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2023 Med QSR Benthic Habitats (EO1) assessment

UNEP/MAP
Athens, 2023

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Note by the Secretariat

The 2023 MED QSR Roadmap and Needs Assessment was endorsed by COP 21 (Naples, Italy, December 2019) with Decision IG.24/4. It defines the vision for the successful delivery of the 2023 MED QSR, and outlines key IMAP-related processes, milestones and outputs to be undertaken, with their timelines.

The main assessment chapters of the 2023 MED QSR are based on assessments of Common Indicators (CI) and some Candidate Common Indicators (CCI) within Ecological Objectives (EO) for biodiversity and fisheries, pollution and marine litter and cost and hydrography clusters. Where feasible, and where the data allow, CIs are integrated within and across EOs.

As a contribution to the 2023 MED QSR biodiversity (EO1) and non-indigenous species (EO2) chapters, SPA/RAC has prepared six thematic assessment reports for benthic habitats, cetaceans, Mediterranean monk seal, seabirds, marine turtles and non-indigenous species (NIS).

The present proposal of the 2023 MED QSR chapter related to benthic habitats was presented and discussed during the CORMON Biodiversity and Fisheries meeting (Athens, 9-10 March 2023). The conclusions and suggestions of the meeting were integrated in the current version that is submitted for discussion by the Meeting of the Integrated Ecosystem Approach Correspondence Groups (CORMONs) with a view of its finalization and consideration by the 10th Meeting of the EcAp Coordination Group to be held in September 2023.

Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

CCI	Candidate Common Indicator (of IMAP)
CI	Common Indicator (of IMAP)
DPSIR	Drivers, Pressures, State, Impact and Response (assessment framework)
EC	European Commission
EEA	European Environment Agency
EMODnet	European Marine Observations and Data Network (of European Commission)
EO	Ecological Objective (of IMAP)
ETC-ICM	European Topic Centre on Inland, Coastal and Marine Waters (of EEA)
EU	European Union
EUNIS	European nature information system (of EEA)
EUSeaMap	Modelled mapping product of seabed habitats for European marine regions (of EMODnet)
FRA	Fisheries Restricted Area (of GFCM)
GES	Good Environmental Status (of IMAP, of MSFD)
GFCM	General Fisheries Commission for the Mediterranean
GSA	Geographical subarea (of GFCM)
HELCOM	Helsinki Commission, implementing the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area
ICES	International Council for the Exploration of the Sea
IMAP	Integrated Monitoring and Assessment Programme (of UNEP/MAP)
MSFD	Marine Strategy Framework Directive (of EU)
OSPAR	Oslo-Paris Commission, implementing the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
QSR	Quality Status Report
RSC	Regional Sea Convention
SPA/RAC	Special Protected Areas Regional Activity Centre (of UNEP/MAP)
UNEP/MAP	United Nations Environment Programme – Mediterranean Action Plan, implementing the Barcelona Convention for the protection of the marine environment and coastal region of the Mediterranean
VME	Vulnerable Marine Ecosystem
WFD	Water Framework Directive (of EU)

2023 Med QSR Benthic Habitats (EO1) assessment

1 KEY MESSAGES

1. The seabed and its benthic habitats are a key component of the Mediterranean's marine ecosystem. It holds a high diversity of marine communities and species and provides a range of essential ecosystem services including provision of seafood, natural coastal protection and carbon sequestration.

2. The seabed is subject to a wide range of anthropogenic pressures, arising from land-based activities which lead to pollution (contaminants, nutrient enrichment, litter) and sea-based activities that cause physical damage and loss of habitat (bottom fishing, mineral extraction, coastal and offshore infrastructure), introduce non-indigenous species, and disrupt the natural carbon cycle.

3. The seabed is under severe pressure in the coastal zone where extensive stretches of coast have lost their natural marine habitat through the building of coastal infrastructure and sea defences. Offshore, down to depths of 1000m, the most wide-spread and extensive damage to seabed habitats comes from bottom fishing using trawls and dredges. Below this depth, these fishing practices are banned, thereby providing protection to sensitive deep-sea habitats throughout the Mediterranean. However, there is increasing evidence of litter from land-based sources accumulating at these depths.

4. Particularly threatened habitats, including coralligenous habitats, maerl/rhodolith habitats and *Posidonia oceanica* seagrass meadows, and, are now subject to IMAP monitoring programmes under Ecological Objective (EO) 1 (biodiversity). Consideration of the wider sea-floor under EO6 (sea-floor integrity) is less well developed.

5. Given the current level of development of assessment techniques for EO1 and EO6, it is only possible to present a preliminary approach to seabed habitat assessments for the 2023 Med QSR. This is done at a broad scale and with a focus on assessing the extent of pressures, as a proxy for impacts on habitats.

6. A pilot assessment for the Adriatic Sea shows all coastal and offshore habitats are subject to multiple pressures, but habitats in the south which are below 1000m depth are less affected. The most widespread pressure is physical disturbance by bottom fishing which, using data at a 10km-by-10km grid resolution, affects 90% of this subregion.

2 BACKGROUND INFORMATION AND METHODOLOGY

7. This assessment builds upon the 2017 MED QSR chapter on benthic habitats, aiming to provide a more data-driven assessment of benthic habitats across the Mediterranean Sea region, based on available datasets.

8. The assessment addresses both Ecological Objective 1 (benthic habitats) and Ecological Objective 6 (sea-floor integrity), following a similar approach based on Common Indicator 1 (CI-1 habitat distribution) and Common Indicator 2 (CI-2 habitat condition) of the Integrated Monitoring and Assessment Programme (IMAP).

9. A demonstration of the proposed framework for EO6 is provided, whilst acknowledging it is under development and discussion (UNEP/MAP-SPA/RAC 2023a). The assessment focuses on a set of broad habitat types[1] to give an overview of the pressures affecting sea-floor integrity across the region with a pilot study for the Adriatic Sea subregion.

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[1] The broad habitat types from Table 2 of Commission Decision (EU) 2017/848 under the Marine Strategy Framework Directive (2008/56/EC).

10. The assessment reflects the Driver-Pressure-State-Impact-Response (DPSIR) environmental assessment framework through identification of the key activities and pressures affecting seabed habitats. Data on the distribution and extent of the main pressures on the seabed is drawn from a European Environment Agency assessment of pressures in European seas using a 10km-by-10km grid (Korpinen et al., 2019 - ETC/ICM Technical Report 4/2019). This report includes the following pressures:

a) non-indigenous species;
b) physical loss of seabed (dredging, dumping, oil and gas rigs, ports, sand and gravel extraction, windfarms);
c) physical disturbance (demersal fishing, dredging, sand and gravel extraction, anchorage sites, windfarms, oil platforms, aquaculture, shipping in shallow water);
d) hydrographical pressures.

11. Assessment of CI-1 and CI-2 is presented, to the extent possible, on the basis of the datasets above. For CI-2[2] the pressure information is used as a proxy assessment for the possible extent of impacts on habitat condition.

12. Narratives on the status of benthic habitats according to the sections of the QSR template are provided, drawing from recent reports, including ETC/ICM (Korpinen et al., 2019) and UNEP/MAP-SPA/RAC (2022) and from the above analyses.

13. The assessment of benthic habitats under EO1 and CI-1 and CI-2 is not yet well established. The approach presented here, extending to broad habitat types under EO6, aims to provide a more holistic assessment of the Mediterranean seabed and the pressures upon it, whilst acknowledging that further methodological development is needed in order to provide a full good environmental status (GES) status assessment for seabed habitats.

2.1 EO1, EO6 and relationships with the other EOs

2.1.1 *Objectives for EO1 Biodiversity and EO6 Sea-floor integrity*

14. The seabed and its habitats are addressed specifically by two Ecological Objectives (EO1 Biodiversity and EO6 Sea-floor integrity). Within the IMAP, Contracting Parties have adopted two Common Indicators for EO1, with associated GES definitions, operational objectives and targets set out in the CI guidance fact sheets (UNEP(DEPI)/MED WG.444/6/Rev.1, 2017, **Table 1**).

***Table 1**. Definitions of GES, operational objectives and targets for Common Indicators 1 and 2 on benthic habitats of Ecological Objective 1.*

Indicator Title	***Common Indicator 1: Habitat distributional range***		
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**	
		State	**Pressure**
The habitat is present in all its natural distributional range	Coastal and marine habitats are not being lost	The ratio Natural / Observed distributional range tends to 1	Decrease in the main human causes of the habitat decline

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[2] Data (species composition and abundance data at specific monitoring sites) submitted to the IMAP Info System for the three EO1 habitat types has been presented as maps but has not been analysed due to a lack of agreement on methodology for analysis and a threshold value for defining good condition of each habitat.

Indicator Title	***Common indicator 2: Condition of the habitat's typical species and communities***	
Relevant GES definition	**Related Operational Objective**	**Proposed Target(s)**
The population size and density of the habitat-defining species, and species composition of the community, are within reference conditions ensuring the long-term maintenance of the habitat	Coastal and marine habitats are not being lost	**State:** - No human induced significant deviation of population abundance and density from reference conditions -The species composition shows a positive trend towards reference condition over an increasing proportion of the habitat (for recovering habitats)

15. At the time of adoption into the IMAP in 2014 of a GES definition, objectives and targets for EO1 (and other EOs) the state of knowledge and availability of data for EO6 was not considered sufficiently advanced, and so EO6 is not yet included in the IMAP. However, SPA/RAC prepared a first draft proposal for EO6 and presented this to CORMON Biodiversity in March 2023 (UNEP/MAP-SPA/RAC, 2023a), with a view to it being adopted into the IMAP in 2023. The EO6 proposal includes operational objectives, broad indicators, a GES description and targets (**Table 2**).

Table 2. *Proposed definitions of GES, operational objectives and targets for EO6 sea-floor integrity (from UNEP/MAP-SPA/RAC, 2023a).*

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

2.1.2 *Habitats addressed by EO1 and EO6*

16. Whilst EO1 and EO6 both address the seabed and its habitats they have different perspectives and can be considered complimentary. The focus of EO1 is on specific habitat types which are considered to be threatened, while it is proposed that EO6 addresses the entire seafloor through a set of broad habitat types. In view of the wider importance of sea-floor integrity to the quality and functioning of the Mediterranean ecosystem, including its role in mitigation against climate change, this QSR chapter also addresses EO6, drawing from the EO6 proposal, while acknowledging that EO6 is not yet part of the IMAP.

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

2.1.2.1 EO1 habitats

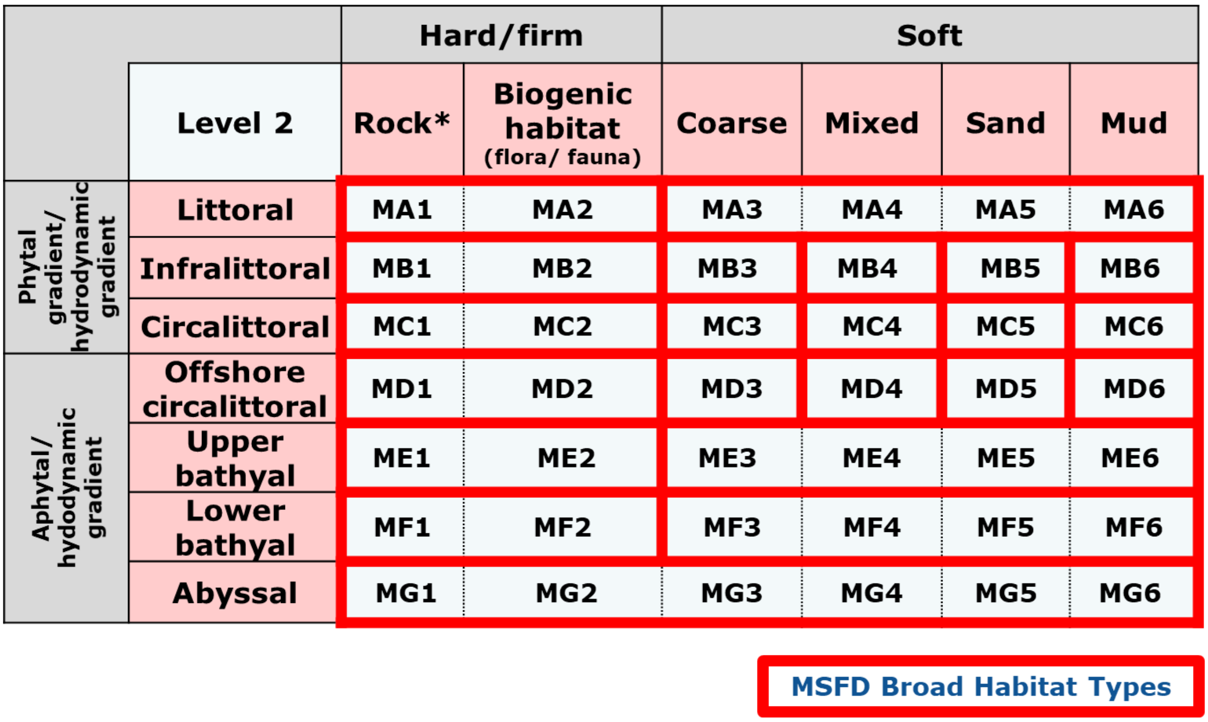
17. The IMAP process has considered a number of habitat types for inclusion under EO1. To date methods for monitoring have been established (UNEP/MED WG.502/16 Rev.1.Appendix A Rev.1, 2021) and data flows into the IMAP Info System (codes B1, B2, B3) initiated for the following habitat types (with Barcelona Convention habitat typology codes):

a. B1 - Coralligenous platforms (MC2.51);
b. B2 – Association with maerl or rhodoliths (MB3.511)
c. B3 – *Posidonia oceanica* meadow (MB2.54)

18. There is ongoing work by SPA/RAC to consider additional habitat types that could be proposed for EO1 monitoring and assessment (UNEP/MAP-SPA/RAC, 2023b).

2.1.2.2 EO6 habitats

19. The scope of EO6 is broad, referring more generally to ‘sea-floor integrity’. Under the Marine Strategy Framework Directive (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 MSCG_29-2021-05). For BC codes add '.5' to the EUNIS code (e.g., 'MB1.5' for Infralittoral rock).

2.1.3 Relationships to other EOs

20. EO1 and EO6 have important links to each other and to other Ecological Objectives in the IMAP that directly deal with seabed habitats and to other EOs that address pressures that may affect the sea-floor and its habitats. These are presented in **Table 3**, together with comments on how these synergies could be exploited in an integrated approach to IMAP implementation.

***Table 3**. Links between EO1, EO6 and other EOs and their Common Indicators (CI) and Candidate Common Indicators (CCI) (UNEP/MAP, 2016). Links are to 2017 MED QSR indicator assessments.*

Ecological Objective	**Common and Candidate Indicators**	**Relevance to EO 1 and EO6**
EO1 Biodiversity	CI-1: Habitat distributional range CI-2: Condition of the habitat's typical species and communities CI-3, CI-4 and CI-5 address marine birds, mammals and reptiles (Species distributional range, Population abundance and Population demographic characteristics)	Relevant. EO1 addresses seabed habitats (as well as species of marine birds, mammals and reptiles), thereby providing a direct overlap with EO6 in cases where the seabed addressed under each EO overlaps. 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 CI-6, 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	To be developed	Potentially relevant. Food webs include interactions between the seabed, water column and marine species living in and above the sea. When CIs are being developed for EO4, it would be sensible to consider whether the data and CIs available under EO1 and EO6 could be reused for EO4 purposes, and how future CIs for EO4 could address specific functional aspects of food webs that also contribute to EO1 and EO6.
EO5 Eutrophication	CI-13: Concentration of key nutrients in water column CI-14: Chlorophyll-a concentration in water column	Limited relevance at present. Eutrophication can affect the seabed as well as the water column and in the Mediterranean is mostly confined to coastal waters; CI-13 and CI-14 relate to the water column; in cases where their assessment indicates high pressure levels it may indirectly indicate there may be eutrophication problems on the seabed.

Ecological Objective	Common and Candidate Indicators	Relevance to EO 1 and EO6
EO7 Hydrography	CI-15: Location and extent of habitats impacted directly by hydrographic alterations	Relevant. Hydrographical alterations to seabed habitats are directly relevant to EO6 (and EO1). Assessments of CI-15 need to provide the extent of adverse effect per habitat so results can feed into assessments of EO-6 and EO-1.
EO8 Coastal ecosystems and landscapes	CI-16: Length of coastline subject to physical disturbance due to the influence of man-made structures 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. 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 CCI-27: Levels of continuous low frequency sounds with the use of models as appropriate	Not currently relevant. The CCIs 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 currently of direct use to assess effects to seabed habitats.

21. 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) and EO1 (as seabed habitats) with 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.

22. There are strong links to EOs which address specific pressures that can yield a measurable footprint of impact on the seafloor 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 EO 1 and EO6 is limited.

23. These inter-relationships provide an opportunity to reuse indicators, data and assessments from other EOs for EO1 and EO6 purposes. This is especially valid when their outputs are made with direct use in mind (e.g., producing footprints of impact per habitat type for a given pressure). This QSR assessment of seabed habitats makes cross-links to these other EOs; however, direct reuse of QSR assessment results from other EOs needs further development.

3 DRIVERS, PRESSURES, STATE, IMPACT, RESPONSE (DPSIR)

3.1 Introduction

24. Various authors have modified the DPSIR conceptual framework to help clarify its components and their inter-relationships. For the marine environment, Elliott & O'Higgins (2020) distinguish **Drivers** from **Activities** and discuss **Impact** in relation to both the **State** of the environment and how this affects **Ecosystem Services**. A similar adaptation of DPSIR was developed to support implementation of the Marine Strategy Framework Directive (MSFD) (European Commission, 2020).

25. Drivers can be considered as basic human needs (such as demand for food) which lead to specific activities to meet these needs (e.g., agriculture, aquaculture, fishing). Other basic human needs are (clean) air and water, protection from elements, shelter (homes) and energy (warmth) (Maslow, 1943). In our modern society, our energy needs also support our communications (internet, phones).

26. Our human activities cause environmental pressures (**Pressures**) on the marine environment. Multiple activities can lead to the same type of pressure (e.g., physical disturbance of the seabed), and multiple pressures can adversely affect the condition of seabed habitats (**State**) (see section 3.4). In turn, a degraded state of the seabed has a knock-on effect to the ecosystem services it provides (Impact), such as reduced production of seafood, less effective natural coastal defences and reduced capacity to absorb (sequester) carbon from the water column and atmosphere.

27. In terms of assessing the state of the seabed, it is important to consider the range of activities that cause pressures on the seabed (section 3.3) and assess the distribution, extent and intensity of the pressures themselves (section 3.2, section 3.4). The prime means to achieve and maintain good environmental status (GES) of the seabed and its habitats is to manage the pressures which adversely affect[4] the condition (state) of the seabed, keeping these pressures and impacts within levels compatible with GES. This, in turn, requires management of the activities to reduce the pressures to necessary levels.

28. Assessment of the state of seabed habitats, and whether they are in GES, requires an assessment of the impacts from the multiple pressures that affect each habitat type. This needs knowledge of the state of seabed habitats: their biotic and abiotic characteristics at present, and a comparison of this state to what is considered to be a reference state (i.e., the habitat is largely free of impacts from anthropogenic pressures) or a good state (the habitat has only minor effects from pressures). Such assessments require

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

extensive knowledge and data to perform purely from a state perspective, and so are increasingly conducted using data and models of pressures to act as a proxy for environmental impacts.

29. Under the IMAP for EO1, biological sample data on three habitats started to be submitted by Contracting Parties to the IMAP Info System in 2020. There are currently insufficient data coverage and a lack of agreed methodology on how to interpret these data (through a suitable indicator). This severely limits how the three habitats can be assessed in relation to the two indicators for EO1, particularly CI-2 on habitat condition.

30. However, data on the main pressures affecting the seabed have been compiled as a 10km-by-10km grided dataset for the Mediterranean region as a whole by the EEA's European Topic Centre for Inland Coastal and Marine Waters (Korpinen et al., 2019). This offers the opportunity to make preliminary broadscale assessments on the state of the seafloor using pressures as a proxy. The assessments of other relevant EOs can also inform this assessment (section 2.1.3).

3.2 Anthropogenic pressures affecting the sea-floor

31. Anthropogenic pressures, stemming from activities in both the marine and terrestrial environments, can adversely affect the Mediterranean's 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 Seafloor and its habitats (**Table 4**).

Table 4. *Anthropogenic pressures, including from climate change, which can adversely affect the marine environment, with an indication of their relevance to the Mediterranean Seafloor 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.

Pressure	**Possibility to affect sea-floor**
Biological pressures	
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 seafloor not often studied as monitoring is primarily focused on coastal water quality (e.g., bathing waters).
Input of genetically modified species and translocation of native species	Possible; unlikely to be a significant pressure on the seabed except if there is a risk of spreading by some species (e.g., from marine culture or coastal translocations by vectors like fishing or extraction discards); not often monitored.
Loss of, or change to, natural biological communities due to cultivation of animal or plant species	Possible; seabed cultivation activities are limited in extent in the Mediterranean[5].
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[6].
Extraction of, or mortality/injury to, wild species (by commercial and	Yes; widespread and extensive effects where bottom fishing using benthic-impacting fishing gears occurs, including Illegal, Unreported and Unregulated (IUU) fishing.

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

[6] See, for example, Price (2008) in Lunney, Munn & Meikle Ed., 2008 http://dx.doi.org/10.7882/FS.2008.023.

Pressure	Possibility to affect sea-floor
recreational fishing and other activities)	
Physical pressures	
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[7] 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 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[8], but monitoring is focused on water quality or at species level; point-source pollution has potential to cause localised effects at 'community level'.
Input of litter (solid waste matter, including micro-sized litter)[9]	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[10]; 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 pressures	
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,	Yes; widespread and extensive[11], particularly for coastal and nearshore habitats.

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[7] Commission Decision (EU) 2017/848 defines 'permanent change' as a change which has lasted or is expected to last for 12 years or more.

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

[9] Includes lost and abandoned fishing gear.

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

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

Pressure	**Possibility to affect sea-floor**
sea-level, wave action/storms, currents, freshwater inputs)	

32. From **Table 4**, it can be seen that the anthropogenic pressures causing most widespread and extensive adverse effects to the seafloor 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).

3.3 Human activities affecting the Mediterranean Seafloor

33. This section provides a review of the main human activities affecting the Mediterranean Seafloor. An initial overview of the activities affecting seabed habitats and CI-1 and CI-2 was provided under the IMAP for the Biodiversity and Fisheries theme (18wg450_03). **Table 5** provides a relationship between these human activities and the main sea-floor pressures (a-h) identified in section 3.2.

***Table 5**. Human activities their effects (pressures) on the Mediterranean Seafloor. 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 species	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 exploration and exploitation				🟧	🟧					
	Mining			🟧	🟧	🟧					
Production of energy	Offshore wind farms & other renewable energy generators				🟧	🟧					

	Pressure theme	**Biological**		**Physical**			**Substances, litter & energy**		**Climate change**		
Activity theme	**Pressure** **Activity**	Non-indigenous species	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)
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						■	■	■	■	■

34. 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 further; a downward trend was only envisaged for commercial fisheries (Piante & Ody, 2015).

35. UNEP/MAP-SPA/RAC (2022) provides a review of the main activities affecting the Mediterranean seabed. The ranking of the activities causing habitat loss and/or disturbance proposed for the Mediterranean Sea by ICES (2019a) was used as a starting point and a reference document concerning the impact of anthropogenic activities on Mediterranean Seafloor.

3.3.1 Bottom trawling fishing activities

36. 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 seafloor (Eigaard et al., 2016, 2017).

37. In the Mediterranean Sea, bottom trawling fishing is recognised as being the major activity creating disturbance to seafloor (ICES, 2019a) 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 seafloor. IUCN (2016) reports that more than 25% of marine benthic habitat types are under threat from benthic trawling. The degree of damage caused to the seafloor 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.

38. 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.

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

40. 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 2). Despite the extensive area of seabed covered by the FRAs below 1000m depth (approximately 1,470,000km^2), the majority of the soft-bottom benthic habitats of the continental shelf and slope are threatened by bottom trawling activities.

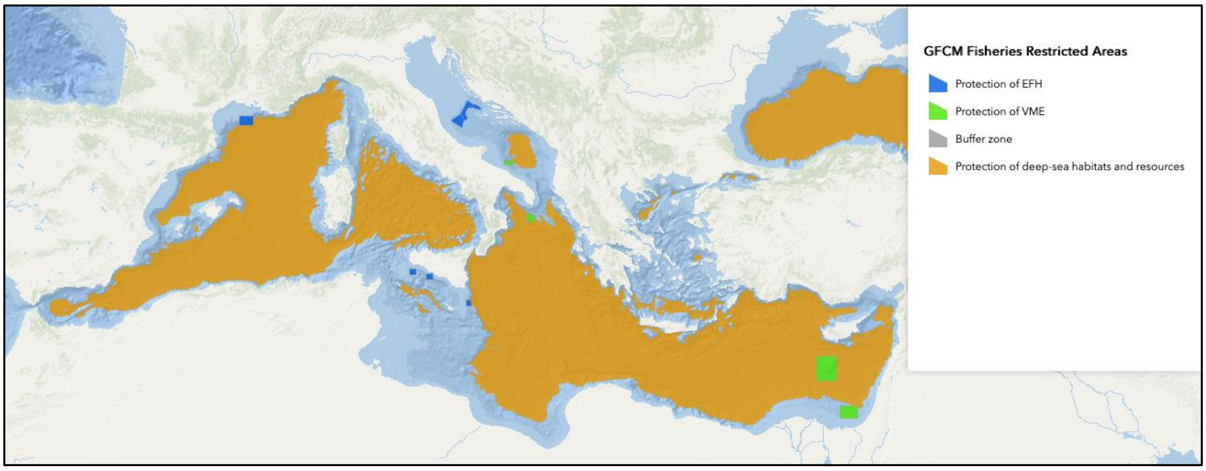

Figure 2. *Distribution of GFCM Fisheries Restricted Areas (EFH = Essential Fish Habitat, VME = Vulnerable Marine Ecosystem) (from https://www.fao.org/gfcm/data/maps/fras/en/, accessed 20/04/2023)*

41. Some Mediterranean areas, such as the Aegean Sea, Adriatic Sea and Western Mediterranean Sea are subject to multi-annual fishery 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).

3.3.2 Bottom otter trawling fishing activities

42. Bottom otter trawling is generally used on sediment seafloor (sandy and muddy). It consists of a large conical net kept open on the seafloor 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 concentrate mainly on depths 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.

43. 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) [Spain’s CORMON representative, March 2023 – add reference]. The data on fishing effort in number of fishing days and by depth strata are shown for these areas in **Figure 3**. 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).

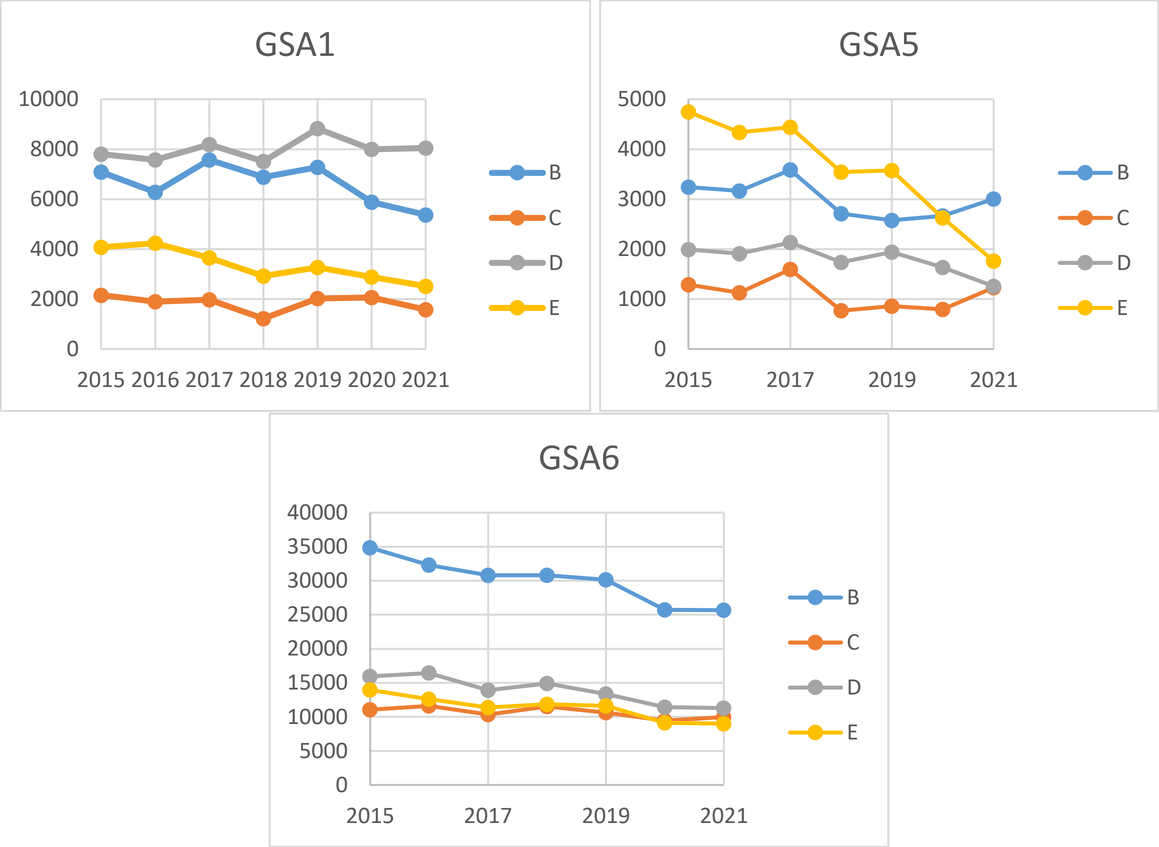

***Figure 3**. Fishing effort in number of days of the bottom-trawl fleet in GSA1, GSA5 and GSA6 (western Mediterranean) calculated from VMS data by depth strata (B: 50-100m; C: 101-200m; D: 200-500m; and E: 500-800m).*

44. 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).

45. 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).

46. 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).

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

a. severe physical damage to large areas of the seafloor, 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 3.4.9 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).

48. 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 seafloor (Smith et al., 2000; Paradis et al., 2021a).

3.3.3 Beam trawlers and dredges

49. 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.

50. ***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[12].

51. 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).

52. 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).

53. **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 seafloors 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 seafloor 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 seafloor and macrobenthos suffer severe changes especially in shallow coastal areas (e.g., Morello et al., 2005; Lucchetti and Sala, 2012).

54. **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

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[12] 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 bottom community composition (Pranovi et al., 2001).

3.3.4 Non-trawling small-scale fisheries and recreation fishing

55. 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).

3.3.5 Coastal artificialisation

56. Coastal artificialisation implies direct physical loss of seafloor but also indirect disturbance to the surroundings by changing hydrological conditions or increasing turbidity during construction.

57. Coastal artificialisation or urbanisation affects mainly the littoral and upper infralittoral seafloor and habitats. Littoral constructions such as ports, keys and dams, and beach management lead to sea-floor sealing and physical disturbance but also changes in hydrological conditions that change substrate and disturb habitats. The result is a physical loss of the seafloor 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).

58. There is no general overview of the scale of coastal artificialisation at the Mediterranean scale, although some countries have assessed the length of coastal artificialisation. For example, Italy estimated in 2006 that almost 16% of its coastline was artificial and Montenegro estimated that 32% of its coastline was built in 2013 (UNEP/MAP, 2017). The French Mediterranean coastline has an overate rate of artificialisation of 12% (MEDAM[13]).

3.3.6 Dredging and dumping

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

60. Dredging can be carried out for the following reasons[14]:

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***).

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[13] French MEDiterranean Coasts. Inventory and Impact of Reclamations from the Sea (MEDAM)

[14] European Dredging Association

61. 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 seafloor 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.

62. 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.

63. **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).

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

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

66. Capital dredging disturbs the dredged surroundings, also with an increase in turbidity, and represents a physical loss of seafloor 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 seafloor 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.

3.3.7 Anchoring

67. Anchors mechanically damage habitats by digging into the seafloor, 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 seafloor, 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).

68. 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.

69. 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.

70. 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.

3.3.8 Aquaculture activities

71. 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 seafloor (Knight et al., 2021). The impacts on the seafloor 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).

72. 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.

3.3.9 Gas and oil exploration and exploitation

73. 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).

74. 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).

75. For the Mediterranean Sea, experts consider that once platforms are installed, the actual physical damage to the seafloor (physical loss in this case) is relatively limited in terms of surface area compared to other activities (ICES, 2019a). 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; Harry, 2020). Gas and oil extraction has been ranked 15 on a scale that classifies 31 activities, rank 1 considered to be causing the greatest amount of physical disturbance to seafloor in the region (ICES, 2019a). 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 seafloor 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.

76. The installation of platforms disturbs the seafloor in the close vicinity but for a short time. Platforms though represent also a localised loss of seafloor 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.

3.3.10 Offshore wind farms

77. Installation of offshore wind farms impacts directly the sea-floor by loss of sea-floor habitat where the foundations are set and 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).

78. 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.

3.3.11 Mining

79. 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.

3.4 Pressures on the seabed

80. Assessing the state of the seabed can be done from two perspectives:

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.

81. 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.

3.4.1 Biological - non-indigenous species

82. 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).

83. 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 (

84. **Figure 4**). 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.

***Figure 4**. 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).*

3.4.2 Biological – extraction of wild species

85. Korpinen et al. (2019) provide data on bycatch 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 5**).

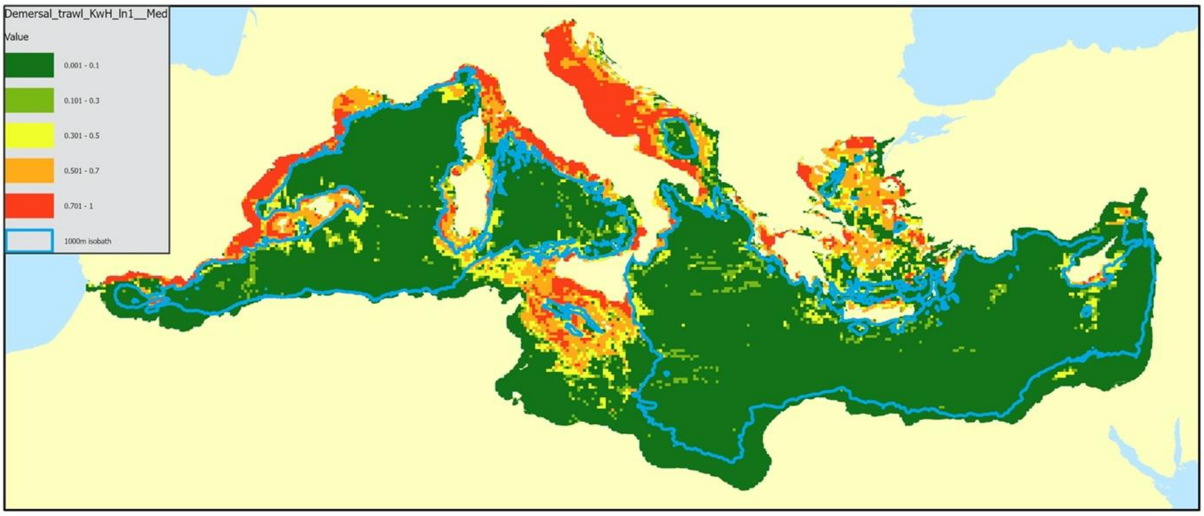

***Figure 5**. Distribution and intensity of demersal fishing for the year 2015, normalized to 0-1 scale, with 1 representing 1,549,089 kilowatts per fishing hour (redrawn from data in Korpinen et al., 2019). 1000m isobath also shown.*

86. 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. Data maybe lacking

for southern and eastern waters of the Mediterranean. Fishing activity was particularly intensive in the northern and western Adriatic, on the coast of Spain and on Italy's west coast. The general fishing pattern for 2015 (i.e., in areas above 1000m depth across the Mediterranean), is expected to be typical for each year.

87. 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).

88. 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 6**.

89. 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 3.3.2, **Figure 3**, **Figure 6**) 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.

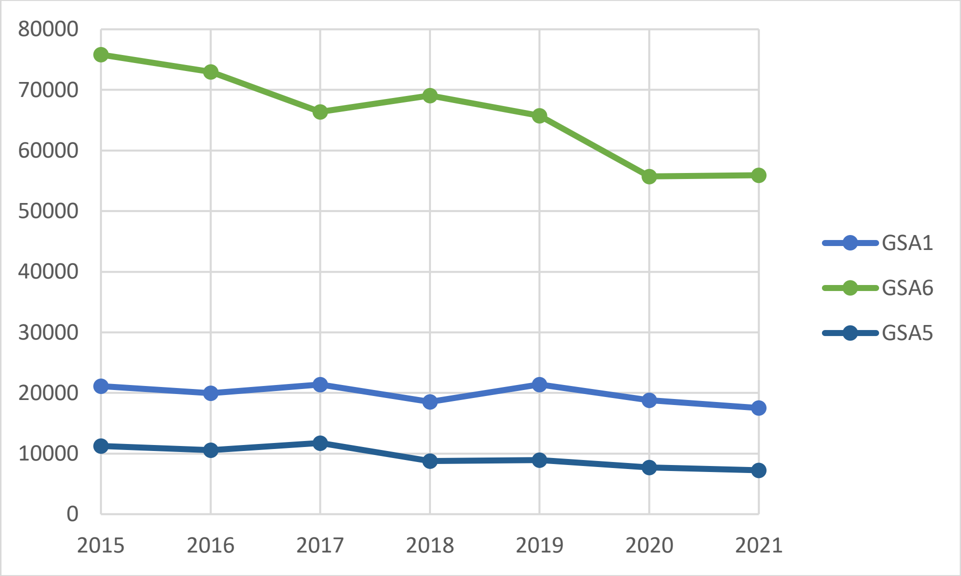

***Figure 6**. Total fishing effort in number of days for the bottom-trawl fleet in GSA1, GSA5 and GSA5 Mallorca and Menorca (western Mediterranean) calculated from VMS data..*

90. Demersal fishing is a major contributor to physical disturbance of the seabed (see section 93).

3.4.3 Physical - loss of the seabed

91. Physical loss of the seabed[15] 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 seabed, disposing waste material and dredged matter and all kinds of construction activity in or over the seabed (Korpinen et al., 2019).

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

92. 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). Figure **7** shows the number of physical loss-causing activities 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

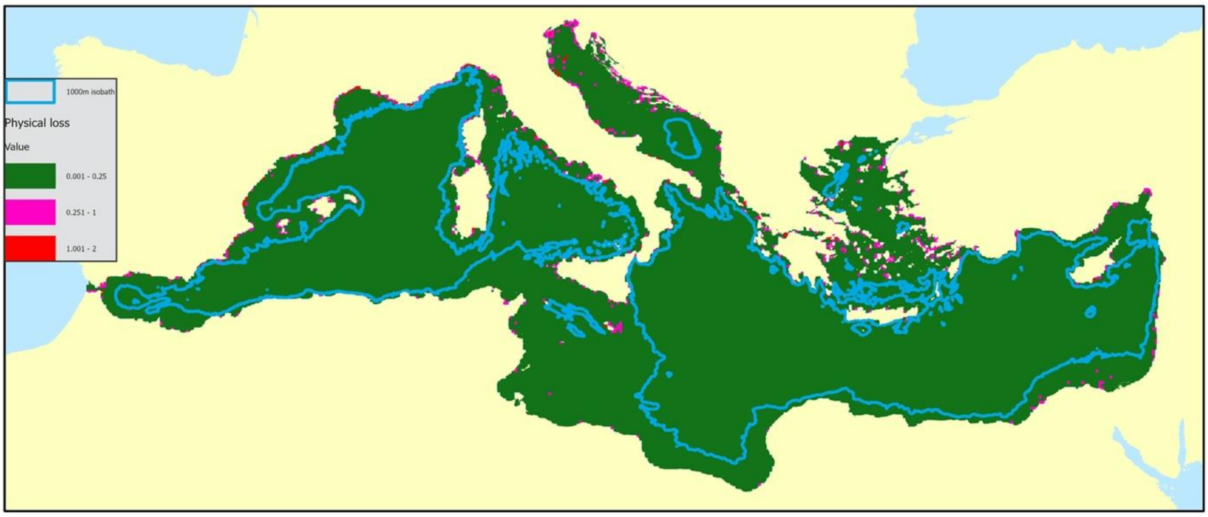

Figure 7*. Number of different activities causing physical loss of the seabed per 10km-by-10km grid cell (redrawn from data in Korpinen et al., 2019). See text for further details.*

93. 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-PAR/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).

94. 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-PAR/RAC (2023).

3.4.4 Physical - disturbance to the seabed

95. 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.

96. Korpinen et al. (2019) have prepared a data layer depicting the sum of all physical disturbance-causing activities per 10km-by-10km grid cell (Figure **8**), 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)
6. Windfarms (partial generation / under construction)
7. Windfarms (decommissioned)
8. Windfarms (operational)
9. Deposit of dredged matter
10. Oil platforms (offshore installations)

11. Aquaculture (finfish)
12. Aquaculture (shellfish)
13. Shipping in shallow water

97. All layers were converted to presence/absence data per 10km-by-10km grid cell[16] 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.

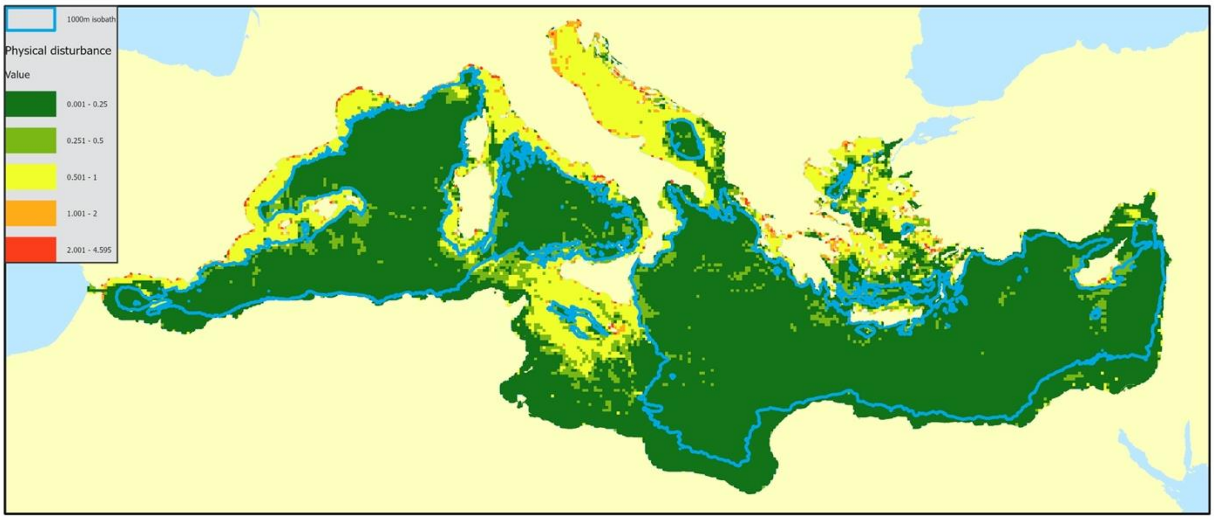

Figure 8*. Number of different activities causing physical disturbance to the seabed per 10km x 10km grid cell (redrawn from data in Korpinen et al., 2019). See text for further details. 1000m isobath also shown.*

98. 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 5**).

3.4.5 Physical – hydrographical pressures

99. 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 (**Figure 9**). Equivalent data for non-EU countries is not available.

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[16] 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.

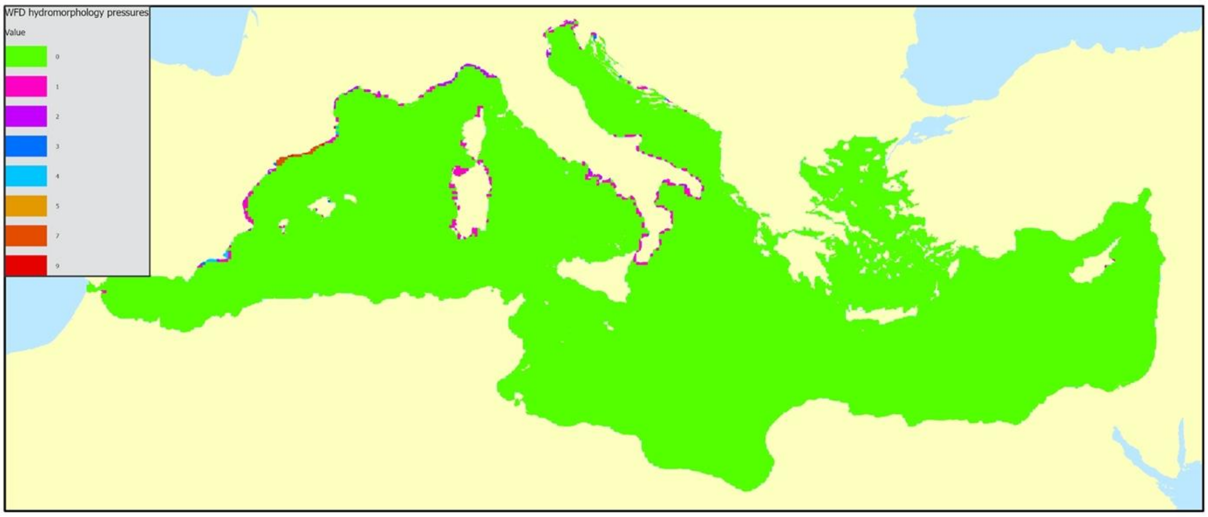


***Figure 9**. Number of different hydrographical pressures per 10km-by-10km grid cell, as reported by EU Member States for the Water Framework Directive in 2016 (redrawn from data in Korpinen et al., 2019).*

3.4.6 Land-based pollution – nutrient enrichment and contaminants

100. 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.

101. 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).

102. 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 (in total 25 % of the total discharge) are from the Rhone and the Po (Korpinen et al., 2019).

103. 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.

104. For the 2023 Med QSR under EO5, a eutrophication assessment was undertaken in the Adriatic Sea using the NEAT assessment tool (UNEP/MAP-MEDPOL, 2023a). The results indicate there is good to high overall status for all assessed areas, based on CI-13 (N and P) and CI-14 (Chlorophyll-a) (**Figure 10**), although several areas on the Italian coast are in moderate status for Total Phosphorus (TP).

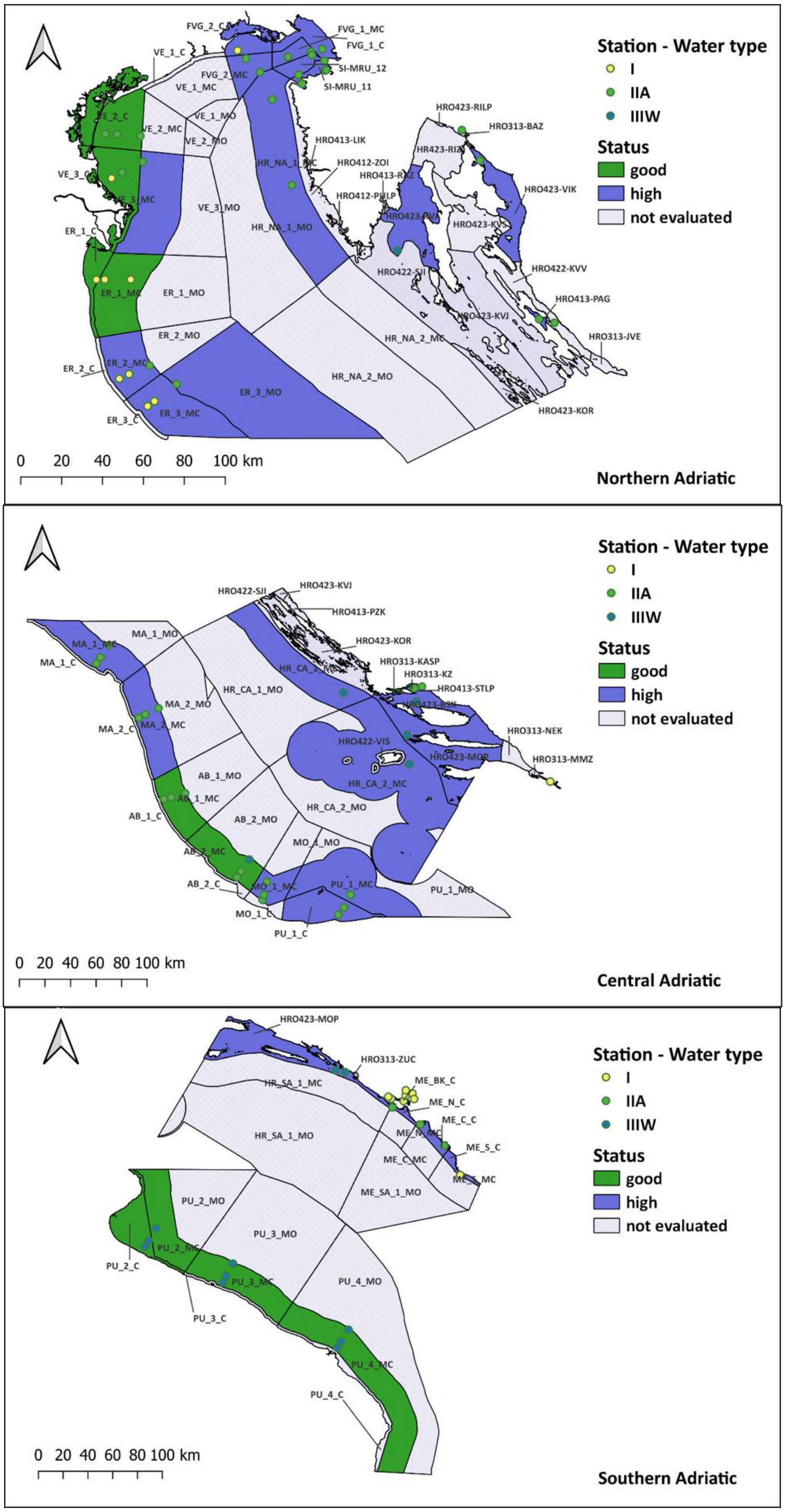


***Figure 10**. Eutrophication status under EO5 in north, central and south Adriatic Sea, based on NEAT assessment results for IMAP CI-13 and CI-14 in the North Adriatic Sea (UNEP/MAP MEDPOL, 2023a).*

105. In the Levantine Sea subregion, a simplified eutrophication assessment was undertaken for EO5 in the 2023 Med QSR, using satellite Chlorophyll-a data. Due to high geographical variability in the

biogeochemical processes at the 1km-by-1km scale used, only an indication of the possible environmental status is given (Figure 11). However, these additional assessment results indicated the main biogeochemical controlling processes in the Levantine Sea, i.e. the main impacted area located in front of Mersin and in the Iskenderun Bay, a slight impact along the coast of Israel and in the OW in the southern part of the Eastern Levantine Sea, as well as in front of Port Said and Alexandria, the weak influence of the Nile River, confirming the changes in the area caused by construction of the Aswan dam, and finally a coastal impact in the Tobruk area in the waters of Libya (UNEPMAP MEDPOL, 2023b).

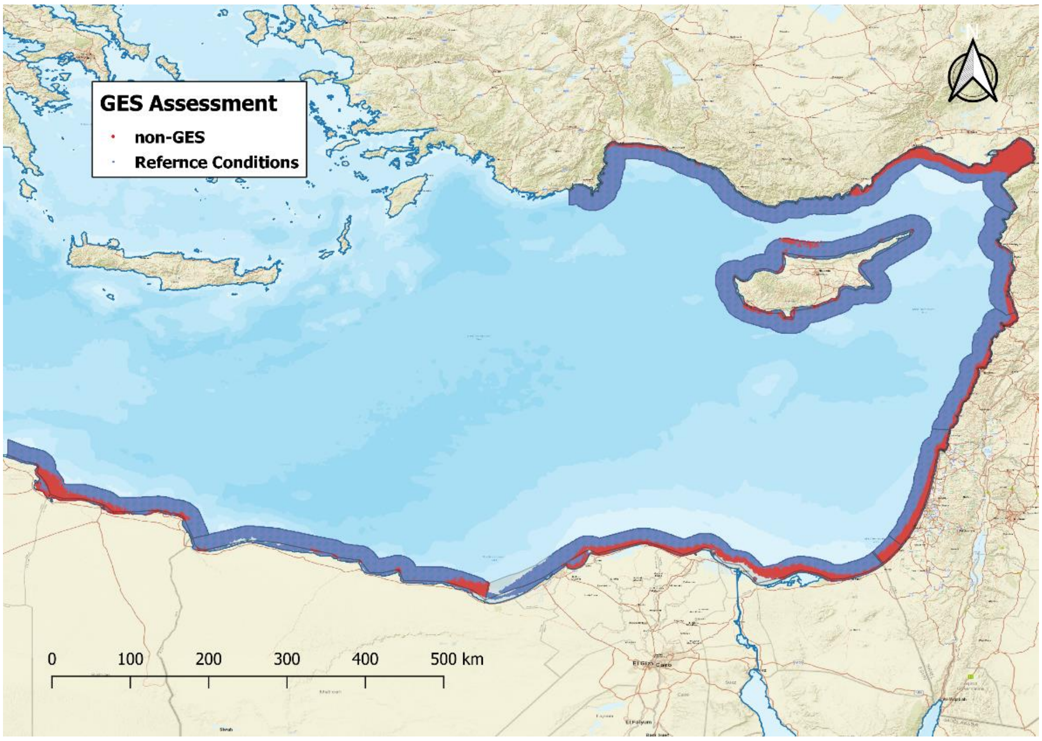


Figure 11. EO5 eutrophication assessment results for CI-14 in the Levantine Sea subdivision, based on satellite-derived Chlorophyll-a on a 1km-by- km (UNEP/MAP MEDPOL, 2023b).

106. 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.

107. 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).

108. 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.

3.4.7 Litter

109. 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).

110. On the sea-floor, plastic litter concentrates in specific depositional areas and although coastal areas show higher concentration in 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).

111. 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.

3.4.8 Climate change

112. 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).

113. 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 seafloor from climate change since these effects accumulate with other effects.

3.4.9 Blue carbon and the effects of bottom fishing

114. 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).

115. 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 CO2 (Liusetti et al. 2019).

116. 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).

117. 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).

3.4.10 Cumulative effects

118. 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 seafloor and its vulnerability. It is difficult to assess the cumulative impacts due to scattered data (Bevilacque et al., 2020). Although little is known about the cumulative impact threat, littoral Mediterranean habitats are more subject to an accumulation of threats than others. More generally, it is estimated that 20% of the entire Mediterranean basin is heavily impacted by cumulative impacts (Micheli et al., 2013a).

119. 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.

4 ASSESSMENT OF STATE

4.1 Theme selected for GES assessment

120. The assessment of seabed habitats (EO1) and sea-floor integrity (EO6) falls under the Biodiversity and Fisheries cluster of the IMAP. Both Ecological Objectives are considered in relation to the two agreed Common Indicators:

a. CI-1 – Habitat distributional range
b. CI-2 – Condition of the habitat's typical species and communities

121. These Common Indicators can be applied to the specific habitats of EO1 and the broad habitats of EO6. They can be considered equivalent to the MSFD criteria D6C4 (habitat extent) and D6C5 (habitat condition) respectively.

122. To assess environmental status of a habitat, and the extent to which GES has been achieved, requires agreed assessment methodology for each indicator, together with 'threshold values' which distinguish a habitat in a good state from one in a poor state. For CI-1, an 'extent threshold' value needs

to be set for the maximum allowable extent of loss of each habitat in the assessment area. For CI-2, a ‘quality threshold’ is needed for habitat condition to enable distinction between good and poor state at any given location of the habitat. A second ‘extent threshold’ is required for the maximum allowable extent of each habitat that can be in a poor state in the assessment area; the two thresholds are used together to define when a habitat is in GES. Following the approach adopted under the MSFD, this latter ‘extent threshold’ should include the ‘loss extent threshold’ (i.e., the loss is not in addition to the allowable extent of poor state, but part of it).

123. Under EO1, monitoring methods have been established and Contracting Parties have initiated data flows into the IMAP Info System (section 2.1.2.1). The agreed monitoring methods cover a wide range of possible techniques, yielding a variety of data types. The method of assessment of these data, and threshold values, are yet to be agreed under the IMAP.

124. For EO6, a proposal for a GES description, operational objectives and possible targets has been developed and will be considered within the IMAP during 2023 (UNEP/MAP-SPA/RAC 2023a).

125. Given the current level of development of assessment techniques for EO1 and EO6, it is only possible to present a preliminary approach to seabed habitat assessments for the 2023 Med QSR. This is done at a broad scale and with a focus on assessing the extent of pressures, as a proxy for impacts on habitats.

126. The assessment is presented as a pilot study for EO6 in the Adriatic Sea based on assessment of:

a. Three subdivisions of the Adriatic Sea (north, central, south);

b. Six habitat zones (e.g., infralittoral, circalittoral);

c. Four main pressures on the seabed (e.g., NIS, physical disturbance).

4.2 Assessment for CI-1 - Habitat distributional range

4.2.1 EO6 habitats

127. The current known distribution of broad habitat types is shown in **Figure 12** (Mediterranean Sea region) and **Figure 20** (Adriatic Sea subregion).

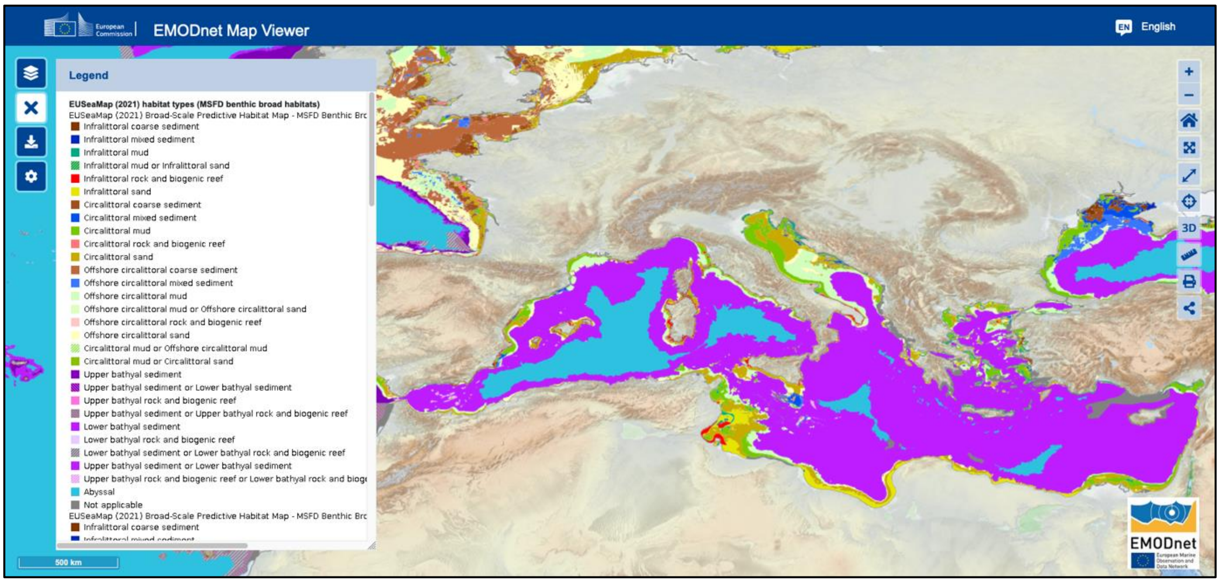


Figure 12. *EUSeaMap (2021) predicted map of MSFD broad habitat types in the Mediterranean Sea region, based on EUNIS (2019) habitat typology (from EMODnet, accessed 6 February 2023).*

128. The GES definition for CI-1 is 'the habitat is present in all its distributional range'. All broad habitat types are considered to exhibit a distributional range across the Mediterranean which is in line with prevailing physiographic, geographic and climatic conditions. Broad habitat types, at EUNIS level 2, are defined based on their substrate type and biological zonation. At this resolution, and because these broad habitat types are generally distributed throughout the Mediterranean (north to south, east to west), it is considered unlikely that distributional range will vary, although there is a slight possibility for the depth range of the infralittoral zone to vary due to changes in water clarity.

129. In addition to distributional range, the guidance fact sheet for CI-1 indicates there is a need to also consider loss of habitat extent. This aspect is relevant for all habitat types and can result from the building of infrastructure on the coast and offshore, from installation of artificial coastal sea defences, from bottom fishing, dredging and other activities. Habitat loss tends to be highest in coastal areas, due to the proximity to human populations and associated activities; it is also of more concern here because of the amount of loss relative to the limited extent of coastal habitats (zonation patterns in the coastal zone give rise to rapid changes in habitat type compared with offshore areas). Placement of offshore structures, such as gas platforms and wind turbines, provides a relatively small footprint of habitat loss compared to the larger scale of broad habitat types, but may be more concerning for specific threatened habitats (under EO1). Persistent use of mobile bottom-contacting fishing gears, over multiple years, can lead to significant changes in seabed substrate and morphology such that it is classed as habitat loss (EC, 2022).

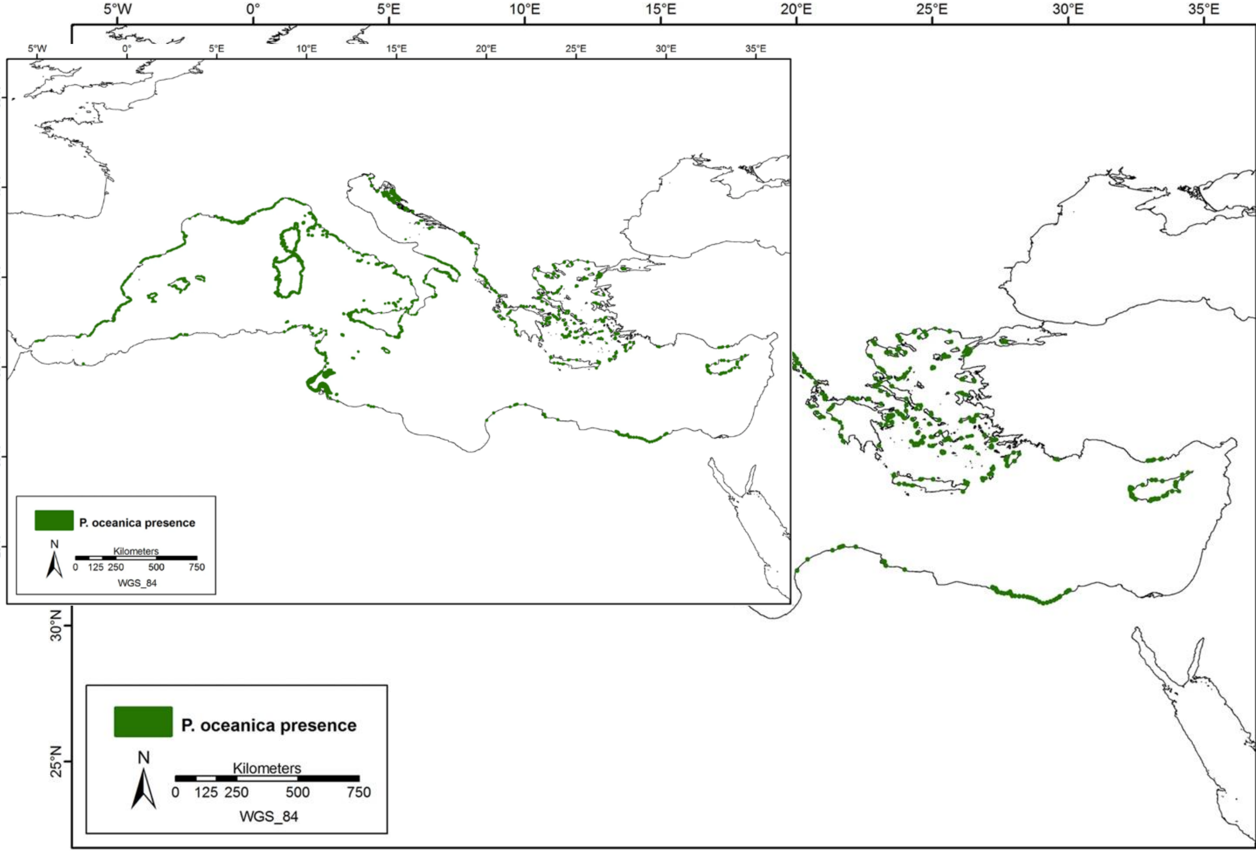
130. An assessment of status for CI-1 for EO6 requires a compilation of data on the extent of habitat loss per broad habitat type in each assessment area and an evaluation of these data in relation to a GES threshold value (value X% as maximum allowable extent of habitat loss in **Table 2**). Suitable data should be available from EU Member States who have undertaken an MSFD Article 8 assessment for Descriptor 6 criteria D6C1 and D6C4 and could start to be compiled by other Contracting Parties when the proposal for EO6 is adopted into the IMAP.

4.2.2 EO1 habitats

131. Distribution maps for the three EO1 habitats for which data are being reported under the IMAP monitoring programme are shown with IMAP data reported up to December 2022 (from Israel, Italy, Malta, Spain and Slovenia), as well as data and models from other sources:

a. Coralligenous habitat (**Figure 13**, **Figure 14**);
b. Maerl and rhodoliths habitat (**Figure 15**, **Figure 16**);

c. Posidonia oceanica meadows (**Figure 17**, **Figure 18**).



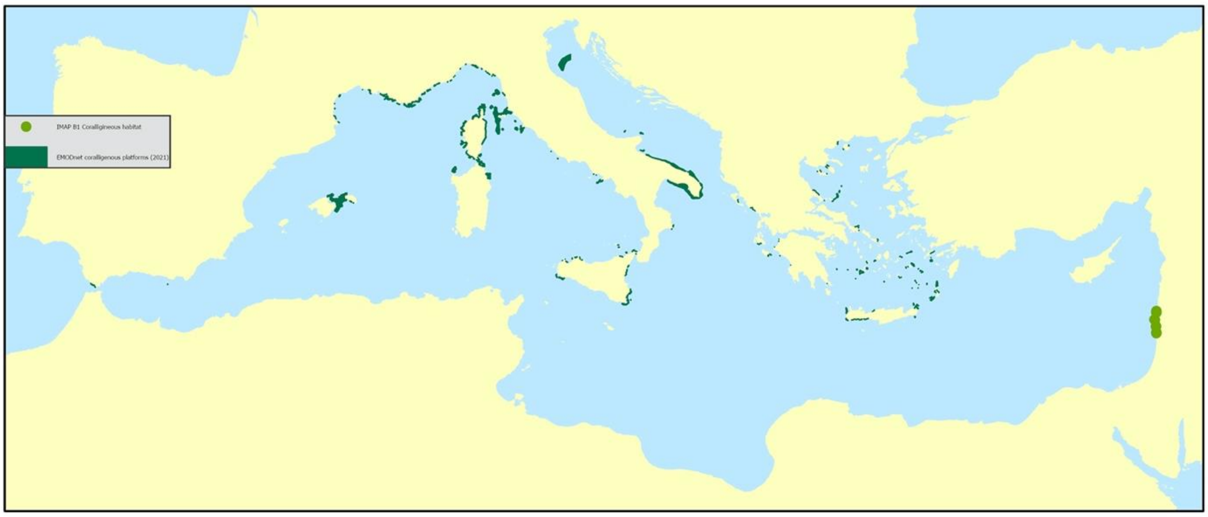


Figure 13*. Distribution of Coralligenous habitat in the Mediterranean Sea, based on data reported under IMAP (up to December 2022) (data points enlarged to enhance visibility) and from EMODnet (2021).*

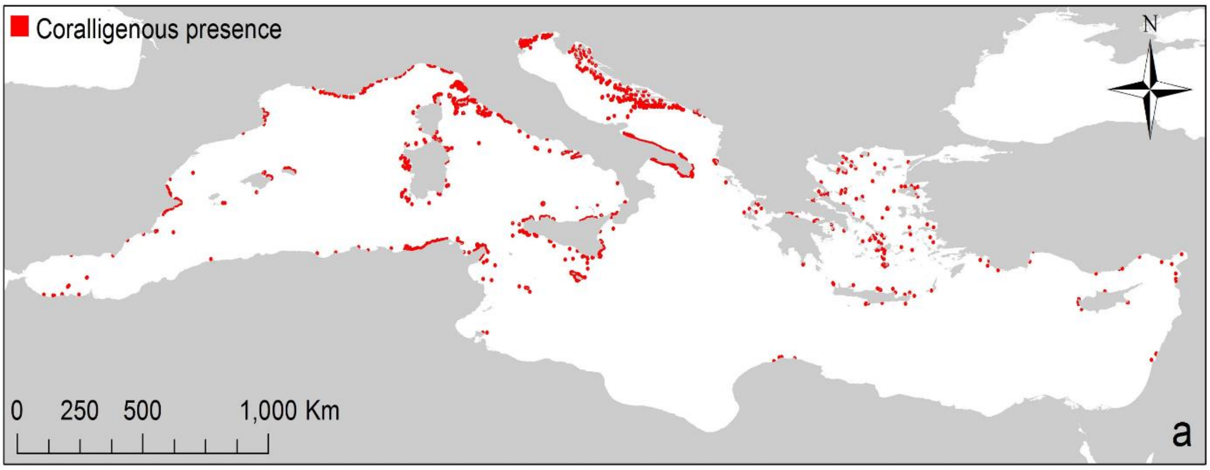


***Figure 14**. Modelled distribution of Coralligenous habitat in the Mediterranean Sea (red areas) (from Corine et al., 2014).*

***Figure 15**. Distribution of maerl and rhodoliths habitat in the Mediterranean Sea, based on data reported under IMAP (up to December 2022) (data points enlarged to enhance visibility).*

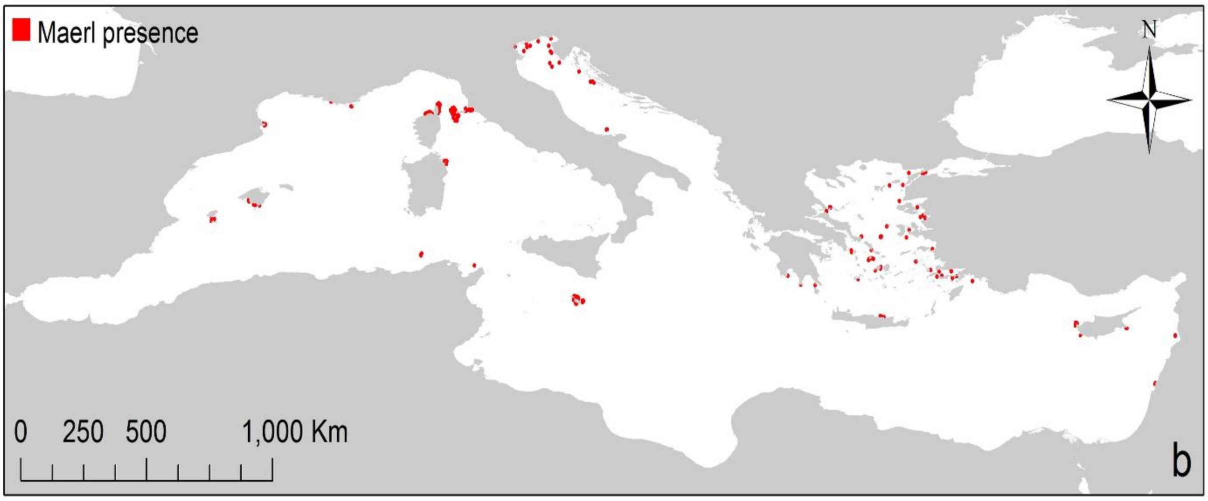


***Figure 16**. Modelled distribution of maerl habitat in the Mediterranean Sea (red areas) (from Corine et al., 2014).*

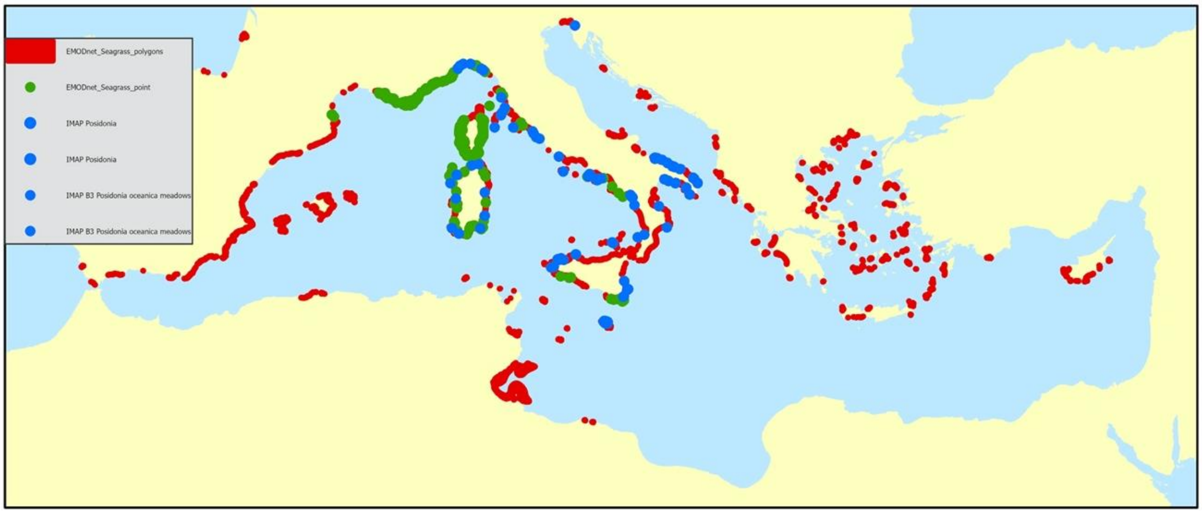


***Figure 17**. Distribution of* Posidonia oceanica *meadows, based on data reported under IMAP (up to December 2022) and from EMODnet (2021) (data points enlarged to enhance visibility).*

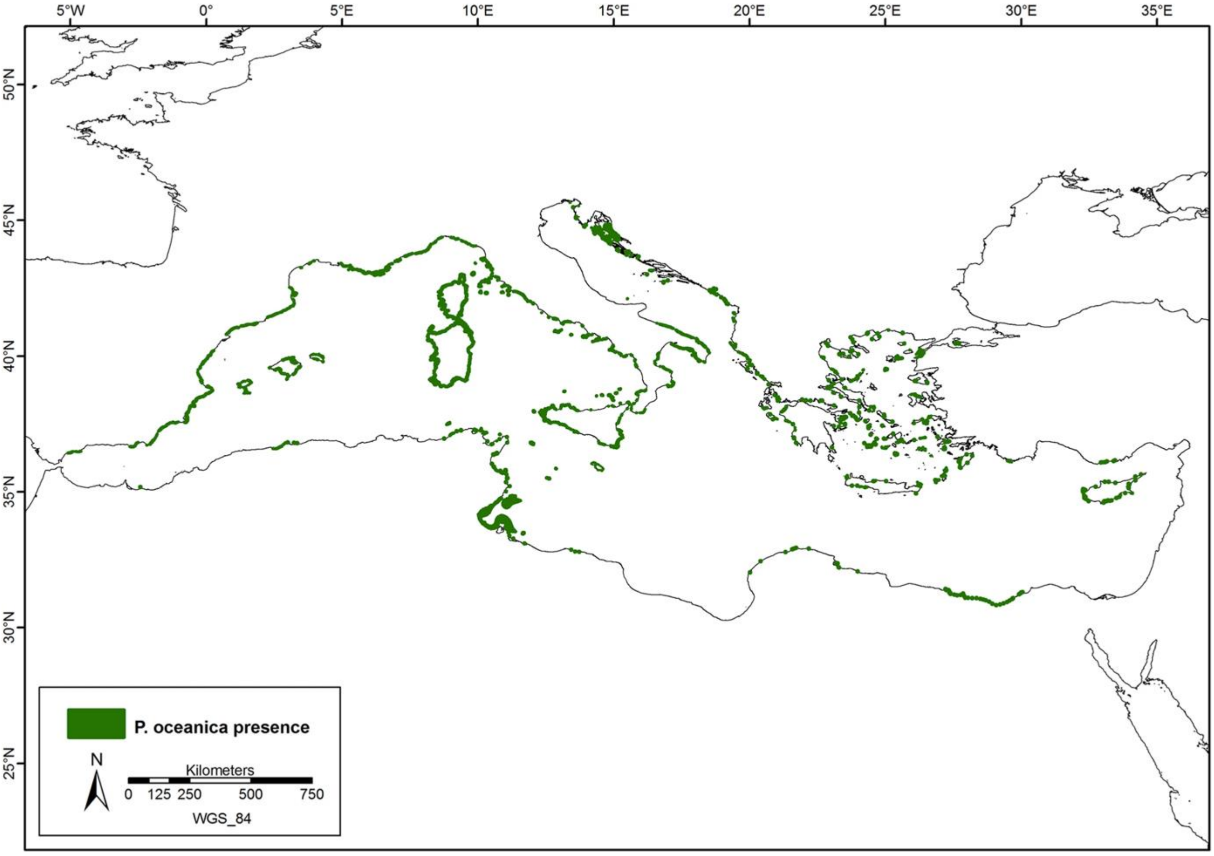


***Figure 18**. Distribution of Posidonia oceanica meadows in the Mediterranean Sea (green areas) (from Telesca et al., 2015).*

132. The GES definition for CI-1 is ‘the habitat is present in all its distributional range’. All specific habitat types currently addressed by EO1 are considered to exhibit a distributional range across the Mediterranean which is in line with prevailing physiographic, geographic and climatic conditions. Despite the finer resolution of EO1 habitats compared with the broad habitat types under EO6, these EO1 habitat types are generally distributed throughout the Mediterranean (north to south, east to west), making it difficult to detect changes in distributional range will vary at the Mediterranean Sea scale. There is a slight possibility for the depth range of infralittoral/circalittoral habitats, such as maerl, to vary due to changes in water clarity (e.g., by changing the depth of the infralittoral zone).

133. In addition to distributional range, the guidance fact sheet for CI-1 indicates there is a need to also consider loss of habitat extent. This aspect is relevant for all habitat types and is often a particular concern for habitats which are sensitive to specific pressures, such as physical loss and disturbance, and hence there inclusion as threatened habitats under EO1. Use of certain bottom fishing gears and anchoring of large vessels leads to habitat loss and damage of *Posidonia oceanica* meadows, other types of seagrass beds and maerl beds. Poor water quality in coastal areas, from input of contaminants and nutrient enrichment, also leads to loss in habitat extent.

4.3 Assessment for CI-2 - Habitat condition

4.3.1 EO6 habitats

134. Assessment of broad habitat types over large sea areas and the entire Mediterranean Sea basin requires a different approach to that traditionally applied to specific habitats, such as those under EO1. This can be achieved through use of modelled data and collation of data on activities and pressures. See section 4.4 for a pilot assessment, based on pressure data layers for the whole Mediterranean Sea region.

4.3.2 EO1 habitats

135. As indicated in section 4.1, monitoring methods have been established for three EO1 habitats and Contracting Parties have initiated data flows into the IMAP Info System (section 2.1.2.1). The agreed monitoring methods cover a wide range of possible techniques, yielding a variety of data types. The method of assessment of these data, and threshold values, are yet to be agreed under the IMAP. At present, it is therefore not feasible to assess CI-2 for EO1 habitat types. There is, however, a rich scientific literature that describes the state of these habitats and provides evidence of poor state in multiple locations across the region.

4.4 Pilot assessment for EO6 – Adriatic Sea

136. A pilot assessment of broad habitat types in the Adriatic Sea is presented here, based on:

a. Three assessment areas (subdivisions of the Adriatic Sea) (north, central, south)[17];

b. Six habitat zones (infralittoral, circalittoral, offshore circalittoral, bathyal <1000m, bathyal >1000m, abyssal)[18];

c. Four pressures (non-indigenous species, physical loss, physical disturbance, hydrographical changes)[19].

137. The assessment has been undertaken at a relatively coarse scale (biological zones, each representing five broad habitat types) as the available data on pressures is at a 10km-by-10km resolution. The extent of pressures, and their intensity, is used as a proxy for impacts on the seabed.

4.4.1 Input data

138. The input data sets are shown below.

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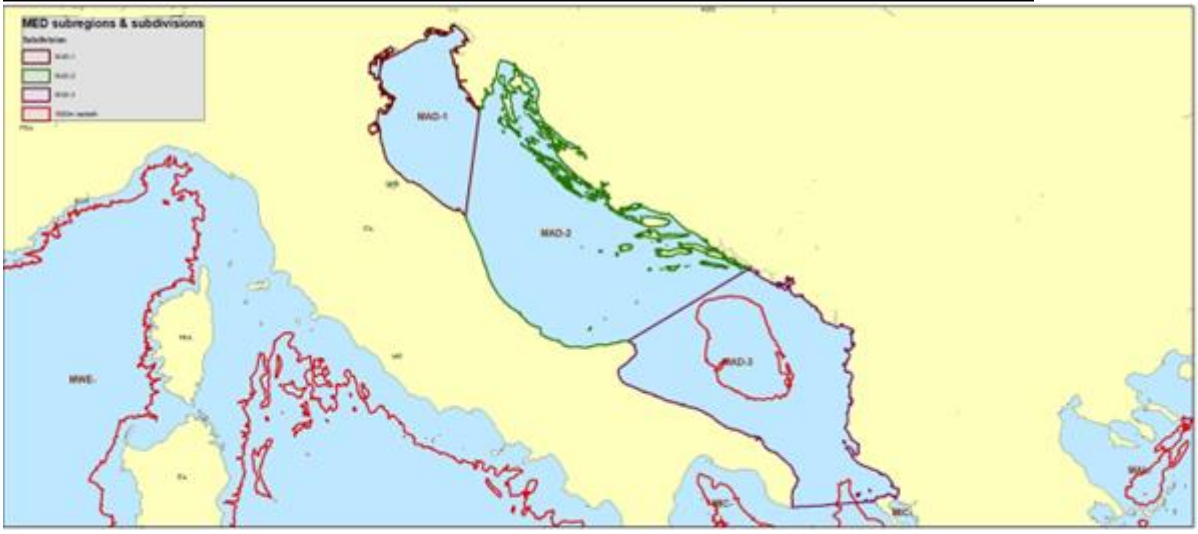
[17] Subdivisions provided by EC DG Environment for a study on the distribution and intensity of bottom fishing (STECF, 2022) undertaken to support preparation of the EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries for the EU Biodiversity Strategy for 2030.

[18] These biological zones form the basis of the habitat typologies of the Barcelona Convention (Montefalcone et al., 2021) and EUNIS (2019), and are used to prepare the EUSeaMap (2021) predicted habitat map of EMODnet.

[19] Pressure data from Korpinen et al. (2019), provided by ETC-ICM (Samuli Korpinen, Syke, Finland).

Subdivisions of the Adriatic Sea (**Figure 19**)



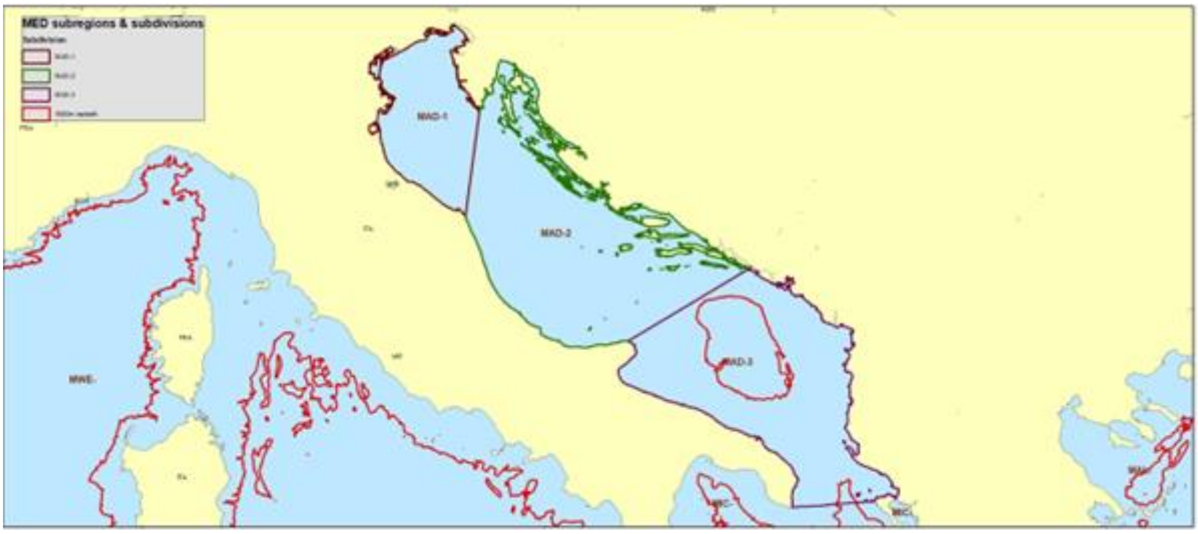


Figure 19*. Subdivisions of the Adriatic Sea subregion, and 1000m isobath*[20]

Habitat zones

139. See **Figure 20** for a map of the MSFD broad habitat types from EUSeaMap (2021). The pilot assessment has been undertaken at the level of the biological zone, rather than the individual broad habitat types (rock and biogenic reef, coarse sediment, mixed sediment, sand, mud) within each zone, as the resolution of the pressure data, on a 10km-by-10km grid cell scale, does not justify a finer analysis. Note that in the assessment the bathyal zone has been split at 1000m depth (**Figure 21**) to show the differences in physical disturbance by bottom fishing above and below this isobath (bottom fishing is banned below 1000m depth in the Mediterranean Sea).

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[20] Isobath data from Tools4MSP, provided by CNR (Elizabeth de Maio, Italian National Research Council).

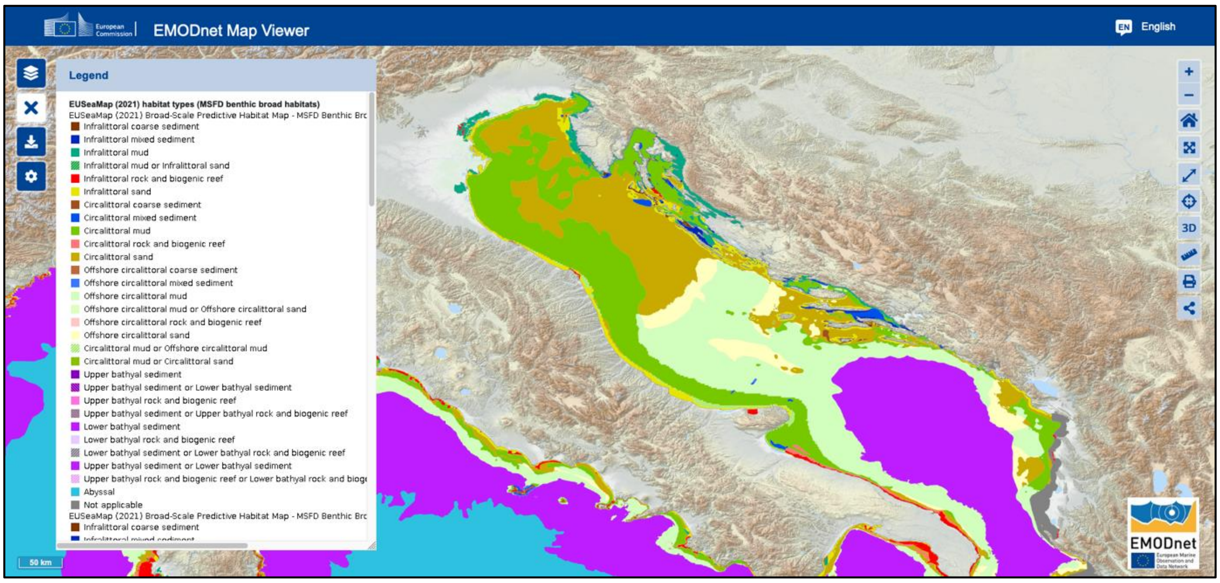


Figure 20. *EUSeaMap (2021) predicted map of MSFD broad habitat types in the Adriatic Sea subregion, based on EUNIS (2019) habitat typology (from EMODnet, accessed 6 February 2023)*

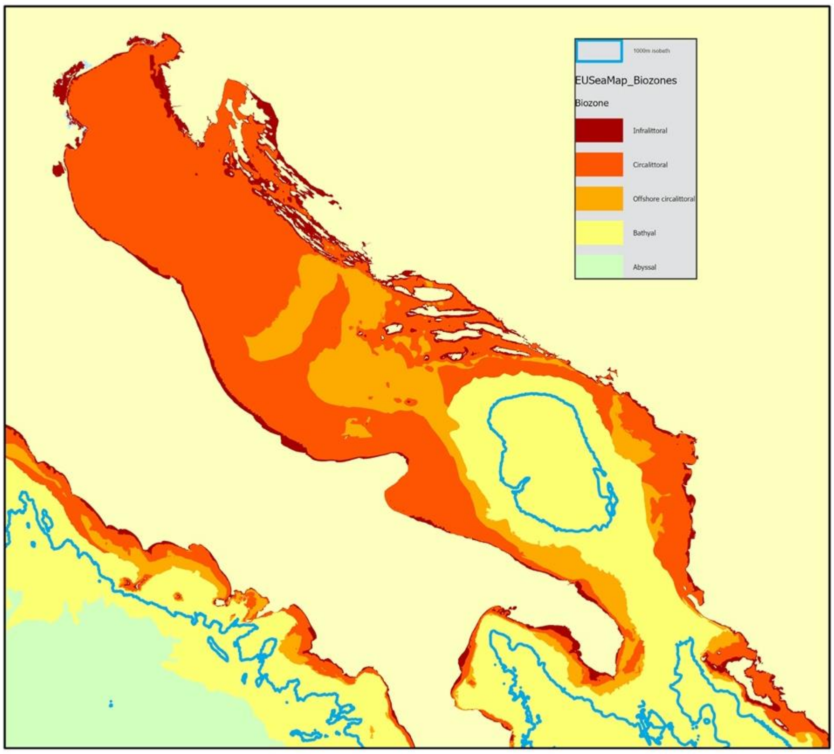


Figure 21. *Biozones from EUSeaMap (2021) predicted map of MSFD broad habitat types in the Adriatic Sea subregion, based on EUNIS (2019) habitat typology (redrawn from EMODnet, 2021). 1000m isobath also shown.*

Pressures

140. The input data on pressures, as described in section 3.4, is shown for the Adriatic Sea as follows:

a. non-indigenous species (**Figure 22**)

b. physical loss (**Figure 23**)**Erreur ! Source du renvoi introuvable.**

c. physical disturbance (**Figure 24**)

d. hydrographical changes (**Figure 25**)

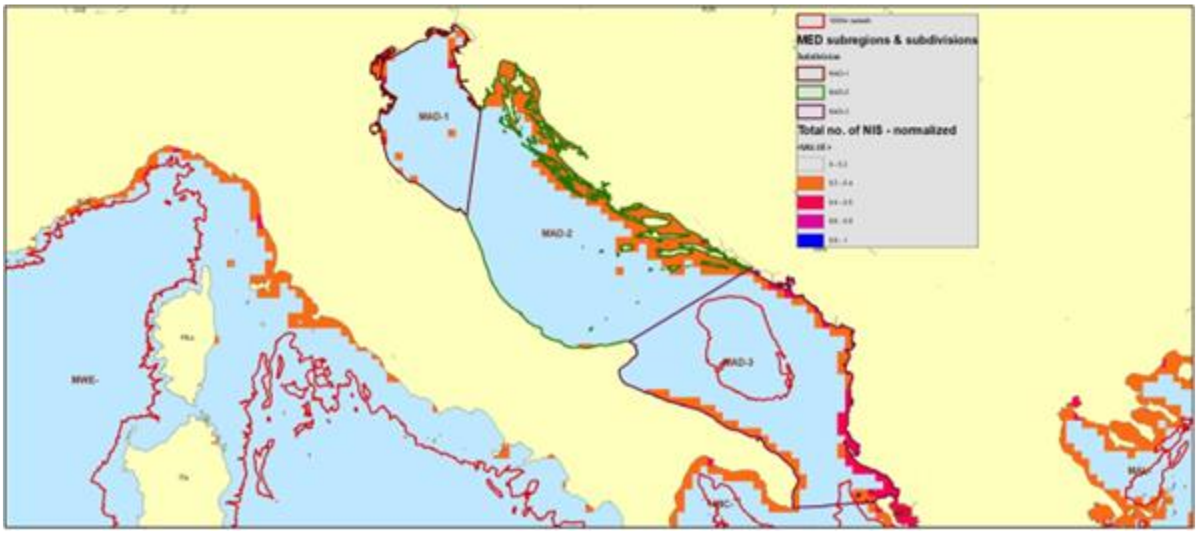


Figure 22. *Total number of non-indigenous species per 10km-by-10km grid cell (maximum 39 in full dataset), normalised to 0-1 scale (redrawn from data in Korpinen et al., 2019). See section 3.4.1 for details.*

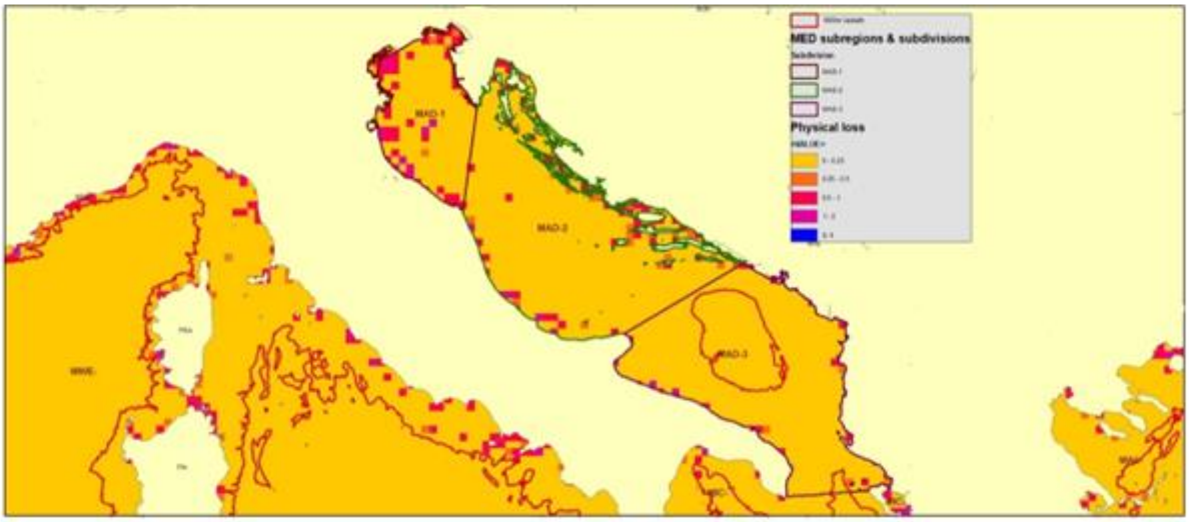


Figure 23. *Total number of physical loss-causing activities per 10km-by-10km grid cell (maximum 4) (redrawn from data in Korpinen et al., 2019). See section 3.4.3 for details.*

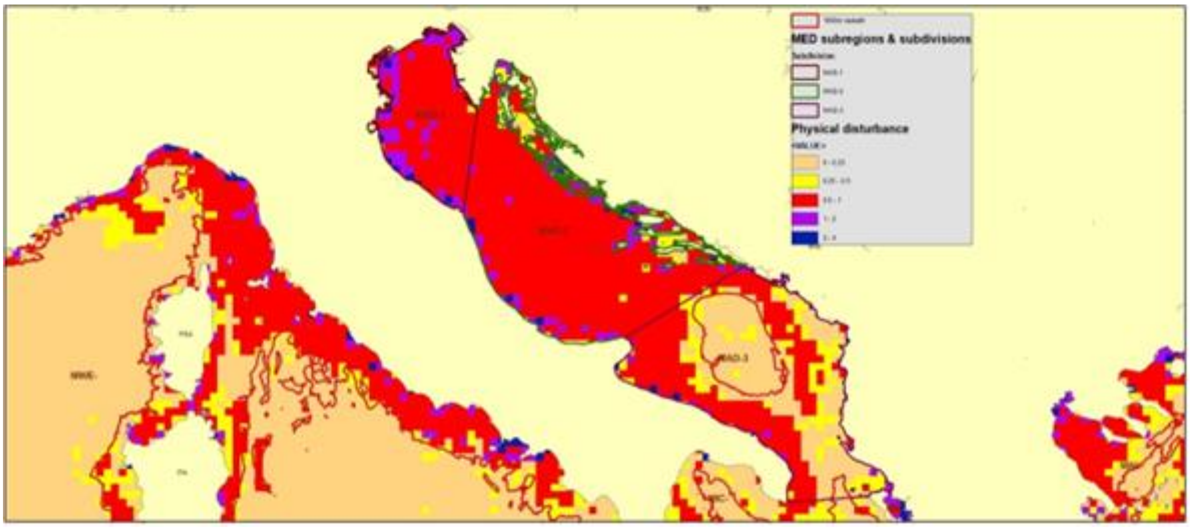


Figure 24. Total number of physical disturbance-causing activities per 10km-by-10km grid cell (maximum 4) (redrawn from data in Korpinen et al., 2019). See section 93 for details.

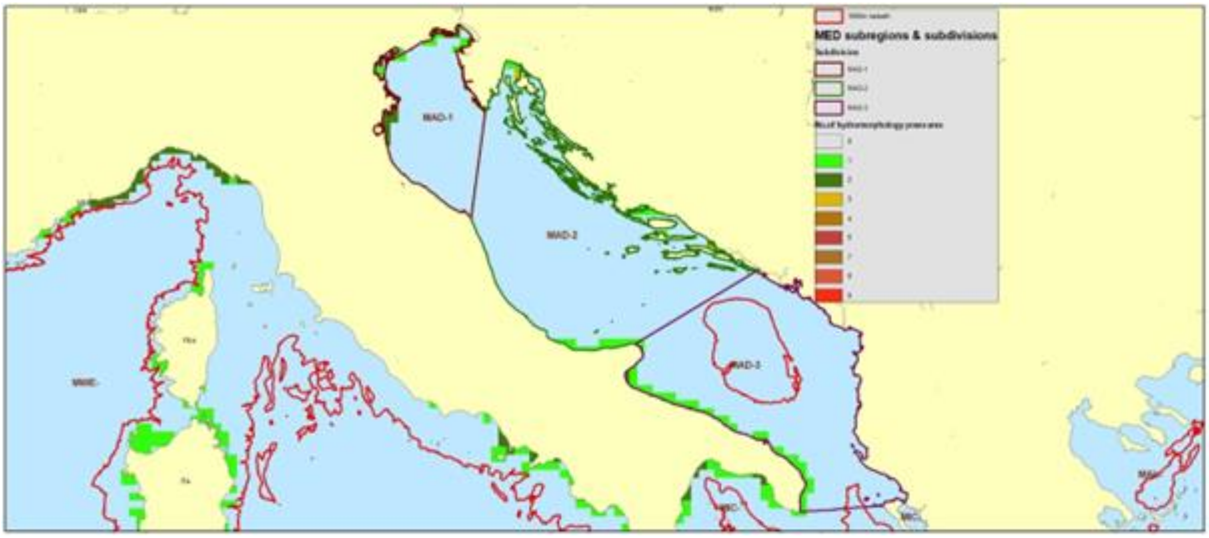


Figure 25*. Total number of hydrological pressures per 10km-by-10km grid cell (maximum 9) reported under WFD (redrawn from data in Korpinen et al., 2019). See section 3.4.5 for details.*

141. The data from Korpinen et al. (2019) are in a common format per pressure (10km-by-10km grid), making it possible, for the first time, to undertake a pan-Mediterranean analysis in relation to seabed habitats. It should, however, be noted that the physical loss, physical disturbance and hydrographical changes data layers provide the number of activities yielding each pressure in each grid cell, but do not indicate the extent, intensity or frequency of those activities within the grid cell; consequently, they may both underestimate and overestimate the amount of pressure (and its impacts) per grid cell. For example, a grid cell with a score of one for physical disturbance indicates it is affected by a single activity (e.g., bottom fishing), but the extent and intensity of bottom fishing is not reflected: the grid cell could be fished over 10 times per year across 100% of the grid cell, or it could be the result of a single fishing event in one part of the grid cell. In this sense, the use of the pressure data should be considered a first estimate of the scale of pressures affecting the seabed per grid cell.

4.4.2 Data processing

142. The assessment was undertaken as follows for each of the three subdivisions of the Adriatic Sea:

a. The proportion (%) of each habitat zone was estimated;
b. The proportion (%) of each pressure in each zone was estimated;

c. The proportion (%) of each pressure in the subdivision was calculated from the values in (a) and (b);

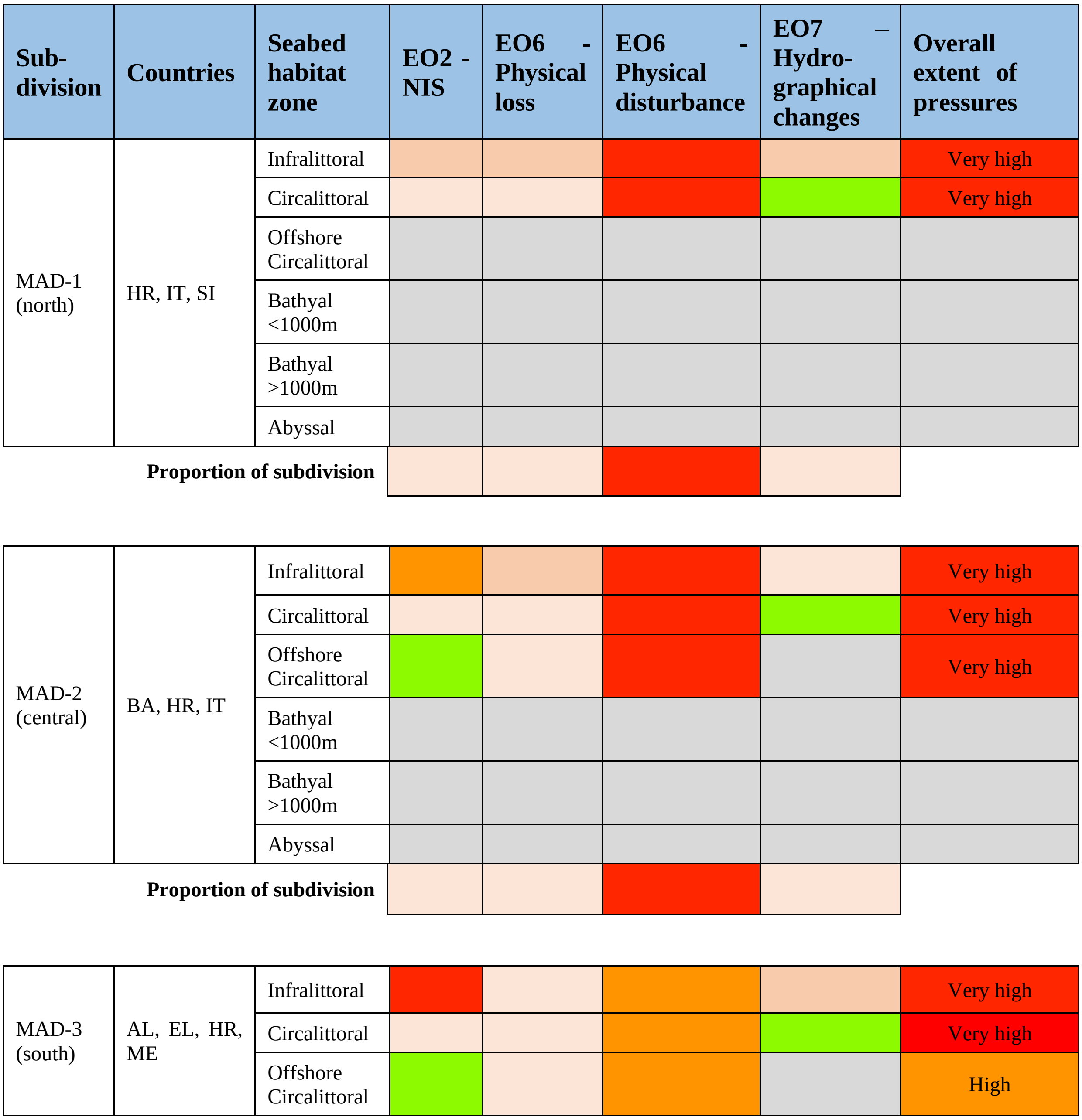
d. The values for (b) and (c) were allocated to one of five pressure classes (0, 1-25%, 26-50%, 51-75%, 76-100%) to indicate the extent of pressure per zone and subdivision, plus an overall ranking across all pressures per zone. This generalisation of the data is because the interpolation between 10km-by-10km pressure data and the habitat mapping data may not justify a finer level of precision. It also allows for a colour coding of the results that is easier to visualise.

4.4.3 Results of the pilot assessment

143. The results are presented in **Table 6**.

***Table 6**. Pilot assessment of three areas (subdivisions) in the Adriatic Sea.*

The extent of four pressures in relation to six seabed habitat zones provides an indication of the level of pressure to which each habitat zone is subject, and the overall extent of pressures per zone. See key for colour codes.



Sub-division	**Countries**	**Seabed habitat zone**	**EO2 - NIS**	**EO6 - Physical loss**	**EO6 - Physical disturbance**	**EO7 – Hydro-graphical changes**	**Overall extent of pressures**
MAD-1 (north)	HR, IT, SI	Infralittoral	▒	▒	🟥	▒	🟥 Very high
		Circalittoral	░	░	🟥	🟩	🟥 Very high
		Offshore Circalittoral	▨	▨	▨	▨	▨
		Bathyal <1000m	▨	▨	▨	▨	▨
		Bathyal >1000m	▨	▨	▨	▨	▨
		Abyssal	▨	▨	▨	▨	▨
		Proportion of subdivision	░	░	🟥	░	
MAD-2 (central)	BA, HR, IT	Infralittoral	🟧	▒	🟥	░	🟥 Very high
		Circalittoral	░	░	🟥	🟩	🟥 Very high
		Offshore Circalittoral	🟩	░	🟥	▨	🟥 Very high
		Bathyal <1000m	▨	▨	▨	▨	▨
		Bathyal >1000m	▨	▨	▨	▨	▨
		Abyssal	▨	▨	▨	▨	▨
		Proportion of subdivision	░	░	🟥	░	
MAD-3 (south)	AL, EL, HR, ME	Infralittoral	🟥	░	🟧	▒	🟥 Very high
		Circalittoral	░	░	🟧	🟩	🟥 Very high
		Offshore Circalittoral	🟩	░	🟧	▨	🟧 High

Sub-division	Countries	Seabed habitat zone	EO2 - NIS	EO6 - Physical loss	EO6 - Physical disturbance	EO7 – Hydro-graphical changes	Overall extent of pressures
		Bathyal <1000m	🟩	🟩	🟧	▨	High
		Bathyal >1000m	🟩	🟩	◻	▨	Low
		Abyssal	▨	▨	▨	▨	▨
		Proportion of subdivision	◻	◻	🟧	◻	

Key:

% of zone with pressure	0	1-25	26-50	51-75	76-100	Habitat not present or not assessed
Pressure class	None	Low	Moderate	High	Very high	

144. The results indicate:

a. The four pressures affect nearly all habitat zones in all assessment areas;

b. The extent of physical loss and hydrographical changes is low to moderate in most habitat zones and assessment areas;

c. The extent of non-indigenous species is high to very high in central and south Adriatic Sea areas;

d. Physical disturbance is by far the most extensive pressure, with a very high extent in all habitat zones in north and central Adriatic Sea (MAD-1, MAD-2). In south Adriatic Sea (MAD-3) it has a high extent in all habitat zones, excepting below 1000m depth; this slightly lower extent of the pressure compared to north and central areas may be due in part to a lack of data in eastern areas.

e. The combined effects of the four pressures means that all habitats in north and central assessment areas (MAD-1, MAD-2) are subject to pressures across a very high proportion of each habitat zone. Only offshore circalittoral and bathyal zones <1000m in the south Adriatic area (MAD-3) exhibit a slightly lower (high) extent of pressure, and bathyal >1000m has a low extent of pressure.

f. Extent of pressures (individual and cumulatively) provides a preliminary indication of the state of the seabed in these three assessment areas and needs to be supported by direct observational data for the different habitat types to enable an assessment of habitat condition.

5 KEY FINDINGS PER CI

5.1.1 CI-1 – habitat distributional range

145. The distributional range of broad and fine habitat types is considered to generally be in line with prevailing physiographic, geographic and climatic conditions.

146. All habitats may be subject to habitat loss; this is more pronounced in the coastal zone, due to the greater intensity of coastal infrastructures and sea defences; habitat loss is of particular concern for specific habitats under EO1. However, persistent use of bottom-contacting fishing gears can also lead to habitat loss, which may affect extensive areas on the continental shelf and slope.

147. Assessment of CI-1 requires the setting of an ‘extent threshold’ and improvement in the availability of data on habitat extent and loss. A key basis for this is the provision by Contracting Parties of improved habitat maps (both broad- and fine-scale), making these available for compilation at Mediterranean-region scale (broad habitat maps via EMODnet, other habitat types via the IMAP Info System).

5.1.2 CI-2 – habitat condition

148. Habitat condition in the Mediterranean Sea region is affected by multiple pressures. There is a greater range of pressures in the narrow coastal zone, whilst the offshore and bathyal zones, down to 1000m depth, are most affected by physical disturbance pressures.

149. Due to narrow nature of the continental shelf across much of the Mediterranean (excepting in the Adriatic Sea and the Strait of Sicily), the bathyal zone, below 1000m depth, and abyssal zone account for a very high proportion of the Mediterranean Sea. In these zones, bottom fishing is banned leading to much lower levels of physical disturbance, although the seabed may be subject to effects of contaminants accumulating in deep-sea sediments and to the accumulation of litter, such as in canyons.

150. Bottom fishing accounts for the vast majority of the physical disturbance, covering up to 90% or more of the seabed (at 10km-by-10km grid cell resolution) in coastal and offshore areas. In some areas this may represent an overestimate of the extent of physical disturbance, due to the grid-cell resolution and use of presence/absence data.

151. Under the IMAP, Contracting Parties have started to submit data on the condition of three specified habitats for EO1; data across the entire region are needed to enable an assessment of habitat condition for these habitat types. In addition, methods of interpreting these data (through specific indicators) and a setting of threshold values are needed to enable assessment against the GES definition in future QSRs.

152. For broad habitat types, improvements in the availability and resolution of pressure data, and in relating these data to the state (condition) of the habitats are needed. This would lead to a more robust assessment than has been presented here in the pilot study.

153. Data on pressures and habitat state are generally more available in northern parts of the Mediterranean, which may incorrectly imply that these areas are in a worse state than southern areas. An effort should therefore be made to ensure an even level of data are available across the region

6 MEASURES AND ACTIONS REQUIRED TO ACHIEVE GES

154. Despite many decades of scientific study on particular habitats in specific locations, systematic assessment of seabed habitats, both broad-scale and fine-scale, for the Mediterranean Sea as a whole is generally at an early stage of development. However, the knowledge base and assessment methodologies are under rapid development and offer good prospects for future QSRs.

155. Improvement in the availability of data is needed for:

a. Habitat maps – these provide the fundamental basis for habitat assessments and need to be further improved in quality and accuracy. The EUSeaMap full coverage map of broad habitat types relies on the quality of the underlying input data, especially on seabed substrates, and needs to be improved across much of the region. Countries should be encouraged to contribute mapping data to help improve the region-wide seabed mapping;

b. Activities and pressures – the mapping of pressures, using activities as a basis, provides a good means to assess the wider seabed of the region. These data are generally more easily (and cheaply) collected than direct observational data of the seabed, offering a more cost-effective means to undertake assessments. Further, such data are important for management of pressures (i.e., reducing pressures in areas to help achieved GES) and for marine spatial planning; further data collection is needed, particularly in the south and east, to provide an even coverage across the Mediterranean. The current region-wide datasets of activities and pressures (from the EEA/ETC-ICM) are at a 10km-by-10km grid resolution – for use in relation to seabed assessments, the data need to be prepared at a finer resolution;

c. Monitoring data on the state of the seabed – the traditional collection of direct observations of the seabed (e.g., through video and sampling) remains an important aspect of data collection programmes, providing a means to validate pressure data to assess seabed habitat condition. Monitoring programmes are costly and need to be focused on the needs of assessment and measures to ensure good value. To facilitate pan-regional assessments, the monitoring data need to be compatible between countries, following specified data standards; further data collection is needed, particularly in the south and east, to provide an even coverage across the Mediterranean;

d. Pressure-state interactions – there is continued need for study of pressure-state interactions, both at research level and through state assessments, to improve confidence in use of pressure data (such as a proxy for broad-scale state assessments);

e. Climate change – the effects of climate change on the seabed and its communities need to be better understood; of particular importance is assessment of the carbon storage capacity of marine habitats and the contribution this makes to mitigation of climate change effects; the importance of shallow vegetated habitats, such as *Posidonia oceanica* meadows, for blue carbon is often highlighted, but the carbon sequestration capacity of the much more extensive soft sediment habitats of the shelf zone and its disruption by physical disturbance pressures is ultimately a more important knowledge gap;

f. Assessment methods – further work is needed to develop specific indicators (or test existing indicators available in other regions) for use with the monitoring data, and to bring the assessment methods to a fully operational level. Based on these methods, Contracting Parties need to agree threshold values to provide a clear means to assess the extent to which GES has been achieved;

g. Assessment results – the availability of seabed assessment results, including visualisation of the extent of GES in each part of the region, provides an important output that demonstrates the work of the IMAP and Contracting Parties, stimulates improvements and helps direct actions towards achieving GES.

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