UNITED NATIONS

UNEP

EP

UNEP/MED WG.547/Inf.4

United Nations
Environment Programme
Mediterranean Action Plan

Distr.: Limited
24 February 2023

Original: English

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

Athens, Greece, 9-10 March 2023

Agenda Item 4: Development of IMAP EOs

4.2. Development of the EO6

Outcomes of the desk review of available data sources, best practices and methodologies in the Mediterranean for the monitoring and assessment of seafloor damage

SPA/RAC
Tunis, 2023

Note by the Secretariat

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

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

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

In view of supporting the development of the Ecological Objective (EO6) on Sea floor integrity and its related Common Indicators (CIs), a desk review study (presented in this Information Document to this meeting) was elaborated to inventory the available data sources, best practices and methodologies in the Mediterranean for the monitoring and assessment of seafloor damage.

The proposal of the EO6 including GES descriptions, related targets, indicators, the broad benthic habitats and the sources of pressures to be considered is presented in Working Document UNEP/MED WG.547/10 to this meeting.

Disclaimer

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Environment Programme/Action Plan for the Mediterranean (UNEP/MAP) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Report prepared by:

Maia FOURT, SPA/RAC consultant

Citation

UNEP/MAP -SPA/RAC. 2022. *Outcomes of the desk review of available data sources, best practices and methodologies in the Mediterranean for the monitoring and assessment of seafloor damage*. Report prepared by Maïa Fourt under Contract No. 01_2022_SPA/RAC EcAp-MED III Project. 79p.

List of abbreviations and acronyms

ABNJ	Areas Beyond National Jurisdiction
AIS	Automatic Identification System
AUV	Autonomous Underwater Vehicle
BHT	Broad Habitat Type (used in MSFD)
CBD	Convention on the Biological Diversity
CFP	Common Fishery Policy of the European Union
CI	Common Indicator
D1-D11	MSFD Descriptors 1 to 11
D6C1-C5	MSFD Descriptor 6 “Seafloor integrity” Criteria 1 to 5
EC	European Commission
EcAp	Ecosystem Approach
ECApMED I	Implementation of the Ecosystem Approach in the Mediterranean by the Contracting parties in the context of the Barcelona Convention for the Protection of the Marine Environment and the Coastal region of the Mediterranean and its Protocols (2012-2015).
EcApMED II	Mediterranean Implementation of the Ecosystem Approach, in coherence with the European Union Marine Strategy Framework Directive (EU MSFD) (2015-2019).
EcApMED III	Support to efficient implementation of the Ecosystem Approach-based Integrated Monitoring and Assessment of the Mediterranean Sea and Coasts and to delivery of data-based 2023 Quality Status Report in synergy with the EU MSFD (2020-2023)
EEC	European Economic Community
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
EO	Ecological Objective (used in IMAP)
EU	European Union
EUNIS	European Union Nature Information System
FAO	Food and Agriculture Organization
FRA	Fisheries Restricted Area
GES	Good Environmental Status
GFCM	General Fisheries Commission for the Mediterranean
HD	Habitat Directive (92/43/EEC)
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management (EU or UNEPMAP Protocol)
IMAP	Integrated Monitoring and Assessment Programme
IOC-UNESCO	Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation
IUCN	International Union for Conservation of Nature
MAP	Mediterranean Action Plan
MEDAM	French Mediterranean coasts. Inventory and Impact of reclamations from the Sea
MEDOCC	Mediterranean Occidental Index
Med-LME	Mediterranean Large Marine Ecosystem

MED POL	Mediterranean Pollution Assessment and Control and Control Programme
MED QSR	Mediterranean Quality Status Report
MS	Member State
MSFD	Marine Strategy Framework Directive
MSP	Marine/Maritime Spatial Planning
MSSD	Mediterranean Strategy for Sustainable Development
NEAT	Nested Environmental status Assessment Tool
NIS	Non-indigenous species
QA	Quality Assurance
QC	Quality Control
RCE	Risk of Cumulative Effects
ROV	Remotely Operated underwater Vehicle
SPA/RAC	Special Protected Areas / Regional Activity Centre
UN	United Nations
UNCLOS	Unites Nations Convention on the Law of the Sea
UNEP/MAP	United Nations Environment Programme/Mediterranean Action Plan
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System
WFD	Water Framework Directive (EU)
WWTP	Wastewater Treatment Plant

Content

1. Introduction

1.1. Object of the study

1. This report summarizes the outcomes of the desk review study on available data sources, best practices and methodologies in the Mediterranean for the monitoring and assessment of seafloor damage. It has been carried out within the framework of the EcAp-MED III project, in view of supporting the development of the IMAP Ecological Objective 6 (EO 6) on Seafloor integrity and its related Common Indicators (CIs).

2. The EcAp-MED III project (2020-2023) aims to contribute to the assessment of the status of the Mediterranean Sea and Coast by supporting efficient implementation of the Ecosystem Approach through the Integrated Monitoring and Assessment Programme and the delivery of data-based 2023 Quality Status Report in synergy with the EU MSFD. The Ecosystem Approach for the Mediterranean Sea has been integrated in the UNEP/MAP and Barcelona Convention framework and is being implemented in the Mediterranean, supported amongst others by the Integrated Monitoring and Assessment Programme (IMAP).

3. In line with the EU Marine Strategy Framework Directive (MSFD), 11 Ecological Objectives have been defined within IMAP, 9 for which Common Indicators have been agreed on, two require further development EO 4 on marine food webs and EO 6 on seafloor integrity. This report provides available information on monitoring and assessment of seafloor damage in the Mediterranean to support EO 6 development and related Common Indicators definition.

1.2. Definition of seafloor

4. Seafloor is characterized by physical, chemical and biological components that determine the diversity, the structure and functions of dependent ecosystems. Rice et al., (2010) define seafloor as encompassing both physical structure and biotic composition of the benthic community.

5. Within the Ecosystem Approach definition, the document UNEP(DEPI)/MED WG.382/15 on “Proposed GES and Targets regarding Ecological Objectives on biodiversity and fisheries”, specifies : “*The priority habitats to be considered for the determination of GES in relation to Ecological Objective 6 are coastal lagoons and marshes, intertidal areas, seagrass meadows, coralligenous communities, sea mounts, submarine canyons and slopes, deep-watercoral, hydrothermal vents and the marine vegetal assemblages listed as natural monuments by the Marine Vegetation Action Plan (Barrier reefs of Posidonia, organogenic surface formations,terraces (platforms with vermitids covered by soft algae) and certain Cystoseira belts).*

2. Desk review methodology

6. To acquire a background knowledge of the policy framework related directly or indirectly to Mediterranean seafloor, the chapter 12 “Regulation and Planning in the Mediterranean Sea” (Röckmann, Fernández & Pipitone, 2018) from the book entitled “Building Industries at Sea: 'Blue Growth' and the New Maritime Economy” was used as a starting point. Documents and subjects of interest to which it referred, were searched for on internet.

7. To assess and monitor seafloor damage, it is necessary (i) to identify the human activities that threaten seafloor and eventually estimate the degree of pressure, (ii) to assess the damage on different habitats taking in account the vulnerability of the seafloor features, (iii) to develop thresholds against which comparison can be done (define Good Environmental Status).

8. Anthropogenic impacts on seafloor are identified on a global scale as being offshore anthropogenic seabed exploitation and mining (exploration, drilling, extraction etc.), other offshore constructions (e.g. wind farms), fishing with bottom contact, coast artificialisation and port and coastal maintenance works (dredging, dumping etc.), various pollution (chemical, litter, oil spills), maritime transport and climate change. The damage caused by these threats though varies with the region studied (ICES, 2919a). Therefore, a first step was to identify the main human impacts that most affected the Mediterranean seafloor.

9. Concerning the threats, scientific publications and reports were searched for by a literature review that was carried out through bibliographic databases such as Archimer[1], Google scholar, BASE[2] (Bielefeld Academic Search Engine) and CORE[3] and World Wide Science[4]. The search terms used were “Mediterranean” and “seafloor” and “damage” in a first review. Further research was conducted replacing “damage” by one of the threats identified. These terms were also searched for in French in Archimer database. The references to pertinent articles or reports were registered in a Zotero database[5] in folders corresponding to the major threats referred to. A total of 551 documents were retained in the Zotero database, the main subjects of these documents were:

- Assessment methods and indicators 204 documents
- Policy and programmes 90 documents
- General threats, 28 documents
- Fisheries as threats to seafloor and habitats, 67 documents

A total of 171 documents sere finally selected to constitute the references of this document.

10. For assessment methods, best practices, information on indicators and monitoring methods the same proses was used adding Google as a research engine and using search terms such as: threat and “indicator” and “seabed”, or “database” and “Mediterranean Sea”. The search was not limited to the Mediterranean because best practices and relevant assessment methods applied out of the Mediterranean can be of interest. Nevertheless, the selected documents or internet database sites generally concerned Mediterranean region and/or European countries. Assessment and monitoring methods as well as programmes and data-sources were referenced with basic information and links to their site in a dedicated Access database.

[1] Archimer bibliographic database
[2] Bielefeld Academic Search Engine
[3] CORE open access research
[4] Wolrd Wide Science
[5] Zotero

3. Background and Mediterranean policy context

3.1. The Mediterranean Sea region

11. The Mediterranean Large Marine Ecosystem (Med-LME) is one of the main hot-spots of marine biodiversity and one of the most populated 66 LMEs (IOC-UNESCO & UNEP, 2016). Growing coastal populations of the countries surrounding the Mediterranean Sea are predominantly highly dependent on Mediterranean living marine resources and environment. Furthermore, Med-LME shows one of the greatest increases in fishing effort since 1950 (IOC-UNESCO & UNEP, 2016). The Mediterranean area is also one of the most popular touristic destinations, intensifying accordingly human pressures and activities on coastal areas during summer months.

12. Med-LME is considered under high levels of risk related to floating plastic debris, persistent organic pollutants (POPs) and cumulative human impacts (IOC-UNESCO & UNEP, 2016).

13. Overall, the Mediterranean marine ecosystems are under high constrain and increasing risk considering the developing pressures.

3.2. Overview of the legal status of the Mediterranean Sea and its seabed

14. The United Nations Convention on the Law of the Sea (UNCLOS) is the international agreement that sets a framework for the regulation of marine and maritime activities. Open for signature in 1982, the Convention entered in force in 1994 with the Implementation agreement (Loengarow, 2022).

15. The rights and obligations of countries on the Mediterranean seafloor depend on its legal status which varies mainly with the distance to the coast.

Territorial seas

16. According to the United Nations Convention on the Law of the Sea (UNCLOS), sovereignty of Mediterranean coastal states extends beyond the land to a belt of sea stated as territorial sea. "*This sovereignty extends to the air space over the territorial sea as well as to its bed and subsoil*". Nevertheless ships of all states have the right of *innocent passage* through the territorial sea as defined in the Convention. The territorial sea can extend up to 12 nautical miles (approximately 22.2 km) from the baseline (lower line along the coast) and in case, between two states with opposite coasts, the territorial seas can extend to a median line. In the Mediterranean Sea, for historical reasons and/or disagreement with neighbouring countries, the width of the territorial seas varies, some states having a reduced territorial sea belt of 3 or 6 nautical miles (Röckmann, Fernández & Pipitone, 2018).

Exclusive Economic Zones (EEZs)

17. The Exclusive Economic Zone (EEZ) is defined as an area beyond and adjacent to the territorial sea, not exceeding 200 nautical miles from the coastal baseline (Article 57, UNCLOS). In its EEZ, among other rights and duties, the coastal state has "*sovereign rights*

for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living of the waters superjacent to the seabed and of the seabed and its subsoil and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds" (Article 56, UNCLOS). The coastal state must also ensure, through conservation and management measures, to maintain or restore living resources (Article 61, UNCLOS) but can share the surplus of the allowable catch of living resources it has determined, through agreements with other states (Article 61 and 62, UNCLOS). Detailed information can be found in part V of UNCLOS.

18. In the Mediterranean Sea, "high seas" exist because a number of countries have not yet declared an EEZ mainly due to complex geopolitical situations (Katsanevakis et al., 2015). Some countries though are in the process of establishing maritime zones beyond their territorial seas, but not always backed by a legal publication of these areas (IUCN, 2010) and with different jurisdictional regimes (Röckmann, Fernández & Pipitone, 2018). A table giving an overview of EEZ status of countries bordering the Mediterranean Sea dating of March 2017 can be found in Röckmann, Fernández & Pipitone (2018).

High Seas or Areas Beyond National Jurisdiction (ABNJ)

19. In 2012, 29% of the Mediterranean Sea was under "high seas" designation and jurisdiction. This proportion decreases with the progressive increase of EEZs declared. High seas are open to all States (Article 87, UNCLOS). All Mediterranean seabed already falls under national jurisdiction, belonging to the continental shelf of one or another coastal State, and no seabed having the legal condition of the Area does exist in the Mediterranean (UNEP-MAP-RAC/SPA, 2011). Consequently, High Seas and Areas Beyond National Jurisdiction define the same territories for the specific case of the Mediterranean.

20. In 2012, territorial seas represented 19% of the Mediterranean Sea and EEZs 26% (Suárez de Vivero & Rodríguez Mateos, 2016) but the situation has evolved since, especially in the Eastern Mediterranean. Katsanevakis et al. (2015) and Röckmann, Fernández & Pipitone (2018) see in the increase of Mediterranean EEZs an opportunity to activate marine conservation efforts arguing that the coastal state of an EEZ has the responsibility of conserving and managing natural resources including the seafloor.

3.3. Mediterranean Sea policy context relevant to seafloor concerns

21. At a world-wide scale, all UN Member States adopted the 2030 Agenda for Sustainable Development in 2015. Through this Agenda, Countries are called to act so as to end poverty, protect the planet and improve lives of everyone, everywhere[6]. 17 Sustainable Development Goals (SDGs) were adopted by the world leaders. Goal 14 "Conservation and sustainably use the oceans, seas and marine resources"[7] calls for a careful management of marine life and actions to reduce ocean acidification, overfishing and marine pollution. This includes seafloor management.

[6] See https://www.un.org/sustainabledevelopment/development-agenda/
[7] See https://www.un.org/sustainabledevelopment/oceans/

22. Between the world-wide and national scales, the regional scale for an area that represents an ecological unit plays a significant role. In the framework of world-wide environmental programmes and conception, Regional Sea Programmes and their policies interact with national policies and conservation programmes. For the Mediterranean Sea region, The Mediterranean Strategy for Sustainable Development (MSSD) 2016-2025 was adopted by the Barcelona Convention contracting parties to provide support to translate the 2030 Agenda for Sustainable Development, at regional, sub regional and national levels (UNEP/MAP, 2017).

23. Furthermore, in the Mediterranean Sea region, the European Union (EU) environmental policy applies to 8 EU Member States out of 21 states surrounding the Mediterranean Sea where regional and EU policies overlap. Moreover, Albania and Montenegro are official candidate countries that are being supported by EU through projects and programmes to answer European environmental directive requirements (e.g. EU Strategy for the Adriatic and Ionian region with its action plans that incorporates the Maritime Strategy for the Adriatic and Ionian Seas)[8].

24. For the Mediterranean region, both regional and EU framework policies enhance national environmental and marine policies. Seafloor being a key compartment for marine ecosystems, its conservation is an integral part of marine conservation and management policies.

3.3.1. Mediterranean Sea Regional policy

25. The diversity of cultures, socio-economic and political situations of the countries bordering the Mediterranean Sea contributes widely to diversity and richness of the area, but add to the disparity of the region. Management of marine resources and biodiversity and ecosystem conservation are complex to implement in the Mediterranean Sea. Yet Mediterranean states need to collaborate to be able to face and tackle increasing threats to marine biodiversity. Transboundary and international policies need to interconnect and interoperate through an ecosystem approach to successfully ensure Good Environmental Status (GES) and sustainable practices in the Mediterranean Sea.

26. Policies exist at a sub-regional and regional level as well as at EU level for the conservation and management of marine ecosystems, habitats and species. These generate national actions, enhance strategic action plans and the implementation of national regulations in favour of marine resource sustainable management (Röckmann, Fernández & Pipitone, 2018).

27. The Mediterranean Action Plan, the first Regional Sea Programme under the UNEP auspices with the Barcelona Convention for the protection of the Marine Environment and the Coastal Region of the Mediterranean, focus on conservation, management and sustainable practices actions and strategies to be endorsed and implemented at national level by the 22 Contracting Parties (21 countries surrounding the Mediterranean Sea plus the EU). It is a unique legal framework in the region ensuring coherence and regional cooperation. The Mediterranean Action Plan also assists countries in implementing national environmental policies and

[8] See https://ec.europa.eu/regional_policy/en/policy/cooperation/macro-regional-strategies/adriatic-ionian/

enhances the acquisition and exchange of scientific knowledge and data. The overall objective is to achieve sustainable development, at present and in the future, in a healthy Mediterranean.

28. Seven protocols are associated to the Barcelona Convention on specific concerns:

(i) Dumping Protocol from ships and aircrafts,

(ii) Prevention and Emergency Protocol (concerning oil and other harmful substances),

(iii) Land-Based Sources Protocol,

(iv) Specially Protected Areas and Biological Diversity Protocol,

(v) Offshore Protocol (pollution from exploration and exploitation),

(vi) Hazardous Wastes Protocol and

(vii) Protocol on Integrated Coastal Zone Management.

All seven pertain at various degrees to the protection and conservation of the Mediterranean seafloor.

29. The Convention on Biological Diversity (CBD) defines the Ecosystem Approach (EcAp) as "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way* […]. *It recognizes that humans, with their cultural diversity, are an integral component of ecosystems."* It is the primary framework for action under the Convention on Biological Diversity.

30. Following the recommendations of the CBD pertaining to the implementation of the Ecosystem Approach principals in 2000[9], the Contracting Parties of the Barcelona Convention adopted the Ecosystem Approach Roadmap (2008-2021) in 2008[10], with the objective of achieving and maintaining Good Environmental Status (GES) of the Mediterranean Sea and coasts[11]. Within the UNEP/MAP-Barcelona Convention, the Ecosystem Approach is an overarching principal and process that has been implemented through the EcAp Roadmap at regional, sub-regional and national levels. Implementation of this integrative approach was further detailed in the following years[12] through Decisions IG.20/4, IG.21/03, IG.22/07.

31. The Ecosystem Approach roadmap 2008-2021 is based on seven steps defined as follows (Decision IG.17/6, COP 15, 2008):

i) Definition of an ecological Vision for the Mediterranean.
ii) Setting of common Mediterranean strategic goals.
iii) Identification of important ecosystem properties and assessment of ecological status and pressures.

[9] CBD/COP 5 Decision V/6
[10] Decision IG.17/06: Implementation of the ecosystem approach to the management of human activities that may affect the Mediterranean marine and coastal environment
[11] https://www.unep.org/unepmap/what-we-do/ecosystem-approach and https://www.rac-spa.org/ecap
[12] Decision IG.20/04 - Implementing MAP ecosystem approach roadmap: Mediterranean Ecological and Operational Objectives, Indicators and Timetable for implementing the ecosystem approach roadmap
Decision IG.21/03 - Ecosystems Approach including adopting definitions of Good Environmental Status (GES) and targets

iv) Development of a set of ecological objectives corresponding to the Vision and strategic goals.
v) Derivation of operational objectives with indicators and target levels.
vi) Revision of existing monitoring programmes for ongoing assessment and regular updating of targets.
vii) Development and review of relevant action plans and programmes

32. The EcAp Roadmap (2008-2021) is currently being evaluated in view of a renewed EcAp Roadmap.

33. The Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP), which is the backbone of the Mediterranean ecosystem approach was adopted by the Barcelona Convention Contracting Parties in 2016[13]. It results from the implementation of the Ecosystem Approach and defines operational objectives, Ecological Objectives (EO), GES targets and Common Indicators (CI) to assess and monitor the Mediterranean Sea and Coast (UNEP/MAP, 2016a). Contracting Parties report to UNEP/MAP-Barcelona convention on the assessment and monitoring of the indicators. With regard to EO 6, two operational objectives, four indicators with proposed GES descriptions and targets had been proposed in document UNEP(DEPI)/MED WG.382/15.

34. The 2017 Quality Status Report for the Mediterranean (2017 MED QSR) is the first assessment document produced for the Mediterranean Sea based on the Ecosystem Approach, the Ecological Objectives and Common Indicators defined within the IMAP framework. National data reporting was not yet effective; therefore the report is based on best available information (UNEP/MAP, 2017). The Ecological Objective EO 6 Seafloor integrity had not been developed therefore it was not specifically assessed in 2017 MED SQR.

35. The UNEP/MAP Integrated Coastal Zone Management (ICZM) Protocol Decision IG.18/04 adopted in 2009, for which ecosystem approach is a guiding principal, acts through the associated ICZM Action Plan (2012-2019) (Decision IG.20/2), as well as the Common Regional Framework (CRF) for Integrated Coastal Zone Management (Decision IG.24/5). Through these tools, national ICZM and related planning of land and sea based marine activities, therefore including Marine Spatial Planning (MSP), are implemented in Mediterranean countries. Coastal seafloor and habitats are therefore taken in consideration under these frameworks.

36. Through Decision IG.25/11, the Contracting Parties to the Barcelona Convention and its Protocols, adopted the Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region (Post-2020 SAPBIO). It is a Mediterranean action oriented marine and Coastal Biodiversity Conservation Policy aiming at contributing to the achievement of the good environmental status, to the Sustainable Development Goals and their respective targets, and the CBD Post-2020 Global Biodiversity Framework. In Post-2020 SAPBIO, clear actions have

[13] Decision IG.22/07 - Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria

been defined to attain three main goals (i) reduce the threats to biodiversity by addressing pressures, (ii) ensure that biodiversity is preserved and maintained or enhanced in order to meet people's needs, (iii) enable the necessary transformative change, putting in place tools and nature-based solutions for implementation and mainstreaming. "*In the spirit of the Barcelona Convention, most of the Post-2020 SAPBIO Actions are designed to support the needs of the less advanced countries, optimizing the north/south collaboration opportunities; the Strategy aims at narrowing the gap between subregions, on underlying concerns such as data availability, GES status, MPA coverage, institutional capacities, disparities in human and financial resources." (Decision IG. 25/11, p. 374).*

37. The Roadmap for a Comprehensive Coherent Network of Well-Managed Marine Protected Areas (MPAs) to Aichi Target 11 in the Mediterranean (UN Environment/MAP, 2017) concerns Mediterranean MPAs, including in ABNJ. It provides general guidance aiming at supporting the development of MPAs and MPA networks, including in ABNJ. Further guidance on how to reach qualitative aspects of Aichi Target 11 in the Mediterranean are provided in the framework of the MedMPA network project in SPA/RAC-UN Environment/MAP, 2019.

38. The Mediterranean Strategy for Sustainable Development (MSSD) is an integrative policy framework that provides strategic guiding to transpose the 2030 Agenda for Sustainable Development at regional, sub-regional and national levels (UNEP/MAP, 2016c). It has been revised for the period 2016-2025. The MSSD 2016-2025 aims to contribute to the long-term sustainable development vision of the Mediterranean region by providing "*a strategic policy framework to secure a sustainable future for the Mediterranean region*" and adapting "*international commitments to regional conditions, to guide national strategies and to stimulate regional cooperation*" and "*to link the need to protect the environment to socio-economic development*" (UNEP/MAP, 2016b).

39. The General Fisheries Commission for the Mediterranean (GFCM) is a regional fishery organization counting 22 member countries and the EU and operating in the Mediterranean Sea and the Black Sea. Its main objectives are to ensure conservation and sustainable use of living marine resources as well as a sustainable development of aquaculture in the region. Many resolutions have been taken concerning Mediterranean fisheries including binding decisions some of which concern seafloor threats such as bottom trawling activities.

40. The GFCM precautionary ban (GFCM/2005/1)[14] adopted in 2005 on bottom trawling activities at depths beyond 1000 m in the Mediterranean Sea protects 58% of the seafloor from this threat. This regulation is legally binding. GFCM has established a 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea (FAO, 2021), detailing its 5 targets, associated outputs and actions.

3.3.2. European Union Policy

41. The EU Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC completed by Commission decision 2017/848/EU) is required to be applied to 8 Mediterranean

[14] See GFCM recommendations and resolutions

countries out of 21 and aims to achieve "Good Environmental Status" (GES) of the EU marine waters. The directive is a legal framework in which it is required to EU countries to manage human activities which have an impact on marine environment by handling environmental protection and sustainable use, by implementing a national marine strategy for its waters in cooperation with neighbouring countries. Five steps are included in the strategy[15]:

(i) Assessment of environmental status of the sea and human activities' impacts
(ii) Define good environmental status (GES) of the sea
(iii)Establish a series of environmental targets and indicators
(iv)Establish and implement a monitoring programme and regularly update targets
(v) Develop a programme of measures to achieve or maintain GES

42. These steps should be accomplished within the 6-year cycles and reviewed to be repeated for the following marine strategy cycle[16]. Countries report to the European Commission and in return, a technical report is elaborated by country and region including recommendations. Taking in account the implementation reports, the MSFD is to be reviewed by the European Commission by 2023 and amendments will be proposed if necessary.

43. Monitoring the progress towards achieving GES is still a challenge for all Mediterranean states. In the framework of MSFD, the reasons are that suitable monitoring programmes still haven't been well defined, or they are partially appropriate or unappropriated to meet MSFD requirements (European Commission, 2020). Concerning seabed habitats, this is primarily due to the lack of methodological standards according to the European Commission (2020). Furthermore, the coherence of the monitoring programmes of the Member States for the Mediterranean Sea region are mainly considered to be of medium degree, in particular concerning seabed (Descriptor 6 seafloor integrity) . Further coordination is needed among Members States at regional and sub-regional level to deliver consistent and comparable data and address transboundary pressures and impacts. GES for seafloor integrity of EU states has not yet clearly been determined.

44. The Habitat Directive (HD, Directive 92/43/EEC) aims to ensure biodiversity of the EU, including in marine environment, through restauration and conservation measures of natural habitats and species of Community interest. Species and habitats should reach favourable conservation status and their long-time survival secured in their natural range within Europe (EU, 2012a). Special Areas of Conservation (SACs) are to be defined by the countries for this purpose. SACs, together with the Special Protection Areas (SPAs) of the Bird Directive (BD, Directive 2009/147/EEC) are part of the Natura 2000 network.

45. EU Common Fishery Policy (CFP) sets, amidst other, rules for a sustainable management of European fishing fleets and conservation of fish stocks[17]. The objectives are to guarantee ecological, economic and social sustainability (Libralato et al., 2018). Some restrictions concern directly or indirectly the conservation of benthic habitats such as the prohibition of using explosives, of fishing with bottom trawls, seines and similar nets above

[15] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/reports_en.htm
[16] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/reports_en.htm
[17] Common fishery policy

Posidonia beds. EU is a member of GFCM and regulations concerning the Mediterranean Sea fisheries are taken in coordination between the two bodies.

46. The EU Water Framework Directive (2000/60/EC)[18] establishes a framework for the protection of waters (including inland surface waters, transitional waters, coastal waters and groundwater), with the objective of achieving and maintaining good water status for all European waters. Concerning the coastal waters, the directive applies to seawater and seafloor up to 1 mile from the coastline. Guidance documents are available for different water bodies[19]. Concerning the coastal waters, a number of Quality Elements (QE) are required (20000/60/EC, Annex V.1.2) and others are recommended. Of these elements, especially the biological elements, some are pertinent for IMAP EO1 (Biodiversity) and EO6 (Seafloor integrity).

47. EU Integrated Coastal Zone Management recommendation (EU ICZM Recommendation, 2002/413/EC)[20] gives the principals and good practices to ensure good coastal zone management in the Member States. A national strategy for each state should be developed in partnership with regional authorities and inter-regional organisms. For the Mediterranean region, the European Commission ratified the Barcelona Convention Protocol on Integrated Coastal Zone Management[21] in 2010 and the Protocol entered in force in 2011. This means that the Protocol becomes part of EU law and has binding effects. The overall objective of ICZM is to understand and adapt land-sea interactions and achieve sustainability through an integrated management of the coast. ICZM process can lean on maritime spatial planning (see following MSP Directive 2014/89/EU).

48. The EU Integrated Maritime Policy and Directive 2014/89/EU[22] establishes a framework for maritime spatial planning of the member states. Member States should establish and implement maritime spatial planning by considering economic, social and environmental aspects to support sustainable development in the maritime sector and applying an ecosystem-based approach. Röckmann, Fernández & Pipitone (2018) give an overview of the existing implemented marine/maritime spatial plans by Mediterranean country (see Röckmann, Fernández & Pipitone, 2018, Table 12.4).

49. The EU Directive relative to Environmental Impact Assessment (2011/92 EU) amended by (2014/52/EU)[23] requires from European member states "to adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment are made subject to a requirement for development consent and an assessment with regard to their effects."[24] Within the factors that must be assessed is the biodiversity, with particular attention to species and habitats protected under Directive 92/43/EEC (Habitat

[18] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
[19] See Guidance WFD Documents
[20] Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe
[21] Protocol on integrated coastal zone management in the Mediterranean
[22] Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning
[23] Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment
[24] https://www.fao.org/faolex/results/details/fr/c/LEX-FAOC109726/

directive) and Directive 2009/147/EC (Bird directive). Amongst other projects, the environmental impact assessment (EIA) procedures concern offshore platforms and pipelines.

50. The EU Biodiversity Strategy for 2030 is a plan to protect nature and reverse the degradation of ecosystems. It contains specific commitments and targets including:

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

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

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

3.3.3. Partial overlap of policies

51. The overlapping of the environmental policies should not be considered as a redundancy but should enhance coordination, strengthen the paths for attaining the objectives and, motivate countries to assess, monitor and report on marine ecosystems as well as act for sustainable use of marine environment.

52. For the Mediterranean Sea and its seafloor, UNEP/MAP-Barcelona Convention and IMAP concerns and roadmap, are in synergy with the EU MSFD. Mediterranean EU countries must report on their assessment and monitoring of marine ecosystems for IMAP, MSFD, WFD and HD with common parts. Some MSFD requirements can lean on, but also complete, WFD assessment and monitoring programs on coastal seafloor (1 mile), although some differences in the requests of the two policies exists. It is therefore crucial to ensure that data collected and quality elements assessed are coherent and in line with what is required for the reports intended to different policies. Through cooperation and synergy, IMAP Ecological Objectives and Common Indicators already defined are in line with EU MSFD Descriptors and Criteria. Importance should also be given to timescales for reporting. For different EU Directives for example, timescales are not entirely synchronized (see EU, 2012).

53. The General Fisheries Commission for the Mediterranean (GFCM) works in collaboration with the EU Common Fishery Policy to manage fisheries in the Mediterranean and Black Sea and ensure sustainable use of living marine resources and coherence between the Mediterranean fishery policies.

4. Main anthropogenic activities impacting seafloor in the Mediterranean

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

55. 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.

4.1. Bottom trawling fishing activities

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

(Özalp, 2022)[25]

57. 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 impacting 35% of the European continental shelf area and 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 on seafloor is dependant of the type of gear, of the frequency at which an area is submitted to trawling, the substrate and the benthic habitats and ecosystems of the area.

58. Benthic biogenic habitats and species are particularly vulnerable to bottom trawling such as macrophyte dominated habitats such as *Posidonia oceanica* (González-Correa et al., 2005), *Laminaria rodriguezii* (Žuljević et al., 2016), maerl beds (Bordehore et al., 2000), coralligenous habitats, Cold Water Corals (e.g. D'Ognia et al., 2017) especially *Isidella elongata* (e.g. Maynou & Cates, 2011), and other benthic assemblages. They are either

25 Photograph shows the gold coral *Savalia savaglia* which is considered to be near to a risk of extinction (NT – Near Threatened, IUCN). The coral is very vulnerable to fishing impacts. In the mesophotic zone of the Sea of Marmara, trawlers, seine and beam trawls and associated underwater tools have impacted them severely. Although this species and its facies in the Sea of Marmara and the Çanakkale Strait are highly important, and at some locations form a hotspot of biodiversity for other animals, they are under a huge risk of mortality in these regions (Barış Özalp, pers. comm., December 2022).

threatened directly by the mechanical abrasion or by the plume of sediment that is suspended in the water column by the gear.

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

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

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

4.1.1. Bottom otter trawling fishing activities

62. Bottom otter trawling is generally used on sediment seafloor (sandy and muddy). It consists of a large conical net maintained 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 10 to 2500 m depth (Eigaard et al., 2016). In practice, in the Mediterranean, trawlers concentrate mainly on depths between 200 to 500 meters depth (Eigaard et al., 2017), as in the Gulf du Lion where trawling traces were observed between 150- and 600-meters depth mainly on sandy-muddy substrate (Fourt et al., 2014). But Eigaard et al., (2017) estimate that in the Mediterranean, around 40% of macro-phyte dominated sediments and biogenic habitats have been trawled. Hiddink et al., 2017 consider that 6% of the biota per pass are removed.

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

64. Depending on the depth and the area, by-catch and discards from trawling fisheries in the Mediterranean are important, amounting from over 35% to 70% by weight (European parliament, 2014; Damalas et al., 2018; Tiralongo et al., 2021). Targeted species can constitute much less than the discard in weight, highlighting the low selectivity of this fishery. Amidst the species constituting the discards, they are many benthic invertebrates (e.g. corals, sponges, echinoderms) and algae (Sacchi, 2008).

65. Otter trawlers smoothen the seafloor surface, modify consistently the first centimetres disrupting benthic fauna habitats complexity, ecosystems and species (PERSEUS, 2013). Some parts of the gear (doors) can penetrate the seabed to depths up to 30cm or more while other

parts cause abrasion (Lucchetti and Sala, 2012). The physical impact of otter trawlers, which can be of variable sizes and gear, depends on the penetration of some elements, the collision and abrasion and the sediment mobilisation (Rijnsdorp et al., 2016).

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

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

67. In different parts of the Mediterranean Sea as in Crete (Greece, SE Mediterranean) and Palamos canyon (Spain, NW Mediterranean), management strategies with periodical 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).

4.1.2. Beam trawlers and dredges

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

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

70. 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 depths contributing largely to the depletion of the Posidonia meadows and the surrounding ecosystems (Zaouali, 1993; Zerelli et al., 2018; Mosbahi et al., 2022). The boats and gear are rather small but the mesh size of the nets used is also much smaller (18 compared to 28 mm and other trawlers) (Mosbahi et al., 2022).

71. 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 (Pravoni et al., 2000).

72. Dredges and especially hydraulic dredges for shellfish cause great seafloor surface disturbance by higher penetration of the gear in the seafloor (Pitcher et al., 2022). Penetration is comparable for gravel and mud seafloors but is less in sand bottoms (Pitcher et al., 2022). It is estimated that hydraulic dredges cause the depletion of 41% of the biota on each pass (Hiddink et al., 2017). In shallow sandy bottoms in the northern and central Adriatic (3 to 12 m depth), about 380 boats operate dredges that plough up to 15-16 cm in the seafloor to collect the shells (Lucchetti & Sala, 2012; Hiddink et al., 2017). Many studies show that in the Adriatic Sea where the number of dredges is important, seafloor and macrobenthos suffer important

changes and alteration especially in shallow coastal areas (e.g. Morello et al., 2005; Lucchetti and Sala, 2012).

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

4.2. Non trawling small-scale fisheries and recreation fishing

Non trawling small-scale fisheries and recreational fishing (mainly gillnets, trammel nets, long lines and various bottom traps) may locally have an impact on habitats in particular from by-catch and mechanical damage by entanglement creating derelict fishing gear. Cold Water Corals may constitute by-catches by gillnets and longlines on depths between 200 and 700 m as reported by Mytilineou et al., (2012) for the Ionian Sea where *Isidella elongate* and *Leiopathes glaberrima* appeared as the most often reported CWC by-catch. Observations by 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).

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

4.3. Coastal artificialisation

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

76. There is no general view of the coast artificialisation at the Mediterranean scale. Some Mediterranean countries though have assessed the length of coastal artificialisation such as Italy where in 2006 almost 16% of the coastline was identified as built, Montenegro where in 2013, 32% of the coastline was built (see UNEP/MAP, 2017) and French Mediterrenean where MEDAM[26] has assessed in detail the artificialisation of the coast in time and space. The French

[26] French Mediterranean Coasts. Inventory and Impact of Reclamations from the Sea MEDAM

Mediterranean coastline shows a global rate of artificialisation of 12% (see MEDAM), but as for other countries, they are wide spatial differences.

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

4.4. Dredging and dumping

77. Dredging generally concerns littoral and infralittoral seafloor but dumping may occur on circalittoral habitats.

78. Dredging can be carried out for the following reasons[27]:

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

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

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

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

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

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

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

82. 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 of abundance of benthic community and a modification of the seafloor topography and hydrological

[27] See link

conditions (Van Dalfsen et al., 2000; Trop, 2017). After sand extraction activities, recovery of the impacted seafloor and associated fauna depends amongst other, on the local hydrology, the frequency and on the depth (Van Dalfsen et al., 2000).

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

84. Capital dredging disturbs the dredged surroundings by an increase of turbidity and represents a physical loss of seafloor especially since it is done to construct and therefore seal the area concerned. Mineral dredging consists generally in the Mediterranean of sand extraction and therefor 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 seems possible. Dumping areas of dredged materials should be managed with more attention.

4.5. Land based pollution

85. It is estimated that 80% of the marine pollution comes from land-based human activities (Piante & Ody, 2015). Here we consider only the pollution by nutrients, heavy metals and Persistent Organic Pollutants (POPs), litter being developed farther in 4.6. In the Mediterranean, the main sources are: industries, untreated urban and domestic wastewaters, surface run-off, dumping grounds, river discharges to the sea. Assessment of land-based pollution and its different components has become a common approach in marine waters and sediments, although littoral sands are less considered (Galgani et al., 2011). Impact on seafloor concerns mainly coastal areas, such as for chemical contamination that decrease in the sediment when moving off-shore (Gómez-Gutiérrez et al., 2007). Nutrients can change benthic community compositions in shallow rocky habitats especially macroalgae communities (Arévalo et al., 2007) and benthic communities of soft sediments seem strongly affected by heavy metals in sediments (Chatzinikolaou et al., 2018). Furthermore, sediments integrate heavy metal pollution on several years and represents therefore an archive of the changes (Chatzinikolaou et al., 2018).

86. The development of Wastewater Treatment Plants (WWTPs) and their increasing efficiency in treating wastewaters, has considerably improved the quality of the treated water released in the sea.

87. Land based pollution will mainly cause chemical damage on algal, macrophyte and other benthic communities. Physical damage to seafloor is limited to eventual increase of turbidity. It may lead though to a loss of biogenic habitats. Moreover, land-based pollution is covered by EO9 (CI17).

4.6. Litter

88. The Mediterranean Sea by its configuration of semi enclosed sea surrounded by a highly populated coast and being one of the first touristic destination, is highly threatened by litter and more specifically by plastic litter. Litter has been confirmed in all compartments of marine environment and more than 50% of the seabed marine litter in the Mediterranean is plastic litter

(UNEP/MAP & Plan Bleu, 2020) and can count up to 62% in weight in some areas (e.g. Adriatic see Pasquini et al., 2016).

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

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

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

92. Micro-plastics though by their small size can penetrate in biogenic habitats and soft substrates and the impact there is still unknown. The impact of litter is covered by EO10 (CI22 and 23)

4.7. Anchoring

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

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

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

96. Regarding commercial vessels, an interesting tool to easily identify anchoring locations of commercial vessels and obtain details is the website VESSELFINDER that tracks vessels

with AIS. In a given area it is possible to count all boats at anchor and obtain easily details on each boat (length, tonnage, draft) in particular the status that indicates if the boat is at anchor (see Figure 1). By crossing with bathymetric data and habitat information, pressure by anchoring of commercial vessels or large motorboats (see Figure 2) can be estimated for a given area and a given habitat. A certain number of data is free of access, though historical data going back to 2009 are not free.

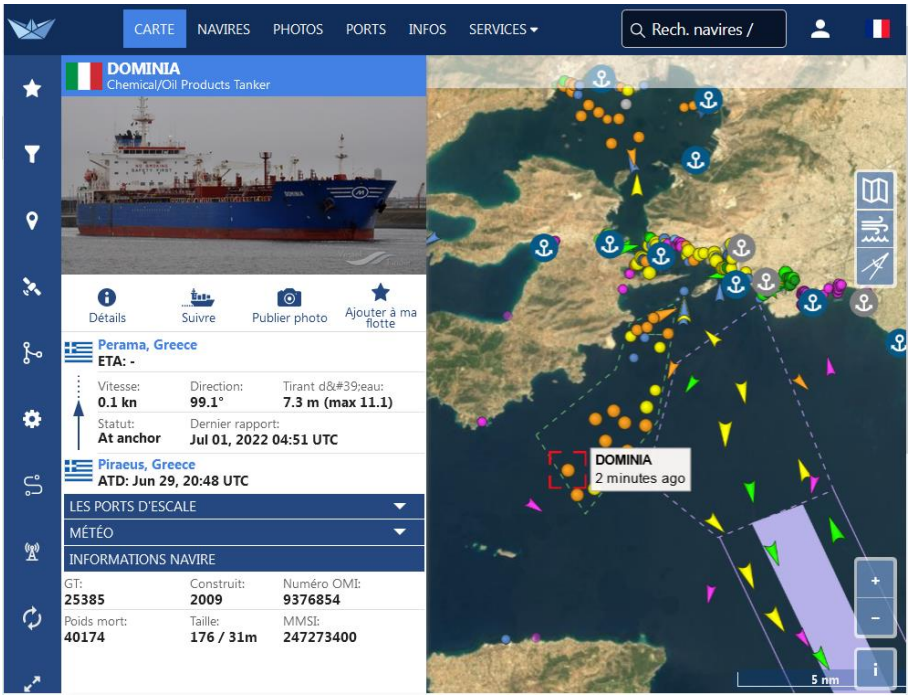

Figure 1: Snapshot of the internet site VESSELFINDER following boats with AIS captured 31/06/2022. It shows the boats at anchor (circles) and those underway (arrows) in front of the Greek port of Piraeus and associated information on length, draft, tonnage and status of the selected vessel. Entry of channel and anchoring area are delimited.

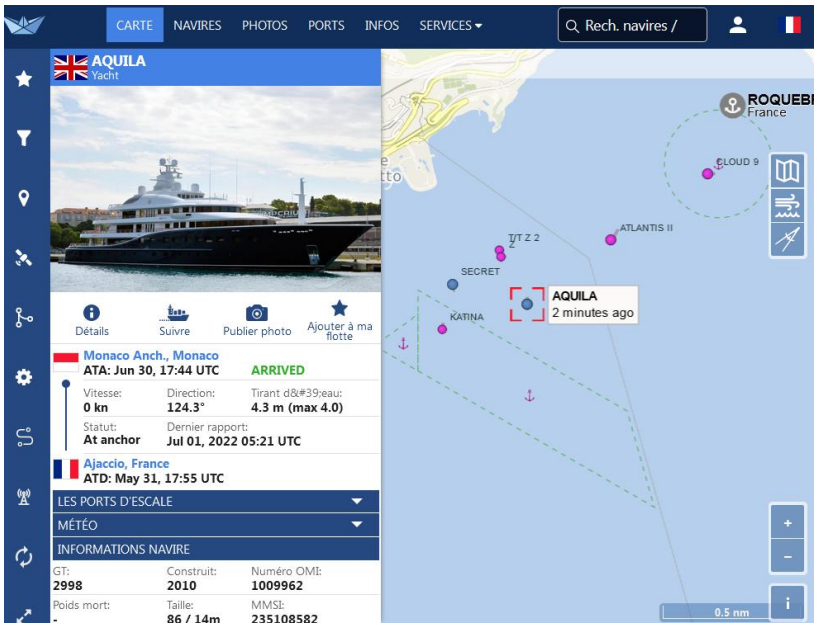

Figure 2: Snapshot of the internet site VESSELFINDER following boats with AIS captured 31/06/2022. It shows the boats at anchor in front of Monaco and associated information on length, draft, tonnage and status of the select vessel. Also, anchoring areas are delimited but here little respected.

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

98. For French coasts a freely accessible application DONIA can be downloaded on telephones (MEDTRIX, 2019). It gives access to bathymetrical maps with very detailed information on habitats 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.

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

4.8. Aquaculture activities

100. Aquaculture (brackish and marine) in the Mediterranean Sea has rapidly grown since the 1970's (Piante & Ody, 2015). The development is expected to steadily grow up to 100% by 2030 in terms of production and value (Piante & Ody, 2015). Aquaculture releases organic matter creating bacterial mats and inorganic wastes that deposit on the 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).

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

4.9. Gas and oil exploration and exploitation

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

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

104. For the Mediterranean Sea, experts consider that once platforms are installed, the actual physical damage of seafloor (physical loss in this case) is relatively limited in terms of surface (ICES, 2019a) compared to other threats. Moreover, the platform structure offers new hard substrate that is often colonised by various benthic species, including NIS (Manoukian et al., 2010; Harry, 2020). Gas and oil extraction has been ranked 15 on a scale that classifies 31 activities, rank 1 considered to be causing the greatest amount of physical disturbance to seafloor in the region (ICES, 2019a). Oil offshore production discharge are considered to be limited compared to other sources of inputs (Harris, 2020) and it is estimated that less than 1% of total oil pollution in the Mediterranean Sea originates from plateforms (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.

105. The implementation of platforms disturbs 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 recommendation for these installations so as to limit impact on the environment.

4.10. Offshore wind farms

106. Installation of offshore wind farms impacts directly the seafloor by loss of seafloor and benthic habitats where the foundations are set and disturbance during the implementation of the wind farms. But the impact is limited in surface and damage can be reduced if properly planned in areas without vulnerable benthic habitats. Boero et al. (2016) even consider that the

foundations of the wind farms could increase connectivity between ecosystems since benthic species will develop on the foundations. Prevention of fishing activities within the wind farm could even create refuge habitats for many species including fish and increase connectivity (Boero et al., 2016).

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

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

109. The implementation of offshore wind farms (OWF) disturbs seafloor in the close vicinity but for a limited time. Offshore wind farms 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. Spatially well planned OWF could possibly increase connectivity between benthic communities and therefore favour biodiversity.

4.11. Climate change

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

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

4.12. Non-indigenous species

112. The presence of Non-Indigenous Species (NIS) in the Mediterranean has clearly increased these last years (Zenetos et al., 2022). The phenomenon is rapidly growing given that increase of sea temperature due to climate change that favours the establishment of lesseptian species. Some benthic NIS can develop rapidly and impact native habitats by increasing competition for space (Pergent et al., 2008). Others impact coralligenous habitats by growing in epibiosis on sessile species (e.g. Sempere-Valverde et al., 2021). In the Mediterranean, NIS impact marine ecosystems including benthic habitats in multiple ways (Katsanevakis et al., 2016). To mitigate impact of NIS on Mediterranean ecosystems and societies, UNEP/MAP and contracting parties have adopted the *Action Plan concerning species introductions and invasive species in the Mediterranean Sea*[28].

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

4.13. Mining

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

4.14. Cumulative effects

115. Seafloor 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 are heavily impacted by cumulative impacts (Micheli et al., 2013a).

116. 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 (0-200 m depth) by Quemmerais-Amice et al. (2020). In this work, the contribution of bottom trawling to RCE is from far the most important.

4.15. Mediterranean seafloor habitats impacted by anthropogenic activities

117.

118. Table ***1*** summarises the main anthropogenic pressure on seafloor in the Mediterranean, either to the benthic habitats or to the substrate. Coastal littoral and infralittoral seafloor undergo the most anthropogenic pressure (

[28] AP concerning Species Introductions and Invasive Species in the Mediterranean Sea

119. Table *1*). Vulnerable benthic habitats such as *Posidonia oceanica* meadows have lost 25% of their surface in 30 years, with coastal areas showing co-occurrence between multiple stressors and significant depletion of the meadows (Blanco-Murillo et al., 2022a, b).

120. The lost or disturbed seabed is not evenly distributed in the Mediterranean Sea: coastal areas and the top continental shelf are exposed to more numerous threats than offshore areas (Korpinen et al., 2019). Coastal areas can harbour significant ecosystems in terms of biodiversity and ecosystem functioning such as Posidonia medows and coralligenous assemblages (Zampouka et al., 2014). In parallel, some vulnerable and slow growing benthic species and habitats thrive in circalittoral and bathyal zones. These vulnerable communities and species are more sensitive to anthropogenic pressure, therefore although they are under less anthropogenic threats, their impact can be more severe. Therefore, anthropogenic pressure does not have the same impact and does not create the same damage on all areas, recovery being generally much slower in deeper habitats. A similar pressure will not create the same damage on different habitats.

121. Anthropogenic activities can damage seafloor either by disturbing the seafloor or provoking the loss of seafloor, but the intensity and recurrence of physical disturbance may lead to physical loss through time (ICES, 2019a). On this continuum between "physical disturbance" and "physical loss", the curser between the two has been placed differently in (EU) 2017/848 and in the advice on seafloor assessment process from ICES (2019) to EU eco-regions.

122. Physical loss of seafloor is defined in (EU) 2017/848 to include all impacts on seabed and benthic habitats which take more than 12 years to recover (see also Korpinen et al., 2019). ICES (2019) defines physical loss as a changes of EUNIS level 2 habitat type to another level 2 type and discriminates sealed physical loss and unsealed physical loss. It can be caused by sealing, coastal construction, offshore constructions, removal of hard substrate or biogenic reef, capital dredging, dumping waste material (Korpinen et al., 2019). Between 2011 and 2016 it is estimated that the European Mediterranean area lost 3.7% of its seafloor (Korpinen et al., 2019).

123. Disturbance of seafloor and associated benthic habitats is the consequence of anthropogenic activities that alter the habitats and seafloor either directly or indirectly such as resuspension of material from abrasion (e.g. trawling). In the Mediterranean, seafloor disturbance occurs on much larger surfaces than seafloor loss but the intensity and frequency of disturbance can lead to deep changes in ecosystem functioning and loss of the seafloor habitat.

124. In the Mediterranean Sea, the greatest pressure on seafloor in terms of surface impacted is caused by bottom trawling fishing activities (otter trawlers, beam trawlers and fishing dredges). Such anthropogenic activities that are moreover recurrent and frequent on the same seafloor surfaces, have deeply changed soft bottom seafloor and associated ecosystems of the continental shelf and slope throughout the Mediterranean. Moreover, indirect impacts of these activities have been reported on deeper vulnerable and slow growing habitats.

125. Coastal and maritime development around the Mediterranean leads to an increase in coastal artificialisation and sealing of littoral habitats, capital and maintenance dredging for

maritime access, mineral dredging for beaches, anchoring pressure and land-based pollution and litter represent the most important sources of damage on Mediterranean seafloor.

***Table 1**: Pressure of main anthropogenic activities on Mediterranean seafloor by broad habitat types. Red: major impact is seafloor loss, orange: major impact is seafloor disturbance (two degrees), red star: localized and relatively reduced seafloor loss. FBTG: Fisheries using bottom trawling gear (all gear), NT-SSF: Non-Trawling Small Scale Fisheries, CA: Coastal artificialisation, Dr-Du: Capital, maintenance, mineral dredging and dumping, LBP: Land Based Pollution, Lit: Litter, Anch: Anchoring, AQ: Aquaculture, Off-sh: Offshore platforms (gas, oil extraction, offshore wind farms), CC: Climate Change and acidification, NIS: Non-Indigenous Species.*

Threats/ Broad habitat types	FBTG	NT-SSF	CA	Dr-Du	LBP	Lit	Anch	AQ	Off-sh	CC	NIS
Littoral rock and biogenic reef				Capital dredging							
Littoral sediment				Capital dredging							
Infralittoral rock and biogenic reef				Capital dredging			*		*		
Infralittoral coarse sediment				Capital dredging			*		*		
Infralittoral mixed sediment				Capital dredging			*		*		
Infralittoral sand				Capital and mineral dredging			*		*		
Infralittoral mud				Capital dredging			*		*		
Circalittoral rock and biogenic reef											
Circalittoral coarse sediment									*		
Circalittoral mixed sediment									*		
Circalittoral sand											
Circalittoral mud									*		
Offshore circalittoral rock and biogenic reef											
Offshore circalittoral coarse sediment											
Offshore circalittoral mixed sediment									*		
Offshore circalittoral sand											
Offshore circalittoral mud									*		
Upper bathyal rock and biogenic reef											
Upper bathyal sediment									*		
Lower bathyal rock and biogenic reef											
Lower bathyal sediment									*		
Abyssal											

5. Summary of anthropogenic activities impacting Mediterranean seafloor and relevant policy framework

126. Table 2 presents the main anthropogenic activities impacting Mediterranean seafloor and the type of damage caused as well as the policy framework in relation to the pressure.

***Table 2**: Table summarizing impacts of anthropogenic activities on Mediterranean seafloor and related regulation and policy framework*

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
Bottom trawling	Disturbance from: - abrasion - increased turbidity - ploughing of the sediments	From littoral to bathyal depending on the gear and the Mediterranean area, widespread.	- REC. GFCM/29/2005/1 trawling ban over 1000 m - REC. GFCM/30/2006/3 - Council Regulation (EC) 1967/2006 - EU Common Fishery Policy - EU Regulation (EU) 1343/2011 - EU MSFD 2008/56/EC and (EU) 2017/848 Indirectly by area and habitat protecting policies e.g. : - Habitat Directive 92/43/EEC - SPA/BD Protocol - Action Plan “Dark Habitats” - Action Plan for the conservation of marine vegetation	EO3 /CI10 Fishing effort (for trawling effort) EO3/CI12 Bycatch of vulnerable and non-target species (for assessment of benthic vulnerable species bycatch)	Need of law enforcement in some areas. Lack of sub-regional management taking benthic habitats in account and not only target fish. The development of VMS should help assess and monitor degree of pressure from trawling boats

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
Coastal artificialisation	Seafloor loss from: - sealing Disturbance from: - Changes in hydrodynamics - Increased turbidity	Coastal areas localised but becoming, widespread.	- Barcelona Convention Protocol on Integrated Coastal Zone Management - EU ICZM Recommendation, 2002/413/EC) - EU Integrated Maritime Policy and Directive 2014/89/EU on MSP - EU Directive relative to Environmental Impact Assessment (2011/92 EU) amended by (2014/52/EU) - EU MSFD 2008/56/EC and (EU) 2017/848	EO7 /CI15 Location and extent of the habitats impacted directly by hydrographic alterations EO8/ CI16 Length of coastline subject to physical disturbance due to the influence of man-made structures	Actual state of Mediterranean coastline artificialized could be estimated and mapped through satellite imagery
Dredging and dumping	Physical loss from: - extraction - recovery of habitats by dredged material Disturbance from: - increased turbidity - chemical pollution with dumping material - changes in hydrodynamics	Mainly littoral and upper infralittoral soft sediments. Localised areas	- Barcelona Convention Dumping Protocol from ships and aircrafts and Protocol on Integrated Coastal Zone Management. - EU Water Framework Directive (2000/60/EC) - EU ICZM Recommendation, 2002/413/EC) - EU Integrated Maritime Policy and Directive 2014/89/EU - EU Directive relative to Environmental Impact Assessment (2011/92 EU)	EO9/CI17 Concentration of key harmful contaminants measured in the relevant matrix (here for sediment to be dumped)	Lack of a common database at Mediterranean scale of dumping areas.

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
			- EU MSFD 2008/56/EC and (EU) 2017/848		
Land based pollution	Disturbance from: - chemical pollution from industries agriculture and run-off - organic pollution of sediments	Coastal areas	- Barcelona Convention Land-Based Sources Protocol and ICZM Protocol - MED POL program - EU ICZM Recommendation (2002/413/EC) - EU Water Framework Directive (2000/60/EC) - EU Integrated Maritime Policy and Directive 2014/89/EU - EU Urban Wastewater Treatment Directive (UWWT) 91/271/EEC - EU MSFD 2008/56/EC and (EU) 2017/848	EO9/CI17, CI18, CI19 for sediment	This issue is quite well covered by legislation and assessment but it is not always applied.
Plastic litter	Disturbance from: -accumulation in certain areas of plastic by covering seafloor and entanglement in benthic species -microplastic accumulation in sediments	Coastal areas but also aggregation zones in bathyal zones, widespread.	- EU directive on plastics bags (EU) 2015/720 - EU directive on single-use plastics (EU) 2019/904 - European strategy for plastics	EO10/CI22 and CI23 for seabed	For seafloor it is mainly microplastics that is a threat.

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
Anchoring	Physical loss from: - By outrooting macrophytes (mainly *Posidonia oceanica* meadows) Disturbance from: -abrasion on habitat from anchors and chains -sediment ploughing	Coastal up to 40 m depth, localised impacts	- French decree (123/2019) regulating anchoring on protected species such as *Posidonia* seagrass - Other national decrees regulating anchoring to protecting benthic habitats	EO1/CI1	Mediterranean map of anchoring hotspots (tourism and commerce) would be of interest feed cumulative effects hotspots. Development of AIS or
Aquaculture	Disturbance from: -Organic and other deposits under feeding cages	Coastal localised impacts	- EU Common Fishery Policy - EU Directive relative to Environmental Impact Assessment (2011/92 EU) amended by (2014/52/EU) - COM/2021/236 Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030		
Offshore constructions	Seafloor loss from: -sealing the platforms on the seabed Disturbance from: - noise and vibration during drilling	Infralittoral, circalittoral and bathyal localised impacts	- Barcelona Convention Offshore Protocol (pollution from exploration and exploitation) - Mediterranean Offshore Action Plan (Decision IG.22/3) agreed on in 2016.	EO11 with the two candidate indicators for the constructing period	

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
	-potentially from exploration (unknown)		- EU Directive on safety of offshore oil gas operations (2013/30/EU) - Directive on the conditions for granting and using authorisations for the prospection, exploration and production of hydrocarbons (94/22/EC) - EU Directive relative to Environmental Impact Assessment (2011/92 EU) amended by (2014/52/EU)		
Climate change	Disturbance from: - increase in sea temperature affecting habitats - increase in mortality events - extreme climatic events - sea level rise	Widespread throughout the Mediterranean Sea			
Non-indigenous species	Disturbance from: -changes in benthic community ecosystems due to replacement of key species	Widespread throughout the Mediterranean Sea although circalittoral and bathyal areas seem less impacted	- Action Plan concerning species introduction and invasive species in the Mediterranean Sea - Regulation (EU) No 1143/2014 on the prevention and management of the introduction and	EO2/CI 6 for benthic species	

Anthropogenic activities	Type of pressure on seafloor	seafloor concerned	Main relevant regional policies/legislation /Action Plans framework	Relations with IMAP EOs and CIs	Gaps/Comments
			spread of invasive alien species		
Mining	<u>Seafloor loss:</u> -excavation of metals and minerals				

6. Seafloor integrity assessment and monitoring in EU MSFD

127. The Marine Strategy Framework Directive (MSFD 2008/56/EC) is the EU tool to achieve and maintain Good Environmental Status (GES) for marine waters. The MSFD applies to waters, seabed and sub-seafloor including deep-sea areas, on which Member States exercise jurisdictional rights (see MSFD 2008/56/EC).

128. The 11 MSFD qualitative descriptors define the objectives for GES. IMAP Ecological Objectives and Common Indicators are in line with MSFD Descriptors and Criteria although some differences exist.

129. Concerning MSFD Descriptor 6, D6, "Seafloor integrity", GES is defined as "*Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected*". Developed criteria under this descriptor where to be defined by the Member States to evaluate to which extent GES is achieved. A Task Group was established for each qualitative Descriptor to help develop criteria and methodological standards. A report of the Task Group on Descriptor 6 (D6) sets a framework for this complex descriptor in terms of scales, of methodology and approach (see report Rice et al., 2010 for Descriptor 6 and Rice et al., 2012). Indicators are classified using the Drivers, Pressure, Impact, State, Response DPSIR model.

130. The framework and context of the criteria and methodological standards to be developed by Member States for marine waters were first described in 2010 under the Commission decision 2010/477/EU. In 2017, the Commission decision (EU) 2017/848 further developed the criteria and methods taking in consideration the analysis of the Task Group D6 (Rice et al., 2010) and ICES advice and guidance (ICES, 2014a, b).

131. Criteria elements, criteria and methodological standards are defined for each Descriptor and specifications are given regarding methods for assessment, the broad habitats and units (for D6 see p57, 58 and 70-73 of (EU) 2017/848). Table 3 is an excerpt of the latest MSFD criteria from (EU) 2017/848 concerning D6 Seafloor integrity. Table 4 shows the correspondence between benthic Broad Habitat Types (BHT) as mentioned in (EU) 2017/848 and the Barcelona Convention classification system level 2 (as in Montefalcone, Tunesi & Ouergui, 2021).

132. <u>For the MSFD criteria:</u>

> "physical loss" should be understood as a permanent change to the seabed which has lasted or is expected to last for a period of two reporting cycles (12 years) or more.
>
> "physical disturbance" should be understood as a change to the seabed from which it can recover if the activity causing the disturbance pressure ceases.

133. ICES (2019) advice on seafloor assessment process for physical loss and physical disturbance on benthic habitats, places the curser between "disturbance" and "loss" differently (see next chapter 7).

Table 3 : *Excerpt of the criteria and methodological standards for Descriptor 6 "Seafloor integrity" from (EU) 2017/848.*

Criteria elements	Criteria	Methodological standards
Physical loss of the seabed (including intertidal areas).	D6C1 — Primary: Spatial extent and distribution of physical loss (permanent change) of the natural seabed.	Scale of assessment: As used for assessment of the benthic broad habitat types under Descriptors 1 and 6. Use of criteria: The outcomes of assessment of criterion D6C1 (the distribution and an estimate of the extent of physical loss) shall be used to assess criteria D6C4 and D7C1. The outcomes of assessment of criterion D6C2 (the distribution and an estimate of the extent of physical disturbance pressures) shall be used to assess criterion D6C3. The outcomes of assessment of criterion D6C3 (an estimate of the extent of adverse effect by physical disturbance per habitat type in each assessment area) shall contribute to the assessment of criterion D6C5.
Physical disturbance to the seabed (including intertidal areas)	D6C2 — Primary: Spatial extent and distribution of physical disturbance pressures on the seabed.	
Benthic broad habitat types or other habitat types, as used under Descriptors 1 and 6	D6C3 — Primary: Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions (e.g. through changes in species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), by physical disturbance. Member States shall establish threshold values for the adverse effects of physical disturbance, through regional or subregional cooperation.	
Benthic broad habitat types as listed in Table 2 and if present in the region or subregion, and other habitat types as defined in the second paragraph. Member States may select, through regional or subregional cooperation, additional habitat types, according to the criteria laid down under 'specifications for the selection of species and habitats', and which may include habitat types listed under Directive 92/43/EEC or international agreements such as Regional Sea Conventions, for the purposes of: (a) assessing each broad habitat type under criterion D6C5; (b) assessing these habitat types. A single set of habitat types shall serve the purpose of assessments of both benthic habitats under	D6C4 — Primary: The extent of loss of the habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area. Member States shall establish the maximum allowable extent of habitat loss as a proportion of the total natural extent of the habitat type, through cooperation at Union level, taking into account regional or subregional specificities.	Scale of assessment: Subdivision of region or subregion, reflecting biogeographic differences in species composition of the broad habitat type. Use of criteria: A single assessment per habitat type, using criteria D6C4 and D6C5, shall serve the purpose of assessments of both benthic habitats under Descriptor 1 and sea-floor integrity under Descriptor 6. The extent to which good environmental status has been achieved shall be expressed for each area assessed as: (a) for D6C4, an estimate of the proportion and extent of loss per habitat type and whether this has achieved the extent value set; (b) for D6C5, an estimate of the proportion and extent of adverse effects, including the proportion lost from point (a), per habitat type
	D6C5 — Primary: The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), does not exceed a specified proportion of	

Criteria elements	Criteria	Methodological standards
Descriptor 1 and sea-floor integrity under Descriptor 6	the natural extent of the habitat type in the assessment area.	and whether this has achieved the extent value set; (c) overall status of the habitat type, using a method agreed at Union level based on points (a) and (b), and a list of broad habitat types in the assessment area that were not assessed.

134. MSFD requires GES for seafloor including broad benthic habitats types (see Table 4) which is covered by two descriptors:

- D1 "*Biological diversity is maintained.* " and
- D6 "*Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected*".

***Table 4** : Benthic Broad Habitat Types relevant for D6 which correspond to one or more BC benthic habitats*

Benthic broad habitat type (BHT) as in (EU) 2017/848	Barcelona Convention Habitat (see Montefalcone, Tunesi & Ouerghi, 2021)
Littoral rock and biogenic reef	MA1.5 Littoral rock ; MA2.5 Littoral biogenic habitat
Littoral sediment	MA3.5 Littoral coarse sediment ; MA4.5 Littoral mixed sediment ; MA5.5 Littoral sand ; MA6.5 Littoral mud
Infralittoral rock and biogenic reef	MB1.5 Infralittoral rock ; MB2.5 Infralittoral biogenic habitat
Infralittoral coarse sediment	MB3.5 Infralittoral coarse sediment
Infralittoral mixed sediment	MB4.5 Infralittoral mixed sediment
Infralittoral sand	MB5.5 Infralittoral sand
Infralittoral mud	MB6.5 Infralittoral mud
Circalittoral rock and biogenic reef	MC1.5 Circalittoral rock ; MC2.5 Circalittoral biogenic habitat
Circalittoral coarse sediment	MC3.5 Circalittoral coarse sediment
Circalittoral mixed sediment	MC4.5 Circalittoral mixed sediment
Circalittoral sand	MC5.5 Circalittoral sand
Circalittoral mud	MC6.5 Circalittoral mud
Offshore circalittoral rock and biogenic reef	MD1.5 Offshore circalittoral rock ; MD2.5 Offshore circalittoral biogenic habitat
Offshore circalittoral coarse sediment	MD3.5 Offshore circalittoral coarse sediment
Offshore circalittoral mixed sediment	MD4.5 Offshore circalittoral mixed sediment
Offshore circalittoral sand	MD5.5 Offshore circalittoral sand
Offshore circalittoral mud	MD6.5 Offshore circalittoral mud
Upper bathyal rock and biogenic reef	ME1.5 Upper bathyal rock ; ME2.5 Upper bathyal biogenic habitat
Upper bathyal sediment	ME3.5 Upper bathyal coarse sediment; ME4.5 Upper bathyal mixed sediment; ME5.5 Upper bathyal sand; ME6.5 Upper bathyal mud
Lower bathyal rock and biogenic reef	MF1.5 Lower bathyal rock ; MF2.5 Lower bathyal biogenic habitat
Lower bathyal sediment	MF3.5 Lower bathyal coarse sediment; MF4.5 Lower bathyal mixed sediment; MF5.5 Lower bathyal sand; MF6.5 Lower bathyal mud

Benthic broad habitat type (BHT) as in (EU) 2017/848	Barcelona Convention Habitat (see Montefalcone, Tunesi & Ouerghi, 2021)
Abyssal	MG1.5 Abyssal rock ; MG2.5 Abyssal biogenic habitat ; MG3.5 Abyssal coarse sediment ; MG4.5 Abyssal mixed sediment ; MG5.5 Abyssal sand ; MG6.5 Abyssal mud

135. Criteria D6C4 and D6C5 apply both to MSFD D1 and D6 (see). Criteria from other Descriptors that address aspects of seafloor quality should also be taken in account for D6C5 (see Figure 3). Besides, many seafloor benthic habitats are assessed through other EU policies such as the Water Framework Directive and the Urban Waste Water Treatment Directive (European Commission, 2020). It is therefore important to harmonise concepts, seafloor assessment methods and establish links between these policies.

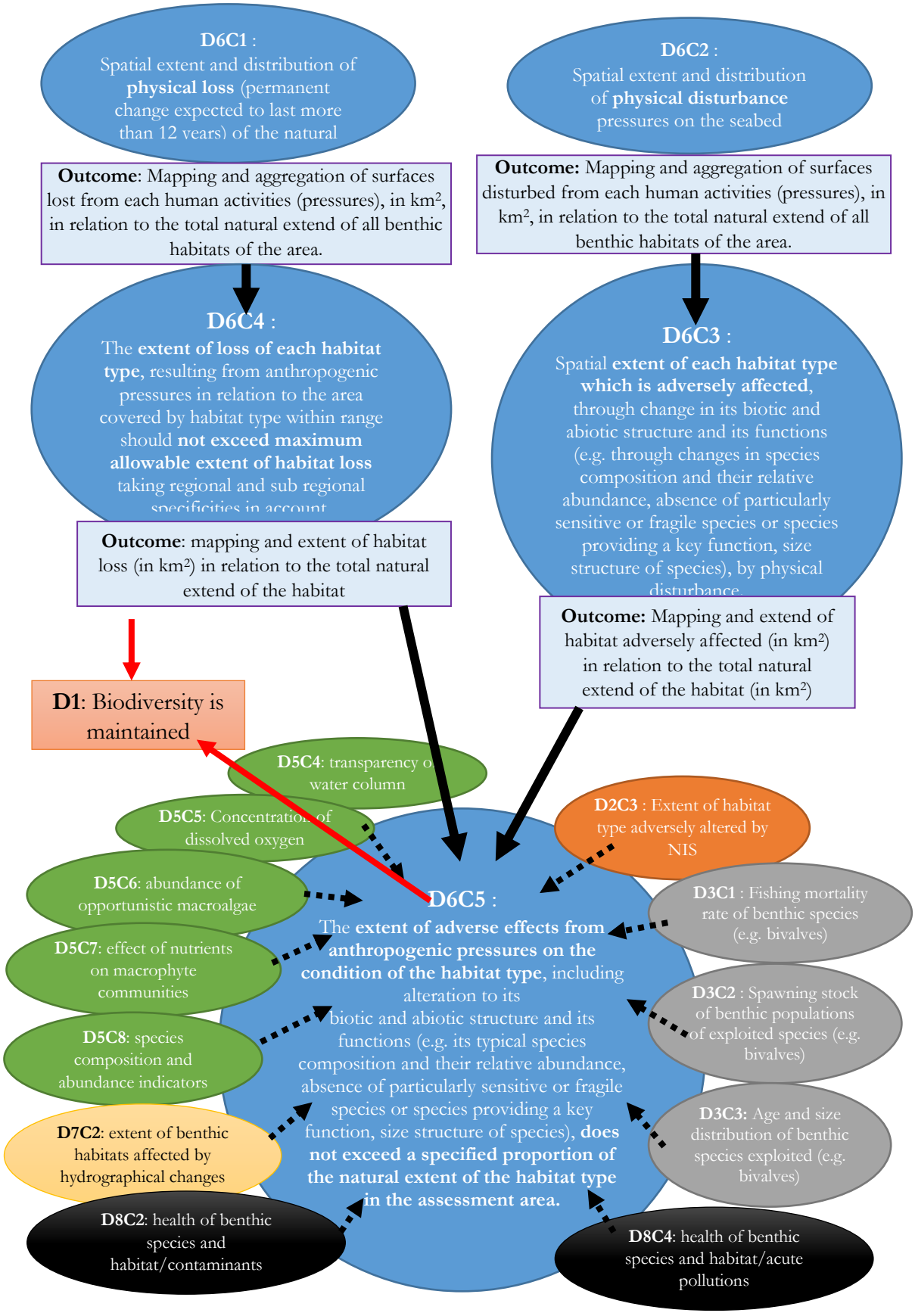

Figure 3 : Schematic representation of relations between MSFD criteria relative to seafloor integrity (based on (EU) 2017/848)

136. The draft schematic for benthic assessment elaborated by the Baltic Marine Environmental Protection Commission, Expert Network on Benthic Habitats (2020)[29] is particularly interesting to understand the MSFD requests for D6 and the complex relations between Criteria, the requirements and how they feed into each other. An excerpt is presented hereafter Figure 4.

137. Criteria C1 and C2 do not request a threshold value for Good Environmental Status. For C3, C4 and C5 threshold values are requested and should be defined at the European level, but appear not to have been defined yet (Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a and b).

[29] See online Baltic Marine Environmental Protection Commission HELCOM document

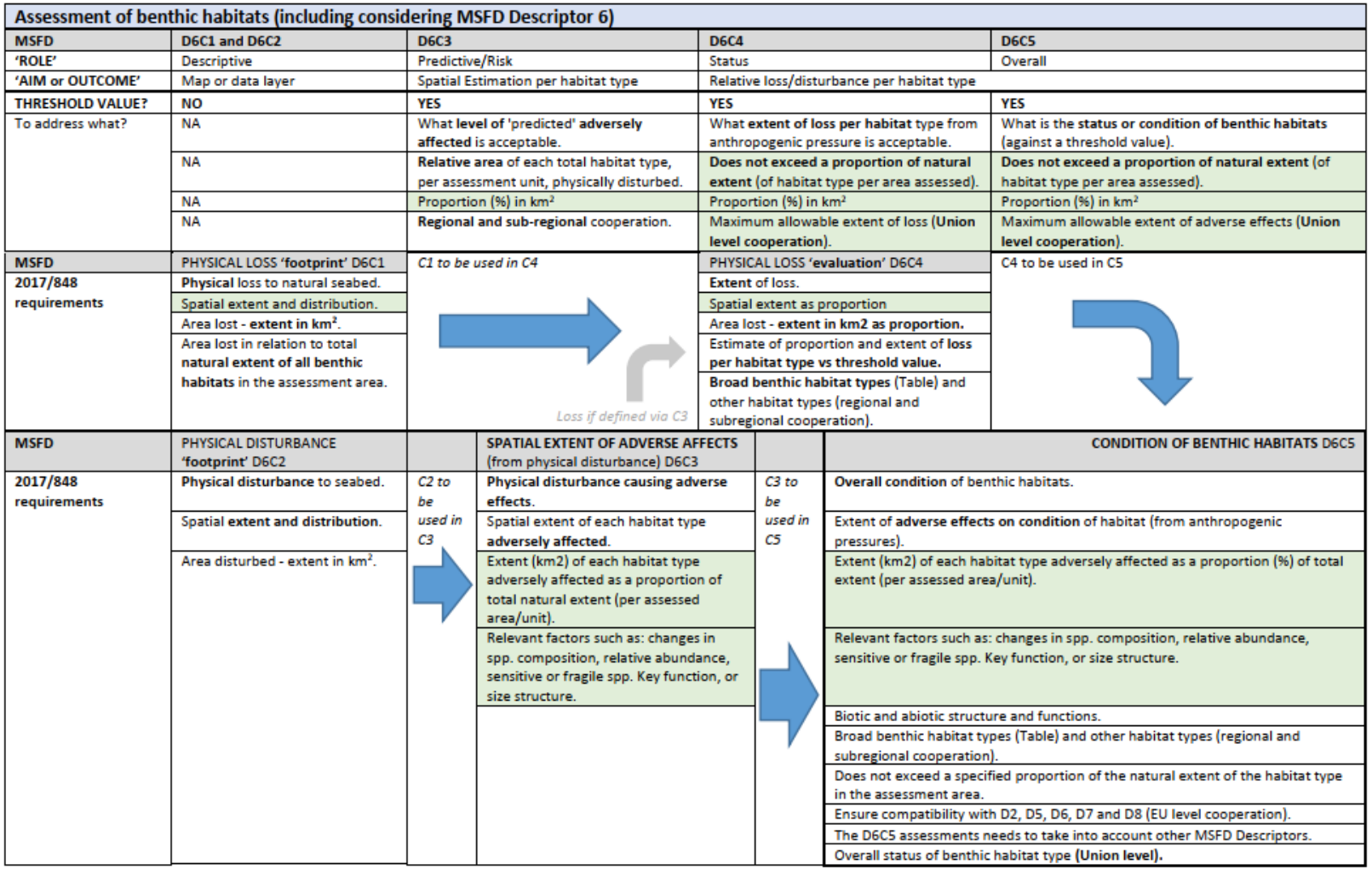

Figure 4: Excerpt of the HELCOM draft schematic for benthic assessment (from

138. Recommendations for the implementation of MSFD have been conducted by the DEVOTES project (Patrício et al., 2014) where in particular inconsistencies regarding the habitat classification proposed by the MSFD have been underlined calling for a hierarchical and nested habitat system and clear and concise definition of terms. Other inconsistencies, need clarifications and gaps have been underlined. Some have been taken in consideration in the (EU) 2017/848 which brings precisions to the initial MSFD text, but many gaps and needs of clarification remain unaddressed. Also, Patrício et al. (2014) consider that the fact that D6 is a combined pressure and state descriptor which implies the use of combined status and pressure indicators is confusing. Criteria should therefore be clearly divided between pressure and status as well as the subordinate indicators (Patrício et al., 2014). Furthermore this report underlines the high variability and heterogeneity of methods, thresholds and limits from the Member States' reports.

139. The review and analysis of the MSFD 2018 EU Member States' reports concerning Descriptor 6 "*Seafloor integrity"* was conducted by the Joint Research Centre (JRC) and published in 2021 (Boschetti, Palialexis, & Connor, 2021). This technical report reveals that work is still to be done regarding consistency and quality of the reports but also harmonization of methods, common understanding of key concepts, data accessibility and management (Boschetti, Palialexis, & Connor, 2021). Information appeared also to be frequently misreported with data and methodological gaps and assessment periods ranging from 4 to 7 years instead of the 6-year cycle (Boschetti, Palialexis, & Connor, 2021).

140. These two documents (Patrício et al., 2014 and Boschetti, Palialexis, & Connor, 2021) are of great interest for the assessments strategies and monitoring to be set up by BC Member States and their reporting in the framework of IMAP Ecological Objectives and Common Indicators.

141. Assessment and monitoring programs for addressing "seafloor integrity" need to be carefully prepared so as to use and/or address requirements of different IMAP Ecological Objectives but also existing policies.

142. Furthermore, difficulties and gaps that appeared for the MSFD Descriptor 6 in terms of data access, data management, common understanding of concepts, compatible time, space scales etc. (see e.g. Patrício et al., 2014; Piet & Royo Gelabert, 2019; Boschetti, Palialexis, & Connor, 2021), but also advice given by DEVOTES project (Patrício et al., 2014) and ICES concerning D6 (ICES, 2019a) should be well examined for the elaboration of Common Indicators of the Ecological Objective 6 "seafloor integrity".

7. Assessment process for seafloor damage advised by ICES with regard of MSFD process

143. ICES advised to EU on a seafloor assessment process for the MSFD descriptors D6C1, D6C4 relative to physical loss and D6C2 relative to physical disturbance on benthic habitats (ICES, 2019a). The publication develops a clear process applicable to states and that further facilitates the development of an overarching regional framework (see Figure 5). Demonstrations at a state or sub-regional level are illustrate the concepts and tables present for

example ranked anthropogenic activities that affect seafloor, data type etc. for each EU region including EU Mediterranean Sea.

144. The process is based on three stages to access D6C1, D6C2 and D6C4 and could accommodate for the assessment of D6C3 if needed. These are (Figure 5):

Stage 1. Identifying the main anthropogenic activities disturbing the seabed

These activities are classed in 4 pressure subtypes:

- Abrasion (e.g. by trawling gear or anchor)
- Removal (either directly such as mining, or indirectly by changes of hydrodynamics)
- Deposition (e.g. dredging deposits or indirectly by changes in hydrodynamics)
- Sealing (e.g. constructions)

Stage 2. Data and methodology to create and assess pressure maps

Stage 3. Assessing adverse effects on seabed habitat

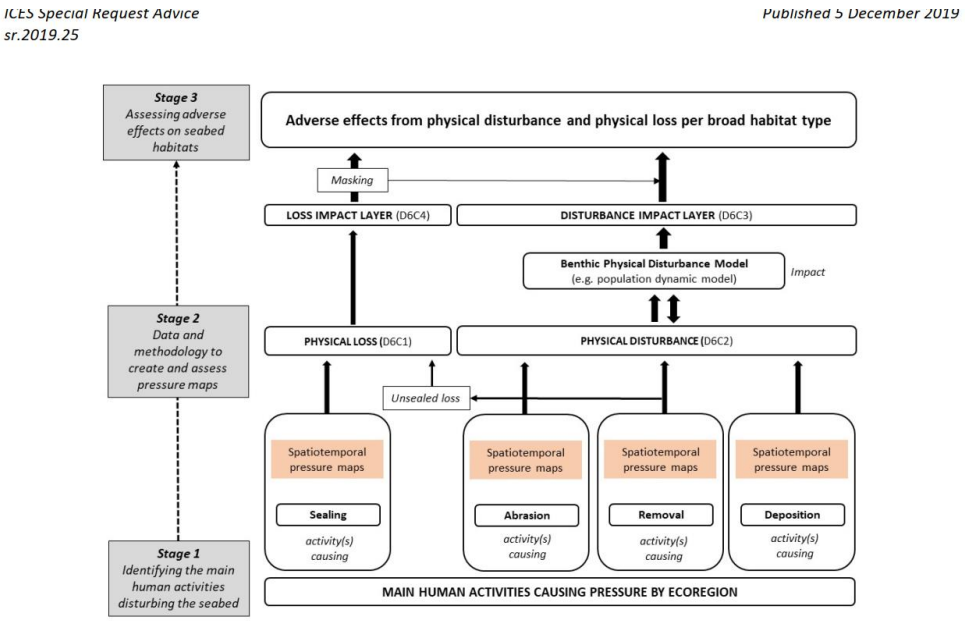

Figure 5: Excerpt from (ICES, 2019a) describing the seafloor assessment process

145. As mentioned before, ICES (2019a) defines the terms "physical loss" and "physical disturbance" slightly differently than the definition given in (EU) 2017/848. These terms are defined as follows in ICES (2019)

> "*Physical loss is defined as any human-induced permanent alteration of the physical habitat from which recovery is impossible without further human intervention. An alteration of the physical habitat refers to a change from one EUNIS level 2 habitat type to another EUNIS level 2 habitat type. Recovery indicates the re-establishment of the*

original natural EUNIS level 2 habitat by means of a human intervention. Two types of physical loss are identified:

- *Sealed physical loss results from the placement of structures in the marine environment (e.g. wind turbines, port infrastructure) and from the introduction of substrates that seal off the seabed (e.g. dredge disposal).*
- *Unsealed physical loss results from changes in physical habitat, either from human activities or from the indirect effects of the placement of man-made structures (e.g. aggregate extraction or a structure causing changes in water flows, ultimately changing the EUNIS level 2 habitat type).*

Physical disturbance is defined as a pressure that disturbs benthic biota but does not permanently change the habitat from one EUNIS level 2 habitat type to another EUNIS level 2 habitat type. With sufficient time, recovery can be expected without human intervention. Physical disturbance to physical loss can be regarded as a continuum, where the intensity of a physical disturbance may lead, in time, to a permanent change from one EUNIS level 2 habitat type to another and hence physical loss." (ICES, 2019a, p3-4).

146. The fact of referring to a change from one habitat level 2 to another to define physical loss, helps discriminate physical disturbance from physical loss. This point does not appear in the definitions of (EU) 2017/848 but may be a threshold of interest to consider for Mediterranean seafloor damage. In this case though, it would perhaps be of interest to integrate in the habitat classification used an "artificial substrate" or "artificial reef" at littoral, infralittoral, circalittoral and bathyal level.

147. Although Common Indicators have not yet been defined for IMAP EO6 "Seafloor integrity", the assessment process described in the document ICES (2019a) gives an interesting framework that could most probably be adapted to upcoming CI that will be defined for EO6.

148. In ICES (2019a), relevant information concerning the EU Mediterranean region are given in tables. The information concerns a ranking of anthropogenic activities that affect the seabed, data type, footprint and metrics for the 4 pressure types (abrasion, removal, deposition and sealing) as well as gaps impediments to operations. These could be a good starting point to further define and specify these elements at the Mediterranean Sea level (not only EU). These will be needed for EO6 whatever the CI may be.

149. The examples in ICES (2019a) concern mainly other areas than the Mediterranean Sea but the assessment process and the assessment of D6 (C1-C5) for French Mediterranean area described in the documents Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique (2019a and b) represent a comprehensible example of a similar process applied in the Mediterranean Sea, although it is not point for point the same approach and they are some gaps.

150. These three documents together (Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a and b and ICES, 2019a) draw a framework that could be useful in the definition of the assessment process of CIs to assess seafloor damage at the Mediterranean level but also at the sub-regional and national level.

8. Indicative draft process to assess Mediterranean seafloor damage

151. This desk review on best practices and methodologies for the monitoring and assessment of seafloor damage underlined the importance of a clear, step-by-step and straightforward framework for defining seafloor damage. Based mainly on the advice by ICES to EU on seafloor assessment process for physical loss and physical disturbance on benthic habitats (ICES, 2019a) but also on the approach of the French documents relative to the assessment of GES for MSFD (Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a, b) and on the analyse of EU reports for MSFD (Boschetti, Palialexis, & Connor, 2021), the following step-by-step questions intend to facilitate and support the process of establishing an assessment and monitoring of seafloor damage for a state but in a regional defined framework. Boschetti, Palialexis, & Connor (2021) underlined the need to harmonize assessments and have common approaches, parameters etc. at a regional level after analyzing the reports by EU countries. Many assessments where incomplete and incomparable due to a lack of initial precisions in the assessment process at a regional or sub-regional level.

8.1. Which anthropogenic activities damage the state's seafloor?

152. Anthropogenic activities affecting seafloor need to be clearly and precisely identified for each Mediterranean state. These are not the same for each state or sub-area (e.g. dredging for shellfish will be an anthropogenic activity with high impact on seafloor in the North Adriatic whereas it is inexistent off Algerian coasts; on the other hand, red coral harvesting will have an important impact on habitats in Algeria but not in Libya).

153. To help Mediterranean states clearly identify these activities for their seas, an exhaustive and precise list of potential anthropogenic activities affecting seafloor at the Mediterranean scale could be drawn and proposed.

154. A list of anthropogenic activities damaging the seafloor at the level of a state will help identify the authorities that possess or have access to physical damage data and to the data sources available. The possibility that data of interest has already been collected for other monitoring programmes should be also checked (e.g. through data-sources).

8.2. What type of damage (pressure) can these anthropogenic activities individually exert on seafloor?

155. The type of damage affecting seafloor is variable and can be regrouped in sub-classes (abrasion, removal, deposition, sealing) as proposed by ICES, (2019a), although it does not seem necessary for assessing seafloor damage (see Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a, b).

156. However, the degree of damage is variable and the ultimate damage is the physical loss of seafloor which is irreversible. Yet, the definition proposed in the MSFD seems unclear and inappropriate *("physical loss" should be understood as a permanent change to the seabed which has lasted or is expected to last for a period of two reporting cycles (12 years) or more*) since it is time dependent and subjective (what is a change?). The limit between high physical

damage and physical loss proposed by ICES (2019a) is clearer or at least more definite: a physical loss implies a change from one EUNIS habitat level 2 to another level 2. This could be satisfactory but "artificial substrate" is not considered in the habitat classification. How can a littoral rock or biogenic reef covered by a concrete structure be considered as a change in level 2 habitats? A definite distinction between high physical disturbance and physical loss needs to be more precisely defined. This definition is important because there is no gradient in physical loss therefore it is much easier to assess and monitor than variable degrees of seafloor disturbance.

157. Listing the potential disturbances/losses (that are here considered together) induced by the anthropogenic activities will facilitate the definition of the data to ask for from the competent authorities (these are already identified in step1 but can be completed here). The data series or data packages requested should:

- Be an indicator of physical disturbance/loss including frequency of damage or contribute to define an indicator
- Be delimited in time (e.g. past year, past five years but should have a year as unit, not seasonal)
- Be spatialized
- Have reliable attribute information

158. Precious and clear information concerning data management to have in mind even at the data requirement stage is given in Annex 1 "Data management" in the documents (ICES, 2019a and b). The *ICES User Handbook: Best practice for Data Management* (ICES, 2019b) details also steps for the acquisition of already existing data and gives best practices for all the levels of data management. It is made for ICES Community but the working framework is clear. A much more synthesized version exists in Annex 1 of ICES advice to EU on disturbance and loss of seafloor habitats (ICES, 2019a).

159. Precisely defining the data requested is part of quality assurance (QA) even if quality control (QC) of the data received will have to be processed. This point, although crucial, will not be developed here, it is addressed in the UNEP(DEPI)/MED IG.22/Inf.7 text on IMAP definition (see UNEP/MAP, 2016b, p. 21-22 and within the various chapters) and the ICES (2019a, b).

8.3. Where and what surface is possibly affected by anthropogenic activities?

160. The data acquired should be georeferenced and mapped and enable localisation of potential seafloor areas affected, to produce a footprint of physical disturbance and physical loss, to create maps and address spatial extent in terms of surface area (in km2) and/or proportion of damaged surface relatively to the total seafloor of the assessed area.

161. Mapping seafloor physical loss is mainly based on littoral artificialisation including capital dredging and off-shore platforms and wind farms. A relation should be established with the EO8 CI16 "*Length of coastline subject to physical disturbance due to the influence of man-made structures*". Dumping areas and mineral dredging if repeated in the same area could also be considered as seafloor physical loss (e.g. global dredging activities and dumping have been considered as indicators of seafloor loss in the French Mediterranean report on D6C1 (see

Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a)). Data for seafloor loss are relatively easy to acquire and map. Satellite images for example can be used if needed.

162. Concerning seafloor physical disturbance, it is evident that the disturbance can be of variable degree depending on the anthropogenic activity, the frequency etc. The question should be studied at this point: should variable degrees (classes) of disturbance be defined? In the example of the Mediterranean French report (Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019a) it was not the case. For example a grid cell was defined as a surface "bottom trawl disturbed" whether only one bottom trawler passed once (in fishing action) during the studied period or if bottom trawlers passed frequently.

163. Common guidelines for the Mediterranean MS should help define amidst other points:
- What projected coordinate system use
- What grid cell size should be used
- How should a grid cell be considered if it is only partially covered by e.g. physical loss

164. Various operating guidelines for seabed mapping exist (e.g. Davies et al., 2001), others are more specific to mapping pressure especially trawling pressure (Kavadas et al., 2014; ICES Advisory Committee, 2014 and 2019). Fishing intensity data may be delicate to treat and analyse when obtained and disparities in datasets and (resolution, quality etc) makes comparisons difficult (see Piet & Royo Gelabert, 2019).

165. Trawling impacts being one of the most spatially extended seafloor damage in the Mediterranean, it seems important to edit guidelines on the treatment and use of VMS/AIS data for example as indicator of trawling impact (see recommendations in ICES Advisory Committee, 2014). This was the object of the Deliverable N°3.4 of the PERSEUS project and comprehensible information as well as case studies are available in the final report (Kavadas et al., 2014). Also, the type of grid cells size should be as much as possible common or at least nested for the Mediterranean Sea to ensure comparability, in particular for analysing trawling track (either linear or points). Using for example degree based grid cells, can create grid cells of different size between northern areas and southern areas (see Piet & Royo Gelabert, 2019) although the Mediterranean Sea is relatively near the equator, therefor e.g. 1'x1' cells must cover a comparable size between North and South Mediterranean.

166. QA and QC are here again essential to ensure comparability within a study of seafloor damage but also between studies.

8.4. Which anthropogenic activity presumably damages which habitat?

167. Crossing at a national level the potentially seafloor damage from anthropogenic activities with habitat types (as in
168. Table ***1***) would help identifying also the habitats that are the most under pressure, which doesn't necessarily mean the most damaged. An important point is that the classification type (broad habitat type as used for MSFD or other) but also the level to be used should be common to the Mediterranean states. It should be taken in consideration that European Mediterranean

countries have to report in the framework of MSFD using the board habitat types (BHT) but UNEP/MAP classification nests in BHT therefore a higher level of UNEP/MAP classification may be decided on. It appears also that the understanding of littoral, infralittoral, circalittoral and bathyal need to be clearer in terms of depths.

169. The "Habitat distributional range and extend" is the Common Indicator 1 of the IMAP EO 1 Biodiversity. The Member States are invited to report on the spatial distribution of three main habitats: Coralligenous, Maerl/Rhodolith and *Posidonia oceanica* meadows habitats. Assessment and monitoring guidelines are proposed for each habitat (see documents UNEP(DEPI)/MED IG.22/Inf.7 published in 2016, UNEP/MED WG.467/16 or WG. 474/3 for monitoring protocols published in 2019). These results should be used here.

170. The overlay of the "loss and disturbed areas" map with the results of CI1 for the three habitats will already allow to identify potentially damaged areas for these habitats. The use of national seafloor habitats or EMODnet habitat layers can complete the gaps of national benthic habitat maps.

171. The pressure indicators of anthropogenic activities affecting the seafloor taken individually will underline the potential damaged surface and position linked to each anthropogenic activity on each habitat present in the Member State.

172. It is possible also to use Spatial Assessment Units which were successfully used in the Nested Environmental status Assessment Tool (NEAT)[30] developed by DEVOTES project (Berg et al., 2019; Borja et al., 2016; Teixeira et al., 2016; Uusitalo et al., 2016).

173. It may be interesting to collect specific ground-truth data at least for certain areas of habitats to obtain a fine definition of the spatial extent of the habitat. Then the means of acquisition will have to be defined.

174. For habitat mapping methodologies and best practices, it is interesting to consult the three documents: *Marine Monitoring Handbook* (Davies et al., 2001), the *Review of standards and protocols for seabed habitat mapping* (Coggan et al., 2007) and the *MESH Guide to Habitat Mapping: a synopsis* (MESH Project, 2008).

8.5. Can damage intensity and habitat sensitivity to anthropogenic activities be assessed?

Is it possible to categorise damage intensity and score sensitivity of habitats or key species of a habitat against pressure from anthropogenic activities to estimate their resistance. This is where a categorisation of the impacts may appear usefull. Sensitivity and resistance of seabed habitats to fishing activities have been assessed e.g. by Eno et al. (2013) and Rijnsdorp et al. (2017, 2018). Eigaard et al. (2016) has conceptualized the footprint of the different bottom trawling gear in an attempt to model bottom trawling impact. The BENTHIS program (Benthic Ecosystem Fisheries Impact Study) studied the different possibilities to mitigate the impact of bottom trawling activities by proposing new gear and studying the possibility of assessing a "fisheries credit system" aiming to reduce trawling intensity in some areas without

[30] The NEAT tool and Guidance are available on Zenodo here

compromising the fishery (Rijnsdorp et al., 2017). In this work, a case study was in the Mediterranean Sea was studied but carried only on otter trawlers. Pitcher et al. (2022) have carried out a worldwide study of trawling impacts on the communities of seabed sedimentary habitats in 24 regions using a biotic indicator. Amidst the studied areas, the area studied in the Adriatic Sea showed the most depleted seafloor (Pitcher et al., 2022).

Habitat sensitivity is dependent of many factors, but body size and longevity (linked to recovery rate) of the benthic and especially sessile species appear to increase habitat sensitivity to bottom trawling activities (Rijnsdorp et al., 2018). Scales and character of the anthropogenic impacts need to be evaluated especially for VMEs in view of an effective management (Marín, Perry, & Aguilar, 2017).

8.6. What is the state of seafloor in the presumably impacted and not impacted areas?

175. Assessment of the entire seafloor condition of a MS is not possible. Here, ground-truth data are required to assess the seafloor state and help initiate monitoring plan. Assessment can be based on:

- *in situ* sampling (e.g.grabs, box-corer etc)
- remote sensing (e.g. satellite, aircraft images)
- acoustic surveys (e.g. ide-scan sonar, multi-beam echo-sounder)
- image/video data

176. All should be geolocalised by GPS directly or indirectly (e.g. acoustic transponder with the ship for underwater vehicles).

177. Autonomous Underwater Vehicles (AUVs), Remotely Operated underwater Vehicles (ROVs), gliders and towed systems can be more or less equipped with sensors including for the acquisition of image/video or acoustic data. Each have limits, some can sample others not, costs are different as well as needs. But all should use a predefined sampling design. The objectives need to be clear before acquiring data. Means of data acquisition are multiple and it is worth going through specific guidelines such as those for marine benthic monitoring using AUVs or ROVs (e.g. JNCC, 2018a, b) to assess the possibilities, the costs and the needs. Some ROVs have been developed in collaboration with marine scientist to answer to specific needs for practical observation of Mediterranean seafloor (e.g. Gori et al., 2009).

178. The objective is to obtain a picture of the seafloor state in areas under anthropogenic pressure but also in areas with minimised anthropogenic pressure, reference sites. Both are important also to be able to define GES of seafloor whether ground-truth data acoustic, image or seafloor samples. In the French evaluation of GES for French Mediterranean seafloor, although assessments data was based on sediment biotic index (BenthoVAL), it was not possible to define weather GES was reached because of a lack of reference stations. This was due to the fact that the data used were provided Water Framework Directive that focussed essentially on disturbed areas. The WFD monitoring of this indicator will therefore be extended to include reference station so as to better fit MSFD requirements (Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique, 2019b).

179. The temporal changes will be revealed by a monitoring program.

180. The assessment of the seafloor needs a sampling plan or design that should cover various habitats (especially vulnerable habitats) and cover, as much as possible, a gradient of anthropogenic activities pressures. This plan can, at least partially, serve for monitoring programs to detect temporal changes. They should also be realistically feasible taking in account financial coasts but also scientific or expert availability needed and cover different impacts. Well-constructed sampling plans that can be effectively monitored through time give robust datasets. Therefore, methods used must be in accordance with local possibilities. The assessment and monitoring can progressively build on cost-effective and well-fit initial plan.

181. Initial planning and setting-up phase of a monitoring program are essential steps that take time (see UNEP/MAP, 2019a document WG. 474/3).

182. To draw the sampling plans, the previous steps 1-5 will contribute by identify which areas and which habitats are the most impacted for each human activity but also regarding a cumulating pressures due to plural activities impacting the seafloor.

183. The state of three habitats is assessed under EO1 CI2 (Posidonia meadows, coralligenous habitats and maerl/rhodolith habitats) and these assessments can be used also to estimate seafloor damage but they are not sufficient. If the assessment for CI2 has not yet been planned, the resulting map crossing anthropogenic pressure and habitats can help in the monitoring planning for these habitats that could be used for CI2 and EO6.

184. At the end of this process, one should be able to answer at a national level:

- how much seafloor surface is considered damaged/ total seafloor
- how much seafloor surface is considered damaged by habitat/total surface of habitat
- Which seabed areas undergo the most damage taking in account anthropogenic pressure and sensitivity of the habitat or key-species

185. Here again models can produce indicators but of existing models in European Union, only 8% concern seafloor integrity descriptors (Piroddi et al., 2015).

8.7. Can threshold values be defined?

186. Threshold values should probably be defined at a sub-regional level and not a national level to conserve the functionalities and integrity of the seafloor and the depending ecosystems. These would probably be easier to define once assessment of the seafloor state has been done. The definition of threshold values to determine whether or not GES is achieved is necessary but appears difficult to apply even for EU countries reporting for MSFD since many years.

8.8. Management to reduce damage

187. Management should take in consideration socio-economic variables in an ecosystem approach. It must coast the least to the society and benefit the most to the seafloor. It is a section that will not be developed in this document but authors such as McConnaughey et al. (2019) have published best practices for managing impacts of trawl fishing on seabed and Bastardie et al. (2020) have created a model to study different management scenarios.

9. Relevant methodologies and tools for assessing and monitoring anthropogenic pressure on seafloor

188. Table 5 summarises tools, indicators and acquisition methods appropriate for assessing seafloor damage in the Mediterranean Sea. Only the main anthropogenic activities impacting the seafloor are addressed in this table. Many already covered by other IMAP Ecological Objectives such as land-based pollution, litter and NIS are not addressed in this table.

Table 5: Pertinent indicators, tools and methods relative to assess the anthropogenic activities that damage the most seafloor in the Mediterranean Sea. PT: Pressure type (D: physical disturbance of seafloor, L: physical loss of seafloor).

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
Bottom Trawling (BT) fisheries							
BT fisheries - otter trawlers	D	-Abrasion	Circalittoral and bathyal sediment (sand, mud, mixed sediments)	-VMS data and logbook (see e.g. ICES Advisory Committee, 2014) -AIS (see Armelloni et al., 2021 for Med. Fishing boats) -Number of bottom trawlers by port -Vessel size -Type of gear by vessel and by fishing day -Fishing zone -Time spent fishing (hours) -fishing seasons - fishing depths -CPUE -discard list To date it appears that these elements can give the best estimate of bottom	-Video sledge transects (see Coggan et al., 2001) -ROV spot checks (see Coggan et al., 2001) -Side scan sonar (see Coggan et al., 2001; Lucchetti & Sala, 2012) For acquiring seafloor samples Van Veen, corers and grabs (see e.g. Davis et al., 2001)	-Number and diversity of sessile species -Bioturbation -depth of tracks -presence of visible tracks on transects (vertical tracks in canyon and continental slope) Biodiversity indicators from sediment samples are not specific to trawling impacts. Damage of megabenthic species can indicate existence of trawling activities but may not give a degree of impact that needs to be estimated by the frequency of	Modelling appears as an alternative for the footprints of different gear (see Eigaard et al., 2016, 2017) or to estimate presumed optimal environmental status (Foveau et al., 2017) or directly trawling impacts from different gear on different substrates by modelled indicators (Hiddink et al., 2017; Pitcher et al., 2022). Useful freeware Mediterranean: VMSbase for R (see Russo et al., 2014) European: VMStools for R (see Hintzen et al., 2012)
BT fisheries - dredges and beam trawlers	D to L depending on frequency and seafloor	-Abrasion -Ploughing seafloor	Littoral/Infralittoral sediment (sand, mud, mixed sediments) Infralittoral macrophyte habitats				
		-Uprooting macrophytes	Shallow macrophyte habitats (impact from beam trawling)		Diving visual methods (see IMAP Guidelines for monitoring marine vegetation WG. 474/3) but direct links between trawling and state of macrophyte habitats seems difficult to establish.		No indicator specific to beam trawling has been developed on these habitats. General state habitats indicators can be found in Guidelines for monitoring marine vegetation WG. 474/3 Usefull freeware Mediterranean: VMSbase for R (see Russo et al., 2014)

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
				trawling impacts. (see Eigaard et al., 2016, 2017) For VMS methodology see (PERSEUS Project)		trawling activities by gear for a given area.	European: VMStools for R (see Hintzen et al., 2012)
Non-trawling small-scale fisheries and recreational fishing							
Fishing activities using long-lines and gillnets mainly	D	-Abrasion	Infralittoral and circalittoral hard substrate and biogenic reefs	These small boats generally do not have VMS or AIS. Oral surveys with fishermen (long-line, gillnets, recreational fishing) will allow to determine depths and coralligenous and CWC habitats susceptible to be impacted	-ROV video images	-Number of derelict fishing gear observed/m^2 -Number of sessile megabenthic species entangled and damaged by fishing gear/m^2 -type of fishing gear	-Mytilineou et al., 2012 -Giusti et al., 2019
Anchoring							
Anchoring	D, locally L (Posidonia meadows)	-Uprooting and abrasion of macrophytes -Abrasion on sediment seafloor -Excavation in sediment	Infralittoral and circalittoral (locally) biogenic reefs and sediment seafloor	-AIS see website VESSELFINDER that traces boats with AIS (all commercial boats, cargos have AIS) and determines if they are at anchor or not Efficient method using AIS is described in Deter et al., 2017 See also the use of applications such as DONIA or Anchor Watch	-image acquisition through diving or ROV or small AUV (for deep or dangerous areas). In commercial boat anchoring areas in front of ports sediment samples could give information on pollution by heavy metals	-Number of boats anchored by day , length and tonnage of boats, type of anchor shows pressure on the area considered	- Deter et al., 2017 -MEDTRIX, 2019 -Watson et al., 2022 on impact of commercial boat anchoring

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
				that could in the future provide location of vessels.			
Dredging and dumping							
Mineral dredging (e.g. sand extraction)	L and D	-Removal -Turbidity during extraction in the vicinity of the area	Infralittoral sediment seafloor	-Mineral extractions (localisation, tons extracted granulometry, frequency by year)	Sampling when extracting or acquiring seafloor samples Van Veen, corers and grabs (see e.g. Davis et al., 2001) before (if possible) and after extraction in the extraction area but also around (few hundred meters)	-granulometry -content of organic matter (OM) -species richness -relative abundance (number of ind/m2)	-Boyd et al., 2005 (Mediterranean) -Krause et al., 2010 (Baltic Sea) - Erftemeijer & Robin Lewis, 2006 (impacts on seagrass) -Van Dalfsen et al., 2000 General biotic pressure indicators or indexes applied to sediments can be associated, although they are not specific to dredging impacts: -H’ Shanon diversity Index -AMBI index (see Borja, Franco & Pérez, 2000 and Muxika et al., 2005) -MEDOCC Index -BENTIX index (Simboura & Zenetos, 2002) -BQI indicator (Rosenberg et al. 2004), Benthoval (France)

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
Capital dredging	L	-Removal -turbidity increase	upper coastal infralittoral and littoral	-MSP -Future coastal constructions planned	Depending on situation	Before and after landscape, community, species biodiversity assessment depending on the situation	The NEAT tool would probably be of interest but actually not accessible.
Maintenance dredging	D	-Removal -Turbidity increase	Sediment of upper coastal infralittoral and littoral (ports, canals, passages)	-Ports needing regular cleaning -Canals -Frequency, tonnage and dumping area for dredged ports		Before and after: -granulometry -content of organic matter (OM) -species richness -relative abundance (number of ind/m2) -increase of turbidity in time and space -other	-Newell et al., 1998 -Erftemeijer & Robin Lewis, 2006 (impacts on seagrass) -Layglon et al., 2020 (Mediterranean)
Dumping	L and D	-Deposit -Turbidity	Generally infralittoral sediment seafloor but can affect adjascent habitates by turbidity increase and pollution	-assessment of dumping areas including number of dumping actions/year/site, type of material dumped	For acquiring seafloor samples Van Veen, corers and grabs (see e.g. Davis et al., 2001)	Before and after: -granulometry -content of organic matter (OM) -species richness -relative abundance (number of ind/m2)	-Erftemeijer & Robin Lewis, 2006 (impacts on seagrass) -Layglon et al., 2020 (Mediterranean) Before and after:

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
						-increase of turbidity in time and space -parameters relative to heavy metal pollution	General biotic pressure indicators or indexes applied to sediments can be associated
Coastal artificialisation							
Coastal constructions	L and D during construction and changes in hydrological conditions	-Sealing -Deposition/ removal due to hydrological changes -Loss of habitat continuity (habitat fragmentation)	All type of littoral upper sublittoral in coastal areas (sealing) -sediment littoral or upper sublittoral coastal habitats (removal/deposition)	-National authorities -MSP -Satellite images -Aerial photos -linear kilometres constructed	Parameters relative to hydrology should be locally assessed	-depth changes -siltation -turbidity during new construction or port enlargement	-Santiago-Ramos and Feria-Toribio, 2021 -Tejada et al., 2007
Aquaculture activities							
Aquaculture fixed infrastructures	D	-Deposit of OM and possibly fish treatments under the cages -Locally changes	Coastal upper infralittoral	-Number of cages -surface occupied -type of aquaculture - depth of cages -fish tonnage	Acquiring seafloor samples Van Veen, corers and grabs, divers (see e.g. Davis et al., 2001) under and around cages -water samples	-turbidity -granulometry -content of organic matter (OM) -temperature -oxygen in water -species richness	General biotic pressure indicators or indexes applied to sediments e.g.: -H' Shanon diversity Index

Anthropogenic activity	PT	Main pressures on seafloor	Type of seafloor	Indicators for spatial extent of impact	Ground truth data acquisition methods for assessing damage	Parameters to assess in sampling	Indicative indexes and indicators / References
		light conditions due to cages but also increased turbidity		Data should be acquired through national authorities		-relative abundance (number of ind/m2) -increase of turbidity in time and space -parameters relative to heavy metal pollution	-AMBI index (see Borja, Franco & Pérez, 2000 and Muxika et al., 2005) -MEDOCC Index -BENTIX index (Simboura & Zenetos, 2002) -BQI indicator (Rosenberg et al. 2004), Benthoval (France)

9.1. Additional information on assessing damage caused by bottom trawling fisheries

189. Damage afflicted by bottom trawling fishing gear and their impact on seafloor habitats is undeniable but difficult to assess. Many difficulties are encountered to assess the impact especially the state of the seafloor before trawling activities occurred. General biotic pressure indicators or indexes applied to sediment (Shanon diversity Index, AMBI, MEDDOC index, BENTIX, BQI etc.) are not sufficient. No indicators or index is satisfactory.

190. In some areas, intense trawling and trawling since many years have probably eradicated the large sessile VMEs that existed before such as *Isidella elongate* (Cartes et al., 2013). Therefore, historical approaches mapping the occurrences of VMEs, e.g. *Isidella elongata* on sediment seafloors, could be informative to determine areas that have been heavily trawled. Authors such as Lauria et al. (2017) used models to show that distribution of *I. elongate* was strongly negatively correlated with the presence of bottom trawling. This suggests that the todays observed distribution of the species has been significantly reduced (Maynou & Cartes, 2011; Lauria et al., 2017). It appears relatively clear that today's distribution and density of populations of *I. elongata* has shrank at the Mediterranean scale due to bottom trawling activities (see Maynou & Cartes, 2011; Pierdomenico et al., 2018).

191. The work by Rijnsdorp et al. (2018) estimating sensitivity of seabed habitats to disturbance by bottom trawling based on the longevity of benthic fauna is of interest. Longevity composition of the benthic community differed across habitats but habitat-specific patterns could be developed. The authors showed that in the North Sea trawling shifts community composition towards shorter-lived taxa, although it was not the case in all the conditions. Probably the approach could be adapted to the Mediterranean Sea and could possibly lead to the development of an easy-to-process trawling pressure indicator or index.

192. Acoustic methods can inform of trawling scars and their impact in terms of depth but not necessarily on the recent pressure since life span of trawling tracks persist for months or even years on seafloor depending on conditions (Schwinghamer et al., 1998). Underwater images (from e.g. ROV, video sledge) have improved definition but cover a smaller field of view (Coggan et al., 2001). Images though can give more information on the age and depth of the trawl tracks and additional information on bioturbation features following disturbance though good skills are required from the ROV pilot and the analyst (Coggan et al., 2001).

10.Relevant past and actual programs and projects

193. Current programmes on Mediterranean seafloor seem to be to date rare. Table 6 present a list of programs in connection with seafloor assessment but the majority are past programs.

Table 6: List of programs in relation with Mediterranean seafloor assessment

Project/program	Subject	Years	Area	Interest for seafloor	References
BENTHIS Benthic Ecosystem Fisheries Impact Study	The project studied the impacts of fishing on benthic habitats and provided the science base to assess the impact of current fishing practices.	2012 - 2017	Case studies in: Western Baltic North Sea Western Waters Mediterranean Black Sea	One of the case studies in the Mediterranean and focused on the alternatives of demersal otter trawl fisheries.	BENTHIS website Final report (Rijnsdorp et al., 2017)
CIGISMED Coralligenous based Indicators to evaluate and monitor the "Good Environmental Status" of the Mediterranean coastal waters	Enhance knowledge, protocols and monitoring of coralligenous habitats in the entire Mediterranean and develop indices and indicators for the determination of GES in LSFD framework.	2013-2016	Mediterranean Sea (France, Greece, Turkey)	Identification of threats to coralligenous habitats and development of indicators as well as citizen science network implementation -Protocol for monitoring coralligenous habitats	CIGESMED website CIGISMED, 2014 Féral et al., 2016
COCONET Project Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea),	Collate, analyse and integrate information to design MPAs network with a holistic approach coupling environmental protection and clean energy production.	2012-2016	Mediterranean and Black Sea	Conceptualising strategic areas for the implementation of Offshore Wind Farms to also serve connectivity between MPAs	Website not functional see project outline here. Boero et al., 2016

Project/program	Subject	Years	Area	Interest for seafloor	References
coupled with sea-based wind energy					
DEEPEASTMED State of the knowledge of deep-water vulnerable species and habitats in the Eastern Mediterranean	State of the knowledge of deep-water vulnerable species and habitats in the Eastern Mediterranean	2017-2019	Eastern Mediterranean	Better knowledge of the Eastern Mediterranean seafloor and habitats.	DEEPEASTMED page See different chapters of the DEEPEASTMED Atlas: Otero & Mytilineou, 2022
DEVOTES DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status	DEVOTES has developed tools to understand and describe biodiversity status at an European scale, including as many components of the ecosystem as possible, providing the scientific knowledge, upon which appropriate monitoring and management strategies under the MSFD can be designed and made available for managers, policy-makers and scientists.	2012-2016		Development of the NEAT (Nested Environmental status Tool) to understand and describe biodiversity status at a European scale including many components and help design monitoring strategies. Indicator catalogue (to be consulted with the software NEAT)	Website not functional see project outline here. NEAT software and manual may be downloaded through Zenodo website here Teixeira et al., 2016 Berg et al., 2019
GHOST MED	Mapping fishing gear with associated information (depth, type, date of observation etc) using also participatory science	Since 2015	French Mediterranean Sea	Identify where small-scale and recreational fishing impact habitats	GHOST MED

Project/program	Subject	Years	Area	Interest for seafloor	References
	but also scientific data from observation campaigns (ROV during canyon exploration)				
HERMES Hotspot Ecosystem Research on the Margins of European Seas	Acquisition of knowledge on biodiversity, structure, function and dynamics of ecosystems along Europe's deep-ocean margin to better understand European's deep-water ecosystems.	2005-2006	Mediterranean and Black Sea	Data acquisition through observations to distribution knowledge on deep-sea habitats of the margin but also to feed model aimed to improve the forecast of anthropogenic pressure on ecosystems.	Website not functional see project outline here Weaver et al., 2005 Weaver & Gunn, 2009 Danovaro et al., 2009
HERMIONE Hotspot Ecosystem Research and Man's Impact on European Seas	Followed the HERMES project but focused on human impact on deep-sea and translation of information into policy	2009-2012	Mediterranean, Black Sea, North Atlantic Ocean, Norwegian Sea	Knowledge acquisition on deep-sea seafloor. Datasets and data acquired on seafloor explored partly available through SeaDataNet	Website not functional see project outline here Weaver et al., 2009
IDEM MSFD Deep Med Implementation of the MSFD to the Deep Mediterranean Sea	Aims to support MSFD implementation in terms of coordination, coherence, assessment and GES determination for the Mediterranean deep-sea (bellow 200m)	2017-2019	Mediterranean Sea	Quantification of anthropogenic impacts on deep-sea seafloor	IDEM MSFD Deep Med website See reports at website especially IDEM Project 2018a, b, 2019 a, b

Project/program	Subject	Years	Area	Interest for seafloor	References
MEDISEH Mediterranean sensitive habitats	Within an ecosystem approach to fisheries, the project aimed to compile information on historical and current data on the locations and the status of seagrass beds, coralligenous and maerl beds all over the Mediterranean basin, the identification and mapping of suitable areas for *Posidonia*, coralligenous and maerl communities by developing habitat distribution models at different spatial scales.	2011-2013	Mediterranean Sea	Localising sensitive benthic habitats	See the page here -Giannoulaki et al., 2013
MedKeyHabitats I & II Mapping of key marine habitats in the Mediterranean and promoting their conservation through the establishment of Specially Protected Areas	The project aims at establishing cartographic inventory of marine habitats of conservation interest to extend the Specially Protected Areas of Mediterranean Importance network (SPAMI), as required by Barcelona Convention's Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol).	2013-2016	Mediterranean Sea	Localising sensitive benthic habitats	MedKeyHabitats page
MedPosidonia	The project aims primarily to collect information on the presence and the evolution of the Posidonia meadows in	2006-2009	Algeria Libya, Tunisia, Turkey	Localising a sensitive habitat Posidonia meadows	MedPosidonia Project page

Project/program	Subject	Years	Area	Interest for seafloor	References
	selected sites in order to enable the participating countries to establish/adjust their biodiversity conservation and sustainable management programs.				
MEDTRENDS	This program aimed to illustrate and map the most likely integrated scenarios of marine economic growth at the transnational level in EU Mediterranean countries for the next 20 years.		Mediterranean	Anticipate future trends in anthropogenic pressures on Mediterranean seafloor	MEDTRENDS website See report on webpage.
MIDAS Managing Impacts of Deep-seA reSource exploitation	The MIDAS project was conceived to address increasing concerns over the lack of scientific knowledge required to understand and mitigate the likely impacts associated with the extraction of mineral resources from the deep sea.	2013-2016	EU	Assess potential impacts of seafloor mining an activity that could develop in the future in the Mediterranean Sea	MIDAS website See report on website
MPN Mediterranean Posidonia Network	The network aims to bring together different stakeholders such as authorities, scientists, international environmental organizations, professionals including yachting agents,		Mediterranean	Assessing and working to reduce anchoring impacts on Posidonia meadows	MPN website

Project/program	Subject	Years	Area	Interest for seafloor	References
	marinas from the Mediterranean countries. The objective is to increase each country's capacity building to better protect *Posidonia oceanica* and prevent its future degradation.				
PERSEUS Policy-oriented marine Environmental Research in the Southern EUropean Seas	The project assessed the dual impact of human activity and natural pressures on the Mediterranean and Black Seas. Natural and socio-economic sciences were merged to predict the long-term effects of these pressures on marine ecosystems. The project aimed to design an effective and innovative research governance framework, to provide the basis for policymakers to turn back the tide on marine life degradation.	2012-2015	Southern European Seas	Anthropogenic impacts are assessed although not specific to seafloor, some outputs such as the Atlas of riverine inputs may be of interest for coastal seafloor assessment. Recommendations for VMS using with case study (see Kavadas et al., 2014)	PERSEUS website PERSEUS, 2013 Kavadas et al., 2014 Crise et al., 2015

11. Data-sources and data-sets relevant for assessing and monitoring seafloor damage

194. Data-source and dataset specific to seafloor damage assessment in the Mediterranean are rather rare. Table 7 lists data-sources that can be of interest to search for seafloor damage. Data-sets on seafloor assessment in the Mediterranean need to be acquired to be able to assess the state of Mediterranean seafloor.

Table 7: Relevant data-sources and data-sets that can be of interest for the assessment and monitoring Mediterranean seafloor damage

Datasources/datasets	Subject	Reference	Comments
Copernicus Marine Service	Provides free and open marine data and services to enable marine policy implementation, support Blue growth and scientific innovation.	Copernicus website	Past and future trends are also available on Mediterranean Sea physico-chemical parameters mainly for water colomn not for seafloor
EMODnet	Maps and cartographic models and data available for download : -bathymetry -physics -seabed habitats -geology -human activities	EMODnet page giving link to the divers subjects	Very useful. Some maps such as the different anthropogenic impacts are not yet complete
JERICO-RI	It is an integrated pan-European multidisciplinary and multi-platform research infrastructure dedicated to a holistic appraisal of coastal marine system changes.	JERICO-RI website	
MAPAMED the database of MArine Protected Areas in the MEDiterranean.	Marine Protected Areas in the Mediterranean and their status	MAPAMED website	

Datasources/datasets	Subject	Reference	Comments
MEDAM Côtes mediterrannéennes françaises. Inventaire et impact des aménagements gagnés sur le domaine marin	Assessment of French Mediterranean coast artificialisation	MEDAM website	Site accessible also in English. A map viewer gives access to the artificialisation of French Mediterranean coast, year of construction, surface etc. Surfaces gained on the Sea are also visible. Site well done and valuable data can be found. Database also with temporal evolution.
Mediterranean Biodiversity Plateform	Tool to inventory, catalog and store data on marine and coastal biodiversity in the Mediterranean and view them	Website	Cartographic information Biodiversity, physical-chemical features and policies in the Mediterranean Sea
MEDITS MEDIterranean Trawl Survey	The MEDITS survey program (International bottom trawl survey in the Mediterranean) intends to produce basic information on benthic and demersal species in term of population distribution as well as demographic structure, on the continental shelves and along the upper slopes at a global scale in the Mediterranean Sea, through systematic bottom trawl surveys.	MEDITS website	A list of reports and publications are available up to 2009. For recent experimental trawling campaigns see here and here
OBIS Ocean Biodiversity Information System	OBIS is a global open-access data and information clearing-house on marine biodiversity for science, conservation and sustainable development.	OBIS website	
OBPS Ocean Best Practices System	The OBPS is a global, sustained system comprising technological solutions and community approaches to enhance management of methods	OBPS website	Interesting for guidance documents

Datasources/datasets	Subject	Reference	Comments
	as well as support the development of ocean best practices.		
OceanOps Integrated information, maps and tools to help coordinate and monitor global ocean observation efforts.	Information and location of ocean observing systems	OceanOps dashboard	World-wide interactive map giving the possibility to create maps, reports and stats on ocean observing systems.
PANGAEA Data Publisher for Earth & Environmental Science	Archiving and publishing environmental science datasets	PANGAEA website	To date 666 datasets concerning the Mediterranean Sea. Search with the terms “Mediterranean Sea” AND “monitoring” and “benthos” returned 95 datasets with meta data.
SeaDataNet	European infrastructure to facilitate the access to marine data measurement. Publication of data is also possible	SeaDataNet website	Very useful and easy to use. Gives also access to useful software such as Ocean Data View but also research projects, permanent observing systems, datasets etc. Data do not concern only Mediterranean Sea
SISMER Systèmes d'informations scientifiques pour la Mer	SISMER (Scientific Information Systems for the Sea) is Ifremer's service in charge of managing numerous marine databases and information systems which Ifremer is responsible for implementing.	SISMER website	Datasets and documents including satellite data, geoscience data (e.g. bathymetry, geological samples), water analysis, fisheries data, coastal environmental data and deepsea data.
VESSELFINDER	Active geolocalisation and associated data of vessels that have AIS	Website	Vessel localisation from AIS data useful e.g. for assessing commercial vessels and yachts at anchor

Datasources/datasets	Subject	Reference	Comments
WISE Marine	WISE-Marine provides access to information and data on the state of Europe's seas, on the pressures affecting them, and on the actions being taken to protect and conserve the marine environment.	WISE Marine website	Outcomes from MSFD reports. Country profiles informs on the assessments reported to the European Commission by EU Member States under different legal instruments that contribute to the protection of Europe's seas, namely the Marine Strategy Framework Directive (MSFD), Habitats Directive, Water Framework Directive (WFD) and Bathing Water Directive (BWQ). Therefore it displays an overview of the status of the coastal and marine environment by country.

12.Key-points

195. Mediterranean seafloor is under significant pressure that will increase due to development of coastal infrastructures and anthropogenic activities around and in and on the Mediterranean Sea.

196. A variety of anthropogenic activities damage at different degrees the seafloor.

197. Seafloor can be "physically disturbed" or "physically lost" by anthropogenic activities, the curser between the two is unclear.

198. EU Mediterranean states are required to assess seafloor status to attain GES through 5 criteria, the fifth criteria being integrative and difficult to assess.

199. Definition of GES concerning seafloor need to be defined at a sub-regional level with an ecosystem approach. This appears to be a difficult task e.g. in the MSFD framework.

200. The anthropogenic activity that damages the most Mediterranean seafloor in terms of surface is the impact of bottom trawling activities (all gear).

201. Coastal seafloor areas are under increasing cumulative pressures from various sources.

202. Coastal development and constructions gain on littoral areas and increase seafloor physical loss.

203. Data is lacking concerning assessment of seafloor status and few habitat monitoring programs carry on in time.

Bibliographic references

Angiolillo, M., & Fortibuoni, T. (2020). Impacts of Marine Litter on Mediterranean Reef Systems: From Shallow to Deep Waters. *Frontiers in Marine Science*, *7*. doi: https://doi.org/10.3389/fmars.2020.581966

Arévalo, R., Pinedo, S., & Ballesteros, E. (2007). Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: Descriptive study and test of proposed methods to assess water quality regarding macroalgae. *Marine Pollution Bulletin*, *55*(1–6), 104–113. doi: 10.1016/j.marpolbul.2006.08.023

Arjona-Camas, M., Puig, P., Palanques, A., Durán, R., White, M., Paradis, S., & Emelianov, M. (2021). Natural vs. Trawling-induced water turbidity and suspended sediment transport variability within the Palamós Canyon (NW Mediterranean). *Marine Geophysical Research*, *42*(38). pdf. doi: 10.1007/s11001-021-09457-7

Armelloni, E. N., Tassetti, A. N., Ferrà, C., Galdelli, A., Scanu, M., Mancini, A., … Scarcella, G. (2021). AIS data, a mine of information on trawling fleet mobility in the Mediterranean Sea. *Marine Policy*, *129*, 104571. doi: 10.1016/j.marpol.2021.104571

Baltic Marine Environment Protection Commission, Expert Network on Benthic Habitats. (2020). *Schematic for benthic assessment*. Retrieved from https://portal.helcom.fi/meetings/EN%20BENTHIC%204-2020-754/MeetingDocuments/6-1%20Schematic%20for%20benthic%20assessment.pdf

Bastari, A., Pica, D., Ferretti, F., Micheli, F., & Cerrano, C. (2018). Sea pens in the Mediterranean Sea: Habitat suitability and opportunities for ecosystem recovery. *ICES Journal of Marine Science*, *75*(5), 1722–1732.

Berg, T., Murray, C., Carstensen, J., & Andersen, J. H. (2019). *NEAT – Nested Environmental status Assessment Tool Manual—Version 1.4* (No. Version 1.4).

Betti, F., Bavestrello, G., Bo, M., Ravanetti, G., Enrichetti, F., Coppari, M., … Cattaneo Vietti, R. (2020). Evidences of fishing impact on the coastal gorgonian forests inside the Portofino MPA (NW Mediterranean Sea). *Ocean & Coastal Management*, *187*, 105105. doi: 10.1016/j.ocecoaman.2020.105105

Bevilacqua, S., Katsanevakis, S., Micheli, F., Sala, E., Rilov, G., Sarà, G., … Fraschetti, S. (2020). The Status of Coastal Benthic Ecosystems in the Mediterranean Sea: Evidence From Ecological Indicators. *Frontiers in Marine Science*, *7*. Retrieved from https://www.frontiersin.org/article/10.3389/fmars.2020.00475

Bianchi, C. N., Azzola, A., Bertolino, M., Betti, F., Bo, M., Cattaneo-Vietti, R., … Bavestrello, G. (2019). Consequences of the marine climate and ecosystem shift of the 1980-90s on the Ligurian Sea biodiversity (NW Mediterranean). *The European Zoological Journal*, *86*(S1), 458–487. doi: 10.1080/24750263.2019.1687765

Bitar G., 2008. National overview (on vulnerability and impacts of climate on marine and coastal biodiversity in Lebanon. Contract RAC/SPA, N° 16: 41pp.

Blanco-Murillo, F., Fernández-Torquemada, Y., Garrote-Moreno, A., Sáez, C. A., & Sánchez-Lizaso, J. L. (2022a). *Posidonia oceanica* L. (Delile) meadows regression: Long-term affection may be induced by multiple impacts. *Marine Environmental Research*, *174*, 105557. doi: 10.1016/j.marenvres.2022.105557

Blanco-Murillo, F., Jimenez-Gutierrez, S., Martínez-Vidal, J., Guillén, J. E., & Sánchez-Lizaso, J. L. (2022b). Spatiotemporal Trends Observed in 20 Years of *Posidonia oceanica* Monitoring along the Alicante Coast, Spain. *Water*, *14*(3), 274. doi: 10.3390/w14030274

Bo, M., Angiolillo, M., Bava, S., Betti, F., Cattaneo-Vietti, R., Cau, A., … Bavestrello, G. (2014). Fishing impact on Italian deep coral gardens and management of these vulnerable marine ecosystems. *Proceedings of the 1st Mediterranean Symposium on the Conservation of Dark Habitats, Slovenia*, 21–26. Tunis: RAC/SPA Publ.

Boero, F., Foglini, F., Fraschetti, S., Goriup, P., Macpherson, E., Planes, S., … Rammou, A.-M. (2016). *CoCoNet: Towards coast to coast networks of marine protected areas (From the shore to the high and deep sea), coupled with sea-based wind energy potential*. *6*, 1–95. doi: 10.2423/i22394303v6Sp1

Bordehore, C., Riosmena-Rodriguez, R., & Espla, A. A. (2000). *Trawling as a major threat to Mediterranean Maerl beds*.

Borja, A., Elliott, M., Andersen, J. H., Berg, T., Carstensen, J., Halpern, B. S., … Martin, G. (2016). Overview of integrative assessment of marine systems: The ecosystem approach in practice. *Frontiers in Marine Science*, *3*, 20.

Borja, Á., Franco, J., & Pérez, V. (2000). *A Marine Biotic Index to Establish the Ecological Quality of Soft-Bottom Benthos Within European Estuarine and Coastal Environments*. doi: 10.1016/S0025-326X(00)00061-8

Boschetti, S. T., Palialexis, A., & Connor, J. (2021). *Marine Strategy Framework Directive. Review and analysis of EU Member States' 2018 reports. Descriptor 6: Sea-floor integrity and Descriptor 1: Benthic habitats* (Technical Report No. JRC125288/EUR 30716 EN; p. 90). Joint Research Centre (JRC). Retrieved from Joint Research Centre (JRC) website: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125288/d6_jrc_ida.pdf

Boyd, S. E., Limpenny, D. S., Rees, H. L., & Cooper, K. M. (2005). *The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging)*. Retrieved from watermark

Cartes, J. E., LoIacono, C., Mamouridis, V., López-Pérez, C., & Rodríguez, P. (2013). Geomorphological, trophic and human influences on the bamboo coral Isidella elongata assemblages in the deep Mediterranean: To what extent does Isidella form habitat for fish and invertebrates? *Deep Sea Research Part I: Oceanographic Research Papers*, *76*, 52–65.

Chatzinikolaou, E., Mandalakis, M., Damianidis, P., Dailianis, T., Gambineri, S., Rossano, C., … Arvanitidis, C. (2018). Spatio-temporal benthic biodiversity patterns and pollution pressure in three Mediterranean touristic ports. *Science of The Total Environment*, *624*, 648–660. doi: 10.1016/j.scitotenv.2017.12.111

CIGISMED. (2014). *Protocole CIGESMED : Coralligenous based indicators to evaluate and monitor the"good ecological status" of the Mediterranean coastal waters* (p. 142). Retrieved from https://www.cigesmed.eu/wp-content/uploads/2022/02/protocolecigesmed_anglais_20140422_v15.1.pdf

Coggan, A., Populus, J., White, J., Sheehan, K., Fitzpatrick, F., & Piel, S. (Eds.). (2007). *Review of Standards and Protocols for Seabed Habitat Mapping*. MESH. Retrieved from https://www.emodnet-seabedhabitats.eu/media/1663/mesh_standards__protocols_2nd-edition_26-2-07.pdf

Coggan, R. A., Smith, C. J., Atkinson, R. J. A., Papadopoulou, K.-N., Stevenson, T. D. I., Moore, P. G., & Tuck, I. D. (2001). *Comparison of rapid methodologies for quantifying environmental impacts of otter trawls. Final Report* (Project Final Report No. DG XIV Study Project No. 98/017; p. 254). Retrieved from http://www.imbc.gr/whats_new/OTIP2.pdf

Crise, A., Kaberi, H., Ruiz, J., Zatsepin, A., Arashkevich, E., Giani, M., … Papathanassiou, E. (2015). A MSFD complementary approach for the assessment of pressures, knowledge and data gaps in Southern European Seas: The PERSEUS experience. *Marine Pollution Bulletin*, *95*(1), 28–39. doi: 10.1016/j.marpolbul.2015.03.024

Damalas, D., Ligas, A., Tsagarakis, K., Vassilopoulou, V., Stergiou, K. I., Kallianiotis, A., … Maynou, F. (2018). The "discard problem" in Mediterranean fisheries, in the face of the European Union landing obligation: The case of bottom trawl fishery and implications for management. *Mediterranean Marine Science*, *19*(3), 459–476. doi: 10.12681/mms.14195

Danovaro, R. (2018). Climate change impacts on the biota and on vulnerable habitats of the deep Mediterranean Sea. *Rendiconti Lincei. Scienze Fisiche e Naturali*, *29*(3), 525–541. doi: 10.1007/s12210-018-0725-4

Danovaro, R., Canals, M., Gambi, C., Heussner, S., Lampadariou, N., & Vanreusel, A. (2009). Exploring Benthic Biodiversity Patterns and Hot Spots on European Margin Slopes. *Oceanography*, *22*(1), 16–25. doi: 10.5670/oceanog.2009.02

Dapueto, G., Massa, F., Pergent-Martini, C., Povero, P., Rigo, I., Vassallo, P., … Paoli, C. (2022). Sustainable management accounting model of recreational boating anchoring in Marine Protected Areas. *Journal of Cleaner Production*, *342*, 130905. pdf. doi: 10.1016/j.jclepro.2022.130905

Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., … Vincent, M. (Eds.). (2001). *Marine Monitoring Handbook*. Peterborough: JNCC. Retrieved from https://hub.jncc.gov.uk/assets/ed51e7cc-3ef2-4d4f-bd3c-3d82ba87ad95

Depe, P., Sazaki, E., & Leotsinidis, M. (2018). Dredges' management: Comparison of regulatory frameworks, legal gaps and recommendations. *Global NEST Journal*, *20*(1), 88–95.

Deter, J., Lozupone, X., Inacio, A., Boissery, P., & Holon, F. (2017). Boat anchoring pressure on coastal seabed: Quantification and bias estimation using AIS data. *Marine Pollution Bulletin*, *123*(1), 175–181. doi: 10.1016/j.marpolbul.2017.08.065

D'Onghia, G., Calculli, C., Capezzuto, F., Carlucci, R., Carluccio, A., Grehan, A., … Pollice, A. (2017). Anthropogenic impact in the Santa Maria di Leuca cold-water coral province (Mediterranean Sea): Observations and conservation straits. *Deep Sea Research Part II: Topical Studies in Oceanography*, *145*, 87–101. doi: https://doi.org/10.1016/j.dsr2.2016.02.012

Eigaard, O. R., Bastardie, F., Breen, M., Dinesen, G. E., Hintzen, N. T., Laffargue, P., … Rijnsdorp, A. D. (2016). Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. *ICES Journal of Marine Science*, *73*(suppl_1), i27–i43. doi: 10.1093/icesjms/fsv099

Eigaard, O. R., Bastardie, F., Hintzen, N. T., Buhl-Mortensen, L., Buhl-Mortensen, P., Catarino, R., … Rijnsdorp, A. D. (2017). The footprint of bottom trawling in European waters: Distribution, intensity, and seabed integrity. *ICES Journal of Marine Science*, *74*(3), 847–865.. doi: 10.1093/icesjms/fsw194

Eno, C., Frid, C., Hall, K., Ramsay, K., Sharp, R., Brazier, P., … Robinson, L. (2013). Assessing the sensitivity of habitats to fishing: From seabed maps to sensitivity maps. *Journal of Fish Biology*, *83*, 826–846. doi: 10.1111/jfb.12132

Erftemeijer, P. L. A., & Lewis, R. R. R. (2006). Environmental impacts of dredging on seagrasses: A review. *Marine Pollution Bulletin*, *52*(12), 1553.

EU. (2012). *Links between the Marine Strategy Framework Directive (MSFD 2008/56/EC) and the Nature Directives (Birds Directive 2009/147/EEC (BD) and Habitats Directive 92/43/EEC (HD))*. Retrieved from https://ec.europa.eu/environment/nature/natura2000/marine/docs/FAQ%20final%202012-07-27.pdf

European Commission. (2020). *Report from the Commission to the European Parliament and the Council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC)* (p. 44). Brussels. Retrieved from https://ec.europa.eu/info/sites/default/files/swd202060final.pdf

European Commission DG Environment. (2013). *Interpretattion manual of European Union Habitats. EUR 28*. Retrieved from https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf

European parliament (Ed.). (2014). *The obligation to land all catches. Consequences for the Mediterranean*. Retrieved from https://www.europarl.europa.eu/RegData/etudes/note/join/2014/529055/IPOL-PECH_NT(2014)529055_EN.pdf

Ezgeta -Balić, D., Vrgoč, N., Isajlović, I., Medvešek, D., Vujević, A., Despalatović, M., & Cvitković, I. (2021). Comparison of beam trawl catch, by-catch and discard in fishing and non-fishing areas – a case study from the northern Adriatic Sea. *Mediterranean Marine Science*, *22*(1), 108–120. doi: 10.12681/mms.24973

FAO. (2020). *The State of Mediterranean and Black Sea Fisheries 2020* (General Fisheries Commission for the Mediterranean). Rome. Retrieved from https://doi.org/10.4060/cb2429e

FAO. (2021). *GFCM 2030 Strategy for sustainable fisheries and aquaculture in the Mediterranean and the Black Sea* (p. 28). Rome. (pdf). Retrieved from https://doi.org/10.4060/cb7562en

Féral, J.-P., Arvanitidis, C., Chenuil, A., Çinar, M. E., David, R., Egea, E., & Sartoretto, S. (2016). *CIGESMED : Coralligenous based Indicators to evaluate and monitor the 'Good Environmental Status' of the Mediterranean coastal waters* (p. 179). Retrieved from https://hal.archives-ouvertes.fr/hal-01448881/document

Fourt, M., Goujard, A., Pérez, T., Vacelet, J., Chevaldonné, P., & the scientific team of the MedSeaCan and CorSeaCan cruises. (2014). French Mediterranean submarine canyons and deep rocky banks: A regional view for adapted conservation measures. *Proceedings of the 1st Mediterranean Symposium on the Conservation of Dark Habitats (Portoroz, Slovenia, 31 October 2014).*, 33–38. Tunis: RAC/SPA Publ. doi: 10.13140/2.1.3756.3841

Foveau, A., Vaz, S., Desroy, N., & Kostylev, V. E. (2017). Process-driven and biological characterisation and mapping of seabed habitats sensitive to trawling. *PLOS ONE*, *12*(10), e0184486. doi: 10.1371/journal.pone.0184486

Galassi, G., & Spada, G. (2014). Sea-level rise in the Mediterranean Sea by 2050: Roles of terrestrial ice melt, steric effects and glacial isostatic adjustment. *Global and Planetary Change*, *123*, 55–66. doi: 10.1016/j.gloplacha.2014.10.007

Galgani, F., Ellerbrake, K., Fries, E., & Goreux, C. (2011). Marine pollution: Let us not forget beach sand. *Environmental Sciences Europe*, *23*(1), 40. doi: 10.1186/2190-4715-23-40

Garrabou, J., Perez, T., Sartoretto, S., & Harmelin, J. G. (2001). Mass mortality event in red coral *Corallium rubrum* populations in the Provence region (France, NW Mediterranean). *Marine Ecology Progress Series*, *217*, 263–272.

Gerigny, O., Brun, M., Fabri, M., Tomasino, C., Le Moigne, M., Jadaud, A., & Galgani, F. (2019). *Seafloor litter from the continental shelf and canyons in French Mediterranean Water: Distribution, typologies and trends*. Retrieved from https://archimer.ifremer.fr/doc/00507/61868/66074.pdf

Giannoulaki, M., Belluscio, A., Colloca, F., Fraschetti, S., Scardi, M., Smith, C., … Sepicato, M. T. (Eds.). (2013). *Mediterranean Sensitive Habitats* (Final Report).

Giusti, M., Canese, S., Fourt, M., Bo, M., Innocenti, C., Goujard, A., … Tunesi, L. (2019). Coral forests and derelict fishing gears in submarine canyon systems of the Ligurian Sea. *Progress in Oceanography*, 102186. doi: https://doi.org/10.1016/j.pocean.2019.102186

Gómez-Gutiérrez, A., Garnacho, E., Bayona, J. M., & Albaigés, J. (2007). Assessment of the Mediterranean sediments contamination by persistent organic pollutants. *Environmental Pollution*, *148*(2), 396–408. doi: 10.1016/j.envpol.2006.12.012

González-Correa, J. M., Bayle, J. T., Sánchez-Lizaso, J. L., Valle, C., Sánchez-Jerez, P., & Ruiz, J. M. (2005). Recovery of deep Posidonia oceanica meadows degraded by trawling. *Journal of Experimental Marine Biology and Ecology*, *320*(1), 65–76. doi: 10.1016/j.jembe.2004.12.032

Gori, A., Olariaga, A., Orejas, C., Rossi, S., Quesada, S., Valentin, A., … Gili, J.-M. (2009). Bleeper-EVO: An Easy-to-Handle ROV for Benthic Study. *Oceanography*, *22*(1), 75–75. doi: 10.5670/oceanog.2009.07

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., … Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science*, *319*(5865), 948–952. doi: 10.1126/science.1149345

Harris, P. (2020). Anthropogenic threats to benthic habitats. In *Seafloor Geomorphology as Benthic Habitats* (pp. 35–61). Elcevier. Retrieved from https://tethys.pnnl.gov/publications/anthropogenic-threats-benthic-habitats

Hiddink, J. G., Jennings, S., Sciberras, M., Szostek, C. L., Hughes, K. M., Ellis, N., … Kaiser, M. J. (2017). Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. *Proceedings of the National Academy of Sciences*, *114*(31), 8301–8306. doi: 10.1073/pnas.1618858114

Hintzen, N. T., Bastardie, F., Beare, D., Piet, G. J., Ulrich, C., Deporte, N., … Degel, H. (2012). VMStools: Open-source software for the processing, analysis and visualisation of fisheries logbook and VMS data. *Fisheries Research*, *115–116*, 31–43. https://backend.orbit.dtu.dk/ws/portalfiles/portal/56377631/Hinzen.pdf. doi: 10.1016/j.fishres.2011.11.007

ICES. (2019a). *EU request to advise on a seafloor assessment process for physical loss (D6C1, D6C4) and physical disturbance (D6C2) on benthic habitats*. Retrieved from https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/Special_Requests/eu.2019.25.pdf

ICES. (2019b). *ICES User Handbook: Best practice for Data Management* (p. 12). http://doi.org/10.17895/ices.pub.4889. Retrieved from https://www.ices.dk/sites/pub/Publication%20Reports/User%20Handbooks/uh-best-practice-data-management.pdf

ICES. (2014b). Introduction and general advice. EU request to ICES for review of the Marine Strategy Framework Directive: Descriptor 6_Seafloor integrity. In *ICES Adive 2014, Book 11*.

ICES. (2014a). *Report of the Workshop to review the 2010 Commission Decision on criteria and methodological standards on good environmental status (GES) of marine waters; Descriptor 6: Seafloor integrity, 2–3 September 2014* (No. ICES CM 2014/ACOM:61; p. 37). Denmark: ICES Headquarters. Retrieved from ICES Headquarters website: https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2014/WKGMSFDD6/WKGMSFDD6%20Final%20Report%202014.pdf

ICES Advisory Committee. (2014). *OSPAR request on mapping of bottom fishing intensity using VMS data* (Special Request No. 1.6.6.5; p. 11). 26-09-. Retrieved from 26-09-.

ICES Advisory Committee. (2019). *Workshop on scoping for benthic pressure layers. D6C2—From methods to operational data product (WKBEDPRES1), 24-26 October 2018* (No. ICES CM 2018/ACOM:59; p. 69). ICES HQ, Copenhagen, Denmark. Retrieved from https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2018/WKBEDPRES%201/WKBEDPRES%201%20Report.pdf#search=seabed

ICRAM, & APAT. (2007). *Manuale per la movimentazione di sedimenti marini*. Ministero dell'Ambiente e della Tutela del Territorio e del Mare. Retrieved from Ministero dell'Ambiente e della Tutela del Territorio e del Mare website: https://www.isprambiente.gov.it/contentfiles/00006700/6770-manuale-apat-icram-2007.pdf/

IDEM Project. (2019b). *Deliverable 3.3: IDEM Report 3.3. Report on the indicators and thresholds to identify the GES and the key areas for design monitoring programs in the Mediterranean deep sea* (p. 77) [IDEM (Implementation of the MSFD to the Deep Mediterranean Sea) Project]. UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM. Retrieved from UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM website: http://www.msfd-idem.eu/?q=system/files/Deliverable%203.3_IDEM%20Project_ALL_0.pdf

IDEM Project. (2019a). *Deliverable 3.2: IDEM Report 3.2. Report 3.2. Report on the revision of MSFD descriptors/criteria/indicators to be applied on the deep-sea ecosystems* (p. 58) [DEM (Implementation of the MSFD to the Deep Mediterranean Sea) Project]. UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM, UNIV. Retrieved from UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM, UNIV website: http://www.msfd-idem.eu/?q=system/files/IDEM_Deliverable%203.2_0.pdf

IDEM Project. (2018b). *Implementation of the MSFD to the Deep Mediterranean Sea (IDEM). Delivrable 2.3 Report on habitat/ecosystems/pressure mapping in GIS*. Retrieved from http://www.msfd-idem.eu/?q=system/files/IDEM_D2.3.pdf

IDEM Project. (2018a). *Report 2.1 Review and collection of the available datasets on indicators and human pressures/impacts on Mediterranean deep-sea ecosystems* (p. 37) [DEM (Implementation of the MSFD to the Deep Mediterranean Sea) Project]. UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM, UNIV. Retrieved from UNIVPM, CNR, CSIC, DFMR, ENEA, TAU, UB, UM, UNIV website: http://www.msfd-idem.eu/?q=system/files/IDEM_D2.1_06_07_2018_up_0.pdf

Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique. (2019a). *Synthèse de l'évaluation de l'atteinte du bon état écologique au titre du descripteur 6 « Intégrité des fonds marins » (critères D6C1, D6C2 et D6C3) par façade maritime* (No. DCSMM_IFR_BEE_2018_D6; p. 65). Ifremer. Retrieved from Ifremer website: https://doi.org/10.13155/60202

Ifremer, Coordination Nationale Directive Cadre Stratégique pour le Milieu Marin, Bon Etat Ecologique. (2019b). *Synthèse de l'évaluation de l'atteinte du bon état écologique des habitats benthiques au titre des descripteurs 1 et 6 par façade maritime* (No. DCSMM_IFR_BEE_2018_D1_HB). Retrieved from https://archimer.ifremer.fr/doc/00490/60192/

IOC-UNESCO, & UNEP. (2016). *Large Marine Ecosystems: Status and Trends, Summary for Policy Makers.* (No. Volume 4). United Nations Environment Programme (UNEP), Nairobi. Retrieved from United Nations Environment Programme (UNEP), Nairobi website: http://onesharedocean.org/public_store/publications/lmes-spm.pdf

IUCN. (2010). *Vers une meilleure gouvernance pour la Méditerranée*. Gland, Suisse et Malaga, Espagne: IUCN. Retrieved from https://www.iucn.org/fr/resources/vers-une-meilleure-gouvernance-de-la-mediterranee

IUCN. (2016). *European Red List of Habitats: Part 1. Marine habitats*. Retrieved from https://www.iucn.org/content/european-red-list-habitats-part-1-marine-habitats

JNCC. (2018a). *Autonomous Underwater Vehicles for use in marine benthic monitoring*. Peterborough. Retrieved from https://data.jncc.gov.uk/data/f52a772a-1d81-4cab-b850-7a9e32d0fef6/JNCC-MMPG-002-FINAL-WEB.pdf

JNCC. (2018b). *Remotely Operated Vehicles for use in marine benthic monitoring*. Peterborough. Retrieved from https://hub.jncc.gov.uk/assets/4abdba96-8ade-468d-8f80-c23a6ad87dc5

Katsanevakis, S., Levin, N., Coll, M., Giakoumi, S., Shkedi, D., Mackelworth, P., … Kark, S. (2015). Marine conservation challenges in an era of economic crisis and geopolitical instability: The case of the Mediterranean Sea. *Marine Policy*, *51*, 31–39. doi: 10.1016/j.marpol.2014.07.013

Katsanevakis, S., Tempera, F., & Teixeira, H. (2016). Mapping the impact of alien species on marine ecosystems: The Mediterranean Sea case study. *Diversity and Distributions*, *22*(6), 694–707. doi: 10.1111/ddi.12429

Kavadas, S., Carmen, B., Andrea, B., Piera, C., Stefano, C., Camilla, C., … Vasilopoulou, V. (2014). *Common methodological procedures for analysis of VMS data, including web-based GIS applications related to the spatial extent and intensity of fishing effort*. PERSEUS Project. Retrieved from http://www.perseus-net.eu/assets/media/PDF/deliverables/5138.4.pdf

Knight, R., Verhoeven, JTP., Salvo, F., Hamoutene, D., & Dufour, SC. (2021). Validation of visual bacterial mat assessment at aquaculture sites through abiotic and biotic indicators. *Ecological Indicators*, *122*, 107283. doi: 10.1016/j.ecolind.2020.107283

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., … Royo Gelabert, E. (2019). *Multiple pressures and their combined effects in Europe's seas* (p. 164) [ETC/ICM Technical report 4/2019]. Retrieved from https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-report-4-2019-multiple-pressures-and-their-combined-effects-in-europes-seas/@@download/file/MultiplePressuresAndTheirCombinedEffectsInEuropesSeas.pdf

Kostianoy, A. G., & Carpenter, A. (2018). Oil and Gas Exploration and Production in the Mediterranean Sea. In A. Carpenter & A. G. Kostianoy (Eds.), *Oil Pollution in the Mediterranean Sea: Part I: The International Context* (pp. 53–77). Cham: Springer International Publishing. doi: 10.1007/698_2018_373

Krause, J. C., Diesing, M., & Arlt, G. (2010). The Physical and Biological Impact of Sand Extraction: A Case Study of the Western Baltic Sea. *Journal of Coastal Research*, 215–226.

Lauria, V., Garofalo, G., Fiorentino, F., Massi, D., Milisenda, G., Piraino, S., … Gristina, M. (2017). Species distribution models of two critically endangered deep-sea octocorals reveal fishing impacts on vulnerable marine ecosystems in central Mediterranean Sea. *Scientific Reports*, *7*(1), 8049. doi: 10.1038/s41598-017-08386-z

Layglon, N., Misson, B., Durieu, G., Coclet, C., d'Onofrio, S., Dang, D. H., … Garnier, C. (2020). Long-term monitoring emphasizes impacts of the dredging on dissolved Cu and Pb contamination along with ultraplankton distribution and structure in Toulon Bay (NW Mediterranean Sea, France). *Marine Pollution Bulletin*, *156*, 111196. doi: 10.1016/j.marpolbul.2020.111196

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C. F., & Pérez, T. (2010). Climate change effects on a miniature ocean: The highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution*, *25*(4), 250–260. doi: https://doi.org/10.1016/j.tree.2009.10.009

Levin, L. A., & Le Bris, N. (2015). The deep ocean under climate change. *Science (New York, N.Y.)*, *350*(6262), 766–768. doi: 10.1126/science.aad0126

Libralato, S., Colloca, F., Gucu, A. C., Maravelias, C., Solidoro, C., Villasante, S., & Cardinale, M. (2018). Challenges and Opportunities for The EU Common Fisheries Policy application in The Mediterranean and Black Sea. *Frontiers in Marine Science*, *5*. doi: 10.3389/fmars.2018.00299

Loengarow, A. (2022, March 24). Between Maritime Law and Politics in the East Mediterranean. *The Washington Institute for Near East Policy / Policy Analysis*. Retrieved from https://www.washingtoninstitute.org/policy-analysis/between-maritime-law-and-politics-east-mediterranean

Lucchetti, A., & Sala, A. (2012). Impact and performance of Mediterranean fishing gear by side-scan sonar technology. *Canadian Journal of Fisheries and Aquatic Sciences*, *69*(11), 1806–1816. doi: 10.1139/f2012-107

Manoukian, S., Spagnolo, A., Scarcella, G., Punzo, E., Angelini, R., & Fabi, G. (2010). Effects of two offshore gas platforms on soft-bottom benthic communities (northwestern Adriatic Sea, Italy). *Marine Environmental Research*, *70*(5), 402–410. doi: 10.1016/j.marenvres.2010.08.004

Marín, P., Perry, A., & Aguilar, R. (2017). *Defining Mediterranean VMEs (II). Draft list review & key concepts*. OCEANA. Retrieved from https://europe.oceana.org/sites/default/files/fs_gfcm_workshop_vmes_2017.pdf

Martín, J., Puig, P., Palanques, A., & Ribó, M. (2014). Trawling-induced daily sediment resuspension in the flank of a Mediterranean submarine canyon. *Deep Sea Research Part II: Topical Studies in Oceanography*, *104*, 174–183. doi: 10.1016/j.dsr2.2013.05.036

Maynou, F., & Cartes, J. E. (2011). Effects of trawling on fish and invertebrates from deep-sea coral facies of *Isidella elongata* in the western Mediterranean. *Journal of the Marine Biological Association of the UK*, *92*(07), 1501–1507. doi: http://dx.doi.org/10.1017/S0025315411001603

McConnaughey, R. A., Hiddink, J. G., Jennings, S., Pitcher, C. R., Kaiser, M. J., Suuronen, P., … Hilborn, R. (2019). Choosing best practices for managing impacts of trawl fishing on seabed habitats and biota. *Fish and Fisheries*, *21*(2), 319–337. doi: 10.1111/faf.12431

MEDTRIX. (2019). *Cahier de la Surveillance. Edition spéciale: Impact du mouillage des grands navires en Méditerranée française* (L'Oeil d'Andromède/ Agence de l'Eau Rhône Méditerranée Corse). Retrieved from https://medtrix.fr/wp-content/uploads/2019/09/cahier6.pdf

MESH Project. (2008). *MESH Guide to Habitat Mapping* (J. Davis & S. Young, Eds.). Peterborough, UK: Joint Nature Conservation Committee. Retrieved from https://www.infomar.ie/sites/default/files/pdfs/mesh_project_2008.pdf

Micheli, F., Halpern, B. S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., … Rosenberg, A. A. (2013). Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. *PLOS ONE*, *8*(12), e79889. doi: 10.1371/journal.pone.0079889

Mikac, B., Abbiati, M., Adda, M., Colangelo, M. A., Desiderato, A., Pellegrini, M., … Ponti, M. (2022). The Environmental Effects of the Innovative Ejectors Plant Technology for the Eco-Friendly Sediment Management in Harbors. *Journal of Marine Science and Engineering*, *10*(2), 182. doi: 10.3390/jmse10020182

Montefalcone, M., Tunesi, L., & Ouerghi, A. (2021). A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean. *Marine Environmental Research*, *169*, 105387. doi: 10.1016/j.marenvres.2021.105387

Moraitis, M. L., Valavanis, V. D., & Karakassis, I. (2019). Modelling the effects of climate change on the distribution of benthic indicator species in the Eastern Mediterranean Sea. *The Science of the Total Environment*, *667*, 16–24. doi: 10.1016/j.scitotenv.2019.02.338

Morello, E., Froglia, C., Atkinson, R., & Moore, P. (2005). Impacts of hydraulic dredging on a macrobenthic community of the Adriatic Sea, Italy. *Canadian Journal of Fisheries and Aquatic Sciences*, *62*, 2076–2087. doi: 10.1139/f05-122

Mosbahi, N., Pezy, J.-P., Dauvin, J.-C., & Neifar, L. (2022). COVID-19 Pandemic Lockdown: An Excellent Opportunity to Study the Effects of Trawling Disturbance on Macrobenthic Fauna in the Shallow Waters of the Gulf of Gabès (Tunisia, Central Mediterranean Sea). *International Journal of Environmental Research and Public Health*, *19*(3), 1282. doi: 10.3390/ijerph19031282

Muxika, I., Borja, Á., & Bonne, W. (2005). The suitability of the marine biotic index (AMBI) to new impact sources along European coasts. *Ecological Indicators*, *5*(1), 19–31. doi: 10.1016/j.ecolind.2004.08.004

Mytilineou, C., Papadopoulou, K., Smith, C., Bekas, P., Damalas, D., Anastasopoulou, A., … Kavadas, S. (2012). Information From Fishers On The Eastern Ionian Deep-Water Fishery And Its Interaction With Coral Habitats. *Conference Proceedings: 10th Panhellenic Symposium On Oceanography And Fisheries*, 251–252. HCMR. Retrieved from https://publications.jrc.ec.europa.eu/repository/handle/JRC69591

Newell, R., Seiderer, L., & Hitchcock, D. (1998). The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology*, *36*, 127–178. Retrieved from http://www.sussex.ac.uk/geography/researchprojects/coastview/dredging/Impact_of_Dredging_Oc_Bio.Ann_Rev.pdf.

Otero, M. M., & Mytilineou, C. (Eds.). (2022). *Deep-sea Atlas of the Eastern Mediterranean Sea: State-of-the-art knowledge for better protection* (IUCN-HCMR DeepEast Project). IUCN Gland, Malaga. Retrieved from https://www.iucn.org/news/mediterranean/202205/deep-sea-atlas-eastern-mediterranean-sea-state-art-knowledge-better-protection

Özalp, H.B., 2022. *Development, conservation, monitoring and management of coral reef marine biodiversity areas in the Turkish coasts. Çanakkale Strait, Bozcaada Island, Marmara Island. Action Plan.* Özen Publishing. 55pp.

Pairaud, I. L., Bensoussan, N., Garreau, P., Faure, V., & Garrabou, J. (2014). Impacts of climate change on coastal benthic ecosystems: Assessing the current risk of mortality outbreaks associated with thermal stress in NW Mediterranean coastal areas. *Ocean Dynamics*, *64*(1), 103–115.

Paradis, S., Goñi, M., Masqué, P., Durán, R., Arjona-Camas, M., Palanques, A., & Puig, P. (2021a). Persistence of Biogeochemical Alterations of Deep-Sea Sediments by Bottom Trawling. *Geophysical Research Letters*, *48*(2), e2020GL091279. doi: 10.1029/2020GL091279

Paradis, Sarah, Lo Iacono, C., Masqué, P., Puig, P., Palanques, A., & Russo, T. (2021b). Evidence of large increases in sedimentation rates due to fish trawling in submarine canyons of the Gulf of Palermo (SW Mediterranean). *Marine Pollution Bulletin*, *172*, 112861. doi: 10.1016/j.marpolbul.2021.112861

Pasquini, G., Ronchi, F., Strafella, P., Scarcella, G., & Fortibuoni, T. (2016). Seabed litter composition, distribution and sources in the Northern and Central Adriatic Sea (Mediterranean). *Waste Management (New York, N.Y.)*, *58*, 41–51. doi: 10.1016/j.wasman.2016.08.038

Patrício, J., Teixeira, H., Borja, A., Elliott, M., Berg, T., Papadopoulou, N., … Hoepffner, N. (2014). *DEVOTES recommendations for the implementation of the Marine Strategy Framework Directive*.

Pérez, T., Garrabou, J., Sartoretto, S., Harmelin, J.-G., Francour, P., & Vacelet, J. (2000). Mortalité massive d'invertébrés marins: Un événement sans précédent en Méditerranée nord-occidentale. *Comptes Rendus de l'Académie Des Sciences-Series III-Sciences de La Vie*, *323*(10), 853–865.

Pergent, G., Boudouresque, C.-F., Dumay, O., Pergent-Martini, C., & Wyllie-Echeverria, S. (2008). Competition between the invasive macrophyte Caulerpa taxifolia and the seagrass Posidonia oceanica: Contrasting strategies. *BMC Ecology*, *8*(1), 20. doi: 10.1186/1472-6785-8-20

PERSEUS. (2013). *Baseline analysis of pressures, processes and impacts on Mediterranean and Black Sea ecosystems. Delivrable N. 1.3* (p. 39). Retrieved from http://www.perseus-net.eu/assets/media/PDF/deliverables/3292.3_Final.pdf

Petza, D., Maina, I., Koukourouvli, N., Dimarchopoulou, D., Akrivos, D., Kavadas, S., … Katsanevakis, S. (2017). Where not to fish—Reviewing and mapping fisheries restricted areas in the Aegean Sea. *Mediterranean Marine Science*, *18*, 310–323. doi: 10.12681/mms.2081

Piante, C., & Ody, D. (2015). *Blue Growth in the Mediterranean Sea: The Challenge of Good Environmental Status. MedTrends Project.* (WWF-France). Retrieved from https://medtrends.org/reports/MEDTRENDS_REGIONAL.pdf

Pierdomenico, M., Russo, T., Ambroso, S., Gori, A., Martorelli, E., D'Andrea, L., … Chiocci, F. L. (2018). Effects of trawling activity on the bamboo-coral *Isidella elongata* and the sea pen *Funiculina quadrangularis* along the Gioia Canyon (Western Mediterranean, southern Tyrrhenian Sea). *Progress in Oceanography*, *169*, 214–226. doi: https://doi.org/10.1016/j.pocean.2018.02.019

Piet, G. J., & Royo Gelabert, E. (2019). *Development of a pilot 'European seafloor integrity account' to assess the state of seabed habitats from fishing pressure.* (ETC/ICM Technical Report No. 1/2019; p. 70). European Topic Centre on Inland, Coastal and Marine Waters. Retrieved from European Topic Centre on Inland, Coastal and Marine Waters website: https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-reports/development-of-a-pilot-european-seafloor-integrity-account-assessing-fishing-pressure-on-seabed-habitats/@@download/file/01-2019_DevelopmentOfAPilot_EuropeanSeafloorIntegrityAccount_AssessingFishingPressureOnSeabedHabitats.pdf

Piroddi, C., Teixeira, H., Lynam, C. P., Smith, C., Alvarez, M. C., Mazik, K., … Uyarra, M. C. (2015). Using ecological models to assess ecosystem status in support of the European Marine Strategy Framework Directive. *Ecological Indicators*, *58*, 175–191. doi: 10.1016/j.ecolind.2015.05.037

Pitcher, C. R., Hiddink, J. G., Jennings, S., Collie, J., Parma, A. M., Amoroso, R., … Hilborn, R. (2022). Trawl impacts on the relative status of biotic communities of seabed sedimentary habitats in 24 regions worldwide. *Proceedings of the National Academy of Sciences*, *119*(2), e2109449119. doi: 10.1073/pnas.2109449119

Plan Bleu. (2015). *Economic and social analysis of the uses of the coastal and marine waters in the Mediterranean. Characterization and impacts of the Fisheries, Aquaculture, Tourism and recreational activities, Maritime transport and Offshore extraction of oil and gas sectors. Revised edition August 2015* (p. 137) [Technical

report]. Valbon: Pan Bleu. Retrieved from Pan Bleu website: https://planbleu.org/wp-content/uploads/2015/08/esa_ven_en.pdf

Pranovi, F., Raicevich, S., Franceschini, G., Torricelli, P., & Giovanardi, O. (2001). *Discard analysis and damage to non-target species in the 'rapido' trawl fishery*. doi: 10.1007/S002270100646

Pranovi, Fabio, Raicevich, S., Franceschini, G., Farrace, M., Giovanardi, O., & Farrace, G. (2000). Rapido trawling in the northern Adriatic Sea: Effects on benthic communities in an experimental area. *ICES Journal of Marine Science*, *57*, 517–524. doi: 10.1006/jmsc.2000.0708

Quemmerais-Amice, F., Barrere, J., La Rivière, M., Contin, G., & Bailly, D. (2020). A Methodology and Tool for Mapping the Risk of Cumulative Effects on Benthic Habitats. *Frontiers in Marine Science*, *7*. Retrieved from https://www.frontiersin.org/article/10.3389/fmars.2020.569205

RAC/SPA. (2003). *Effects of fishing practices on the Mediterranean Sea: Impact on marine sensitive habitats and species, technical solution and recommendations*. Retrieved from http://www.rac-spa.org/sites/default/files/doc_spabio/d1eng.pdf

Rendina, F., Ferrigno, F., Appolloni, L., Donnarumma, L., Sandulli, R., & Fulvio, G. (2020). Anthropic pressure due to lost fishing gears and marine litter on different rhodolith beds off the Campania Coast (Tyrrhenian Sea, Italy). *Ecological Questions*, *31*(4), 41–51. doi: 10.12775/EQ.2020.027

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J. G., Krause, J., … Norkko, A. (2012). Indicators for Sea-floor Integrity under the European Marine Strategy Framework Directive. *Ecological Indicators*, *12*(1), 174–184. doi: 10.1016/j.ecolind.2011.03.021

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J., Krause, J., … Trabucco, B. (2010). *Marine Strategy Framework Directive—Task Group 6 Seafloor integrity*. Retrieved from https://publications.jrc.ec.europa.eu/repository/handle/JRC58082

Rijnsdorp, A. D., Bastardie, F., Bolam, S. G., Buhl-Mortensen, L., Eigaard, O. R., Hamon, K. G., … Zengin, M. (2016). Towards a framework for the quantitative assessment of trawling impact on the seabed and benthic ecosystem. *ICES Journal of Marine Science*, *73*(suppl_1), i127–i138. doi: 10.1093/icesjms/fsv207

Rijnsdorp, Adriaan D., Bolam, S. G., Garcia, C., Hiddink, J. G., Hintzen, N. T., van Denderen, P. D., & van Kooten, T. (2018). Estimating sensitivity of seabed habitats to disturbance by bottom trawling based on the longevity of benthic fauna. *Ecological Applications*, *28*(5), 1302–1312. doi: 10.1002/eap.1731

Rijnsdorp, Adriaan D., Eigaard, O. R., Kenny, A., Hiddink, J. G., Hamon, K., Piet, G., … Gregerson, O. (2017). *Assessing and mitigating of bottom trawling. Final BENTHIS (Benthic Ecosystem Fisheries Impact Study) Project Report*. Retrieved from https://archimer.ifremer.fr/doc/00425/53653/

Röckmann, C., Fernández, T. V., & Pipitone, C. (2018). Regulation and Planning in the Mediterranean Sea. In *Building Industries at Sea: 'Blue Growth' and the New Maritime Economy* (pp. 365–402). River Publishers.

Rosenberg, R., Blomqvist, M., Nilsson, H., Cederwall, H., & Dimming, A. (2004). Marine quality assessment by use of benthic species-abundance distributions: A proposed new protocol within the European Union Water Framework Directive. *Marine Pollution Bulletin*, *49*, 728–739. doi: 10.1016/j.marpolbul.2004.05.013

Russo, T., D'Andrea, L., Parisi, A., & Cataudella, S. (2014). VMSbase: An R-Package for VMS and Logbook Data Management and Analysis in Fisheries Ecology. *PloS One*, *9*, e100195. doi: 10.1371/journal.pone.0100195

Sacchi, J. (2008). The use of trawling nets in the Mediterranean. Problems and selectivity options. In B. Basurco (Ed.), *The Mediterranean fisheries sector. A reference publication for the VII meeting of Ministers of agriculture and fisheries of CIHEAM member countries (Zaragoza, Spain, 4 february 2008)* (CIHEAM / FAO / GFCM, pp. 87–96). Zaragoza (Spain). Retrieved from https://om.ciheam.org/om/pdf/b62/00800739.pdf

Santiago-Ramos, J., & Feria-Toribio, J. M. (2021). Assessing the effectiveness of protected areas against habitat fragmentation and loss: A long-term multi-scalar analysis in a mediterranean region. *Journal for Nature Conservation*, *64*, 126072. doi: 10.1016/j.jnc.2021.126072

Sardà, R., Pinedo, S., Grémare, A., & Taboada, S. (2000). *Changes in the dynamics of shallow sandy-bottom assemblages due to sand extraction in the Catalan Western Mediterranean Sea*. doi: 10.1006/JMSC.2000.0922

Schwinghamer, P., Gordon, D. C., Rowell, T. W., Prena, J., McKeown, D. L., Sonnichsen, G., & Guigné, J. Y. (1998). Effects of Experimental Otter Trawling on Surficial Sediment Properties of a Sandy-Bottom Ecosystem on the Grand Banks of Newfoundland. *Conservation Biology*, *12*(6), 1215–1222.

Sempere-Valverde, J., Ostalé-Valriberas, E., Maestre, M., González Aranda, R., Bazairi, H., & Espinosa, F. (2021). Impacts of the non-indigenous seaweed Rugulopteryx okamurae on a Mediterranean coralligenous community (Strait of Gibraltar): The role of long-term monitoring. *Ecological Indicators*, *121*, 107135. doi: 10.1016/j.ecolind.2020.107135

Simboura, N., & Zenetos, A. (2002). Benthic indicators to use in Ecological Quality classification of Mediterranean soft bottom marine ecosystems, including a new Biotic Index. *Mediterranean Marine Science*, *3*(2), 77–111. doi: 10.12681/mms.249

Smith, C. J., Papadopoulou, K. N., & Diliberto, S. (2000). Impact of otter trawling on an eastern Mediterranean commercial trawl fishing ground. *ICES Journal of Marine Science*, *57*(5), 1340–1351. doi: 10.1006/jmsc.2000.0927

SPA/RAC–UN Environment/MAP. (2019). *How to reach the qualitative aspects of Aichi Target 11 in the Mediterranean.* By José Amengual Ramis, Diego Álvarez Berastegui, Souha El Asmi, Chedly Rais and Asma Kheriji. Reviewed by the second meeting of the Ad hoc Group of Experts for Marine Protected Areas in the Mediterranean (AGEM) (SPA/RAC, Ed.). MedMPA Network Project, Tunis.

Strafella, P., Fabi, G., Spagnolo, A., Grati, F., Polidori, P., Punzo, E., … Scarcella, G. (2015). Spatial pattern and weight of seabed marine litter in the northern and central Adriatic Sea. *Marine Pollution Bulletin*, *91*(1), 120–127. doi: 10.1016/j.marpolbul.2014.12.018

Suárez de Vivero, J. L. J. C. R., & Rodríguez Mateos, J. C. (2016). Marine Governance in the Mediterranean Sea. In M. Gilek & K. Kern (Eds.), *Governing Europe's Marine Environment: Europeanization of Regional Seas or Regionalization of EU Policies?* (pp. 203–224). London and New York: Routledge. Retrieved from https://books.google.gr/books?hl=fr&lr=&id=GVmrCwAAQBAJ&oi=fnd&pg=PP1&dq=Governing+Europe%27s+Marine+Environment:+Europeanization+of+Regional+Seas+or+Regionalization+of+EU+Policies.&ots=AMs0owSO87&sig=jZpEstKuvub380vJ2kW0NfSR610&redir_esc=y#v=onepage&q=Governing%20Europe's%20Marine%20Environment%3A%20Europeanization%20of%20Regional%20Seas%20or%20Regionalization%20of%20EU%20Policies.&f=false

Teixeira, H., Berg, T., Uusitalo, L., Fürhaupter, K., Heiskanen, A.-S., Mazik, K., … Borja, À. (2016). *A Catalogue of Marine Biodiversity Indicators.* doi: 10.3389/fmars.2016.00207

Tejada, M., Malvarez, G. C., & Navas, F. (2007). A New Environmental Indicator for Coastal Artificialisation and Resilience Mapping. *Journal of Coastal Research*, 67–71.

Tiralongo, F., Mancini, E., Ventura, D., Malerbe, S. D., Mendoza, F. P. D., Sardone, M., … Minervini, R. (2021). Commercial catches and discards composition in the central Tyrrhenian Sea: A multispecies quantitative and qualitative analysis from shallow and deep bottom trawling. *Mediterranean Marine Science*, *22*(3), 521–531. doi: 10.12681/mms.25753

Trop, T. (2017). An overview of the management policy for marine sand mining in Israeli Mediterranean shallow waters. *Ocean & Coastal Management*, *146*, 77–88. https://isiarticles.com/bundles/Article/pre/pdf/95242. doi: 10.1016/j.ocecoaman.2017.06.013

Tsiaras, K., Hatzonikolakis, Y., Kalaroni, S., Pollani, A., & Triantafyllou, G. (2021). Modeling the Pathways and Accumulation Patterns of Micro- and Macro-Plastics in the Mediterranean. *Frontiers in Marine Science*, *8*. Retrieved from https://www.frontiersin.org/article/10.3389/fmars.2021.743117

UN Environment/MAP. (2017). *Roadmap for a comprehensive coherent network of well-managed MPAs to achieve Aichi target 11 in the Mediterranean*. Athens, Greece: UN Environment/MAP. Retrieved from https://www.rac-spa.org/sites/default/files/action_plans/fdr_en.pdf

UNEP/MAP. (2017). *Mediterranean 2017 Quality Status Report*. Retrieved from https://www.medqsr.org/sites/default/files/inline-files/2017MedQSR_Online_0.pdf

UNEP/MAP. (2016b). *Integrated Monitoring and Assessment Guidance* (Meeting Report No. UNEP(DEPI)/MED IG.22/Inf.7; p. 282). Athens, Greece. Retrieved from https://wedocs.unep.org/handle/20.500.11822/29738

UNEP/MAP. (2016a). *Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria*. Athens: UNEP/MAP. Retrieved from https://wedocs.unep.org/rest/bitstreams/45233/retrieve

UNEP/MAP. (2016c). *Mediterranean Strategy for Sustainable Development 2016-2025*. Valbone: Plan Bleu, Regional Activity Centre. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/7700/-Mediterranean_strategy_for_sustainable_development_2016-2025_Investing_in_environmental_sustainability_to_achieve_social_and_economic_development-20.pdf?sequence=3

UNEP/MAP and Plan Bleu. (2020). *State of the Environment and Development in the Mediterranean*. Nairobi. Retrieved from https://planbleu.org/wp-content/uploads/2021/04/SoED_full-report.pdf

UNEP-MAP-RAC/SPA. (2011). *Note on the establishment of marine protected areas beyond national jurisdiction or in areas where the limits of national sovereignty or jurisdiction have not yet been defined in the Mediterranean Sea.* By Scovazzi, T. Ed. RAC/SPA, Tunis: 47pp. Retrieved from https://www.rac-spa.org/sites/default/files/doc_spamis/note_amp_en.pdf

UNEP/MAP-SPA/RAC. (2019a). *Monitoring protocols of the Ecosystem Approach Common Indicators 1 and 2 related to marine benthic habitats* (Meeting Report No. UNEP/MED WG.474/3; p. 171). Tunis. Retrieved from http://www.rac-spa.org/cormon1/docs/wg.474_3_en.pdf

Urra, J., García, T., León, E., Gallardo-Roldán, H., Lozano, M., Rueda, J. L., & Baro, J. (2019). Effects of mechanized dredging targeting Chamelea gallina, striped venus clams, on the associated discards in the northern Alboran Sea (Western Mediterranean Sea). *Journal of the Marine Biological Association of the United Kingdom*, *99*(3), 575–585. doi: https://doi.org/10.1017/S0025315418000462

Uusitalo, L., Blanchet, H., Andersen, J. H., Beauchard, O., Berg, T., Bianchelli, S., … Borja, A. (2016). Indicator-Based Assessment of Marine Biological Diversity–Lessons from 10 Case Studies across the European Seas. *Frontiers in Marine Science*, *3*. Retrieved from https://www.frontiersin.org/article/10.3389/fmars.2016.00159

van Dalfsen, J. A., Essink, K., Madsen, H. T., Birklund, J., Romero, J., & Manzanera, M. (2000). Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. *ICES Journal of Marine Science*, *57*(5), 1439–1445. doi: 10.1006/jmsc.2000.0919

Watson, S. J., Ribó, M., Seabrook, S., Strachan, L. J., Hale, R., & Lamarche, G. (2022). The footprint of ship anchoring on the seafloor. *Scientific Reports*, *12*(1), 7500. doi: 10.1038/s41598-022-11627-5

Weaver, P., & Gunn, V. (2009). HERMES: Hotspot Ecosystem Research on the Margins of European Seas. *Oceanography*, *22*(1), 12–15. doi: 10.5670/oceanog.2009.01

Weaver, P. P. E. (2005). Hotspot ecosystem research on the margins of European Seas. *Eos, Transactions American Geophysical Union*, *86*(24), 226–226. doi: 10.1029/2005EO240004

Weaver, P. P. E., Boetius, A., Danovaro, R., Freiwald, A., Gunn, V., Heussner, S., … Van den Hove, S. (2009). The Future of Integrated Deep-Sea Research in Europe: The HERMIONE Project. *Oceanography*, *22*(1), 178–191.

Zampoukas, N., Palialexis, A., Duffek, A., Graveland, J., Giorgi, G., Hagebro, C., … Zevenboom, W. (2014). *Technical guidance on monitoring for the Marine Stategy Framework Directive. EUR 26499* (Technical Report No. JRC88073). Luxembourg: Publication Office of the European Union. Retrieved from Publication Office of the European Union website: https://publications.jrc.ec.europa.eu/repository/handle/JRC88073

Zaouali, J. (1993). Les peuplements benthiques de la petite Syrte, golfe de Gabès-Tunisie. Résultats de la campagne de prospection du mois de juillet 1990. *Mar. Life*, *3*(1–2), 47–60.

Zenetos, A., Albano, P. G., Garcia, E. L., Stern, N., Tsiamis, K., & Galanidi, M. (2022). Established non-indigenous species increased by 40% in 11 years in the Mediterranean Sea. *Mediterranean Marine Science*, *23*(1). doi: 10.12681/mms.29106

Zerelli, S. (2018). Investigating illegal bottom trawling in the Gulf of Gabès, Tunisia. Retrieved 7 June 2022, from FishAct website: https://fishact.org/2018/12/investigating-illegal-bottom-trawling-in-the-gulf-of-gabes-tunisia/

Žuljević, A., Peters, A. F., Nikolić, V., Antolić, B., Despalatović, M., Cvitković, I., … Küpper, F. C. (2016). The Mediterranean deep-water kelp Laminaria rodriguezii is an endangered species in the Adriatic Sea. *Marine Biology, 163*, 69. doi: 10.1007/s00227-016-2821-2