 for pelagic habitats - in progress or under development	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 seabed habitats. 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 'Vulnerable Marine Ecosystem (VME) species'.
EO4 Marine food webs	In progress or under development	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	Potentially relevant. 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.
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-

Ecological Objective	Common and Candidate Indicators	Relevance to EO6
		15 need to provide the extent of adverse effect per habitat so results can feed into assessments of EO-6 and EO-1. CI-15 is closely linked to CI-16 which assesses habitat loss.
EO8 Coastal ecosystems and landscapes	CI-16: Length of coastline subject to physical disturbance due to the influence of man-made structures CCI-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 to reflect habitat loss. 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 CCI-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	CCI-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	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 benthic species are reported in scientific literature, but the CIs are not

Ecological Objective	Common and Candidate Indicators	Relevance to EO6
	CCI-27: Levels of continuous low frequency sounds with the use of models as appropriate	currently of direct use to assess effects to seabed habitats.

35. From the analysis in **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.

36. 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.

37. 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.

7. Relationship between EO6 and MSFD descriptors and criteria

38. 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, 2019).

39. Building upon the analysis in **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 Common Indicators (CI) and Candidate Common Indicators (CCI) (UNEP/MAP, 2016a) 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
	CI-1: Habitat distributional range		D1 Biodiversity

IMAP Ecological Objectives	Common and Candidate Indicators	MSFD criteria Primary criteria (in bold); secondary criteria (not in bold)	MSFD Descriptors
EO1 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[25] 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		
	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	

25 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
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		
	CCI-25: Land use change		
EO9 Pollution	CI-17: Concentration of key harmful contaminants measured in the relevant matrix	**D8C1 Contaminants in environment**	D8 Contaminants
	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	**D9C1 Contaminants in seafood**	D9 Contaminants in seafood

IMAP Ecological Objectives	Common and Candidate Indicators	MSFD criteria **Primary criteria (in bold);** secondary criteria (not in bold)	MSFD Descriptors
	maximum regulatory levels in commonly consumed 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)**	
	CCI-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	CCI-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
	CCI-27: Levels of continuous low frequency sounds with the use of models as appropriate	**D11C2 Anthropogenic continuous low-frequency sound**	

40. From **Table 4**, it can be seen that 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, however, 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.

41. 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.

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

42. The sea-floor and its marine habitats extend from the littoral zone, periodically uncovered by the tides each day[26], 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.

43. In the context of MSFD Descriptor 6 on sea-floor integrity, the International Council for the Exploration of the Sea (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*".

44. 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 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 maërl 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 (UNEP/MAP SPA/RAC, 2019; Montefalcone et al. 2021); this typology is partially included in the European EUNIS habitat classification (European Environment Agency, 2022).

26 And by wave action and changes in atmospheric pressure.

8.1 Habitat to be assessed – broad and specific types

45. Protection of seabed habitats by the Barcelona Convention has mostly focused on specific habitat types which are considered to be under particular threat, such as *Posidonia* meadows, maërl 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 IMAP Info System were initiated in 2020. Discussions within the CORMON 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 monitoring and assessment elements for EO1 common indicators was recently undertaken (UNEP/MAP SPA/RAC, 2023b) and a proposal for updating these elements presented to CORMON Biodiversity and Fisheries in 2025 (UNEP/MAP SPA/RAC, 2025).

46. The scope of EO6 is broad, referring more generally to 'sea-floor integrity'. Under MSFD, the equivalent Descriptor 6 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 the European Environment Agency's (EEA) EUNIS habitat typology (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.

		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/ hydrodynamic 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 TG Seabed, 2021a). For BC codes add '.5' to the EUNIS code (e.g., 'MB1.5' for Infralittoral rock).*

47. 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 by Regional Sea Conventions (RSC) and under 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 followed for EO1.

48. The Nature Restoration Regulation (NRR) 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 maërl beds) and soft sediments down to 1000 m depth as their carbon sequestration processes are disrupted by bottom fishing and other activities which physically disturb the seabed.

49. **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 (UNEP/MAP SPA/RAC, 2023b) and the NRR, 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 Descriptor 6 and their correspondence with benthic habitats in the Barcelona Convention (UNEP/MAP SPA/RAC, 2019) and EUNIS (EEA, 2022) habitat classifications, plus specific habitats within these broad habitat types that are proposed for use under EO1 and for restoration under the Nature Restoration Regulation.*

MSFD broad habitat type (BHT) Decision (EU) 2017/848 (Table 2)	Barcelona Convention habitat (UNEP/MAP SPA/RAC, 2019)	EUNIS habitat (EEA, 2022)	IMAP EO1 habitats (UNEP/MAP SPA/RAC, 2023b)	Mediterranean marine habitats in Nature Restoration Regulation (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 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; infralittoral oyster beds Sponge, coral & coralligenous beds: MB151E, MB151Q, MB151a
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

MSFD broad habitat type (BHT) Decision (EU) 2017/848 (Table 2)	Barcelona Convention habitat (UNEP/MAP SPA/RAC, 2019)	EUNIS habitat (EEA, 2022)	IMAP EO1 habitats (UNEP/MAP SPA/RAC, 2023b)	Mediterranean marine habitats in Nature Restoration Regulation (Annex II)
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 Shellfish beds: circalittoral oyster beds Sponge, coral & coralligenous beds: MC1519, MC151A, MC151B, MC151E, MC151F, MC151G, MC1522, MC1523, MC251
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

MSFD broad habitat type (BHT) Decision (EU) 2017/848 (Table 2)	Barcelona Convention habitat (UNEP/MAP SPA/RAC, 2019)	EUNIS habitat (EEA, 2022)	IMAP EO1 habitats (UNEP/MAP SPA/RAC, 2023b)	Mediterranean marine habitats in Nature Restoration Regulation (Annex II)
				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: MF1511, MF1512, MF1513
Lower bathyal sediment	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 MG6.5 Abyssal mud	MG1 MG2 MG3 MG4 MG5 MG6		

9 Assessment scales and areas

50. 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.

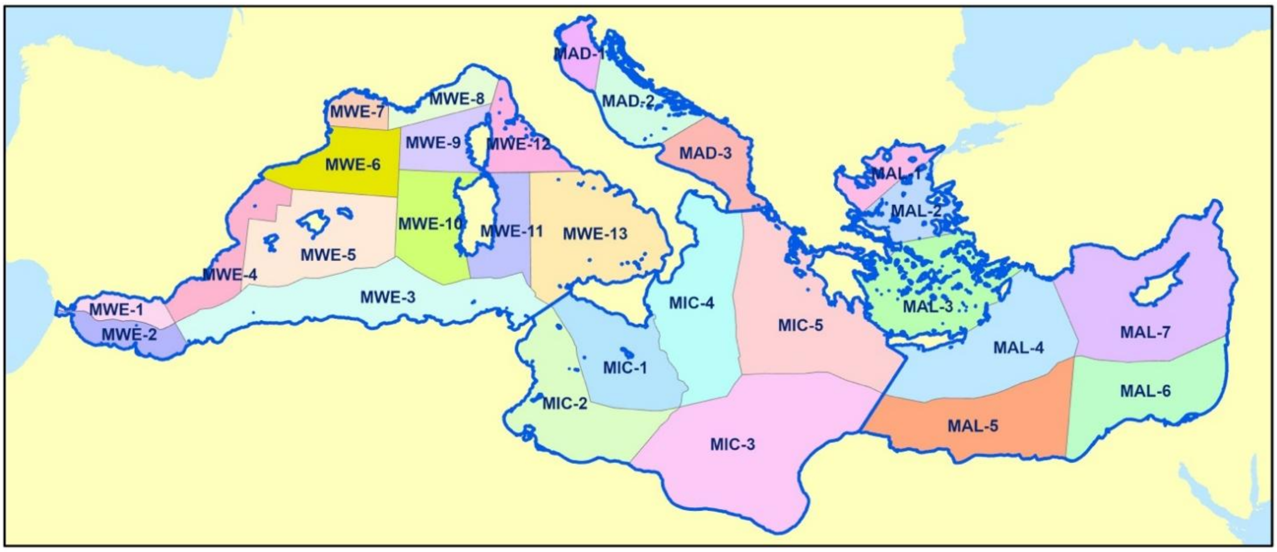
51. To date, assessment scales and areas for the Mediterranean region have not been formally agreed for either EO6 or EO1.

52. 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.

53. According to the GES Decision, assessments of broad habitat types for MSFD Descriptor 6 are to be undertaken at the scale of ‘subdivision of 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, 2023a[27]). Further consideration of the issue of assessment scales and their effects on the outcomes of assessments and for management[28] 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[29].

54. Under the MSFD, the assessment areas for D6 assessments have been defined by each Member State for the purposes of Article 8 reporting[30]; however, a harmonised set of scales/areas for application by the Member States in the Mediterranean has not yet been developed.

55. TG Seabed proposed possible subdivisions of the Mediterranean Sea region (and other regions), based only on biogeographic considerations[31]. These proposals were further developed by the EC’s DG Environment for the purposes of a study on the distribution and intensity of bottom fishing (STECF, 2022[32]) and modified following comments from the OWG/CORMON (**Figure 2**).



27 MSFD GD19, version 12-12-2023; further elaborated in TG Seabed’s extended guidance (latest draft: TG Seabed, 2024, SEABED_19-2024-04).

28 SEABED_12-2022-02

29 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).

30 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.

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

32 Undertaken to support preparation of the EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries for the EU Biodiversity Strategy for 2030.

***Figure 2**. Proposed subdivisions of the Mediterranean Sea region for use under EO6. 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. This map is for assessment purposes only and shall not be considered as an official map representing marine borders. This map shall be used without prejudice to the agreements made between countries under international law in respect of their marine borders.*

56. While the subdivisions shown in **Figure 2** were developed specifically for the STECF study, they were developed to also be 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;
b. Biogeographic considerations, primarily temperature and salinity regimes (at the sea bottom and sea surface, in summer and in winter)[33];
c. National borders of marine waters[34];
d. Management considerations, such as the management of the bottom-fishing sector, including use of some GFCM geographical sub-area boundaries.

57. **Annex II** 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 of 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 sub-area boundary).

58. Note that assessments for the 2023 MedQSR were undertaken through centralised processes (i.e., via the RACs and their contracted experts), using data provided by Contracting Parties and from other sources. This more centralised approach makes it feasible to undertake such transboundary assessments in an efficient manner. For EO6, the results could be presented for each Contracting Party within the subdivision, thereby identifying seabed areas which are adversely affected and in need of management action by the relevant Contracting Party. For the 2023 MedQSR, a chapter on seabed habitats, addressing both EO1 and EO6, was prepared (Connor et al., 2023); this included a pilot assessment for the Adriatic Sea using the assessment areas in **Figure 2**. The approach was further tested to illustrate the results per Contracting Party[35].

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

10 Assessment of sea-floor integrity for EO6

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

60. 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 0 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

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

34 Some marine borders of EU Member States, according to UNCLOS, were used.

35 SEABED_16-2023_Presentation_ScalesReporting.

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.

61. 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 adversely effected (impacted);
   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.

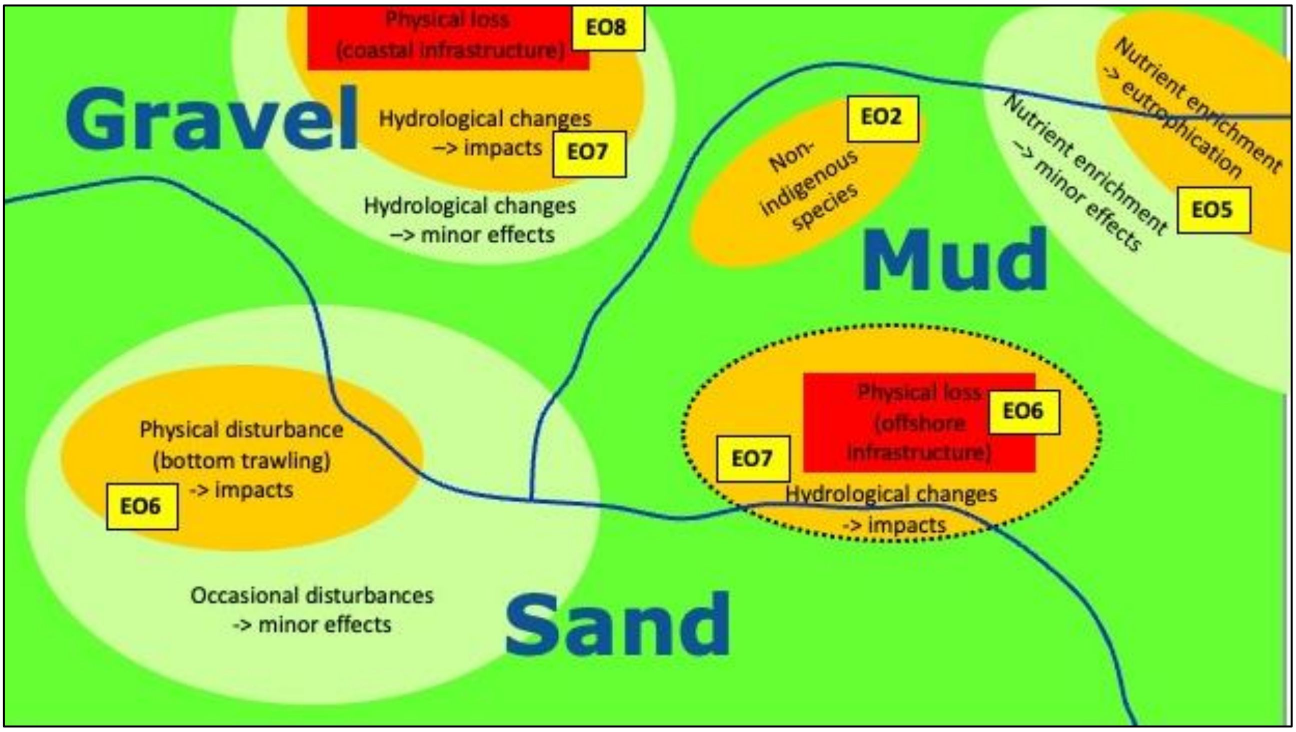


Figure 3. *Scenario for an assessment area with several habitat types and subject to multiple activities and pressures.*

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).

62. 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 MedQSR) 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

63. 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 provides an assessment of the distribution and extent of NIS. For use under EO6, it would need to focus particularly on benthic NIS which occur in high density and are thus likely to be impacting natural communities (i.e. invasive NIS). 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

Theme	Pressure	Ecological Objective	Common Indicators	Application for EO6
				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. 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 including use of modelling, such as from environmental impact assessments (EIAs) for new developments or estimates based on footprint of infrastructures, of CI-15 would need to provide the extent of adverse effect per habitat for results to feed into assessments of EO6 (and EO1). 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 itself. 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 these indicators would be needed to relate litter quantities to impacts on seabed habitats; this could be focused, in the first

Theme	Pressure	Ecological Objective	Common Indicators	Application for EO6
				instance, on areas where litter accumulates in high quantities on the seabed and leads 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 undertook an assessment of ocean acidification for its 2023 QSR[36]; 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. 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 metrics and threshold values for use with the data collected for CI-2 are being developed (UNEP/MAP SPA/RAC, 2025); 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.

64. 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

36 https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/ocean-acidification/

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

65. Further development of indicators, including adaptation of existing indicators from other EOs for application under EO6, should take account of the scale of effects of the different pressures on the seabed, which will vary across the Mediterranean and between different habitat types. It is likely that the key pressures will vary between coastal, offshore and deep-sea zones and this can help determine the need for particular indicators in each assessment area. This prioritisation is important to ensure implementation of EO6 in a cost-effective manner.

10.3.1 Impacts from non-indigenous species

66. 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 Sea 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.

67. 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.

68. 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. More recently, impacts of selected NIS on sensitive habitats have been assessed by Galanidi & Zenetos (2023) for the 2023 Med QSR, following the Cumulative Impact (CIMPAL) methodology of Katsanevakis et al. (2016).

69. 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

70. 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 the pressure is in the Mediterranean, and how damaging it can be to seabed habitats and the carbon cycle.

71. 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 PDsens), 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, ICES, 2022c), and provided advice to DG Environment 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 reports), and the data requirements and data availability, in order to identify the most suitable indicator(s) for IMAP EO6.

10.3.3 Physical loss

70. 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 expanded to other countries for the 2023 MedQSR 2023 (Baučić, Morić-Španić & Gilić, 2023).

71. 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), by transforming the coastline length into a nominal area value.

72. 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) developed guidance for such assessments. This would provide outputs suitable for MSFD criteria D6C1 and D6C4.

73. A similar indicator has been developed for the North-East Atlantic (OSPAR's BH4 indicator in ICES, 2022a) with a pilot assessment prepared for the North Sea as part of OSPAR's QSR 2023[37]. 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

74. 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), guided by results of the 2023 MedQSR. In some areas, it may be necessary to extend the assessments beyond the 1nm zone of coastal waters.

[37] https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/area-habitat-loss-pilot/

75. In the north-east Atlantic, OSPAR has demonstrated reuse of the WFD assessments for the purpose of assessing eutrophication of the seabed (indicator BH2a. OSPAR 2023 QSR). 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).

76. 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

77. 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.

78. 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 oceanica* meadows, maërl beds, coralligenous habitats); methods for analysing the data and threshold values that would allow an assessment of whether the habitat is in GES are currently being developed (UNEP/MAP SPA/RAC, 2025).

10.3.6 Carbon sequestration capacity and rates

79. **Annex I** 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 I** 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 cover only a small fraction of the seabed. In contrast, seabed sediment habitats cover the vast majority of the seabed[38], and their widespread disturbance, by bottom trawling and other activities, can have a major effect on carbon 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.

80. 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 I**, 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 EU Nature Restoration Regulation.

38 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.

81. Further work would be needed to develop an indicator on seabed carbon stocks and sequestration rates, to provide a quantified assessment per habitat type. The European Commission launched a study in 2024[39], to support implementation of the BDS2030 Action Plan, which aims to quantify the EU's seabed carbon storage capacity and possible impacts of bottom fishing activities on this capacity (EC, 2023b).

10.4 Assessing adverse effects

82. 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[40] conditions (reference state) through defining a threshold value, that distinguishes a habitat area in good condition from an area that is adversely affected.

83. 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.

84. TG Seabed is in the process of defining a quality threshold for habitat condition for MSFD criterion D6C5, based on 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)[41]. This description has been further elaborated (TG Seabed, 2023) 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.

85. 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

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[39] Study on the seabed's natural carbon sequestration capacity and related impacts from seabed-disturbing activities **(**CINEA study**);** contract awarded to Nature Bureau**.**

[40] To define a habitat under natural conditions (reference state) it is best to focus on data from areas that are largely free of anthropogenic pressures (acknowledging that there is likely to be some influence from widespread diffuse pressures such as pollution in most parts of the Mediterranean Sea), rather than seek to use historic data as these are generally not available. It is also better to consider a habitat recovering to a state which reflects the 'prevailing physiographic, geographic and climatic conditions' (terminology of MSFD Descriptor 1) rather than expecting it to recover to an historic ecosystem state, as this is unlikely to be realised (TG Seabed, 2021). In cases where habitats are currently considered to be degraded (i.e. there are no data for areas in good state), the characteristics of good state will only become apparent after pressures are removed or sufficiently reduced for the habitat to fully recover.

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

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 (ICES, 2022c). 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).

86. 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).

11 GES and targets for EO6

11.1 Overall goals of IMAP's Ecological Objectives

87. 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, 2016a).*

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.
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.

Ecological Objective	Definition
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.

88. 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

89. As already outlined in section 0, 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 (European Commission, 2020), and further developed by TG Seabed in a paper which sets out the basis for defining thresholds (**Figure 4**) (TG Seabed, 2022a).

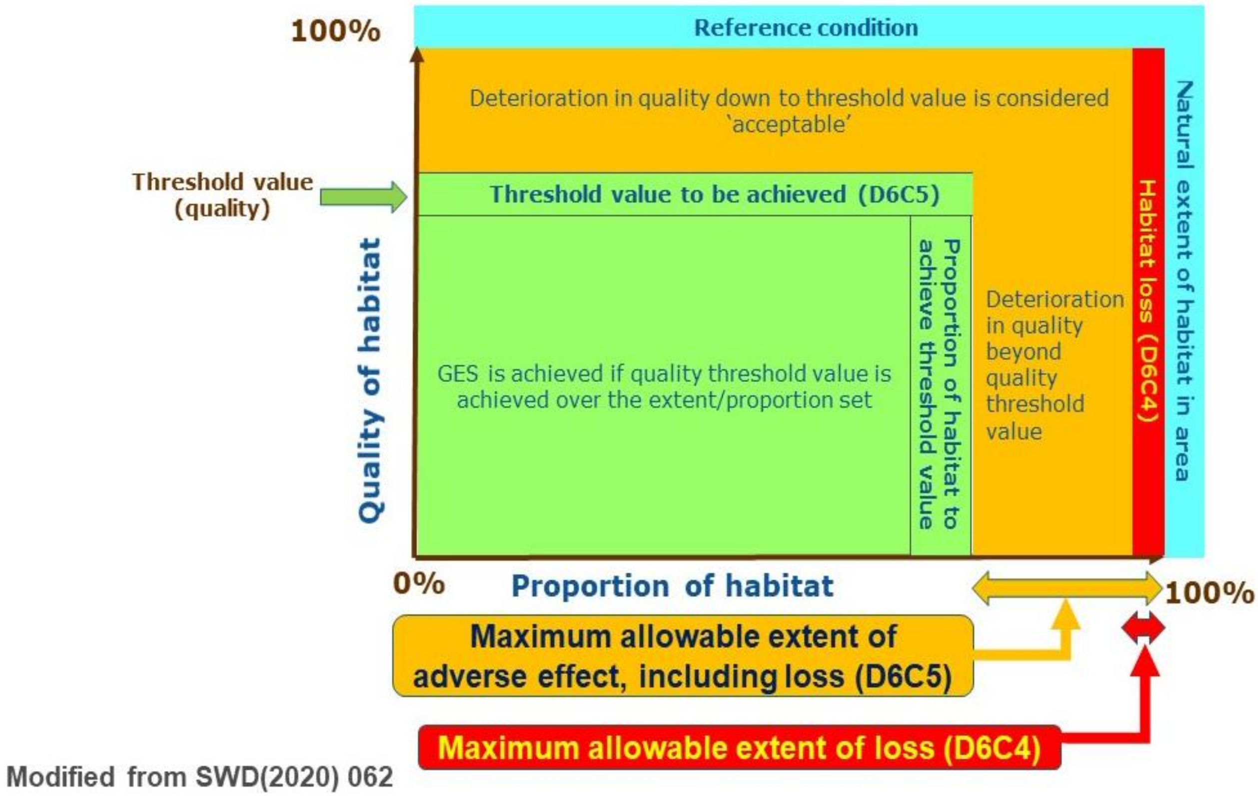

***Figure 4**. Generic quality and proportion framework for determining GES (from TG Seabed, 2022a).*

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.

11.3 Proposal for GES and targets for EO6

90. 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, 2013a), 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.

91. 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**).

92. 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[42] per habitat type does not exceed [Y%] of each habitat's natural extent.

93. In December 2022, the following TG Seabed proposal on threshold values for X (maximum extent of habitat loss) and Y (maximum extent of adverse effects) was adopted by MSCG (TG Seabed, 2022b; EC, 2024, C/2024/2078):

a. The maximum proportion of a benthic broad habitat type in an assessment area that can be lost is **2%** of its natural extent (≤ 2%) (D6C4).
b. The maximum proportion of a benthic broad habitat type in an assessment area that can be adversely affected is **25%** of its natural extent (≤ 25%). This includes the proportion of the benthic broad habitat type that has been lost (D6C5).

42 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, version 12-12-2023) because such losses can be more much extensive than losses due to physical structures.

c. 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) (D6C5).

94. 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.

11.4 Reporting on status of habitats per assessment area

95. 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 version 12-12-2023). An outline table of illustrative 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. These are mock results for illustration purposes only.*

Assessment area	**e.g. MWE-11 (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

96. 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.

97. **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.

98. 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, 2023); selected local maps; maps of *Posidonia*, maërl and coralligenous habitats (MEDISEH)	UNEP/MAP SPA/RAC (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
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	 IDEM WebGIS (cnr.it) STECF (2022) ICES request from DG Environment (eu.2024.05) and WKD6ASSESS for Mediterranean; WGFBIT 2024 report. EMODnet human activities and EMODnet geoviewer

Topic	Data set	Source
	i. Oil & gas j. Pipelines 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 a. WFD data b. MSFD data	VESSELFINDER (see UNEP/MAP SPA/RAC, 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 WISE Marine (MSFD)
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 Relationship between EO6 and EO1

99. The relationship between EO6 and EO1 can be characterised according to different aspects of the IMAP process (**Table 11**), thereby helping to understand their similarities and differences.

Table 11. *Similarities and differences between EO1 and EO6.*

	EO1 Benthic habitats	**EO6 Sea-floor integrity**
Habitats	Specific habitats (EUNIS level 4 & 5), subject to significant threats	Wider sea-floor via broad habitat types (EUNIS level 2), subject to a range of widespread pressures

	EO1 Benthic habitats	EO6 Sea-floor integrity
Threats (pressures)	Same range of pressures	
Focus of measures	Targeted protection measures (e.g. MPAs, Action Plans)	Broader management measures addressing widespread pressures, marine spatial planning
Common Indicators	CI-1 Habitat distribution (extent) CI-2 Habitat condition	Same as EO1 proposed
Scale of assessment	Same as EO6 proposed	28 subdivisions of Mediterranean Sea region
Data for assessment	Specific monitoring methods and sites, focused on biological observations. Reuse of data for EO6, wherever possible.	Data on distribution of activities and pressures, used also for EO1. Reuse of EO1 data on state of seabed. Reuse of assessments from other EOs (EO1, EO2, EO5, EO7, EO8)

100. The 2024 meeting of CORMON considered the relationship between EO1 and EO6 and, in particular, whether there was merit in merging the two Ecological Objectives, given that they both address seabed habitats. It was highlighted that implementation of EO1 and EO6 should exploit their synergies as much as possible, including through use of a common assessment framework (assessment areas, common indicators, assessment criteria and methods) and reuse of the data collected for assessments (e.g. on benthic habitat state and impacts, and on activities and pressures).

14 CORMON conclusions on the EO6 proposal

101. The most-recent version of this EO6 proposal (UNEP/MAP SPA/RAC, 2024) was presented to the CORMON Biodiversity and Fisheries meeting on 6-7 June 2024. At this meeting, the CORMON agreed on the texts presented in boxes at relevant sections in the proposal. These are presented in paragraphs 102-109 below.

102. Framework for EO6:

a. **Seabed habitats addressed:** 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.

b. **Assessment areas:** the 28 subdivisions shown in **Figure 2** should be used as the assessment areas for application of EO6.

c. **Extent and quality thresholds to determine GES:** 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 extent of adverse effects, thereby allowing human activities which cause damage to the habitat to continue, but within specified limits; GES should be achieved for each habitat in each assessment area in order to achieve the overall goal of EO6 Sea-floor integrity.

d. **Operational objectives, indicators and GES descriptions:** The operational objectives, indicators and GES descriptions for EO6 are set out in **Table 8**. Note that the 'extent of adverse effects' indicator is a broad indicator which should comprise several more specific operational indicators and that the indicators equate to CI1 and CI2 under EO1 and to criteria D6C4 and D6C5 under the MSFD.

e. **Targets:** The targets for EO6 are set out in **Table 8**. Possible values for these targets are still to be determined. Note also that under MSFD Descriptor 6 these target values are incorporated as part of the GES determination.

103. **Pressures:** The IMAP process for Ecological Objective 6 on sea-floor integrity should focus on the main pressures (**points a-h in paragraph 30**) 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.

104. **Actions and measures:** actions and measures to achieve GES for EO6 should 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'.

105. **Links to other EOs:** EO6 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. The Common Indicators from other EOs described in **Table 6** and **section 10.3** should be considered for further developed (according to priority pressures) to enable their use under EO6. For this, it is important to provide results per seabed habitat or as a spatial layer to enable their reuse for EO6 assessments.

106. **Relationship between EO1 and EO6:** CORMON recognised the strong links between EO1 and EO6 (**Table 11**) but recommended that they should continue to be treated as separate EOs within the IMAP. However, the synergies between EO1 and EO6 should be exploited as much as possible, such as through aligning the scales and areas for assessment (section 9), reusing indicators and the underlying data (section 10) and aligning GES and targets (section 11).

107. **Relationship to MSFD:** CORMON noted 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. CORMON further noted that 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.

108. **Further development of EO6:** Further development of EO6 should be undertaken in close association with relevant aspects of EO1 implementation (and other relevant EOs) to ensure optimal use of data and resources. It should take account of ongoing developments (e.g. of indicators and assessment methods) within other RSCs, particularly OSPAR and HELCOM. Use of indicators developed elsewhere may need data and testing/calibration in a Mediterranean context and should be prioritised towards indicators for those pressures most affecting sea-floor integrity. CORMON noted the ongoing work by TG Seabed to agree a quality threshold value for application in MSFD criterion D6C5 and the ongoing work by ICES to develop a framework for assessment of habitat impact and condition indicators and to test threshold values.

109. **Continued engagement with OWG**: It is important to continue engaging with the CORMON's OWG on benthic habitats to ensure the development of EO6 benefits from their experiences and addresses the specificities of EO6 implementation across the region.

15 Summary

110. 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 (2022b).

111. 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.

112. 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 (MedQSR) purposes.

113. Implementation of the proposed EO6 framework will need to be undertaken in stages, depending on data availability on pressures, impacts and state which will vary across the range of habitat types and between countries.

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

1. The following review is reproduced from the EO1/EO6 chapter prepared for the 2023 MedQSR (UNEP/MAP SPA/RAC, 2023a), largely based on Fourt (UNEP/MAP-SPA/RAC, 2022). It provides an overview of the main activities affecting the sea-floor in the Mediterranean Sea region and a review of the main pressures.

A1 Introduction

2. 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).

3. The ranking of the activities causing habitat loss and/or disturbance proposed for the Mediterranean Sea by ICES (2019) 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

4. Bottom trawling fisheries use gears of differing 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).

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

6. Benthic biogenic habitats and species are particularly sensitive 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 following the fishing event.

7. Of the total Mediterranean fishing fleet, 7.9% are bottom trawlers; these are 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 ranking third in terms of employment (15.9%) (FAO, 2020).

8. GFCM has defined Fisheries Restricted Areas (FRAs) where towed dredges and nets are regulated. 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 (Vulnerable Marine Ecosystems -VMEs) through establishment of Fisheries Restricted Areas (FRAs) (e.g., GFCM 2005, 2006, 2013, 2019, 2021a, b, c; **Figure 5**). Despite the extensive area of seabed covered by the FRAs below 1000m depth (approximately 1,470,000km^2, 58% of the Mediterranean Sea region), the majority of the soft-bottom benthic habitats of the continental shelf and slope are threatened by bottom trawling activities.

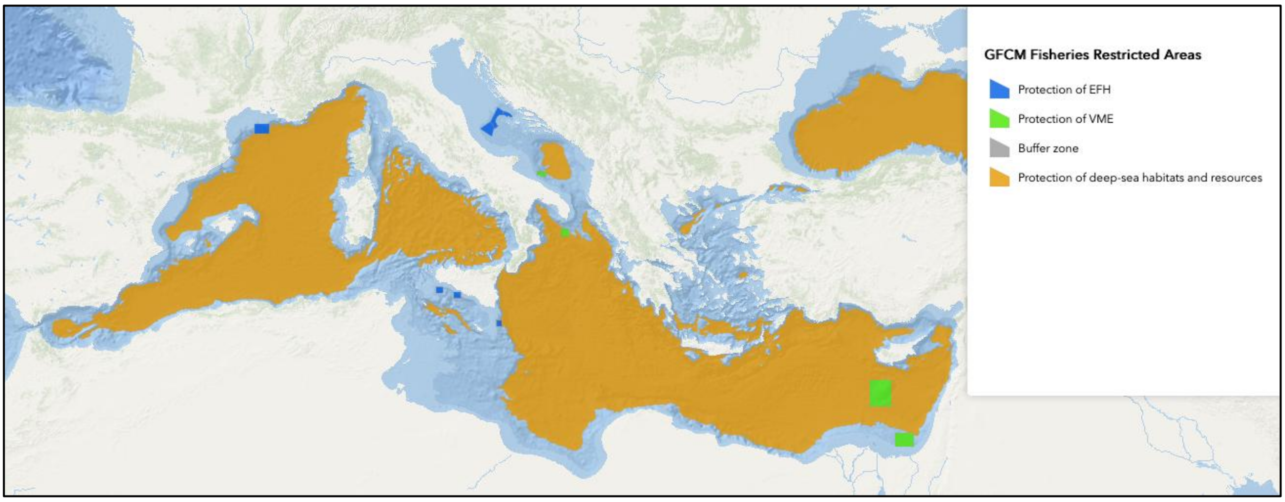

Figure 5*. Distribution of GFCM Fisheries Restricted Areas (EFH = Essential Fish Habitat, VME = Vulnerable Marine Ecosystem) (from https://www.fao.org/gfcm/data/maps/fras/en/, accessed 20/04/2023)*

9. Some Mediterranean areas, such as the Aegean Sea, Adriatic Sea and Western Mediterranean Sea are subject to multi-annual fisheries plans under the EU CFP. These provide important spatial, temporal and gear controls, which offer protection to some areas to protect sensitive seabed habitats and essential fish habitats. This makes monitoring and control very challenging (Petza et al., 2017).

A2.2 Bottom otter trawling fishing activities

10. Bottom otter trawling is generally used on sandy and muddy sediment sea-floor. It consists of a large conical net kept 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 10m to 2,500m (Eigaard et al., 2016). In practice, in the Mediterranean, trawlers fish mainly between 200 to 500m depth (Eigaard et al., 2017), as in the Gulf du Lion where trawling traces were observed between 150 and 600 m 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 are removed per pass of a trawl.

11. In the Western Mediterranean (GFCM geographical subareas (GSA) 1, 5 and 6) there is a great fishing effort on the continental shelves (< 200m depth) and middle slopes (> 500m depth) (Farriols, M.T., Spanish Institute of Oceanography, pers.comm.). The data on fishing effort in number of fishing days and by depth strata are shown for these areas in **Figure 6**. The only area where fishing effort is higher in stratum D (200-500m) is GSA1. For GSA6 the stratum with higher fishing effort is stratum B (50-100m) and for GSA5 it is stratum E (500-800m).

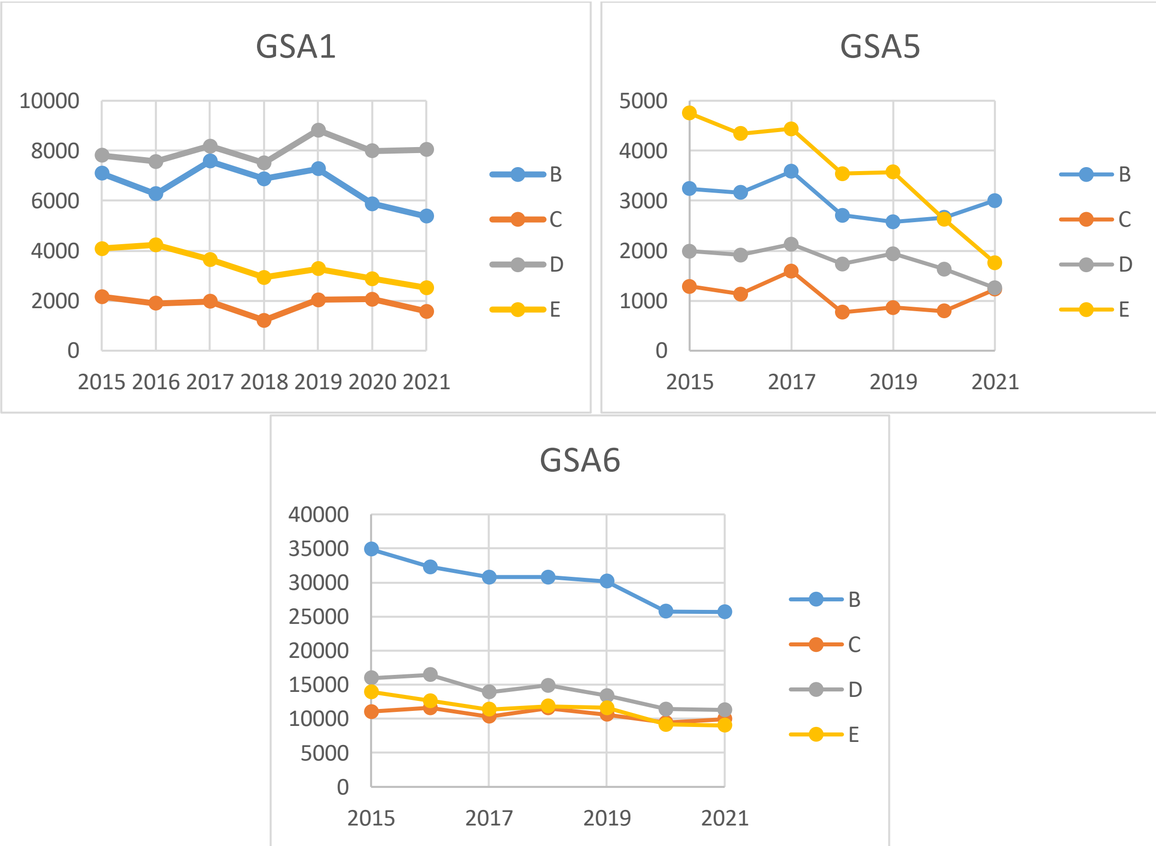

Figure 6*. Fishing effort in number of days of the bottom-trawl fleet in GSA1, GSA5 and GSA6 (western Mediterranean) calculated from VMS data by depth strata (B: 50-100m; C: 101-200m; D: 200-500m; and E: 500-800m) (Farriols, M.T., Spanish Institute of Oceanography, pers.comm.).*

12. The continental shelf and the top part of the 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).

13. Depending on the depth and the area, bycatch and discards from trawling fisheries in the Mediterranean are important, amounting to between 35% and 70% by weight (European Parliament, 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. Amongst the species constituting the discards, there are many benthic invertebrates (e.g., corals, sponges, echinoderms) and algae (Sacchi, 2008).

14. Otter trawlers smoothen the sea-floor surface, constantly modifying the first surface centimetres of sediment and disrupting benthic habitat 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 depends on the penetration of some parts of the gear, the collision and abrasion and the sediment mobilisation (Rijnsdorp et al., 2016).

15. The high frequency of fishing activity on the same grounds causes:

a. severe physical damage to large areas of the sea-floor, to sessile fauna and to the associated benthic ecosystems (Lucchetti and Sala, 2012; PERSEUS, 2013);
b. persistent reduction of available organic matter even after two months of closure (Paradis et al., 2021a) (see section A3.9 on blue carbon);
c. sediment resuspension and increase which also affect deeper benthic habitats in the areas with submarine canyons (Martin et al., 2014; Arjona-Camas et al., 2021; Paradis et al., 2021b).

16. 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

17. 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 are named differently.

18. ***Gangui*** were used in France but were banned in 2002 because of the damage they caused mainly on *Posidonia oceanica* meadows (RAC/SPA, 2003). However, 17 fishing vessels in France currently have derogations to the ban on using gangui; some Croatian vessels use similar gear[43].

19. 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 oceanica* 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 of other trawlers) (Mosbahi et al., 2022).

20. 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 the coast (Pranovi et al., 2000).

21. **Dredges** and especially **hydraulic dredges** for shellfish cause significant sea-floor surface disturbance by higher penetration of the gear into the sediment (Pitcher et al., 2022). The degree of penetration in gravel and muddy sea-floors is similar but is less in sandy sediments (Pitcher et al., 2022). It is estimated that hydraulic dredges cause depletion of 41% of the biota on each pass (Hiddink et al., 2017). In shallow sandy sediments in the northern and central Adriatic (3 to 12m depth), about 380 boats operate dredges that plough up to 15-16cm into the sea-floor to collect shellfish (Lucchetti & Sala, 2012; Hiddink et al., 2017). Many studies show that in the Adriatic Sea where the number of vessels using dredges is high, the sea-floor and macrobenthos suffer severe changes especially in shallow coastal areas (e.g., Morello et al., 2005; Lucchetti and Sala, 2012).

22. **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

[43] DG Environment, pers. comm., September 2022.

(Pranovi 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-sediment community composition (Pranovi et al., 2001).

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

23. 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 are bycaught by gillnets and longlines in 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).

A2.5 Coastal artificialisation

24. Coastal artificialisation implies direct physical loss of sea-floor but also indirect disturbance to the surroundings by changing hydrographical conditions or increasing turbidity during construction.

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

26. Under EO8 for the 2023 Med QSR, a general overview of the scale of coastal artificialisation is provided, based on reporting by 17 countries[44] which cover 57% of the Mediterranean’s 54,992km of coast. These data show that 4,625km (14.8% of the reported coastline or about 8% of the total coastline of the region) is artificial (UNEP/MAP PAP/RAC, 2023).

A2.6 Dredging and dumping

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

28. Dredging can be carried out for the following reasons[45]:

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[44] Data were not available for Cyprus, Greece, Syria and parts of Croatia.

[45] European Dredging Association

a. to create or extend littoral infrastructure (e.g., a port). The dredging of seabed that has never been dredged is called ***capital dredging;***
b. to remove sea-floor substrate that has gathered and is an obstruction to navigation such as in ports, canals and river mouths. In these areas dredging is recurrent and is called ***maintenance dredging;***
c. to extract minerals such as sand, which is termed **mineral dredging;**
d. to remove material purely for environmental reasons, such as from an old industrial site (***remedial dredging***).

29. C**apital and maintenance dredging** mainly affect soft sediments (but not only) that are removed and dumped in another place in the sea from a barge. Capital dredging impacts the 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.

30. Capital and maintenance dredging with associated dumping is undertaken in most Mediterranean countries and has been increasing during the last decade (Depe et al., 2018). The growing pressure of tourism in the Mediterranean region will most probably intensify such activities. Concerns are therefore arising about more efficient management of these activities. Depe et al. (2018) underline the threats of dredging and dumping activities in a context of a poor regulatory framework in the Mediterranean and the lack of a 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 their decision making, characterisation of materials, assessment, sampling and monitoring (see Decision IG. 23/12). Mikac et al. (2022) studied the impacts of the innovative ejectors plant technology which seems to reduce damage from maintenance dredging.

31. **Mineral dredging**, which in the Mediterranean generally concerns extraction of sand (also called sand mining), is collected in areas away from the coast to nourish depleted beaches (e.g., Sardà et al., 2000).

32. 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 in abundance of the benthic community and a modification of the sea-floor topography and hydrographical conditions (Van Dalfsen et al., 2000; Trop, 2017). Following such sand extraction activities, recovery of the impacted sea-floor and associated fauna depends, amongst others, on the local hydrography, the frequency of extraction and on the depth (Van Dalfsen et al., 2000).

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

34. Capital dredging disturbs the dredged surroundings, also with an increase in turbidity, and represents a physical loss of sea-floor especially since it is done to construct and therefore seal the area concerned. In the Mediterranean, mineral dredging consists mainly 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 of the seabed habitat seems possible. Dumping areas of dredged materials should be managed with more attention. Whilst being illegal, the dumping of sewage sludge material is known to occur in some countries.

A2.7 Anchoring

35. Anchors mechanically damage habitats by digging into the sea-floor, uprooting benthic species and creating depressions which result 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 has deteriorated habitats such as *Posidonia oceanica* meadows, as 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 anchoring 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 (Dapueto et al., 2022).

36. The study of damage caused by anchors has been mainly 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. This study used Automatic Identification System (AIS) data and showed 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.

37. Efforts have been made along French Mediterranean coast to protect especially *Posidonia oceanica* meadows from anchor damage, including through local laws that ban anchoring on *Posidonia* meadows.

38. 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.

A2.8 Aquaculture activities

39. Aquaculture (brackish and marine) in the Mediterranean Sea has grown rapidly 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).

40. Physical loss due to aquaculture activities is 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

41. The oil and gas production in the Mediterranean Sea is relatively limited compared to other areas (Piante & Ody, 2015). Nevertheless, the demand for oil and gas continues to increase. Therefore, exploration is taking place in large areas of the Mediterranean Sea (PERSEUS, 2013; Piante & Ody, 2015; Kostianoy & Carpenter, 2018).

42. Offshore platforms exist in various Mediterranean countries where in 2005 over 350 offshore wells were drilled (Kostianoy & Carpenter, 2018). Exploitation, development and/or exploration for oil and gas currently occurs in the waters of Algeria, Cyprus, Egypt, Greece, Italy, Lebanon, Libya, Malta, Spain, Tunisia and Turkiye (Kostianoy & Carpenter, 2018). A large concentration of gas platforms is in operation in the North-Eastern part of the Adriatic and Ionian Sea with over 100 installations (Piante & Ody, 2015).

43. For the Mediterranean Sea, experts consider that once platforms are installed, the actual physical damage to the sea-floor (physical loss in this case) is relatively limited in terms of surface area compared to other activities (ICES, 2019). Moreover, the platform structure offers new hard substrate that is often colonised by various benthic species, including non-indigenous species (NIS) (Manoukian et al., 2010). 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, 2019). Offshore oil production discharges 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.

44. The installation of platforms disturbs the 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 recommendations for these installations so as to limit impact on the environment.

A2.10 Offshore windfarms

45. Installation of offshore wind farms impacts directly the sea-floor by loss of sea-floor habitat where the foundations are set, and by disturbance during the installation phase of the wind farms. But this impact is limited in surface area and damage can be reduced if properly planned in areas without sensitive benthic habitats. Prevention of fishing activities within the wind farm has the potential to create refuge habitats for many species including fish and increase connectivity (Boero et al., 2016).

46. 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-sea areas 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). 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 and France. Greece, Malta and Spain also intend to develop offshore renewable energy.

A2.11 Mining

47. Deep-sea mining for the extraction of metals and minerals (other than sand) is not yet developed in the Mediterranean Sea. However, mining could be started in the near future to meet the increasing

global demands for metals and minerals. In France and Spain, potential areas for seabed mining have been identified (Piante & Ody, 2015), potentially providing conflicts of space with other offshore activities. Furthermore, other than the loss of sea-floor extracted by mining, the impacts of sea-floor mining on Mediterranean deep marine ecosystems are unknown.

A3 Pressures on the seabed

48. Assessing the state of the seabed can be done from two perspectives[46]:

a. Mapping and modelling the distribution, extent and intensity of anthropogenic pressures;

b. Directly observing and sampling the seabed and its communities to provide information on its state which reflects the cumulative impacts of the current and past pressures.

49. This section provides an overview of the main pressures on the Mediterranean seabed, drawing mainly from:

a. a Mediterranean-wide mapping and modelling of key pressures by the EEA's European Topic Centre on Inland, Coastal and Marine waters (Korpinen et al., 2019);

b. a literature review of the effects of non-indigenous species, land-based pollution and litter (Fourt, 2022);

c. a review of blue carbon and effects of physical disturbance by bottom fishing.

A3.1 Biological - non-indigenous species

50. The presence of non-indigenous species (NIS) in the Mediterranean has clearly increased in recent years (Zenetos et al., 2022). Over 1000 species have been reported, of which 73% are considered to have become established in the region, with the eastern Mediterranean most affected (UNEP/MAP-SPA/RAC, 2023c). Their introduction and spread is rapidly growing, as an increase in sea temperature caused by climate change favours the establishment of lesseptian species arriving through the Suez Canal. Maritime transport and aquaculture provide further sources of NIS. 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 on sessile species (Sempere-Valverde et al., 2021). In the Mediterranean, NIS impact marine ecosystems including benthic habitats in multiple ways (Katsanevakis et al., 2016). No loss of biogenic habitats due to NIS has been recorded in the western Mediterranean but changes due to NIS are documented for the eastern (Levant) Mediterranean (Bitar, 2008; SPA/RAC, 2018).

51. It is estimated that 98% of the Mediterranean coastline and 41% of the narrow shelf area is affected by NIS; (Korpinen et al., 2019). This estimate is based on data for 76 marine invasive species that were individually mapped against an EEA 10km-by-10km grid; the number of NIS species per grid cell (maximum 39 species in a single grid cell) was normalised to a 0-1 scale (**Figure 7**). The data show that NIS are particularly concentrated in the eastern Mediterranean. Some species may be pelagic and therefore not have an impact on benthic habitats.

[46] This needs to be supported by defining thresholds for the boundary between a habitat in good condition and one which is adversely affected (in relation to each habitat, taking account of their sensitivity to different pressures).

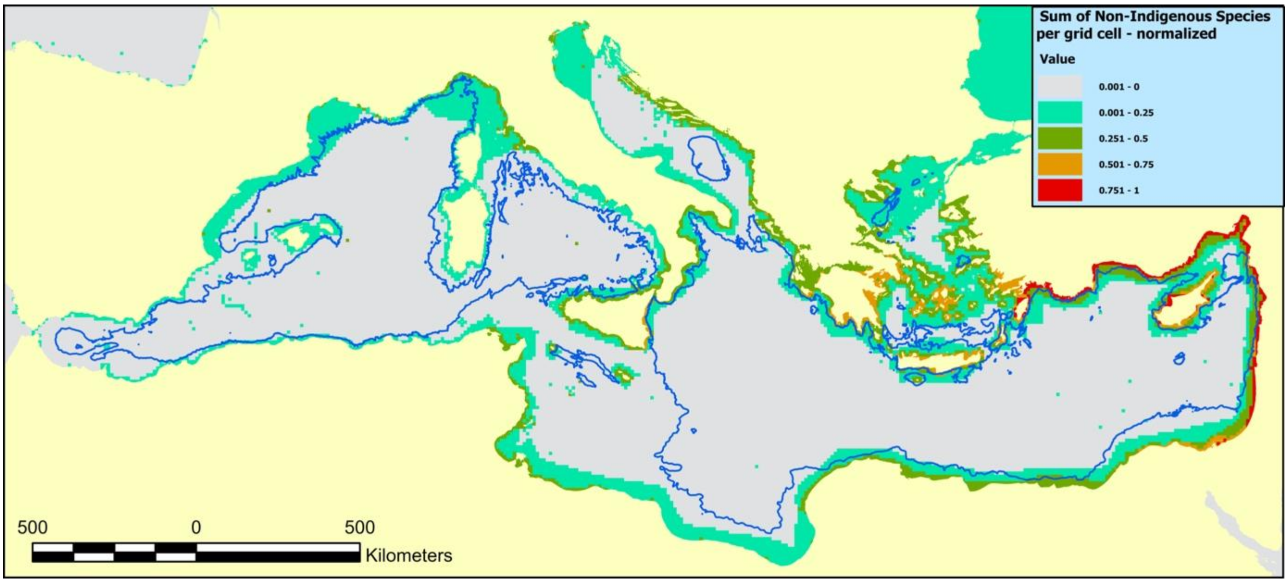

***Figure 7**. Number of invasive non-indigenous species per 10km-by-10km grid cell (maximum 39 species), normalised to 0-1 scale (redrawn from data in Korpinen et al., 2019).*

A3.2 Biological - extraction of wild species

52. Korpinen et al. (2019) provide data on fishing effort by bottom-touching mobile fishing gears, based on the distribution and intensity of demersal fishing using Automated Identification System (AIS) data for the year 2015 (**Figure 8**).

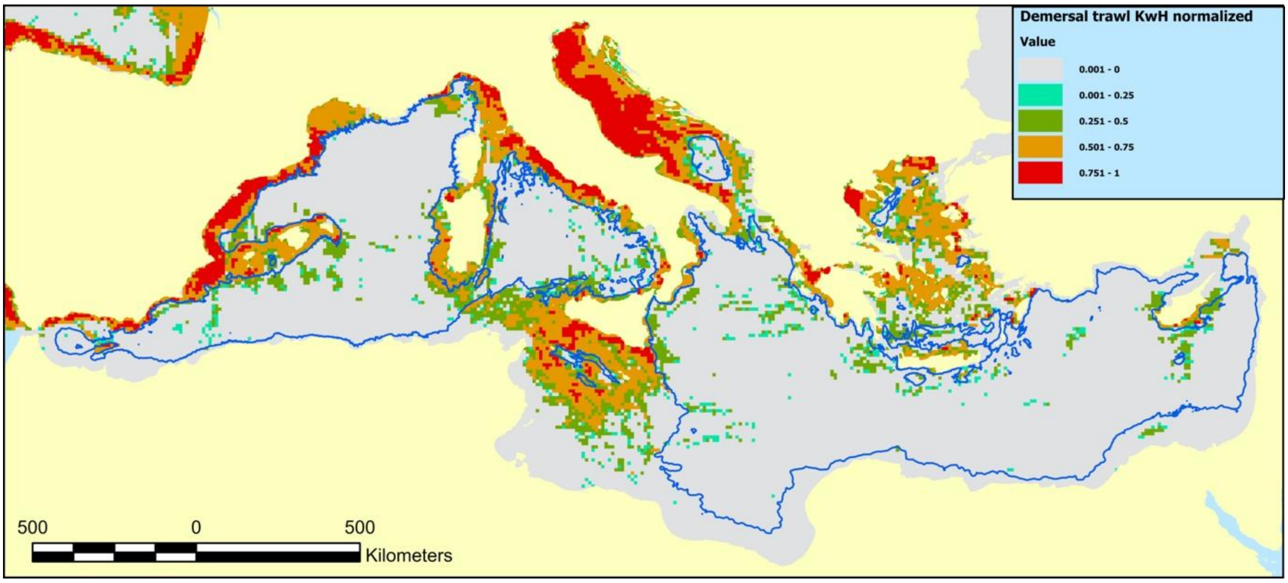

***Figure 8**. Distribution and intensity of demersal fishing for the year 2015, normalized to 0-1 scale, with 1 representing 1,549,089 kilowatts per fishing hour (redrawn from data in Korpinen et al., 2019). 1000m isobath also shown.*

53. The data show that this is type of fishing activity is widespread in the coastal and shelf zones of the Mediterranean region; below 1000m depth, use of demersal fishing gears is banned. Fishing activity was particularly intensive in the northern and western Adriatic, on the coast of Spain and on Italy’s west coast. Data maybe lacking for southern and eastern waters of the Mediterranean. The

general fishing pattern for 2015 (i.e., in areas above 1000m depth across the Mediterranean) (**Figure 8**), is expected to be typical for each year.

54. However, localised variation can be expected due to changes in management practices such as closures to bottom fishing following the designation of marine protected areas. For example, in the Balearic Islands an area of the Menorca Channel, Spain was excluded from bottom trawling in 2016 (Farriols et al. 2022).

55. Also EU Regulation 2019/1022 established a Multi-Annual Plan for fishing in the Mediterranean. This led to a 10% reduction in fishing effort in the first year of the plan and 30% for the second to the fifth year of the plan. To achieve these reductions, areas of temporal and permanent closure to bottom trawling have been implemented in each GSA. The decrease in fishing effort during the 2015-2021 period for GSA1, GSA5 and GSA6 (western Mediterranean) is shown in **Figure 9**.

56. Where bottom fishing ceases in specific areas (e.g., for MPA management or as part of the Multi-Annual Plan), the extent of physical disturbance is reduced and the seabed habitats can recover. However, where the fishing continues over the same area but at a lower intensity, the general reduction in fishing effort (section A3.2, **Figure 6**, **Figure 9**) does not lead to reductions in the extent of physical disturbance of the seabed, and the continued physical disturbance does not allow the seabed to recover.

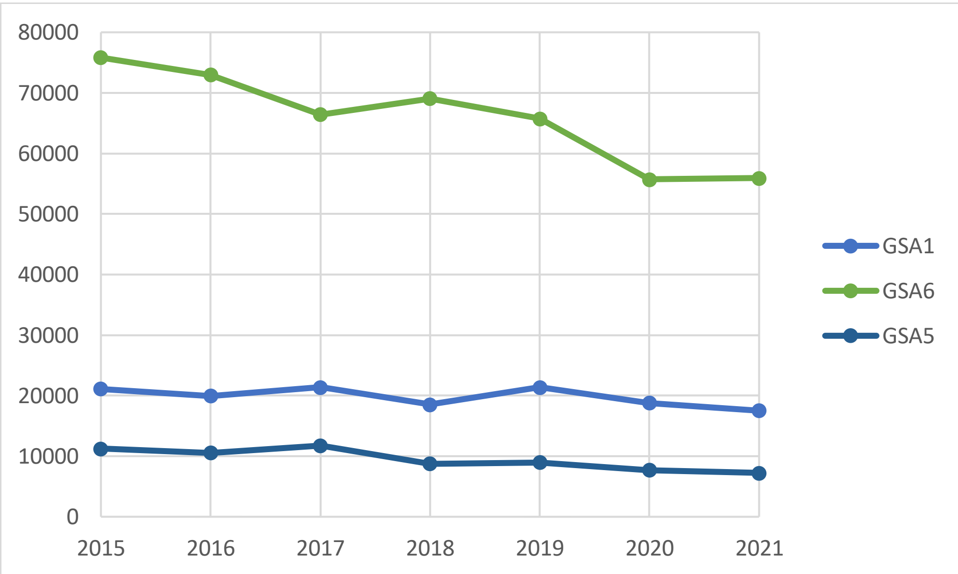

Figure 9*. Total fishing effort in number of days for the bottom-trawl fleet in GSA1, GSA5 and GSA5 Mallorca and Menorca (western Mediterranean) calculated from VMS data (Farriols, M.T., Spanish Institute of Oceanography, pers.comm.).*

57. Demersal fishing is a major contributor to physical disturbance of the seabed (see section A3.4).

A3.3 Physical - loss of the seabed

58. Physical loss of the seabed[47] is an extreme pressure on the marine ecosystem. Seabed habitat is lost if its substrate, morphology or topography is permanently altered. Activities causing such loss are sand and gravel extraction, removal of hard substrate or biogenic reefs, capital dredging of the

[47] Defined to include all impacts on the seabed which take >12 years to recover.

seabed, disposing waste material and dredged matter and all kinds of construction activity in or over the seabed (Korpinen et al., 2019). Persistent use of bottom-contacting fishing gears can change the seabed morphology and sediment characteristics, leading to habitat loss.

59. It is estimated that 3.7% of the Mediterranean seabed has been lost, with most of this concentrated on the coast, particularly near cities with more limited loss away from the coast, such as from offshore infrastructure (e.g., gas installations, wind farms) (Korpinen et al., 2019).

60. **Figure 10** shows the number of physical loss-causing activities[48] per 10km-by-10km grid cell, using data for:

a. Dredging
b. Dumping of dredged material
c. Oil and gas rigs
d. Ports
e. Sand and gravel extraction
f. Operational windfarms

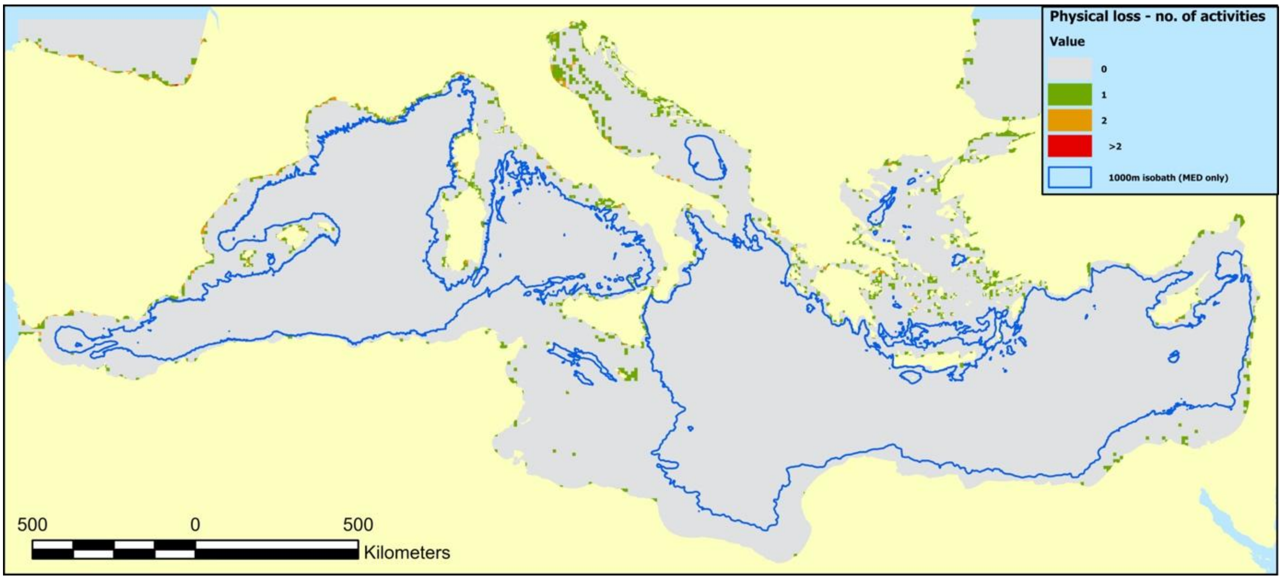

Figure 10. Number of different activities causing physical loss of the seabed per 10km-by-10km grid cell (redrawn from data in Korpinen et al., 2019). See text for further details.

61. Under EO7 and CI-15, it is estimated that about 20% of the Mediterranean coastline comprises artificial habitat, with 45% as rocky coast and 35% as sandy coast (UNEP/MAP-PAP/RAC (2023). These proportions vary markedly between countries (e.g., Croatia has 90% rocky coastline, Libya has 65% sandy coastline and Lebanon has 40% artificial coastline).

62. Under EO8 and CI-16, from country reports covering 57% of the Mediterranean coast, about 85% of the coast is reported as natural while the remaining 15% is artificial. The majority of artificial structures are ports and marinas (UNEP/MAP-PAP/RAC (2023).

[48] Physical loss due to persistent bottom fishing is more difficult to distinguish from physical disturbance, and so is not yet included in the data used for Figure 7.

A3.4 Physical – disturbance to the seabed

63. Physical disturbance is the most extensive pressure on the Mediterranean seabed, particularly affecting the coastal and shelf zones down to 1000m depth, where it affects most habitat types.

64. Korpinen et al. (2019) have prepared a data layer depicting the sum of all physical disturbance-causing activities per 10km-by-10km grid cell (

65. **Figure 11**), based on data from the following sources:

1. Demersal fishing effort
2. Dredging
3. Sand and gravel extraction
4. Port anchorage sites
5. Windfarms (under construction; partial generation/under construction; decommissioned; operational)
6. Deposit of dredged matter
7. Oil platforms (offshore installations)
8. Aquaculture (finfish)
9. Aquaculture (shellfish)
10. Shipping in shallow water

66. All layers were converted to presence/absence data per 10km-by-10km grid cell[49] before summing, except for demersal fishing (kw/h) and shipping in shallow waters (derived from a shipping CO_2 emissions model from the Finnish Meteorological Institute, cropped to 0-25 meters depth zone). Demersal fishing was log-transformed and normalized to 0-1 before summing. Shipping in shallow waters was normalized before summing, but not log-transformed.

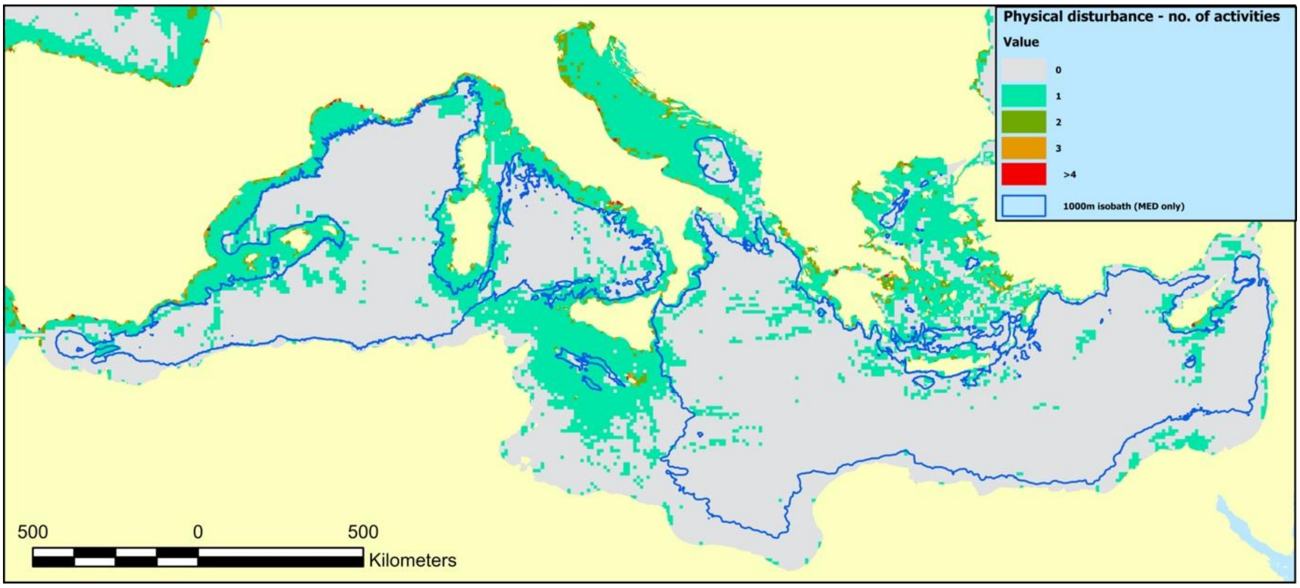

Figure 11. Number of different activities causing physical disturbance to the seabed per 10km x 10km grid cell (redrawn from data in Korpinen et al., 2019). See text for further details. 1000m isobath also shown.

[49] At the scale of the entire Mediterranean Sea region, the use of a 10km-by-10km grid provides a relatively fine level of detail. However, this scale has limitations in relation to assessing seabed habitats from the following perspectives: a) the distribution and extent of seabed habitats, particularly in shallow waters near the coast, can be complex and occur at much finer scale, and b) activities and their pressures are particularly concentrated on the continental shelf area which, for most of the Mediterranean, is quite a narrow zone. The interaction between seabed habitats and the pressures would therefore be improved if the data were available on a finer grid, at least for the nearshore zone.

67. The number of activities causing physical disturbance is typically highest in the coastal zone, whilst further offshore, on the shelf areas down to 1000m depth, the majority of physical disturbance is from demersal fishing activity, some of which can occur multiple times per year (see **Figure 8**).

A3.5 Physical – hydrographical pressures

68. Korpinen et al. (2019) have mapped the distribution and intensity of hydrographical pressures, based on data reported under the EU Water Framework Directive. The presence of different hydrographical pressure types was mapped and summed per 10km-by-10km grid cell (
69. **Figure 12**). Equivalent data for non-EU countries is not available.

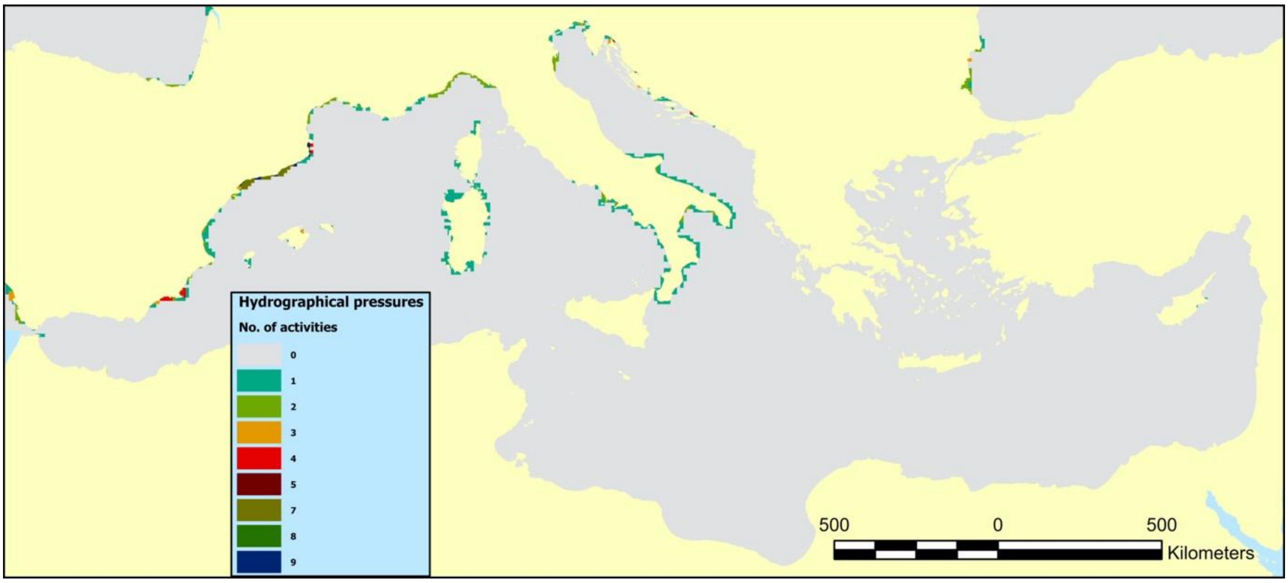

***Figure 12**. Number of different hydrographical pressures per 10km-by-10km grid cell, as reported by EU Member States (by Croatia, France, Italy, Slovenia and Spain) for the Water Framework Directive in 2016 (redrawn from data in Korpinen et al., 2019). Similar data for non-EU countries are unavailable.*

A3.6 Land-based pollution – nutrient enrichment and contaminants

70. It is estimated that 80% of the marine pollution, by nutrients, heavy metals and Persistent Organic Pollutants (POPs), comes from land-based human activities (Piante & Ody, 2015). In the Mediterranean, the main sources of pollution are industries, untreated urban and domestic waste-waters, surface run-off, dumping grounds and river discharges to the sea. Sea-based aquaculture facilities may also provide a source of pollution, particularly nutrients.

71. Impacts on the sea-floor affect coastal areas in particular, with chemical contamination in the sediment considered to decrease when moving offshore (Gómez-Gutiérrez et al., 2007). Benthic communities of soft sediments seem strongly affected by heavy metals which accumulate over time in the sediment (Chatzinikolaou et al., 2018).

72. In the Mediterranean Sea, annual Nitrogen (N) and Phosphorus (P) inputs have been estimated as 1.3 Tg N and 126 Gg P (PERSEUS–UNEP/MAP, 2015). In the region, 50% of N and 75% of P inputs come via rivers and the rest from atmosphere and coastal point sources to the sea. In general, the northern rivers discharge more nutrients than the southern rivers of the sea region (Strobl et al.,

2009). The largest riverine inputs (accounting for 25 % of the total discharge) are from the Rhone and the Po (Korpinen et al., 2019).

73. Eutrophication is generally restricted to the coastal zone and is much less of a problem in the Mediterranean compared with other marine regions around Europe. 16% of sites assessed in the Mediterranean were subject to eutrophication, although there are large data gaps (Korpinen et al., 2019). A 2018 assessment of eutrophication, produced using the HELCOM eutrophication assessment tool (HEAT), indicates that the Mediterranean is mainly in a good state, but eutrophication occurs in coastal areas in the western and north-western Adriatic, off the Egyptian coast, Gulf of Gabès, northern Aegean Sea, and outside bigger cities in Spain and France.

74. For the 2023 Med QSR under EO5, a eutrophication assessment was undertaken using a simplified assessment method (the G/M or good/moderate boundary method) based on Chlorophyll-a data from the COPERNICUS satellite, excepting in the Adriatic Sea subregion which used the NEAT assessment tool for CI-13 (N and P) and CI-14 (Chlorophyll-a) (UNEP/MAP-MEDPOL, 2023) (**Figure 13**).

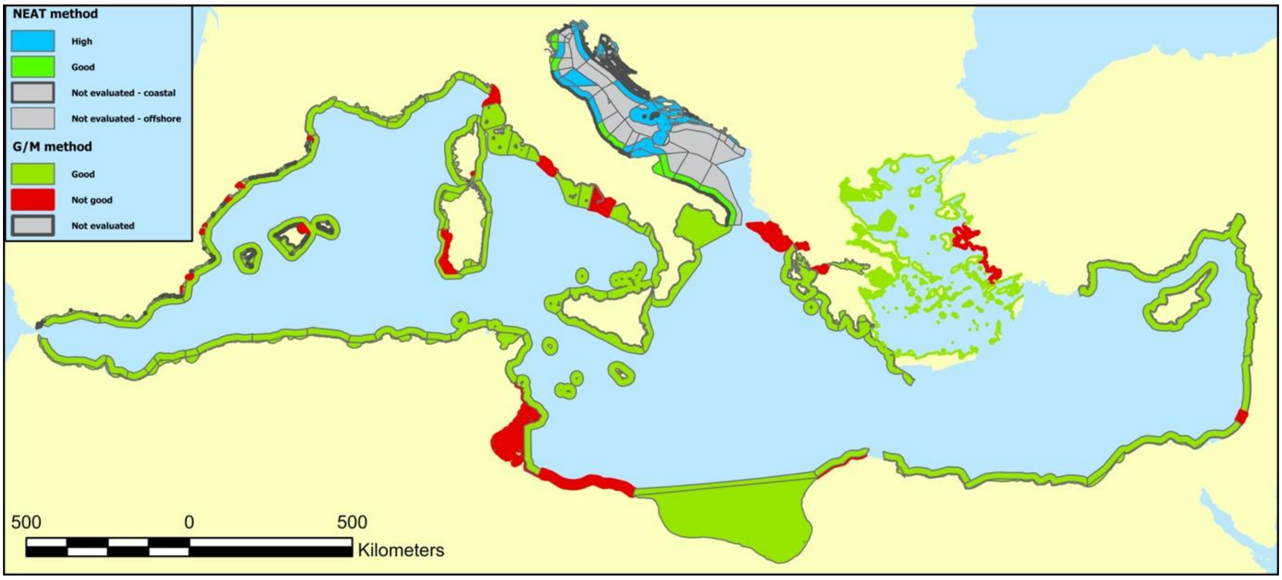

***Figure 13**. Assessment results for EO5, based on CI-14 using the simplified G/M method on satellite-derived COPERNICUS data for Chlorophyll-a for all subregions, except in the Adriatic Sea subregion where the assessment is based on CI-13 and CI-14 using the NEAT method (redrawn from UNEP/MAP-MEDPOL, 2023).*

75. The results for the Adriatic Sea indicate there is good to high overall status for all the coastal areas assessed (offshore areas were not assessed), based on CI-13 (N and P) and CI-14 (Chlorophyll-a), although several areas on the Italian coast are in moderate status for Total Phosphorus (TP) (UNEP/MAP-MEDPOL, 2023).

76. In the other subregions, the simplified eutrophication assessment for EO5, based solely on CI-14 using satellite-derived Chlorophyll-a data, is considered to give only an indication of the possible environmental status for EO5 on eutrophication (UNEPMAP MEDPOL, 2023). The 2023 QSR assessment for EO5 provides additional details on hotspots for eutrophication, likely due to local sources of nutrient inputs, for each subregion.

77. Nutrient enrichment can change benthic community composition in shallow rocky habitats, especially macroalgae communities (Arévalo et al., 2007). The eutrophication effects in the water column can eventually increase turbidity and thus reduce the depth to which macrophytes grow.

78. A marked effect of eutrophication on seabed habitats is due to the development of hypoxic conditions at the seabed. Such conditions have been found only in coastal areas of the Adriatic Sea, northern and western Aegean Sea, eastern Ionian Sea and the Gulf of Lion (EEA, 2019e). The eutrophication of the Adriatic Sea started in the 1970s, but the hypoxic events have become rarer since the 1990s–2000s with the decline of chlorophyll concentrations (Giani et al., 2012; Djakovac et al. 2015).

79. The eutrophication assessments under EO5 for the 2023 Med QSR are based on data about the water column (N, P, chlorophyll-a). These provide only a possible indication of eutrophication effects on the seabed, which would need to be verified by use of benthic indicators of eutrophication, such as those used under the WFD.

A3.7 Litter

80. The Mediterranean Sea, through its characteristics as a semi-enclosed sea surrounded by a highly populated coast and a major destination for tourism, 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 seabed 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) (Pasquini et al., 2016).

81. On the sea-floor, plastic litter concentrates in specific depositional areas. Although coastal areas show higher concentrations of litter (e.g., Strafella et al., 2015), in deeper areas hotspots for 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). Benthic species tend to be affected by entanglement with litter, whilst pelagic species are more affected by ingestion of litter (Abdul Malak, D., ETC-UMA, pers. comm.).

82. Recent concerns focus further on pollution by micro-plastics which can accumulate in marine sediments where their impacts on macrofauna are not yet known. Tsiaras et al. (2021) modelled the distribution of micro-plastics on the Mediterranean continental shelf. With this model, eastern Spain, the Gulf of Lion and the Tyrrhenian Sea appear as the areas most impacted by micro-plastics.

A3.8 Climate change

83. 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 occurred (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).

84. 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 in sea level and erosion of the coastline and beaches. It is difficult to assess damage on the sea-floor from climate change since these effects accumulate with other effects.

A3.9 Blue carbon and the effects of bottom fishing

85. 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 in the Mediterranean) 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).

86. 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). Demersal 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 km^2 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 CO_2 (Liusetti et al. 2019).

87. 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).

88. 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).

A3.10 Cumulative effects

89. 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 impact of cumulative pressures, littoral Mediterranean habitats are subject to a greater accumulation of pressures than others. Micheli et al. (2013) estimated that 20% of the entire Mediterranean basin is heavily impacted by cumulative impacts. In a more recent study, more than 30% of the Mediterranean Sea is considered to be highly impacted (Med-IAMER, 2015). The intensity of individual pressures varies across the region, yet the drivers are similar in the whole Mediterranean Sea. Furthermore, the number of pressures is spatially heterogeneous, showing that cumulative impacts tend to aggregate in specific areas to create hotspots where the intensity of human activities is likely to produce negative effects on the environment (Med-IAMER, 2015).

90. 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 by far the most important.

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Annex II. Basis for assessment areas proposed for EO6

A5 Introduction

1. A proposal for a set of assessment areas for EO6 application was introduced in Section 9 and **Figure 2**. In **Figure 14**, the subregions and subdivisions are labelled/numbered to link to the data provided in **Table 12** on the characteristics of each assessment area (subdivision of the marine region).

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

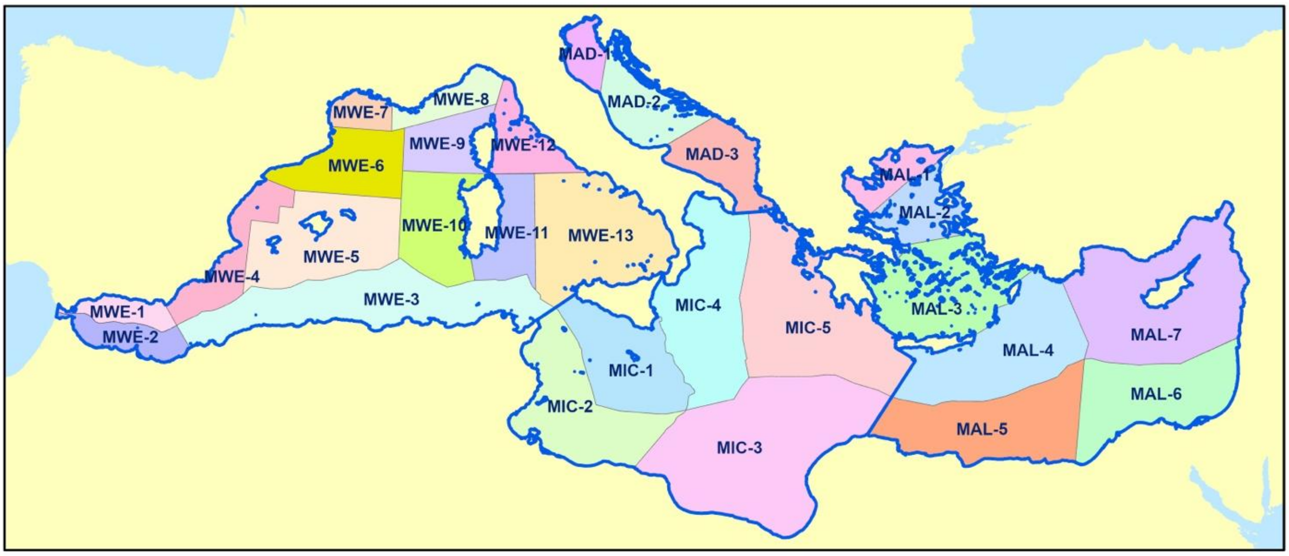


***Figure 14**. Subdivisions proposed for EO6 application. Subdivisions are numbered within each subregion (blue lines) with codes: MWE-Western Mediterranean Sea; MAD-Adriatic Sea; MIC-Ionian Sea and the Central Mediterranean Sea; MAL-Aegean-Levantine Sea. This map is for assessment purposes only and shall not be considered as an official map representing marine borders. This map shall be used without prejudice to the agreements made between countries under international law in respect of their marine borders.*

3. 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[50];
d. Management considerations, such as the management of the bottom fishing sector, including use of some GFCM geographical sub-area boundaries.

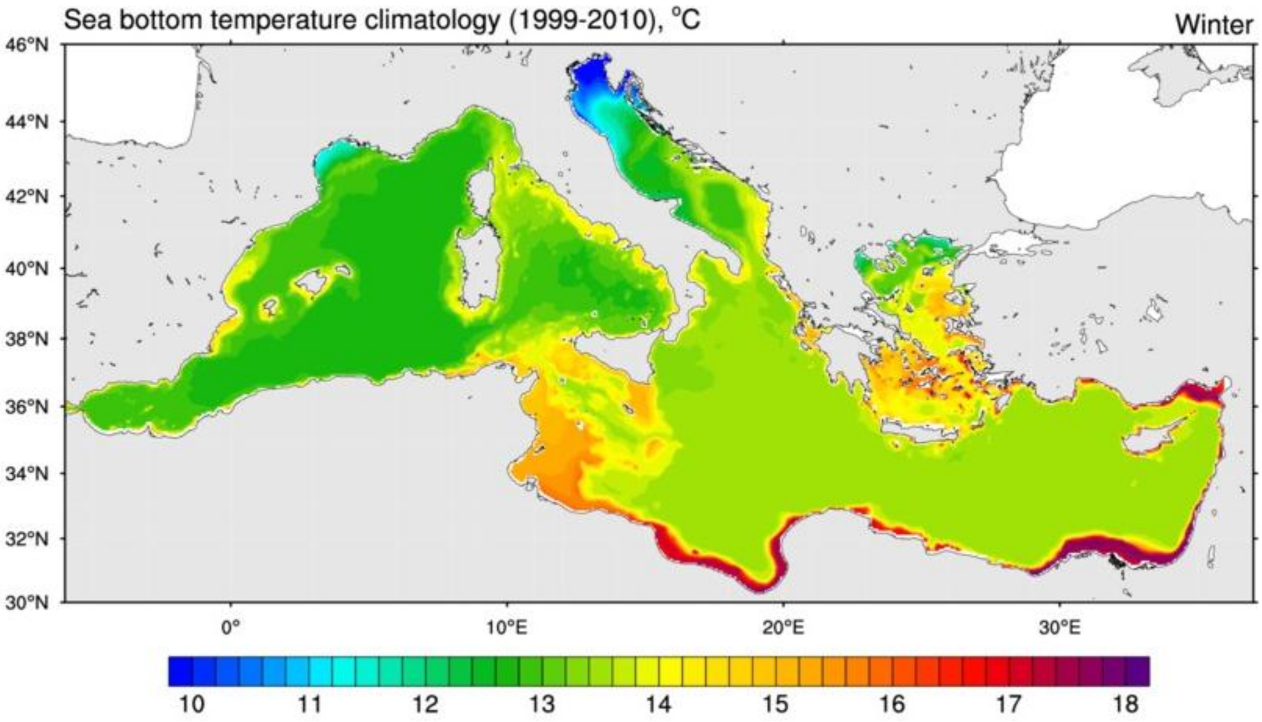
[50] Boundaries for some assessment areas are based on marine borders of EU Member States, according to UNCLOS. This map is for assessment purposes only and shall not be considered as an official map representing marine borders. This map shall be used without prejudice to the agreements made between countries under international law in respect of their marine borders. In cases where the boundaries of certain subdivisions are based on national marine borders and these borders are modified, such as through new agreements with neighbouring countries, the subdivision boundaries should be updated.

A6 Temperature and salinity data used

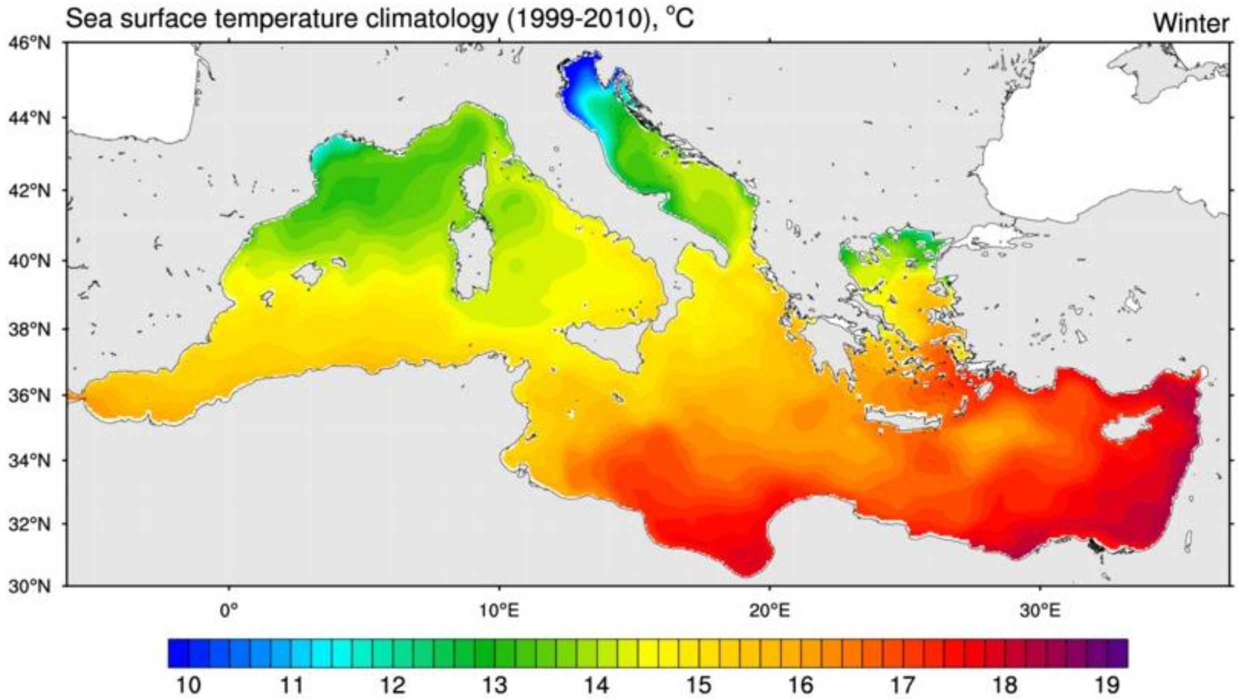
4. Long-term average sea temperature and salinity (climatology) play a key role in determining biogeographic characteristics of marine communities. The species become accustomed to the long-term characteristics of the sea in which they live, and this is reflected in the biological communities of both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

5. 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).

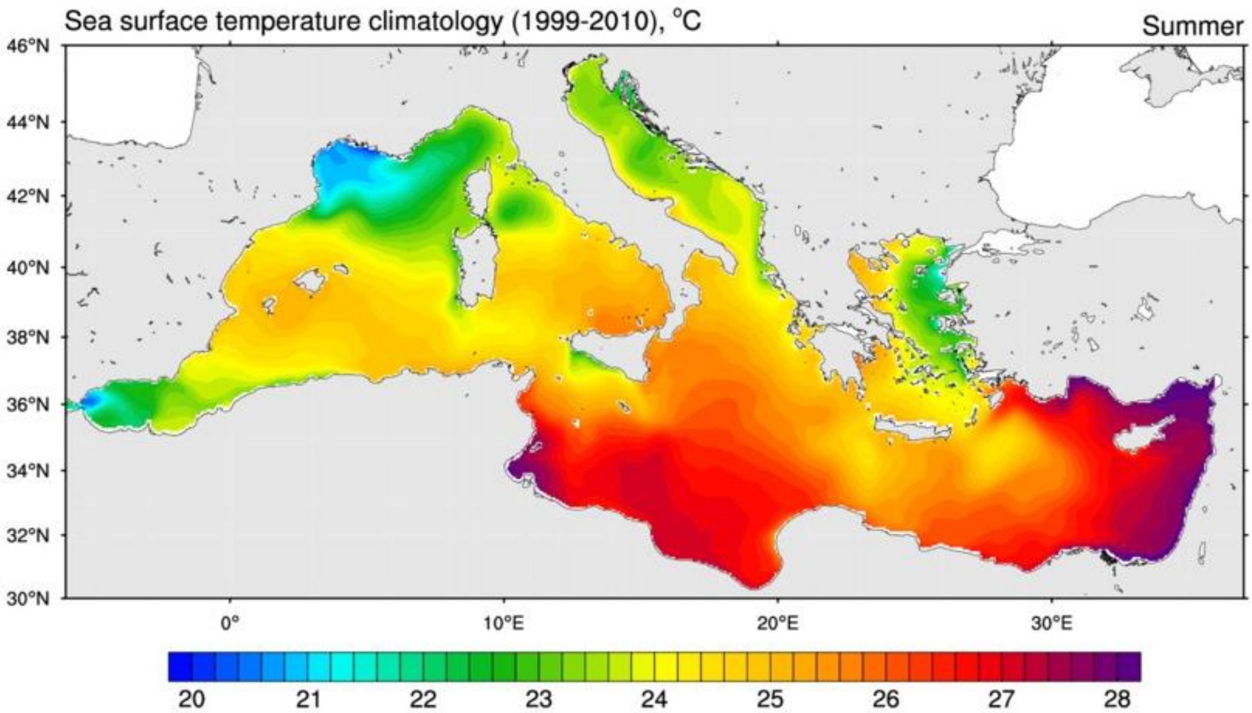
A6.1 Mediterranean Sea bottom temperature - winter (average 1999-2010)



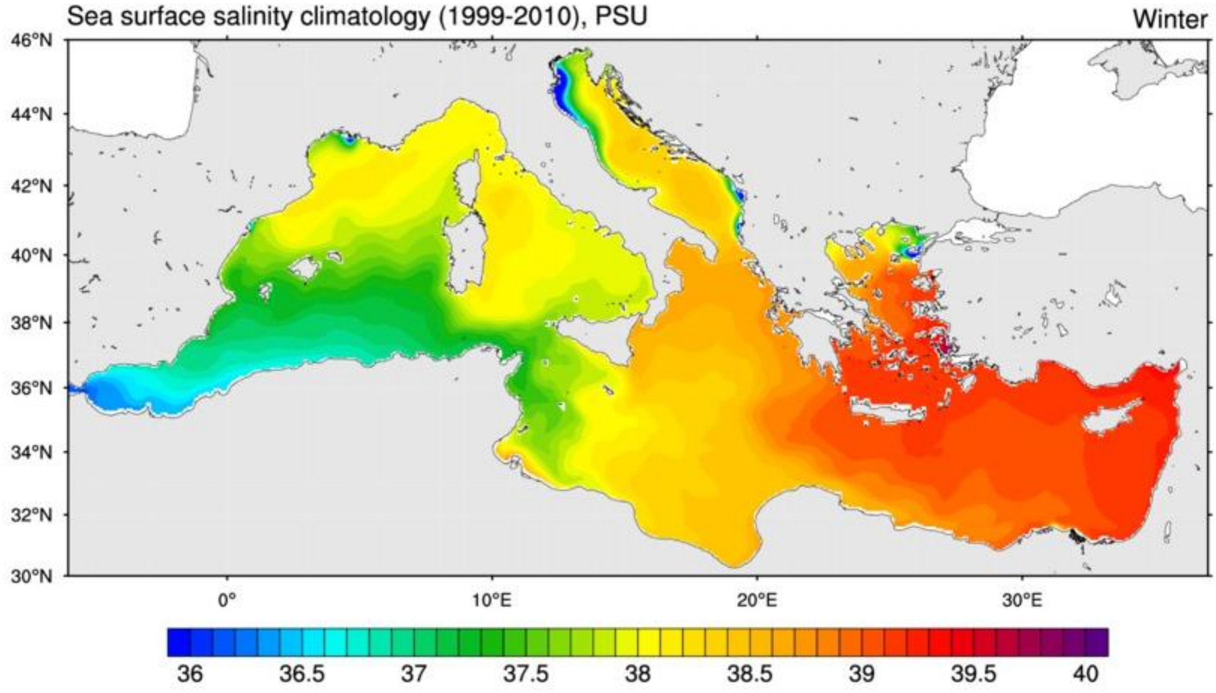
A6.2 Mediterranean Sea surface temperature – winter (average 1999-2010)



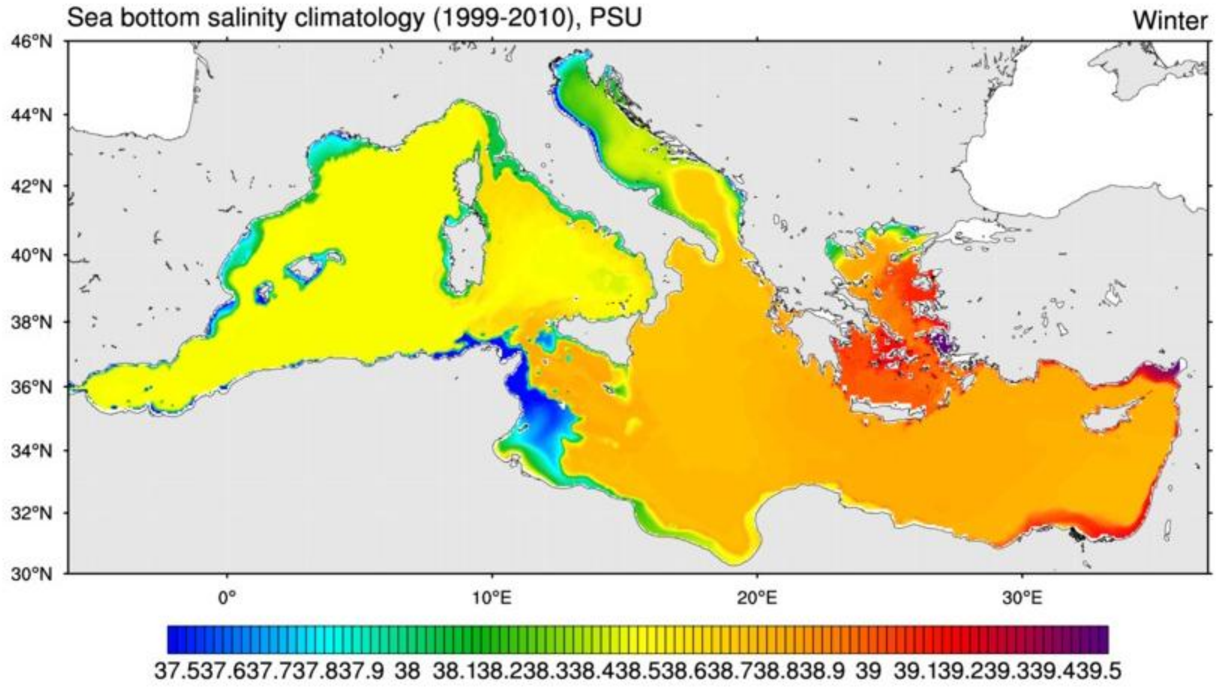
A6.3 Mediterranean Sea surface temperature – summer (average 1999-2010)



A6.4 Mediterranean Sea surface salinity – winter (average 1999-2010)



A6.5 Mediterranean Sea bottom salinity – winter (average 1999-2010)



A6.6 Characteristics of each subdivision

6. More specific information on the subdivisions shown in **Figure 14** is provided in **Table 12**. 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[51], a GFCM subarea boundary).

[51] National borders of relevant EU Member States, defined in accordance with UNCLOS, were used where needed.

***Table 12**: 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	22-23	12.5-13.5	12-13	37.5-38.5	38.5 (coast 38-38.2)	Ecological	GFCM	GFCM, ecological	Marine border ES
MWE	7	FR	20-21	12.5-13.5 (coast 11-11.5)	12-13 (coast 11)	37-38	37.5-38.5	Coast FR	Ecological	Ecological	Coast FR
MWE	8	FR, IT	22-23	13-14 (coast 14-14.5)	12-13	38	38.5	Coast FR, IT	Ecological	Management	GFCM
MWE	9	FR	22-23.5	12.5-13.5	12-13 (coast 13-13.5)	37.5-38	38.5	Management	Coast Corsica	Ecological (GFCM)	GFCM
MWE	10	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	11	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	12	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	13	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

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	2	IT, HR	22-24.5	12-13	12-13	37.5-38.5	38.1-38.5	Ecological	Coast HR	Ecological	Coast IT
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, MT	25-26	14.5-15	13-13.5	38.5-38.8	38.7	Coast IT, subregion	Marine border IT/EL	Marine border IT, MT	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, LY, EG	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, LY, EG	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

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
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

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