UNITED
NATIONS

EP

UNEP/MED WG.642/inf.3

UNITED NATIONS
ENVIRONMENT PROGRAMME
MEDITERRANEAN ACTION PLAN

UNEP

15 June 2026
Original: English

12th Meeting of the Post-2020 SAPBIO National Correspondents

Videoconference, 16 June 2026

Agenda Item 3: Steps undertaken towards the implementation of the Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region (Post-2020 SAPBIO) at regional and national levels

Criteria for full inventory of ecosystems with high ecological relevance and/or regeneration potential in line with action 12 of Post-2020 SAPBIO

SPA/RAC
Tunis, 2026

Table of contents

1. Introduction

1.1 Context of the assignment and link to Action 12 of the Post-2020 SAPBIO

1. The Specially Protected Areas Regional Activity Centre (SPA/RAC) was established in 1985 by the Contracting Parties to the Barcelona Convention and operates under the auspices of the United Nations Environment Programme / Mediterranean Action Plan (UNEP/MAP), with Tunisia as the host country. SPA/RAC serves as the regional mechanism supporting Mediterranean countries in the implementation of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol), adopted within the framework of the Barcelona Convention (UNEP/MAP-SPA/RAC, 2021).

2. The Centre's mission is to promote the protection, conservation, and sustainable management of marine and coastal biodiversity in the Mediterranean region (UNEP/MAP-SPA/RAC, 2021). This includes the establishment and effective management of marine and coastal protected areas, the conservation of threatened species, and the recovery of vulnerable and degraded habitats. SPA/RAC also plays a key role in strengthening regional cooperation and providing technical and scientific support to Contracting Parties, thereby ensuring coherent implementation of the Barcelona Convention and its protocols at regional and national levels.

3. Within this framework, the 23rd Meeting of the Contracting Parties to the Barcelona Convention (Portorož, Slovenia, December 2023) requested SPA/RAC to develop criteria for a comprehensive inventory of ecosystems with the highest ecological relevance and/or regeneration potential, in line with Action 12 of the Post-2020 Strategic Action Programme for Biodiversity in the Mediterranean Region (SAPBIO) and Activity 2.1.1.c of the UNEP/MAP Programme of Work 2025-2025 (UNEP/MAP-SPA/RAC, 2021).

4. Action 12 of the Post-2020 SAPBIO supports the implementation of the Target T1.6 on ecosystem restoration, which aims, by 2027, to establish a full inventory of Mediterranean ecosystems with the highest ecological relevance and/or regeneration potential - such as nursery areas and carbon-rich habitats - and by 2030, to complete the restoration of most of those identified. This target is consistent with Target 2 of the Convention on Biological Diversity (CBD) Global Biodiversity Framework (GBF) and aligned with the objectives of the European Union Nature Restoration Law (CBD, 2022).

5. This work therefore contributes directly to the regional and global restoration agenda by providing the scientific and methodological basis for identifying and prioritizing Mediterranean ecosystems that are ecologically valuable, functionally significant, and capable of regeneration (UNEP/MAP-SPA/RAC, 2021).

1.2 Relevance of Identifying Ecosystems with High Ecological Value and Regeneration Potential

6. The Mediterranean Sea is one of the most ecologically diverse and socio-economically important semi-enclosed seas on the planet. It hosts around 10% of the world's marine species, of which nearly 25% are endemic, and supports crucial ecological functions such as carbon sequestration, nutrient cycling, and maintenance of fisheries productivity (UNEP/MAP-SPA/RAC, 2021; UNEP, 2021a). However, intense anthropogenic pressures, including coastal development, overexploitation, pollution, and climate change, have led to the degradation of many marine and coastal ecosystems (CBD, 2019).

7. Ecosystems with high ecological relevance play a fundamental role in maintaining biodiversity and ecosystem functioning (Costanza et al., 1997). They provide essential services such as coastal protection, carbon storage, water purification, and nursery grounds for numerous species. Ecosystems with high regeneration potential, on the other hand, have the capacity to recover from degradation through natural processes or targeted restoration actions, representing opportunities for cost-effective and sustainable restoration.

8. Identifying such ecosystems is therefore critical for guiding restoration priorities in the Mediterranean (UNEP, 2021b). This approach contributes to achieving the Post-2020 SAPBIO vision of ensuring resilient, functioning, and well-connected ecosystems capable of sustaining biodiversity and delivering ecosystem services under changing climatic and socio-economic conditions (UNEP/MAP-SPA/RAC, 2021; Regulation (EU) 2024/1991).

1.3 Objectives of the consultancy

9. The overall objective of this consultancy is to develop a harmonized set of criteria and indicators to assess and classify marine and coastal ecosystems according to their ecological relevance and regeneration potential. These criteria will serve as a technical tool to support Contracting Parties in:

(i) Developing national inventories of ecosystems with high ecological relevance and/or regeneration potential;
(ii) Identifying and prioritizing areas for conservation, restoration, or enhanced management;
(iii) Aligning national assessment approaches with regional and global frameworks, including the CBD Global Biodiversity Framework, the EU Nature Restoration Law, and the UNEP/MAP Ecological Approach (EcAp) (UNEP/MAP-SPA/RAC, 2021).

10. The methodology will promote coherence across the region, allowing national inventories to be comparable and contributing to a unified regional understanding of ecosystem conditions and priorities under the Barcelona Convention.

1.4 Target ecosystems

11. Restoration priorities focus on key Mediterranean ecosystem types that have been recognized as significant due to their exceptional ecological relevance, substantial contribution to ecosystem services, and notable potential for natural regeneration or restoration. These ecosystems - wetlands, coastal dune systems, seagrass meadows, and bioconstructions - represent the main functional units linking marine and coastal processes across the Mediterranean. Their selection reflects the need to address a full continuum of habitats, from terrestrial coastal zones to benthic marine environments, which together sustain biodiversity, productivity, and resilience in the region.

12. Wetlands are among the most productive and multifunctional ecosystems in the region (Ramsar, 2008). They include lagoons, salt marshes, estuaries, and deltas that perform essential ecological and hydrological functions, such as carbon storage, nutrient retention, water filtration, and flood regulation. Wetlands also serve as critical habitats for migratory and resident bird species and support the livelihoods of local communities. Despite their high ecological and socio-economic value, Mediterranean wetlands have undergone severe loss and degradation over the past century due to land reclamation, water abstraction, and pollution. Their natural regenerative potential can be harnessed when hydrological conditions are restored, and through the implementation of nature-based solutions in the context of the Post-2020 SAPBIO and the Ramsar Convention (UNEP/MAP-SPA/RAC, 2021; CBD, 2022; Regulation (EU) 2024/1991).

13. Coastal dune systems represent the dynamic interface between marine and terrestrial environments (Regulation (EU) 2024/1991). They provide natural coastal protection, regulate sediment transport, and host specialized plant and animal communities adapted to harsh, saline, and nutrient-poor conditions. Dune systems are also key components of coastal landscape connectivity, often linked to wetlands, lagoons, and seagrass habitats through sediment and hydrological exchanges. Although they have a strong natural regenerative capacity, their extent and functionality have been drastically reduced by coastal urbanization, infrastructure development, and trampling. Their inclusion among target ecosystems reflects their ecological relevance and regeneration potential, which support the maintenance of resilient coastal landscapes.

14. Seagrass meadows, and particularly Posidonia oceanica beds, are among the most emblematic and ecologically valuable Mediterranean ecosystems (Burgos et al., 2017). They form extensive underwater meadows that act as major long-term carbon sinks, contribute to nutrient cycling, and provide essential nursery and feeding grounds for a wide range of marine species. Their dense root and rhizome systems stabilize sediments, reduce coastal erosion, and enhance water clarity. Despite their importance, Posidonia oceanica meadows are highly sensitive to physical disturbance, eutrophication, and increasing sea

temperature, making their conservation and restoration a priority under the Barcelona Convention and the EU Nature Restoration Law.

15. Coralligenous assemblages and other bioconstructions, such as Cladocora caespitosa banks, vermetid platforms, serpulid and oyster reefs, constitute the main Mediterranean biogenic hard-bottom habitats. They host exceptionally rich and structurally complex communities, providing refuge, food, and breeding areas for numerous invertebrates and fish species (Salomidi et al., 2012). These bioconstructions also contribute to carbon sequestration through calcareous deposition. However, they are highly vulnerable to rising temperatures, acidification, destructive fishing practices, and mechanical impacts, which severely affect their recovery capacity. Their inclusion among target ecosystems reflects their high ecological relevance and regeneration potential, making them priorities for assessment, conservation, and potential restoration.

16. Together, these four ecosystem types encompass the key ecological gradients and processes that sustain Mediterranean biodiversity and ecosystem functioning. They provide complementary ecosystem services - from carbon sequestration and habitat provision to coastal protection and nutrient cycling - and were selected as priority systems based on their ecological relevance and regeneration potential, making them central targets for assessment, monitoring, and restoration under the Barcelona Convention framework.

1.5 Expected Outputs and Use of the Document

17. The main output of this consultancy is a comprehensive technical document that defines and describes standardized criteria, indicators, and methodological procedures for the assessment and inventory of marine and coastal ecosystems with the highest ecological relevance and/or regeneration potential in the Mediterranean region. The document aims to translate scientific evidence and existing frameworks into a practical and operational tool that can be directly applied by national authorities, scientific institutions, and regional stakeholders.

18. More specifically, the document will:

(i) Provide a clear and harmonized framework for identifying, assessing, and classifying ecosystems of high ecological importance and regeneration capacity, ensuring methodological consistency across Mediterranean countries.

(ii) Define operational criteria and indicators that can be used to evaluate ecosystem functions and services - such as biodiversity support, carbon storage, coastal protection, and nursery provision - within a standardized scoring structure.

(iii) Offer a transparent, science-based approach that can support decision-making processes related to conservation prioritization, restoration planning, and spatial management.

(iv) Serve as a reference for Contracting Parties under the Barcelona Convention to compile their national inventories of priority ecosystems, enabling comparison, integration, and harmonization at the regional scale.

(v) Support the implementation of Action 12 of the Post-2020 SAPBIO and contribute to the broader goals of the UNEP/MAP ecosystem-based approach, in alignment with international commitments such as the Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework, the Ramsar Convention, and the EU Nature Restoration Law.

19. This document will facilitate coherent reporting and synthesis of information through standardized formats and comparable datasets, strengthening regional monitoring and assessment under the Integrated Monitoring and Assessment Programme (IMAP) and other Barcelona Convention mechanisms. It will also serve as a reference for future updates of regional action plans, habitat inventories, and restoration strategies coordinated by SPA/RAC.

20. Ultimately, this document has been developed in direct response to Action 12, Target 1.6 of the Post-2020 SAPBIO, which mandates the creation of a comprehensive inventory of ecosystems with the highest ecological relevance and/or regeneration potential by 2027, and the subsequent restoration of the majority of those selected by 2030. By establishing standardized criteria, indicators, and methodological procedures, it

provides national authorities and regional stakeholders with a scientifically robust and operationally feasible framework to identify, assess, and prioritize these critical ecosystems. Its adoption across the Mediterranean is coherent, evidence-based, and strategically aligned with regional commitments, thereby promoting long-term ecological resilience and the effective safeguarding of key marine and coastal habitats in a changing climate.

21. The methodology adopted to prepare this document directly addresses the consultancy objectives, and the process has been conducted in three distinct phases to ensure thorough assessment and compliance:

1. Phase 1: conducting a thorough desk review of existing frameworks and methodologies related to assessment and inventory of **coastal and marine ecosystems**
2. Phase 2: developing criteria and indicators, with scoring and weighting systems, to evaluate ecological relevance and regeneration potential of **marine ecosystems** and define practical and standard methodology for data collection and assessment
3. Phase 3: preparing the finalized and standardized methodology for **marine ecosystems** inventory with the highest ecological relevance and regeneration potential, following national and regional consultations.

2. Desk review (phase 1)

22. The methodological approach adopted for the desk review was designed to ensure that the development of criteria and indicators for the identification and assessment of Mediterranean ecosystems with high ecological relevance and/or regeneration potential is scientifically sound, operationally feasible, and regionally harmonized. The process combined an extensive review of existing frameworks, a comparative analysis, and a validation phase involving national experts. This sequential yet iterative structure ensured that the proposed methodology is grounded in established scientific principles while remaining adaptable to the diverse ecological and socio-political contexts of the Mediterranean region.

23. The overall workflow of the consultancy was articulated in three main stages. The first stage consisted of a comprehensive desk review of global, regional, and national frameworks relevant to ecosystem classification, assessment, and restoration. This review aimed to identify conceptual definitions, methodological structures, and indicator sets that could inform the Mediterranean approach. The second stage focused on the comparative analysis of these frameworks, evaluating their respective strengths, gaps, and potential for integration within a harmonized regional structure. Finally, the third stage involved the formulation of operational criteria and indicators, along with a methodological framework to guide the inventory and assessment of priority marine ecosystems.

2.1 Structure and scope of the desk review

24. The first phase consisted of an extensive desk review aimed at mapping the conceptual and methodological landscape surrounding ecosystem assessment and classification. This phase was designed to identify, analyse, and consolidate existing frameworks, guidelines, and methodological approaches relevant to the characterization, assessment, state evaluation, and inventory of ecosystems within the scope of Action 12 of the Post-2020 SAPBIO Target 1.6. The review draws upon a wide range of scientific and policy sources, encompassing global standards and regionally adapted methodologies with direct relevance to Mediterranean ecosystems.

25. This desk review is organized into thematic sections reflecting both the hierarchical and ecosystem-specific structure of the analysis. The first section compiles global and cross-cutting frameworks and guidelines, including conceptual and operational standards applicable across multiple ecosystem types. The following sections focus respectively on the key ecosystem categories targeted by this review - wetlands, coastal dunes, seagrass meadows, and bioconstructions. Each ecosystem-specific section includes the most relevant frameworks and methodologies identified in literature, selected for their scientific robustness and applicability to assessment, monitoring, and inventory processes.

26. For each source, the review specifies its scope of application and provides a critical synthesis of its content, structure, and methodological contribution. Each entry concludes with a dedicated subsection of

Strengths, Gaps, and Applicability, which summarizes the main scientific and operational insights derived from the source, identifies limitations and data needs, and evaluates its potential for integration into regional and national frameworks under the SAPBIO initiative. Finally, a summary table is presented at the end of the desk review, consolidating all reviewed sources together with their identified strengths, gaps, and levels of applicability.

2.2 General and cross-cutting frameworks and guidelines

1) REGULATION (EU) 2024/1991 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869

27. The Regulation (EU) 2024/1991 of the European Parliament and of the Council on Nature Restoration, adopted on 24 June 2024, establishes the legal and methodological framework for restoration actions within the European Union. Although regional in scope, its provisions are fully aligned with global restoration commitments such as the UN Decade on Ecosystem Restoration (2021-2030) and the Kunming-Montreal Global Biodiversity Framework. The Regulation introduces binding obligations requiring all EU Member States to develop National Restoration Plans (NRPs) that identify degraded habitats, set measurable restoration targets, and define monitoring strategies. It also links restoration actions to existing marine policies, including the Marine Strategy Framework Directive (MSFD), ensuring coherence between EU-level and regional Mediterranean frameworks.

28. A central concept introduced by the Regulation is the definition of “good condition,” which represents the target state for all restoration actions. This condition is characterized by the maintenance or recovery of the structure, functions, and typical species composition necessary to ensure long-term ecological integrity and resilience. In marine environments, achieving good condition corresponds to the attainment of Good Environmental Status (GES) under the MSFD. Complementary to this is the notion of a “Favourable Reference Area” (FRA), representing the spatial extent needed to ensure the long-term viability of a habitat type.

29. The Regulation provides a detailed and standardized habitat classifications through the use of EUNIS and Habitats Directive codes, which is essential for the inventory ad characterization of Mediterranean ecosystems. For seagrass meadows, Posidonia oceanica is recognized as a priority habitat (1120). Restoration measures should aim to achieve good condition and the FRA through actions such as pressure reduction, habitat protection, and, where appropriate, active replanting or transplantation of seagrass shoots. Given the inherent monitoring challenges in marine environments, indirect indicators - such as water quality or anthropogenic pressures - may be used to assess habitat condition.

30. Regarding coralligenous assemblages and other marine bioconstructions, the document recognizes these habitats as ecologically valuable, carbon-rich, and biodiversity-supporting. While it does not provide detailed operational guidance for all Mediterranean-specific reef types, it establishes a classification system that supports the standardization of inventories and underlines their role in habitat provision and coastal protection.

31. For coastal dunes, the Regulation refers to several key habitat types, including embryonic shifting dunes, white dunes with Ammophila arenaria, fixed grey dunes, and humid dune slacks. Restoration is expected to focus on reinstating natural geomorphological processes rather than solely on replanting, for example by removing artificial barriers to allow natural sand movement.

32. Wetlands are similarly addressed, with estuaries, mudflats, coastal lagoons, and salt meadows identified as priority habitats for restoration. Measures include rewetting drained areas, removing drainage structures, and improving surface and groundwater quality and dynamics.

33. The Regulation also emphasizes the need for monitoring and assessment systems capable of tracking habitat condition and trends over time. Member States are encouraged to integrate spatially explicit data, georeferenced mapping, and, where feasible, GIS and remote sensing tools to support inventory, assessment, and monitoring

Strengths, Gaps, and Applicability

34. The Regulation (EU) 2024/1991 provides a legally binding and scientifically grounded framework. Its definitions of good condition and Favourable Reference Area offer clear ecological benchmarks for inventory, assessment, and restoration planning, and its use of standardized habitat codes ensures consistency across all EU Member States. By establishing obligations for monitoring and data-driven evaluation, it sets a methodological standard that can be adapted for Mediterranean ecosystems.

35. Despite its comprehensive structure, the Regulation does not specify habitat-specific metrics tailored for Mediterranean ecosystems, nor detailed operational guidance for certain bioconstructions.

36. Overall, the Regulation represents a key reference. It provides both the legal basis and a conceptual framework for defining restoration targets, planning restoration actions, and designing monitoring approaches, while leaving flexibility to account for regional ecological contexts and data availability.

2) Nature Restoration Plan Development Process in EU Member States (WWF/BirdLife, 2025)

37. This report provides a European-level overview of the development of Nature Restoration Plans (NRPs) while offering detailed national insights for selected Member States. The report emphasizes the use of Favourable Reference Areas (FRA) and Favourable Reference Values (FRV) as key parameters to define the desired extent and condition of habitats. These parameters are intended to be grounded in scientific evidence, avoiding decisions based solely on administrative or political considerations. This underscores the importance of moving beyond descriptive inventories to quantify how much habitat should be maintained or restored, considering historical baselines and anticipated climate-driven changes.

38. The document stresses the importance of multi-level governance and early identification of funding needs. Achieving restoration targets by 2030 requires timely mobilization of financial resources, including the EU LIFE programme and cohesion funds. By linking governance, finance, and scientific evidence, the report underscores that successful restoration planning depends on integrated institutional, financial, and ecological considerations rather than isolated technical actions.

Strengths, Gaps, and Applicability

39. The WWF/BirdLife report is a valuable resource for understanding the operationalization of restoration planning across European countries. Its strengths lie in providing a clear framework for translating ecosystem inventories into measurable restoration actions, with explicit attention to the definition and use of FRA and FRV, as well as the incorporation of ecological, socio-economic, and governance considerations.

40. At the same time, the report highlights persistent gaps, including limited transparency and engagement in several countries, which restrict the ability of technical experts to assess the ecological adequacy of restoration plans.

41. Overall, the document supports the definition of criteria for ecosystem prioritization and guides methodological approaches to identify and quantify habitats with high ecological relevance and regeneration potential.

3) IUCN Red List of Ecosystems Categories and Criteria Guidelines

42. The IUCN Red List of Ecosystems (RLE) provides the globally recognized framework for assessing the risk of ecosystem collapse, offering a standardized methodology for ecosystem evaluation, classification, and long-term monitoring. Designed to complement the IUCN Red List of Threatened Species, the RLE operates at the ecosystem level, integrating spatial distribution, environmental processes, and the integrity of biotic communities to deliver a comprehensive understanding of ecological risk.

43. The RLE methodology is structured around five quantitative criteria (A-E) that capture both spatial and functional dimensions of ecosystem decline. These criteria consider measurable indicators such as reductions in geographic distribution, environmental degradation, disruption of biotic processes, and quantitative probabilities of collapse. Assessments follow a transparent, rule-based approach, ensuring that

risk classifications are comparable across ecosystem types and biogeographic regions. A critical feature of the RLE is its alignment with the IUCN Global Ecosystem Typology (GET), which provides a hierarchical framework for defining assessment units consistently across local, national, and global scales, and across terrestrial, freshwater, marine, and subterranean realms.

44. The RLE framework offers guidance on selecting appropriate indicators, conceptual modelling, and defining collapse thresholds. Although it is global in scope, the principles of the RLE - including the use of functional indicators, conceptual models, and typological coherence - are readily adaptable to Mediterranean ecosystems. These methods can inform the assessment of seagrass meadows, coralligenous assemblages, rhodolith beds, and coastal wetlands, particularly by identifying habitat-forming species that shape both structure and function. Criteria C and D, which focus on environmental degradation and biotic disruption, can be applied to available Mediterranean data such as benthic cover, temperature anomalies, rugosity, and species composition.

45. Beyond technical assessment, the RLE supports regional and national implementation by guiding the development of sub-global Red List of Ecosystems. While the RLE itself does not prescribe restoration priorities, its outputs - ecosystem maps, risk categories, and threat data - provide a scientifically robust foundation for decision-making, helping to identify ecosystems at greatest risk and enabling proactive restoration interventions.

Strengths, Gaps, and Applicability

46. The main strengths of the RLE lie in its scientific rigour, transparency, and global recognition as a standard for ecosystem risk assessment. It provides a coherent and reproducible methodology, adaptable to a wide range of Mediterranean ecosystem types, while enabling comparability across spatial scales and countries.

47. Gaps include the absence of direct consideration of ecosystem services and socio-economic dimensions, which are important for a holistic view of ecological relevance. Furthermore, the RLE documentation provides few Mediterranean-specific case studies, requiring regional calibration of criteria and indicators. Integrating RLE outputs with complementary frameworks can address these limitations.

48. Overall, the RLE framework supports the definition of criteria for ecosystem prioritization and provides the methodological basis for assessing the state, risk, and regeneration potential of Mediterranean ecosystems.

4) IUCN Global Ecosystem Typology 2.0

49. The IUCN Global Ecosystem Typology (GET 2.0) provides a standardized global framework for classifying and comparing ecosystems. Developed as a hierarchical system, it organizes ecosystems into realms, biomes, Ecosystem Functional Groups (EFGs), and sub-global ecosystem types, integrating both functional and compositional characteristics. This structure supports consistent ecosystem inventory, assessment, and management across scales, from global to national, and underpins the IUCN Red List of Ecosystems (RLE) as well as international policy frameworks such as the Convention on Biological Diversity (CBD).

50. A central feature of GET 2.0 is its focus on spatially explicit units. Each EFG is described by key ecological traits, processes, and drivers, allowing ecosystems to be mapped, measured, and monitored over time. The v2.0 update provides indicative global maps of EFGs at 30 arc-second resolution (~1 km² at the equator), offering a tool for large-scale inventory and assessment initiatives. The typology emphasizes functional attributes such as productivity, structural complexity, and ecological processes, enabling systematic evaluation of ecosystem status and trends.

51. GET 2.0 encourages alignment with regional and national classification systems through the development of "crosswalks", which link local typologies to the global framework. This approach allows inventories and assessments at national or sub-regional levels to maintain consistency with international

standards. However, the typology itself does not prescribe quantitative monitoring indicators or thresholds, which must be derived through integration with complementary frameworks.

Strengths, Gaps, and Applicability

52. The main strengths of the IUCN Global Ecosystem Typology 2.0 lie in its universality, methodological rigor, and scalability. It provides a clear conceptual foundation for harmonizing ecosystem classification, assessment, and inventory across global, regional, and national levels. Its integration with the RLE framework makes it a key reference for assessing ecosystem status and trends. The emphasis on functional traits enhances its relevance for understanding ecosystem processes and informing restoration priorities.

53. Gaps in operational use remain, particularly for Mediterranean ecosystems. While GET 2.0 outlines functional and compositional characteristics, it does not provide region-specific calibration, mapping, or quantitative thresholds for local monitoring. Implementing crosswalks between global EFGs and national or sub-regional classifications requires structured expert input and validation, which remains a methodological challenge.

54. Overall, the IUCN Global Ecosystem Typology 2.0 provides a robust structural framework for building a harmonized and scientifically sound inventory and assessment system for Mediterranean ecosystems.

5) Guidelines for using a Global Standard for the Identification of Key Biodiversity Areas (Version 1.2)

55. The IUCN Global Standard for the Identification of Key Biodiversity Areas (KBAs) (Version 1.2) establishes an internationally recognized methodology for identifying sites that make a significant contribution to the persistence of biodiversity. Developed by the IUCN Species Survival Commission (SSC) and the World Commission on Protected Areas (WCPA), the framework links ecosystem classification and risk assessment (GET and RLE) to the spatial prioritization and management of sites essential for conservation, monitoring, and restoration.

56. KBAs are identified using five criteria (A-E) that address threatened and restricted biodiversity, ecological integrity, ecological refugia, and irreplaceability. Criteria A and B are ecosystem-focused and rely on GET units to ensure consistency between ecosystem typology, risk assessment, and site-level prioritization. The methodology emphasizes the use of spatially explicit data, including georeferenced ecosystem maps and species occurrence data. Boundaries must be ecologically meaningful, documented, and traceable. Data quality and verification are required, and KBAs are reassessed every 8-12 years to track trends over time and inform conservation and restoration measures.

57. A key feature of the document is the recognition of "restoration-dependent KBAs", which allows degraded sites to retain KBA status if restoration is expected to restore their qualifying features within a foreseeable timeframe.

58. In the Mediterranean context, the KBA framework applies to ecosystems such as Posidonia oceanica meadows, coralligenous assemblages, coastal dunes, wetlands, and transitional systems like lagoons and saltmarshes. This framework provides standardized, quantitative approach for identifying and monitoring sites that are ecologically significant, ensuring consistency with global standards and supporting spatial prioritization and restoration planning.

Strengths, Gaps, and Applicability

59. The main strengths of the KBA Standard lie in its integration of scientific rigor, spatial precision, and policy relevance. It provides a quantitative, repeatable, and transparent methodology that bridges ecosystem science with spatial planning. Its explicit cross-referencing with the GET and RLE frameworks ensures

consistency across scales and strengthens the scientific basis for identifying and prioritizing Mediterranean ecosystems.

60. While globally robust, the application of the KBA framework in the Mediterranean faces certain challenges. High-resolution spatial data for some Mediterranean ecosystems remain limited. Certain criteria, especially those addressing ecological integrity and refugia, may require calibration to local ecological conditions. Furthermore, structured crosswalks between KBA ecosystem criteria and national habitat classification systems are needed to ensure full operational applicability and integration with regional inventories.

61. Overall, the KBA Standard provides a robust and operational framework for identifying, mapping, and monitoring Mediterranean ecosystems of high ecological relevance and regeneration potential. Its adoption supports the creation of a scientifically sound, spatially explicit inventory and the prioritization of sites for restoration and conservation, aligning with global biodiversity targets and regional ecological objectives.

6) IUCN Mediterranean blue carbon strategy

62. The IUCN Mediterranean blue carbon strategy provides a regional and strategic framework to guide the protection, restoration, and sustainable management of blue carbon ecosystems across the Mediterranean Basin between 2025 and 2030. Developed by the IUCN Centre of Mediterranean Cooperation, the strategy analyses the policy frameworks of both EU Member States and non-EU Mediterranean countries, identifying gaps, regional disparities, and opportunities for integration.

63. The framework supports the identification and prioritization of ecosystems based on their capacity for carbon storage, nursery function, and coastal protection. Blue carbon ecosystems - particularly Posidonia oceanica meadows - are highlighted as essential carbon sinks that significantly contribute to climate change mitigation, while also providing critical ecosystem services such as coastal stabilization, biodiversity enhancement, and habitat provisioning. The document also identifies the key species underpinning these functions: Posidonia oceanica, Cymodocea nodosa, Zostera noltei, and Zostera marina, as well as coastal wetlands that play equivalent roles in carbon storage and shoreline protection. The document also recognizes the potential contribution of coralligenous assemblages and other hard-bottom bioconstructions, suggesting their integration into blue carbon assessments in the future.

64. The strategy explicitly identifies the lack of comprehensive and up-to-date cartography of blue carbon ecosystems as a key obstacle to effective management. To address this, it establishes a framework for implementing large-scale seabed mapping between 2025 and 2028 as a high-priority action to diagnose the current extent and state of conservation of these ecosystems. Methodological recommendations include the use of advanced mapping and imaging techniques capable of generating precise spatial data on ecosystem distribution and condition.

65. Assessment should quantify ecosystem condition and carbon stocks, with particular attention to sediment carbon, which represents a major component of long-term sequestration. More than half of the total carbon stored within seagrass ecosystems resides in the sediment, confirming the significance of belowground carbon pools as indicators of long-term sequestration potential.

66. Regarding restoration planning for the 2030 target, the strategy establishes a clear hierarchy: the first priority is the protection of existing, living seagrass meadows, followed by passive restoration through mitigation of stressors. Active restoration, including replanting or transplantation, is considered supplementary due to high cost, technical complexity, and long recovery times. Posidonia oceanica meadows require approximately fifty years to achieve full ecological and carbon sequestration functionality, a key parameter for planning and evaluating restoration feasibility.

67. The strategy provides critical insights into the integration of blue carbon into national policy frameworks. Several EU countries have incorporated blue carbon considerations into climate adaptation and coastal management policies, while non-EU countries are progressively embedding marine ecosystem conservation into national climate strategies.

Strengths, Gaps and Applicability

68. The main strength of the IUCN Mediterranean Blue Carbon Strategy is its provision of an integrated regional framework that combines ecological, policy, and financial perspectives to guide the management of blue carbon ecosystems.

69. However, it remains largely conceptual and lacks detailed operational protocols for active restoration, while the spatial and temporal coverage of existing data is uneven, particularly in southern Mediterranean regions.

70. Despite these limitations, the document provides guidance for identifying ecosystems of high ecological relevance, aligning national policies, and supporting the development of coherent, standardized methodologies for inventory, assessment, and restoration.

7) The Ecosystem Approach: Foundational Framework for Integrated Management (CBD guidelines)

71. The Ecosystem Approach (EA), established under the Convention on Biological Diversity (CBD), is recognized as one of the most important frameworks for action aimed at ensuring the integrated management of land, water, and living resources. It provides a comprehensive and scientifically grounded strategy for promoting conservation and sustainable use in an equitable manner, effectively balancing the three fundamental objectives of the CBD: conservation, sustainable use, and the fair and equitable sharing of benefits derived from biological diversity.

72. The approach emphasizes the application of appropriate scientific methodologies across levels of biological organization, focusing on the structural and functional dimensions of ecosystems, the essential structures, processes, and functions that define them, and the interactions among organisms and with their environment. This framework aligns with the characterization of priority Mediterranean habitats, including their ecological integrity, internal complexity, and functional roles in sediment stabilization, habitat provision, and maintenance of ecosystem services.

73. Central to the Ecosystem Approach is its concept of scale and boundaries. Ecosystems are understood as dynamic complexes of plant, animal, and microorganism communities interacting with their non-living environment as functional units. The approach does not prescribe fixed spatial units, allowing ecosystems to range from small ponds or coastal wetlands to large biomes or the biosphere. Appropriate spatial and temporal scales for analysis and management are determined by the specific problem being addressed, providing flexibility to adapt characterization, assessment, and inventory efforts to ecological, social, and policy contexts.

74. A core principle of the EA emphasizes that conservation of ecosystem structure and functioning should be the primary objective, as this underpins the delivery of ecosystem services. The approach also stresses adaptive management to address ecosystem complexity and uncertainty, entailing a "learning-by-doing" process where strategies are continuously refined based on monitoring and research outcomes. Long-term management objectives are encouraged to account for ecological processes that operate over extended timescales, recognizing that restoration outcomes may require decades to become apparent. Intersectoral cooperation is highlighted as essential for integrated management, requiring coordination among sectors such as agriculture, fisheries, forestry, energy, and transport, as well as across governance levels, to ensure that ecosystem-based considerations are embedded into sectoral policies and practices.

75. The global scope of the EA ensures its principles are universally applicable and adaptable to national and regional contexts. This includes attention to impacts on interconnected ecosystems, the adoption of precautionary approaches to avoid exceeding ecological limits, reinforcement of adaptive management as a continuous learning process, and integration of conservation and sustainable use objectives. Management decisions are expected to incorporate diverse sources of knowledge, including scientific and traditional or local systems, supporting comprehensive ecosystem assessment, inventory, and monitoring.

Strengths, Gaps, and Applicability

76. The principal strengths of the Ecosystem Approach lie in its integrative and flexible character, its emphasis on adaptive management, and its ability to harmonize conservation and sustainable use across multiple spatial and institutional scales. These features render it particularly suitable for designing cross-sectoral restoration strategies in contexts where ecological systems and socio-economic drivers are closely interconnected.

77. Its main limitations stem from its broad and largely conceptual formulation, which necessitates careful adaptation and operationalization to guide practical field implementation and monitoring. The approach does not provide quantitative metrics or standardized assessment protocols, thus requiring combination with complementary frameworks. Effective application in specific contexts depends on institutional alignment and the harmonization of data, which can remain incomplete or fragmented.

78. Nonetheless, when applied together with ecosystem-specific tools and regional monitoring systems, the Ecosystem Approach enables the integration of restoration and conservation objectives, fostering more coordinated and effective management interventions.

8) Considerations on ecosystem restoration for the Post-2020 Global Biodiversity Framework, including on a possible successor to Aichi Biodiversity Target 15

79. This source provides the scientific and policy foundation for designing robust and measurable ecosystem restoration targets. It analyses the conceptual and technical challenges faced during the implementation of Aichi Biodiversity Target (ABT) 15, which aimed to restore 15% of degraded ecosystems, and outlines the necessary methodological improvements to ensure that the new Target 1.6 achieves more tangible and ecologically meaningful outcomes.

80. A central contribution of the document is its clarification of the concepts of degradation, restoration, and baselines. Ecosystem restoration is defined as an intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state, aimed at re-establishing biodiversity, ecosystem functions, services, and resilience. Restoration does not necessarily imply a return to pristine pre-disturbance conditions but rather a trajectory towards improved ecological integrity. The establishment of pre-degradation baselines remains a critical prerequisite, as it allows for quantification of the degree of damage and assessment of progress toward recovery targets. In marine contexts, degradation often manifests as shifts in trophic structures due to overfishing, altered benthic composition from bottom trawling, or the loss of structural complexity in biogenic habitats.

81. The document also highlights the importance of integrating spatial prioritization to enhance restoration efficiency and effectiveness. Large-scale, spatially explicit conservation planning allows identification of sites where restoration generates the greatest cumulative gains across biodiversity, climate, and socio-economic dimensions. By optimizing restoration geographically, it becomes possible to achieve multiple objectives simultaneously, particularly in Mediterranean ecosystems with high ecological relevance and regeneration potential. These systems, due to their structural complexity and functional importance, often represent the most cost-effective investments for restoration interventions.

82. The report underscores the need to avoid biases toward easily quantifiable ecosystems such as forests, which dominated previous restoration commitments. This integrative vision underscores the relevance of adopting a landscape and seascape approach, which maintains ecological connectivity and functional continuity across terrestrial, freshwater, and marine interfaces.

83. Key principles for setting restoration targets under Action 12 include representativeness across ecosystem types, maintenance and enhancement of connectivity to support species movements and ecosystem processes, cost-effectiveness through spatial optimization, and the integration of ecological, social, and economic considerations. Collectively, these principles facilitate the design of restoration interventions that are both ecologically sound and operationally feasible within Mediterranean governance frameworks.

Strengths, Gaps, and Applicability

84. The primary strength of this framework lies in its quantitative, outcome-based targets that go beyond simple area metrics, ensuring that restoration progress is scientifically verifiable and ecologically meaningful. It provides clear methodological guidance for incorporating functional indicators and spatial prioritization into national and regional restoration strategies. Its integrative perspective across ecosystem types also reinforces the representativeness and ecological coherence of restoration planning in the Mediterranean.

85. However, the framework provides limited methodological specificity for marine and coastal systems, where data availability and monitoring capacity are often constrained. In particular, indicators for ecosystems such as coralligenous reefs or seagrass beds require adaptation to regional conditions and the development of standardized assessment protocols. Additionally, while cost-effectiveness is acknowledged as a guiding principle, economic and social trade-offs are not always explicitly quantified.

9) UN Decade on Ecosystem Restoration Strategy

86. The UN Decade on Ecosystem Restoration Strategy (2021-2030) provides a global framework to prevent, halt, and reverse ecosystem degradation, offering guidance applicable to both international and regional initiatives. The Strategy emphasizes the identification and restoration of ecosystems with high ecological relevance and regeneration potential. Its holistic approach integrates marine, coastal, and terrestrial ecosystems, establishing a consistent conceptual and operational basis for designing and prioritizing restoration interventions.

87. The Strategy links ecosystem restoration to multiple Sustainable Development Goals, particularly SDG 14 (Life Below Water) and SDG 15 (Life on Land), highlighting the need for restoration activities to contribute to biodiversity conservation, ecosystem services, and human well-being. It provides guidance on technical capacity building, including project design, implementation, monitoring, and long-term sustainability, aligning with internationally recognized standards. Central to this is the use of reference ecosystems and baselines to assess recovery and ensure methodological rigor and comparability across projects.

88. Tools and methodologies such as ROAM are recommended to identify restoration opportunities, inform prioritization, and integrate ecological and socio-economic considerations. The Strategy differentiates approaches according to ecosystem type, providing tailored guidance for marine and coastal systems as well as terrestrial and freshwater habitats, linking global standards to regional and local contexts. Monitoring and reporting are emphasized to ensure transparency, comparability, and compatibility with national and regional systems, with indicators covering changes in ecosystem structure, function, and services.

Strengths, Gaps, and Applicability

89. The primary strength of the UN Decade Strategy lies in its global vision, which provides coherent goals, standardized methodologies, and links to internationally recognized frameworks such as the SER standards and ROAM. Its applicability to Mediterranean ecosystems is reinforced by explicit guidance on marine, coastal, and terrestrial habitats.

90. A notable gap is the need for further operationalization of global tools at local scales, particularly regarding socio-economic quantification and the adaptation of reference ecosystem parameters to Mediterranean-specific contexts.

91. Nevertheless, the Strategy provides a robust framework to guide the selection, implementation, and monitoring of restoration interventions, offering both conceptual justification and technical pathways for achieving the 2027 inventory and 2030 restoration targets.

10) UN Ecosystem Restoration for People, Nature and Climate

92. The UNEP report “Ecosystem Restoration for People, Nature and Climate” provides a comprehensive global assessment of the scientific, ecological, and socio-economic rationale for ecosystem restoration. The

document demonstrates that restoration delivers multiple, quantifiable benefits, including biodiversity enhancement, climate mitigation through carbon sequestration, coastal protection, and support for fisheries and food security. It emphasizes that effective restoration planning must integrate biophysical and socio-economic indicators, ensuring that ecosystem recovery is multidimensional and measurable.

93. A significant contribution of the report is the demonstration of economic benefits from restoration, highlighting that restoration activities can generate substantial returns, including employment opportunities and revenue generation.

94. The ERPNC report also stresses the critical role of restoration in climate change mitigation, noting that degraded ecosystems can contribute substantially to meeting global mitigation targets. Coastal and inland wetlands are highlighted as particularly effective carbon sinks. In addition, restored coastal habitats provide protection and adaptation benefits by attenuating wave energy, reducing flood risks, and mitigating storm impacts, reinforcing the importance of measuring structural and functional attributes of restored ecosystems.

95. Restoration also enhances nursery functions and biodiversity, contributing to increased fisheries productivity and overall ecosystem resilience. Metrics related to species biomass, density, and recruitment are important for designating critical nursery areas. The urgency of restoration is reinforced by data on historical ecosystem losses, including extensive degradation of wetlands and seagrass globally, highlighting the need for rapid assessment, inventory, and prioritization of remaining Mediterranean ecosystems.

Strengths, Gaps, and Applicability

96. The main strength of the ERPNC report lies in its global scope and quantified evidence base, which provide a scientifically robust rationale for integrating ecological, socio-economic, and climate-related metrics into restoration planning. Its applicability to Mediterranean ecosystems is direct, offering guidance on relevant parameters such as carbon sequestration, wave attenuation, and nursery function.

97. Gaps include the need for regionally specific adaptation of some quantified global estimates, such as ecosystem service valuation and climate mitigation potential, which must be localized to Mediterranean contexts.

98. Nonetheless, the report supports methodological rigor, evidence-based prioritization, and monitoring design aligned with global and regional restoration targets.

11) A metric for spatially explicit contributions to science-based species targets

99. The STAR (Species Threat Abatement and Restoration) metric provides a globally applicable, spatially explicit framework for quantifying contributions to species conservation targets. Derived from IUCN Red List data, STAR integrates information on species' extinction risk, threats, and the extent of both current and restorable habitat, allowing policymakers, researchers, and conservation practitioners to prioritize actions based on scientifically robust criteria. The STAR metric offers a quantitative backbone for linking ecosystem assessment, inventory, and restoration activities to measurable contributions toward global biodiversity goals.

100. STAR is composed of two complementary components: the START (Threat Abatement) score and the STARR (Restoration Potential) score. The START score quantifies the potential benefit of reducing ongoing threats to species within their existing habitats. Each species is weighted according to its IUCN Red List status, with higher extinction risk conferring greater priority, and each threat is weighted according to its contribution to species decline. For Mediterranean ecosystems, this principle implies that habitats supporting threatened species - such as Posidonia oceanica beds for Pinna nobilis - should be prioritized in assessments and mapped accordingly. Threat abatement in this context focuses on pollution control, sustainable fisheries management, and the mitigation of habitat loss due to coastal development.

101. The STARR score addresses restoration potential, evaluating the expected benefits of rehabilitating lost habitat. This requires calculating the difference between historical and current habitat extent (restorable Area of Habitat, AOH) and applying a multiplier that accounts for the slower success rate of restoration compared to conservation. Methods for estimating historical habitat extent - such as aerial imagery, sediment surveys, or historical records - are critical for calculating STARR scores for ecosystems.

102. A key strength of STAR is its explicit spatial framework. By enabling fine-scale mapping of current versus restorable habitat, it supports prioritization within Key Biodiversity Areas (KBAs) and Specially Protected Areas of Mediterranean Importance (SPAMIs). High-resolution grid analyses allow planners to distinguish areas with immediate conservation potential from sites suitable for restoration.

103. STAR also incorporates policy-relevant considerations by facilitating engagement of non-state actors, such as local communities, private stakeholders, and cities. Quantifying both ecological and socio-economic contributions encourages investment in restoration projects, creating a link between threat abatement and tangible benefits for stakeholders.

Strengths, Gaps, and Applicability

104. STAR's main strength lies in its rigorous, quantitative, and globally consistent framework. Its spatially explicit design ensures that conservation and restoration actions are targeted where they will deliver the highest impact.

105. Limitations include its current reliance on terrestrial data and the relative scarcity of comparable datasets for marine and Mediterranean species, meaning adaptation and integration with IMAP/Barcelona Convention data is necessary.

106. Despite this, STAR's methodological principles are highly applicable for Mediterranean ecosystem assessment, inventory, and restoration planning, providing a clear pathway to link local restoration actions with global species conservation targets.

12) Scientific Foundations for an IUCN Red List of Ecosystems

107. Keith et al. (2013) provide the scientific and methodological foundation for the IUCN Red List of Ecosystems (RLE), establishing a globally standardized framework to assess ecosystem risk and potential collapse. The RLE framework translates the concept of species extinction to ecosystems, defining "ecosystem collapse" as the loss of defining biotic and abiotic features and their replacement by novel systems. This approach is applicable across marine, terrestrial, and transitional ecosystems, offering a robust basis for inventory, characterization, and restoration prioritization.

108. The RLE methodology operationalizes ecosystem assessment through four essential elements: characteristic native biota, abiotic environment, key ecological processes and interactions, and spatial distribution. These elements ensure consistent and repeatable characterization, enabling the evaluation of ecosystem status and trends over time. Five criteria (A-E) guide risk assessment, incorporating both spatial and functional dimensions. Distributional criteria evaluate declines in area and spatial restriction, while functional criteria quantify environmental degradation and disruption of biotic interactions. A quantitative criterion integrates multiple threats through simulation models to estimate the probability of ecosystem collapse.

109. This framework supports restoration planning by identifying ecosystems most vulnerable to collapse and those with the highest likelihood of resilience under future pressures, such as climate change or pollution. It integrates multiple data sources, including remote sensing, field observations, and expert knowledge, to provide a comprehensive and predictive assessment of distribution, function, and vulnerability. For Mediterranean ecosystems, the RLE approach enables the prioritization of restoration interventions based on scientifically grounded metrics and projected long-term outcomes.

Strengths, Gaps, and Applicability

110. The RLE framework's primary strength lies in its globally recognized, standardized, and theoretically grounded approach, integrating spatial, compositional, and functional metrics for holistic ecosystem assessment. Its predictive capacity and forward-looking design support evidence-based prioritization of restoration actions and compliance with international policy frameworks.

111. Gaps include the dependency on high-quality spatial and functional data, which may be limited in some Mediterranean areas, and the need for local validation of predictive models.

112. Nevertheless, the framework provides science-based, comparable metrics for national and regional reporting, and facilitates the identification of ecosystems with the highest restoration potential and long-term resilience.

13) Manuale di interpretazione habitat Natura2000

113. The "Manuale di Interpretazione Habitat Natura2000" serves an authoritative reference for defining and describing the natural habitat types listed in Annex I of the European Union Habitats Directive (92/43/EEC), covering all EU Member States (EUR28). By standardizing definitions, classification codes, and descriptive parameters, the manual ensures comparability of inventories and monitoring across regions. It supports the systematic characterization and prioritization of Mediterranean coastal and marine ecosystems, and guides restoration planning in alignment with EU and international legal frameworks.

114. The manual establishes operational definitions using multiple classification systems, including Natura 2000 four-digit codes, Palaearctic Classification, and the Barcelona Convention system. Priority habitats are explicitly highlighted to guide conservation and restoration efforts toward ecosystems most at risk. For marine environments, the manual provides detailed characterization of key ecosystems such as Posidonia oceanica beds (1120*) and coralligenous reefs (1170). Coastal and wetland habitats, including estuaries (1130), coastal lagoons (1150*), and dunes (2210, 2250*), are characterized with precise vegetation taxa and ecological descriptors to facilitate accurate monitoring and restoration.

115. The manual emphasizes the legislative and operational context, promoting integration of advanced assessment tools, ensuring that inventory, assessment, and restoration measures are both ecologically robust and regionally appropriate.

Strengths, Gaps, and Applicability

116. The manual's primary strengths lie in its harmonized terminology, standardized codes, and explicit identification of priority habitats, supporting uniform application of conservation and restoration measures across Mediterranean Member States. It facilitates integration with regional monitoring protocols and international frameworks, providing essential baseline definitions for ecosystem characterization and restoration planning.

117. Gaps include the reliance of some habitat types on minimal CORINE interpretation, which requires regional adaptation, and potential limitations in mapping and monitoring deep-water habitats due to technological constraints.

118. Nonetheless, the manual enables consistent inventories, informing restoration strategies, and promoting comparability and policy alignment across the Mediterranean.

14) The ecosystem approach

119. The Ecosystem Approach provides a globally recognized conceptual framework for integrated ecosystem management. It promotes holistic, adaptive, and multi-scale strategies for Mediterranean priority habitats. By framing ecosystems as dynamic complexes of biological communities interacting with their abiotic environment, the approach emphasizes maintaining both structural integrity and functional processes to sustain essential ecosystem services, including carbon sequestration and coastal protection.

120. Operationally, the Ecosystem Approach advocates adaptive management to accommodate ecological variability, non-linear processes, and uncertainty. Management focuses on sustaining natural processes rather than fixed endpoints, incorporating monitoring of ecosystem responses, recognizing functional limits, and accounting for connectivity among habitats, which is critical for mitigating offsite impacts. The framework allows flexible application across spatial scales, from site-level interventions to basin-wide inventories.

121. Socio-economic and governance dimensions are integral to the approach, promoting participatory and multi-stakeholder management. Management objectives are defined through societal choice, economic contexts are incorporated to account for costs and benefits, and decentralization ensures local knowledge

informs decision-making. Intersectoral collaboration is emphasized to manage shared resources effectively, exemplified in Integrated Marine and Coastal Area Management where fisheries, tourism, and conservation intersect. Effective implementation relies on comprehensive information, integrating scientific, local, and indigenous knowledge, with transparent assumptions and evidence-based feedback loops to support adaptive learning throughout inventory and restoration processes.

Strengths, Gaps, and Applicability

122. The Ecosystem Approach provides a scientifically robust and internationally recognized framework for integrated ecosystem management. Its strengths include support for adaptive, multi-scale, and participatory management, and the integration of ecological, socio-economic, and governance considerations, facilitating informed prioritization of restoration interventions.

123. Gaps involve the need for localization to Mediterranean contexts, sufficient technical capacity for monitoring and stakeholder engagement, and translation of broad principles into operational protocols for specific habitats.

124. The framework informs inventory design, assessment strategies, and restoration planning, while supporting stakeholder-inclusive decision-making and the integration of ecological, social, and economic objectives.

15) International principles and standards for the practice of ecological restoration. Second edition

125. With a global scientific and operational scope, the International Principles and Standards for the Practice of Ecological Restoration (Second Edition) establishes a comprehensive framework for the planning, implementation, monitoring, and evaluation of ecological restoration initiatives. The document defines restoration as the process of assisting the recovery of ecosystems that have been degraded, damaged, or destroyed, with the primary objective of reinstating ecological integrity, rather than focusing solely on the re-establishment of vegetation or habitat cover.

126. The framework provides structured methodological guidance for designing restoration interventions grounded in ecosystem functionality, measurable outcomes, and adaptive management. A central component of the framework concerns the evaluation of restoration success. Principle 5 establishes that outcomes should be assessed through measurable indicators derived from key ecological attributes.

127. The Standards identify six core ecosystem attributes that guide both restoration design and evaluation: absence of threats, appropriate physical conditions, species composition, structural diversity, ecosystem functioning, and external ecological exchanges. Together, these attributes provide an integrated lens through which ecosystem recovery can be assessed.

128. The framework also stresses the importance of baseline inventory and diagnostic assessment prior to intervention. Standard 1.4 requires that the causes, extent, and characteristics of degradation be identified to inform restoration planning and define realistic recovery trajectories.

129. In prioritization terms, the Standards promote directing restoration efforts toward ecosystems capable of achieving the highest level of ecological recovery. Principle 6 encourages the pursuit of the maximum achievable restoration outcome, supporting investment in ecosystems that provide significant ecological functions, services, and resilience.

130. To operationalize recovery evaluation, the Standards introduce a five-star recovery scale derived from the six ecosystem attributes. This system provides a structured method for measuring restoration progress and communicating the degree of ecological integrity achieved.

131. The document further underscores the ecological and socio-economic consequences associated with the loss of irreplaceable native ecosystems, thereby reinforcing the need to prioritize systems characterized by slow recovery dynamics or high conservation value.

132. From an implementation perspective, the Standards outline key operational principles to guide restoration practice. Principle 4 promotes harnessing natural regenerative processes wherever possible, including the use of remnant native species and natural succession pathways before resorting to more

interventionist techniques. Principle 8 introduces the concept of the Restorative Continuum, situating ecological restoration within a gradient of restorative actions ranging from mitigation and rehabilitation to full ecosystem recovery. This continuum allows practitioners to align restoration ambition with the degree of ecosystem degradation.

133. The Standards also establish that restoration interventions must address both biotic and abiotic degradation factors. They highlight the importance of adaptive management, emphasizing iterative monitoring, evaluation, and methodological adjustment to ensure that restoration trajectories remain aligned with ecological objectives.

134. At broader spatial scales, the framework advocates for the upscaling of restoration initiatives to generate cumulative ecological benefits. Principle 7 recognizes that restoration outcomes are amplified when implemented across landscape, watershed, or regional scales capable of counteracting systemic pressures.

135. The Standards further highlight the need to integrate climate change considerations into restoration planning, including the use of climate-adjusted provenance and predictive approaches to species selection in order to enhance long-term ecosystem resilience.

136. Finally, the document situates ecological restoration within the broader global policy landscape, aligning restoration practice with international frameworks such as the UN Decade on Ecosystem Restoration and the Sustainable Development Goals, thereby reinforcing the strategic relevance of restoration actions at multiple governance levels.

Strengths, Gaps, and Applicability

137. The Standards provide a globally recognized and scientifically grounded framework that establishes common principles, terminology, and evaluation criteria for ecological restoration across ecosystem types. Their emphasis on measurable ecological attributes, reference models, and adaptive management offers a robust methodological basis for designing and evaluating restoration initiatives. The inclusion of scalable implementation guidance and climate adaptation considerations further strengthens their relevance in the context of large-scale environmental change.

138. At the same time, the framework remains generic, requiring contextual interpretation to address ecosystem-specific dynamics, particularly in complex marine environments where restoration trajectories, structural recovery, and monitoring indicators may differ from terrestrial systems. Implementation may also depend on the availability of long-term ecological data, technical capacity, and sustained monitoring resources.

139. Overall, the Standards constitute a foundational methodological reference for ecological restoration planning and evaluation, providing a coherent scientific structure to guide ecosystem recovery initiatives across diverse geographic and ecological contexts.

16) The value of the world's ecosystem services and natural capital

140. With a global analytical scope, The Value of the World’s Ecosystem Services and Natural Capital presents a quantitative assessment of ecosystem services and natural capital through a comprehensive meta-analysis of 17 ecosystem services distributed across 16 major biomes worldwide. The study establishes an economic valuation framework designed to estimate the Total Economic Value (TEV) of ecosystems, encompassing both marketed and non-marketed contributions to human welfare. By systematically monetizing ecosystem functions, the study provides an economic rationale for conservation and restoration, highlighting how the historical exclusion of ecosystem services from commercial markets has contributed to their undervaluation and to insufficient investment in conservation. The explicit valuation of ecosystem services is therefore presented as a critical instrument to guide sustainable management and policy decisions.

141. The global assessment estimates the annual value of ecosystem services at approximately US$33 trillion, equivalent to about 1.8 times the global Gross National Product at the time of analysis. A substantial proportion of this value derives from non-marketed public goods, particularly nutrient cycling and disturbance regulation, which represent essential ecological functions supporting planetary life-support systems. Marine environments emerge as the largest contributors to global ecosystem service value, accounting for roughly

63% of the total estimated contribution. Within this category, coastal ecosystems alone represent an exceptionally high share of annual value.

142. The study further provides standardized per-hectare valuations for major ecosystem types, enabling comparative assessment of ecological and economic relevance across biomes. High per-area values are attributed to seagrass and algal beds, coral reefs, estuaries, and wetlands, reflecting the intensity and multiplicity of services delivered by these habitats. This valuation evidence highlights the ecological and economic significance of coastal and transitional ecosystems characterized by high productivity, biodiversity support, and regulatory functions.

143. In relation to ecosystem prioritization, the study emphasizes that the scarcity of natural capital and the irreversibility of ecosystem service loss contribute to increasing ecosystem value over time. This reinforces the need for proactive conservation and restoration strategies aimed at preventing irreversible degradation.

144. The analysis also demonstrates that technological substitution of ecosystem services is often complex and economically unfeasible, thereby strengthening the case for preservation, mitigation of pressures, and ecological restoration as cost-effective management pathways.

145. Finally, the study provides a standardized classification of ecosystem services and biome categories that can support ecosystem inventory, ecological characterization, and restoration planning processes by offering a structured valuation framework applicable across governance scales.

Strengths, Gaps, and Applicability

146. The study provides a globally recognized, quantitative valuation of ecosystem services, establishing the economic and ecological significance of natural capital. It also offers per-hectare estimates for coastal and marine ecosystems. By highlighting the impracticality of technological substitution for natural services, it provides a strong economic rationale for preventative conservation measures. Furthermore, the study establishes a standardized framework for ecosystem function classification, enabling harmonized characterization and assessment of Mediterranean coastal ecosystems

147. Limitations include that global scale estimates may not capture local variability in ecological, social, and economic conditions, meaning regional adaptation is required, and that per-hectare valuations do not fully account for spatial heterogeneity, connectivity, or cumulative impacts. Additionally, restoration costs and feasibility vary substantially by ecosystem type, so global valuations provide general guidance but not site-specific management solutions.

148. Overall, the study establishes a scientific and economic foundation for policy advice, particularly for prioritizing conservation of high-value, slow-recovering Mediterranean habitats. It offers a conceptual framework to inform restoration and mitigation planning, including cost-benefit analysis, impact assessment, and justification for nature-based management interventions.

17) The cost and feasibility of marine coastal restoration

149. The document provides a global framework and synthesis of restoration feasibility and cost, based on a meta-analysis of 235 studies encompassing 954 individual restoration observations across marine and coastal ecosystems worldwide. Although the study is global in scope, it is directly relevant for Mediterranean contexts, as part of the analysed projects were conducted in European regions with ecological and socio-economic conditions comparable to those in the Mediterranean basin. The findings provide an empirical foundation for setting realistic restoration feasibility targets and budgeting strategies across Mediterranean countries, supporting operational planning for coastal and marine ecosystem restoration.

150. The synthesis addresses five major categories of marine and coastal ecosystems, including seagrass meadows (Posidonia, Cymodocea, Zostera), oyster reefs, and saltmarshes or coastal wetlands, while coral reef data are used as analogues for complex Mediterranean bioconstructions. The document emphasizes that restoration feasibility, cost-effectiveness, and success rates are critical determinants of the attainability of

restoration goals, and uncertainties in these factors represent primary barriers to effective restoration decision-making.

151. Generalized survival metrics derived from the synthesis provide benchmarks for restoration success across ecosystem types. Seagrass restoration exhibited the lowest median survival rate at 38%, indicating high technical difficulty and ecological fragility, while oyster reefs and saltmarshes achieved median survival rates of 56.2% and 64.8%, respectively. Failure analyses highlight inadequate site selection, including unstable substrates, high-energy wave exposure, and sediment movement, as the most recurrent causes of project failure for seagrass and oyster reefs. For wetlands, stressors such as high salinity, sediment deposition, algal smothering, and faunal disturbance were critical. Only locally adapted native species ensured higher transplant survival and ecological compatibility. The study also identifies short monitoring durations (median 1-2 years) and the focus on organism-based success metrics as limitations, recommending long-term monitoring of 15-20 years and ecosystem-scale indicators including biodiversity, structural complexity, and service provision.

Strengths, Gaps, and Applicability

152. The document provides a comprehensive global framework combining ecological, technical, and economic analyses across major marine and coastal ecosystems, supporting the establishment of scientifically grounded and economically realistic restoration strategies. Median survival rates for seagrass, oyster reefs, and saltmarshes offer benchmarks for defining monitoring targets and performance indicators, while the analysis demonstrates that success is strongly influenced by site conditions and methodological choices rather than financial investment.

153. Limitations include the generalized nature of the data, the lack of ecosystem- or species-specific methodologies for Mediterranean habitats, and the predominance of data from temperate and subtropical developed countries that may differ in ecological, socio-economic, and policy conditions.

154. The study's findings provide relevant methodological and operational elements for defining restoration feasibility, measurable success targets, and cost-effective planning. Benchmarks and failure criteria are translated into standardized site assessment checklists, while the recommendation for long-term monitoring offers guidance for evaluating ecosystem functionality and service recovery.

18) Agenda item 4. Assessment methodologies, assessment criteria and thresholds for biodiversity common indicators CI1 and CI2

155. This document represents the principal regional scientific and methodological framework established under the United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) and the Barcelona Convention. It provides the foundation for harmonized monitoring, inventory, and ecological assessment of marine and coastal habitats throughout the Mediterranean, aligning with the commitments of Contracting Parties (CPs).

156. Within this context, the IMAP framework defines two core Common Indicators (CIs): CI1, which concerns the habitat distributional range and serves as the basis for ecosystem inventory, and CI2, which focuses on the condition of the habitat's typical species and communities and enables the assessment of ecological quality and integrity. CI1 measures the spatial extent and loss of habitat, providing the quantitative baseline for inventory efforts, whereas CI2 evaluates the structural and functional condition of the habitat through standardized biological parameters. These indicators are therefore fundamental to the development of both regional inventories and restoration strategies, ensuring comparability across national monitoring programmes and facilitating consistent reporting for the Mediterranean Quality Status Report (MedQSR).

157. For Posidonia oceanica meadows, the IMAP document specifies parameters and metrics for both inventory (CI1) and condition assessment (CI2), including habitat area in square kilometres for CI1, and shoot density, leaf biomass, epiphyte load, and rhizome production for CI2. These parameters are integrated into indices such as the Posidonia oceanica Rapid Easy Index (PREI) and the Posidonia oceanica Multivariate Index (POMI), with reference conditions derived from unimpacted sites and threshold values ranging from

over 750 shoots per square metre for high-quality meadows to fewer than 50 for degraded sites. These indices are essential for deriving the Ecological Quality Ratio (EQR), the core metric for status classification.

158. For coralligenous assemblages, the methodology adopts multi-parametric assessment approaches reflecting the structural complexity of the habitat. The MACS index incorporates structural and functional descriptors, including the abundance, density, and height of key structuring species, together with degradation indicators including necrosis, epibiosis, and fishing gear entanglement. Threshold values support Ecological Quality Ratio classification, while survey protocols include replicated quadrat sampling in shallow environments and remotely operated vehicle surveys in deeper areas. Spatial inventory data for this habitat remain limited, reinforcing the priority of mapping and spatial modelling activities.

159. For maërl and rhodolith beds, the framework identifies significant regional data gaps. Inventory assessments rely primarily on habitat spatial extent, while ecological condition is evaluated through the ratio of live to dead rhodoliths, a key indicator of degradation linked to trawling and sedimentation. Supporting descriptors include density, species composition, and particulate organic matter.

160. Although primarily developed for benthic marine habitats under Ecological Objective 1, the methodological principles of the framework are transferable to other coastal and transitional systems, including dunes and wetlands. This transferability is based on shared assessment logic involving baseline inventories, pressure identification, and structural and functional condition indicators, supported by consistent habitat typologies and monitoring protocols.

161. The framework further establishes that monitoring must explicitly link ecological state variables to anthropogenic pressures, while both CI1 and CI2 require clearly defined baselines and reference conditions derived from mapping, historical reconstruction, and minimally disturbed sites. Assessments are to be conducted at sub-regional scale across Mediterranean assessment areas, with harmonized data collection and reporting procedures to enable regional aggregation and long-term evaluation.

Strengths, Gaps, and Applicability

162. The framework's principal strength lies in its provision of a fully harmonized and regionally endorsed methodological system for biodiversity monitoring, enabling comparability of habitat inventory and ecological status assessments across Mediterranean Contracting Parties. Its formalization of Common Indicators, thresholds, reference conditions, and operational indices establishes a shared scientific basis for evaluating ecosystem distribution and condition.

163. At the same time, some structural limitations persist, including uneven spatial inventory coverage, particularly for structurally complex or less-mapped habitats, and the incomplete development or standardization of condition indices for certain ecosystem types. Additional challenges relate to data harmonization and intercalibration among national monitoring systems operating under differing technical capacities.

164. Notwithstanding these constraints, the framework provides the central methodological reference for structuring regional habitat inventories, guiding ecological assessments, and supporting the progressive standardization of Mediterranean monitoring and reporting processes.

19) A Meta-Review on New Technologies for Marine Biodiversity Monitoring and Assessment (IEEE, 2025)

165. With a global methodological scope, while maintaining strong operational linkages to regional and national research initiatives, this meta-review provides a consolidated synthesis of emerging technologies supporting marine biodiversity monitoring and ecosystem assessment. The document frames the ongoing transition from traditional invasive sampling techniques, such as dredging and bottom trawling, toward non-extractive and high-resolution monitoring strategies capable of evaluating ecosystem condition without generating additional physical disturbance.

166. In relation to Mediterranean seagrass ecosystems, including Posidonia oceanica meadows, the review identifies bathymetric LiDAR as a key technology for habitat characterization across multiple spatial scales. Deployed from aerial or underwater platforms, LiDAR systems enable three-dimensional morphological reconstruction of submerged habitats, with sufficient water-column penetration to detect structural variation within seagrass canopies. This capacity supports not only the measurement of areal distribution but also structural descriptors such as shoot density proxies and canopy complexity, which contribute to broader evaluations of ecosystem condition and functional capacity.

167. For structurally complex benthic habitats, the review highlights the development of Underwater Legged Robots (ULRs) as an emerging observational platform. Their articulated mobility allows operation across irregular and fragile substrates while minimizing sediment resuspension, thereby enabling localized, high-precision biodiversity observations and structural assessments in environments where conventional tracked or wheeled vehicles may generate disturbance.

168. The review further examines the application of environmental DNA metabarcoding as a complementary inventory tool. By analysing genetic material released by organisms into the water column through standardized molecular markers, eDNA approaches expand biodiversity detection capacity beyond the limits of visual census techniques. The methodology is identified as particularly effective in habitats characterized by cryptic, rare, or elusive species assemblages, thereby strengthening the completeness of biodiversity inventories.

169. Finally, the integration of artificial intelligence and machine learning frameworks is presented through Object-Based Image Analysis methodologies designed to process large volumes of visual and acoustic data generated by remote sensing and robotic platforms. These analytical systems enable automated habitat classification, pattern recognition, and temporal tracking of ecological change, supporting predictive modelling of ecosystem condition and potential recovery trajectories.

Strengths, Gaps, and Applicability

170. The review’s principal strength lies in its interdisciplinary integration of technological innovations spanning remote sensing, robotics, molecular ecology, and artificial intelligence within a unified monitoring perspective. By consolidating methodological advances across these domains, it establishes a forward-looking framework for non-destructive, high-resolution biodiversity assessment applicable to a wide range of marine and coastal habitats.

171. However, the synthesis also acknowledges operational limitations, particularly the absence of fully standardized decision-support frameworks guiding technology selection under differing environmental and logistical conditions. Variability in factors such as water turbidity, depth range, and habitat complexity may influence tool performance, yet comparative operational protocols remain insufficiently defined.

172. The review provides a valuable methodological reference for expanding monitoring toolkits, supporting the integration of innovative technologies into biodiversity inventory and ecosystem assessment programmes where enhanced spatial resolution, detection capacity, and data automation are required.

20) Integrated Meetings of the Ecosystem Approach Correspondence Groups on IMAP Implementation (CORMONs) - Update of Monitoring Protocols on Benthic Habitats (UNEP/MED WG.482/20)

173. The CORMONs update provides authoritative and regionally relevant guidance for monitoring Mediterranean benthic habitats, including Posidonia oceanica meadows and coralligenous bioconstructions. This document establishes standardized methodologies and protocols for measuring the agreed Common Indicators (CIs), ensuring that all monitoring is scientifically robust and comparable across countries.

174. The CORMONs guidance provides a comprehensive framework for both the distributional mapping and condition assessment of benthic habitats. CI 1 focuses on quantifying the total surface area and geographical distribution of seagrass meadows and coralligenous habitats. For large-scale national or sub-regional assessments, low-resolution maps can provide indicative distribution, but for identifying sites with

the highest ecological relevance, high-resolution local-scale mapping is essential. The protocols recommend using remote sensing, complemented by high-resolution side-scan sonar for deeper waters. Critically, all remote sensing outputs must be validated through ground-truthing using SCUBA surveys, ROVs, or towed cameras, ensuring the accuracy of habitat boundaries and density measurements.

175. CI 2 addresses habitat condition by focusing on the status of typical species and community structure. For coralligenous and other bioconstructions, structural complexity and calcified accretion are measured using tools like penetrometers and standardized photographic sampling protocols, including the STAR protocol. These assessments capture both the ecological function and the biodiversity value of the habitat. Rhodolith beds, recognized as significant carbon sinks, are evaluated in terms of live/dead maërl ratio and percentage cover of live thalli, ensuring that restoration priorities consider both structural and functional ecosystem components.

Strengths, Gaps, and Applicability

176. The CORMONs protocols present a major strength in providing harmonized, regionally specific methodologies for Mediterranean benthic habitats. The detailed metrics for Posidonia oceanica, coralligenous, and rhodolith beds allow precise characterization of ecosystem status, functional performance, and restoration potential.

177. The main gaps include limited guidance on integrating socio-economic parameters into monitoring and challenges in scaling intensive local measurements to larger spatial assessments.

178. Nonetheless, the protocols provide a foundation for designing monitoring programs, prioritizing restoration sites, and evaluating ecosystem health and functional performance, offering a defensible scientific foundation for regional conservation planning.

21) Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes (SALOMIDI et al.)

179. The report provides a comprehensive, regionally relevant evaluation of European seabed biotopes, linking habitat types directly to ecosystem goods and services (G&S) and to their vulnerability, conservation status, and functional importance. By explicitly connecting habitat types to quantifiable services, this work provides a clear framework for identifying restoration priorities, selecting monitoring parameters, and evaluating potential recovery trajectories.

180. For Posidonia oceanica and other seagrass beds, the study highlights their central role as high-productivity habitats and globally significant carbon sinks, comparable to tropical rainforests. The dense rhizome mat stabilizes sediments and promotes carbon burial, emphasizing the need to measure rhizome network integrity and sediment-binding capacity when assessing meadow health. Posidonia oceanica meadows are also critical for coastal protection, attenuating wave energy and stabilizing sublittoral sediments, and for their nursery function, supporting diverse marine fauna. The report emphasizes the extreme vulnerability of these ecosystems, with loss rates reaching approximately 7% per year and slow, sometimes irreversible recovery.

181. Coralligenous assemblages are identified as biodiversity hotspots with over 1,600 species, many of which are commercially relevant. Their structural complexity is essential for maintaining habitat function and carbon stock. Vulnerability is high, particularly to mechanical disturbance such as trawling or anchoring, and to indirect climate impacts like thermal stress, underscoring the need for continuous condition monitoring using standardized metrics such as those defined in the STAR protocol. Rhodolith and maërl beds store substantial carbon in calcareous deposits and provide raw materials, but they are extremely slow-growing and sensitive to anthropogenic impacts, necessitating careful evaluation of volume, live/dead ratios, and extraction pressures.

182. Although the study primarily addresses benthic marine habitats, it provides relevant insights for coastal wetlands and dunes. Muddy sediments are high value for water quality regulation and bioremediation, but their slow recovery and susceptibility to sedimentation and trawling highlight the importance of monitoring pollutant load and purification capacity. Coastal dunes and littoral sediments contribute to coastal

protection, act as nursery grounds for key species, and support diverse communities. These habitats are sensitive to human-induced changes such as coastal development and sand extraction, reinforcing the need to include coastal vulnerability and functional services in assessment protocols.

Strengths, Gaps, and Applicability

183. The principal strength of this report lies in its comprehensive integration of ecosystem services, vulnerability, and conservation status into a single framework. The clear linkage between biotopes, their ecological functions, and socio-ecological services provides strong guidance for selecting key monitoring parameters and restoration targets.

184. Key gaps include the limited spatial resolution in some EUNIS assessments, particularly for fine-scale coastal and dune habitats, and the lack of socio-economic valuation for all ecosystem services beyond carbon and coastal protection.

185. Nonetheless, the methodology offers a robust basis for evaluating habitat condition, functional relevance, and restoration potential.

22) BEST PRACTICES, MEASURES AND LESSONS LEARNT FOR BIODIVERSITY RESTORATION, ENSURING CARBON SINK OPTIMIZATION AND BUFFERING RESILIENCE TO CLIMATE EXTREMES (UNEP/MAP-SPA/RAC)

186. This publication provides a detailed synthesis of Mediterranean restoration experiences, presenting both successful and unsuccessful interventions across multiple habitat types. For Posidonia oceanica and other seagrass habitats, the report emphasizes active restoration via transplantation of cuttings and seedlings. Cuttings must be carefully sourced to minimize impact on donor meadows, and where possible, using naturally detached material collected from beach cast. Substrate selection is critical: dead matte or sand colonized by Cymodocea nodosa or macroalgae ensures optimal anchoring and survival, whereas smooth sand is unsuitable. Natural fibre nets fixed with metal stakes have demonstrated high long-term survival. Seedling transplantation, cultivated from seeds collected from beach cast, is recommended to enhance genetic diversity while avoiding donor meadow damage, and requires complex, rough substrates for anchorage. Post-restoration monitoring must track survival rates, shoot density, and shoots per cutting over a period of at least five years. Metrics for carbon fixation, such as Leaf Biomass Index and Leaf Surface Index, are essential to evaluate the long-term Blue Carbon contribution, acknowledging that meaningful carbon sequestration occurs on decadal scales.

187. Coralligenous assemblages and other bioconstructions require targeted species restoration, given the difficulty of restoring entire habitats. For Corallium rubrum, successful techniques involve epoxy resin fixation of colony fragments. Gorgonians benefit from adhesive attachment methods, including the use of fragments from fishing net bycatch to reduce pressure on donor populations. Cost-effective techniques such as the “badminton method” (attaching fragments to pebbles for deployment) are also suggested for deep-sea restoration. Marine litter removal is highlighted as an active restoration measure, particularly for coralligenous habitats. The removal of abandoned fishing gear (AFG) and ropes is necessary to restore seafloor integrity, but care must be taken to avoid additional damage. Post-removal monitoring using the COARSE index and BACI sampling designs has demonstrated limited recovery within one year, reflecting the low resilience of these habitats and emphasizing the need for long-term monitoring.

Strengths, Gaps, and Applicability

188. The main strength of this source lies in its combination of technical guidance with practical lessons from real restoration projects, providing both methodological standards and evidence of measurable outcomes. It offers detailed parameters for seagrass and coralligenous restoration, including survival metrics, structural complexity, and carbon sequestration potential.

189. Key gaps include the limited scale of some interventions, especially regarding full habitat restoration for coralligenous bioconstructions, and the relatively short monitoring periods for assessing long-term ecosystem service recovery.

190. Despite these limitations, the document furnishes regionally validated protocols and critical parameter definitions for restoration planning, monitoring, and evaluation, particularly concerning biodiversity enhancement, carbon sink optimization, and resilience to climate extremes.

23) Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region (SPA/RAC-UN Environment/MAP, 2019a)

191. This document establishes a comprehensive regional framework for the characterization, inventory, and monitoring of Mediterranean benthic ecosystems. It is explicitly designed to standardize habitat nomenclature and coding across the Mediterranean, thereby enabling national and regional monitoring efforts to align with IMAP criteria and supporting the identification of reference habitats to be tracked at the national level. For Posidonia oceanica beds and other seagrasses, the classification provides detailed codes and facies distinctions, including meadows on matte, rock, or sediment, which are essential for assessing carbon stock, structural stability, and coastal protection potential. The inclusion of Cymodocea nodosa and Zostera noltei facilitates the integration of transitional and regenerative habitats into inventory and assessment frameworks. Coralligenous assemblages and other bioconstructions are similarly codified, distinguishing algal- versus invertebrate-dominated coralligenous and capturing bioconstructors facies such as erect sponges and Alcyonacea, while reefs - including vermetid, serpulid, and Cladocora caespitosa - are incorporated as features of structural complexity, nursery function, and coastal protection. Rhodolith beds, critical for carbon sequestration, are documented through maërl associations in coarse sediments across the Circalittoral and Infralittoral zones. Coastal dunes are integrated through supralittoral facies, representing deposits of macrophyte detritus (banquette) essential for foreshore stabilization, while wetlands and transitional waters link marine and terrestrial inventories, ensuring comprehensive coverage of interface ecosystems. Crucially, the framework specifies criteria for identifying habitats of highest ecological relevance and restoration potential, including fragility, resilience, structural complexity, and capacity to modify the physical environment. While not a field-based methodology, the classification serves as the mandatory reference for national and regional assessments, guiding monitoring approaches, inventory coding, and functional evaluation according to ecological, carbon sequestration, and coastal protection criteria. By standardizing nomenclature and coding, it enables the identification of both critically important and highly regenerative habitats, forming the scientific baseline for comprehensive regional ecosystem assessments.

Strengths, Gaps, and Applicability

192. The key strength of this document lies in its provision of a fully standardized, regionally adopted classification system for Mediterranean benthic habitats. It ensures methodological rigor and consistency across national and regional monitoring programs, enabling the defensible identification and prioritization of ecosystems with high ecological relevance and restoration potential. The classification covers a wide spectrum of habitats, from seagrass meadows and coralligenous assemblages to bioconstructions, rhodolith beds, coastal dunes, and wetlands, and explicitly links habitat codes to structural and functional parameters, including carbon storage and coastal protection.

193. The main gap is the absence of operational field protocols or guidance for active restoration, as well as limited integration of socio-economic considerations or site-specific implementation details.

194. Despite this, the framework is applicable for the design of inventories, monitoring frameworks, and restoration planning, providing a robust scientific baseline for evaluating habitat status, ecological function, and recovery potential.

24) Updated Reference List of Marine Habitat Types for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest in the Mediterranean (SPA/RAC-UN Environment/MAP, 2019b)

195. This regional framework constitutes the definitive, legally binding framework for Mediterranean Contracting Parties to identify, classify, and monitor priority marine and coastal habitats. The document consolidates previous draft versions into a unified reference list, thereby serving as a core regulatory instrument.

196. Habitat prioritization within this reference list is based on a quantitative scoring system that evaluates eight ecological and functional traits: (1) fragility, (2) low resilience, (3) rarity, (4) importance for threatened or endemic species, (5) species diversity, (6) structural complexity, (7) bioconstruction capacity, and (8) ecosystem service provision such as nursery function or carbon storage. Each trait is scored from 1 (low) to 3 (high), with priority habitats requiring a total score ≥16 or automatic inclusion if rated 3 in rarity. This transparent scoring system offers a robust scientific justification for the prioritization of certain ecosystems.

197. The EUNIS-aligned classification and habitat codes provided within the reference list establish a standardized taxonomic and ecological framework for inventorying and monitoring Mediterranean ecosystems, ensuring compatibility with global databases. P. oceanica meadows, seagrass beds, rhodolith beds, coralligenous assemblages and other bioconstructions are addressed. Coastal Dunes and wetlands - though less extensive - are formally recognized as priority habitats within the littoral and transitional zones. Methodological guidance emphasizes parameters related to vegetation cover, sediment organic content, and structural stability, aligning with Ramsar and IMAP indicators.

Strengths, Gaps, and Applicability

198. This framework's primary strength lies in its authoritative, legally mandated status and its provision of standardized EUNIS-compatible codes, which enable consistent habitat classification and prioritization across all Mediterranean Contracting Parties. The inclusion of a quantitative scoring system for ecological traits ensures transparency and replicability in identifying priority habitats, including seagrass meadows and bioconstructions with high carbon storage, biodiversity, and coastal protection functions.

199. Main limitations include the lack of field-based methodological guidance for data collection and analysis, limited resolution for transitional or mixed biogenic habitats, and the potential for regional scoring thresholds to overlook local ecological variability.

200. Despite these gaps, the framework supports the identification and prioritization of restoration targets, while providing a robust basis for integrating functional, structural, and ecological criteria into long-term monitoring and management strategies.

25) A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean

201. This document establishes a standardized, hierarchical classification of Mediterranean benthic habitats that all Contracting Parties of the Barcelona Convention are encouraged to adopt for the purposes of habitat mapping, inventory, monitoring, and conservation planning.

202. Strategically, the classification provides a standardized taxonomy with five hierarchical levels encompassing 394 habitat types, enabling robust cross-national comparison of data collected from different sources, including local, national, and regional studies. It underpins the Updated Reference List, which identifies priority habitats based on expert-scored traits that define ecological relevance and restoration potential. Among these traits, Fragility evaluates habitat susceptibility to degradation under natural or anthropogenic pressures; Resilience measures the ability to recover from disturbances, indicating ecosystems that constitute critical legacy stock; Structural complexity assesses the three-dimensional arrangement of biotic and abiotic components, which is directly relevant for nursery function; and the Capacity of the habitat to modify the physical environment evaluates geomorphological influence, bioconstruction, and contributions to coastal protection and carbon storage. Inventory and characterization must rely on detailed Level 5 codes, which allow precise identification of specific facies and associations.

203. The classification integrates physiognomic and structural traits, providing a detailed ecotipological approach suitable for non-destructive field observations, including visual SCUBA surveys and remote video methods. By linking standardized habitat codes to ecological traits and restoration-relevant functions, the classification provides a scientifically defensible, comprehensive, and operationally relevant foundation for inventory, monitoring, and restoration planning across the Mediterranean.

Strengths, Gaps, and Applicability

204. The updated classification provides a fully standardized regional framework under the Barcelona Convention, encompassing all key Mediterranean benthic habitats and linking taxonomy to ecological traits and IMAP/MAP objectives, thereby enabling consistent identification, prioritization, and characterization of habitats with high ecological relevance and restoration potential.

205. The framework lacks detailed operational field protocols for assessment and active restoration and offers limited guidance on socio-economic factors or site-specific application, yet it establishes a scientifically robust basis for identifying priority habitats, designing monitoring approaches, and guiding restoration planning, supporting the achievement of ecosystem inventory and restoration targets.

206. **Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE e** Direttiva 09/147/CE) in Italia: ambiente marino

207. The ISPRA manual, "Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE e Direttiva 09/147/CE) in Italia: ambiente marino (2019)", represents a national-level strategic technical guide for Italy, focused on the Mediterranean marine region. It provides standardized methodological guidance for monitoring marine species and habitat types listed under the EU Habitats Directive (HD) and Birds Directive (BD), ensuring consistency and comparability of data across the Mediterranean Marine Region.

208. The manual establishes a strategic and legislative integration framework, addressing knowledge gaps and heterogeneity in prior national reporting. Methodologies are harmonized with European and international directives and developed with national expert input (SIBM, Società Italiana di Biologia Marina). The manual integrates MSFD and WFD requirements to allow comprehensive assessment of ecological status and pressures, linking directly to the RLE functional criteria. Habitat assessment combines four mandatory parameters: range (distribution), area (extent), structure and functions (ecological processes and structural complexity), and future prospects (current and projected threats). The monitoring design ensures spatial coverage across the full Mediterranean range of each habitat, both inside and outside Natura 2000 sites, in a phased inventory approach.

209. For specific habitats, dedicated methodology sheets are provided:

210. Habitat 1170 - Reefs (coralligenous and bioconstructions): a component-based approach distinguishes between superficial algal assemblages (monitored via CARLIT for Cystoseira abundance), coralligenous circalittoral assemblages, and deep coral biocenoses (e.g., Lophelia pertusa, Madrepora oculata) monitored with ROVs.

211. Coastal Wetlands (1110, 1130, 1140): standardized protocols integrate remote sensing and benthic sampling. Inventory and area are assessed at three-year intervals using high-resolution satellite imagery and drones. Habitat structure and functions are monitored via macrobenthic sampling, granulometry, chemical analyses, and DNA barcoding for cryptic species.

212. The manual defines species-specific monitoring as proxies for habitat quality, such as Pinna nobilis in Posidonia oceanica beds, Lithophaga lithophaga in coralligenous substrates, Corallium rubrum (colony density and size measured via SCUBA or ROV transects for restoration planning), Centrostephanus longispinus (distribution, density, and dermatoskeleton diameter measured to assess associated biota).

Strengths, Gaps, and Applicability

213. The manual's primary strength is its integration of standardized national methodologies with EU directives and monitoring programs, enabling comprehensive assessments across the Mediterranean and linking habitat-level and species-level indicators to actionable conservation and restoration strategies.

214. Key gaps include the need for specialized equipment to monitor certain deep-sea habitats and potential limitations for direct application outside Italian jurisdiction.

215. Despite these constraints, the manual provides a scientifically robust foundation for inventory, ecological assessment, and restoration of Mediterranean marine ecosystems, supporting the identification of priority sites, integration of national data with regional frameworks, and alignment with long-term conservation and restoration objectives.

26) Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest

216. Within the regional Mediterranean context, the framework serves as a technical and operational reference for harmonizing the classification, assessment, and protection of marine and coastal habitats across the Mediterranean Basin. It provides the methodological foundation for compiling national inventories of natural sites of conservation interest. It operationalizes the concept of biocenosis and delivers a detailed typological framework encompassing 18 principal biocenoses and 55 specific facies or associations, spanning all depth zones from the supralittoral to the bathyal. The handbook functions as an integrated decision-making and monitoring tool, designed to guide site management, protection, and long-term ecological assessment.

217. Posidonia oceanica meadows are described as both structurally and functionally unique ecosystems forming "natural monuments" such as barrier reefs and striped meadows, while their associated beach wracks are recognized as essential components for shoreline stabilization. The coralligenous biocenosis is presented as one of the most diverse and aesthetically valuable systems of the Mediterranean, hosting high-value commercial and heritage species but exhibiting slow regeneration due to the gradual formation of biogenic calcareous frameworks. Similarly, bathyal mud facies and deep-sea coral assemblages (Isidella elongata, Funiculina quadrangularis) are characterized by high ecological and economic importance but extreme vulnerable to bottom trawling. Finally, infralittoral algal communities (Cystoseira amentacea, among others) are described as highly productive yet acutely sensitive to sedimentation, turbidity, and invasive species.

218. For coralligenous and deep-sea habitats, this document emphasizes trawling restriction and the establishment of protected areas; for Posidonia oceanica, it prescribes anchoring and mooring regulation and discourages mechanical removal of wrack deposits; and for supralittoral systems, it recommends limiting beach cleaning to macrowaste removal to maintain natural ecological functions. The handbook also integrates recommendations on pollution monitoring, control of land-sea nutrient transfers, and invasive species management, promoting a comprehensive approach.

Strengths, Gaps, and Applicability

219. Strengths include a harmonized, region-wide classification framework for major Mediterranean biocenoses and facies, interoperability with European conservation systems, explicit diagnostic and management guidance for high-value habitats, and integration of scientific and operational perspectives to support monitoring and inventorying.

220. Main gaps include the need for methodological updates to incorporate modern monitoring technologies, quantitative thresholds for facies comparability, and emerging pressures such as climate change, marine litter, and cumulative stressors.

221. Overall, this work provides a foundational reference for prioritizing habitats of high ecological relevance and low regenerative potential, supporting coherent national and regional inventories, and guiding consistent habitat management and monitoring practices across the Mediterranean.

2.3 Wetlands

27) An introduction to the Ramsar convention

222. The Ramsar Convention on Wetlands adopts a global institutional perspective by presenting the international framework established for the conservation, sustainable use, and restoration of wetland ecosystems. Wetlands are defined through a deliberately broad ecological scope that includes natural and artificial systems, inland and coastal environments, and marine waters up to shallow depths. This definitional approach allows multiple coastal and transitional ecosystem types to be encompassed within a single governance and management framework.

223. The Ramsar framework establishes a clear mandate for the “wise use” of wetlands, defined as the maintenance of their ecological character - the combination of ecosystem components, processes, and benefits/services that define the system at a given point in time.

224. To operationalize conservation and management obligations, Contracting Parties are required to develop national wetland inventories supported by structured methodological guidance. Inventory, monitoring, and assessment are framed as interconnected processes aimed at establishing ecological baselines, identifying pressures, and tracking ecosystem change. Classification systems further support consistent ecosystem identification and comparability across countries and regions.

225. Technical guidance is complemented by criteria and assessment tools designed to identify sites of ecological importance and to support biodiversity evaluation across wetland systems. Additional instruments address the description of ecological character and the evaluation of management effectiveness, strengthening the scientific basis for conservation planning and site management.

226. Restoration is addressed through dedicated policy guidance that outlines principles and operational approaches for ecosystem recovery, alongside procedures for detecting and reporting changes in ecological condition. These mechanisms link restoration planning with monitoring and adaptive management processes.

227. At the Mediterranean scale, implementation is supported by cooperative platforms that facilitate coordination, knowledge exchange, and methodological alignment among Mediterranean countries, strengthening the contextual application of the convention’s principles.

228. Strengths, Gaps, and Applicability

229. The framework provides a comprehensive governance and methodological foundation for wetland inventory, assessment, and restoration, supported by standardized definitions, institutional obligations, and technical guidance. Its conceptual strength lies in the integration of ecological characterization, monitoring, and management within a unified international structure, anchored in the operational concept of ecological character as a reference condition for evaluating change. Regional cooperation mechanisms enhance its applicability within Mediterranean contexts by promoting harmonization and shared approaches to inventory and monitoring.

230. At the same time, the framework remains primarily institutional and strategic in scope. While it establishes obligations and methodological orientations, the level of technical and ecological detail available for specific coastal and marine habitat assessment may vary across national implementations, depending on monitoring capacity and data availability.

231. Overall, the source provides a solid policy and conceptual reference for structuring wetland inventory and assessment processes, supporting coherent ecosystem characterization and restoration planning across geographic scales.

28) An Integrated Framework for wetland inventory, assessment and monitoring (HBK 13, 2010)

232. The Integrated Framework for Wetland Inventory, Assessment, and Monitoring (IF-WIAM) provides a structured approach for the characterization, evaluation, and long-term management of wetland ecosystems. It defines the interlinked processes of inventory, assessment, and monitoring, forming a coherent methodology to support the “wise use” principle of the Ramsar Convention.

233. The Ramsar Convention's broad ecological scope is of particular relevance to the Mediterranean region, as it encompasses a wide range of habitats, including coastal areas, saltmarshes, mangroves, and seagrass meadows, as well as shallow marine bioconstructions extending to a depth of six metres at low tide.

234. IF-WIAM distinguishes three main components: Wetland Inventory, which gathers core information on ecosystem characteristics, distribution, and functions; Wetland Assessment, which evaluates status, condition, and pressures; and Wetland Monitoring, which tracks changes over time to support management decisions. This structure clarifies the relationship between describing ecosystems, evaluating their condition, and observing changes.

235. The framework integrates established environmental assessment tools, including Environmental Impact Assessment, Strategic Environmental Assessment, Risk Assessment, Vulnerability Assessment, and Rapid Assessment. This multi-tool approach ensures complementary and consistent evaluation of ecosystem condition, pressures, and trends.

236. IF-WIAM is designed to be applied at multiple scales, from site-specific to national, regional, and global levels. It emphasizes standardized methodologies that can be adapted to different governance contexts. The Mediterranean Wetlands Initiative (MedWet) is cited as an example of applying these principles at the regional scale, demonstrating how inventory and monitoring approaches can be harmonized across countries.

237. The framework also highlights gaps in data coverage for some wetland types and encourages the inclusion of underrepresented habitats such as seagrasses, saltmarshes, and coral reefs, promoting a comprehensive understanding of wetland ecosystems worldwide.

Strengths, Gaps, and Applicability

238. IF-WIAM provides a scientifically coherent structure for wetland inventory, assessment, and monitoring. Its strengths include the integration of multiple assessment tools, applicability to a wide range of wetland habitats including coastal and marine systems, and adaptability across scales. Its use in regional initiatives such as MedWet supports standardized data collection and reporting. Remaining challenges include inconsistent implementation among different countries and incomplete data for some habitats. Addressing these challenges would enhance the framework's effectiveness in supporting long-term wetland management.

29) A Conceptual Framework for the wise use of wetlands and the maintenance of their ecological character (Resolution IX.1 Annex A, 2005)

239. The Resolution IX.1 Annex A (2005) provides a global framework for the wise use of wetlands and the maintenance of their ecological character. Wise Use is defined as maintaining the ecological character, which encompasses the combination of ecosystem components, processes, and benefits or services at a given point in time. The framework highlights the need to address human-induced changes that may alter ecological character and considers such changes as potential degradation.

240. Methodological tools, including Wetland Inventory and Impact Assessment, are identified as key instruments to document, evaluate, and manage the drivers of change. The framework supports a holistic assessment of wetlands, integrating structural, functional, and service-based aspects.

Strengths, Gaps, and Applicability

241. The framework is globally recognized and valued for its comprehensive definition of ecological character, integrating biological structure, ecological processes, and ecosystem services. Strengths include a scientifically grounded approach, consistency with international standards, and support for systematic management of wetlands.

242. Gaps exist in the operational translation of high-level principles into site-specific metrics, particularly for underrepresented habitats.

243. Nevertheless, it provides a coherent conceptual foundation for assessment and restoration, allowing for adaptive management to maintain long-term ecosystem function and biodiversity.

30) A Framework for Wetland Inventory (Resolution VIII.6, 2002)

244. The Resolution VIII.6 (2002) provides a global framework for wetland inventory, with clear applicability to the Mediterranean region. It establishes a methodology for systematically describing wetland ecosystems, tracking changes in ecological character, and collecting comprehensive qualitative and quantitative data for marine and coastal habitats. The framework emphasizes a multi-scalar approach, recommending detailed Level 4 surveys (approximately 1:10,000 scale) to characterize individual wetland sites, including associated plant and animal assemblages. Key data fields encompass geomorphic setting, water regime, water chemistry, and biotic composition, covering ecosystems such as Posidonia beds, coastal dunes, and wetlands. The framework encourages the use of modern tools, including GIS and remote sensing, to accurately map habitats and link ecological changes spatially. Regional standardization is further supported by methodologies developed under the Mediterranean Wetlands Initiative (MedWet), ensuring harmonized assessment across multiple countries.

245. The procedural guidance is organized into a 13-step process that includes defining objectives, determining appropriate scale and resolution, establishing data management systems, planning pilot studies, and conducting field validation. Core data collection focuses on area, boundaries, geomorphic context, water characteristics, and biotic composition. This approach provides a standardized, rigorous, and spatially explicit characterization of ecosystems, supporting consistent monitoring and assessment across Mediterranean wetlands

Strengths, Gaps, and Applicability

246. The strengths of the framework include its detailed operational guidance, global recognition, and multi-scalar approach, which collectively ensure that inventories are comprehensive, scientifically robust, and harmonized across regions. It supports integration of advanced technologies and generates the data necessary to link ecological changes with management interventions, thereby increasing the effectiveness and cost-efficiency of restoration actions.

247. Gaps remain in operationalizing some steps for complex or small-scale habitats, particularly patchy seagrass meadows or shallow bioconstructions, where field validation and fine-scale mapping are critical.

248. Overall, the framework provides a solid methodological foundation for conducting standardized inventories and monitoring of Mediterranean ecosystems, supporting effective planning and management interventions.

31) Describing the ecological character of wetlands, and data needs and formats for core inventory: harmonized scientific and technical guidance (Resolution X.15, 2008)

249. The Resolution X.15 (2008) establishes a global framework for harmonized scientific and technical description of wetlands, building upon earlier guidance to standardize core inventory measures. Central to this framework is the Ramsar Ecological Character Description Sheet (ECD), which defines baseline ecological status and ensures inventories systematically capture structural and functional ecosystem components. The ECD includes data on ecosystem components, processes, and services, covering parameters such as carbon storage, coastal protection, and nursery functions, and provides a structured approach for documenting pressures, trends, and changes in ecological character.

250. The framework specifies collection of detailed ecological components, including geomorphic context (distance to coast, area, boundaries), soil and substrate characteristics relevant for seagrass meadows and coralligenous habitats, water chemistry (temperature, salinity, pH, dissolved gases, nutrients, and organic carbon), and biotic assessments covering plant and animal communities, abundance, and distribution. Functional processes, such as primary production, carbon cycling, reproductive productivity, and succession, are also included, along with ecosystem services like carbon sequestration and shoreline stabilization.

Strengths, Gaps, and Applicability

251. The strength of this framework lies in its harmonized approach, providing globally standardized fields for both structural and functional components, ensuring comparability and reproducibility of data. It provides a clear foundation for multi-scale implementation and supports comprehensive assessment of ecosystem services.

252. Gaps remain in translating some of these measures to fine-scale, patchy Mediterranean habitats, where detailed field validation is required.

253. Overall, the methodology enhances the effectiveness and cost-efficiency of restoration interventions by providing clear, standardized, and actionable data requirements.

32) Wetland Risk Assessment Framework (Resolution VII.10, 1999)

254. The Wetland Risk Assessment Framework establishes a global methodology for identifying, evaluating, and managing threats to wetlands. It presents a six-step process for conducting risk assessments, providing a structured approach to determine degradation drivers, assess potential impacts on ecological character, and design monitoring strategies to detect early signs of adverse changes. The framework supports proactive management of human-induced pressures and is applicable across diverse ecosystems.

255. The methodology emphasizes defining conservation objectives and specifying the components of the ecosystem to be protected. Risk estimation integrates assessment results, often using GIS to spatially link impacts and map potential pathways of degradation. Monitoring functions as an early warning system, capable of detecting ecological changes before they lead to significant harm. Five main categories of degradation are considered: alterations to the water regime, pollution, physical modifications, exploitation of biological resources, and introduction of exotic species. Recommended indicators include laboratory bioassays for pollutant effects, in situ monitoring of species and phytoplankton composition, and rapid surveys using remote sensing to identify ecological hotspots.

Strengths, Gaps, and Applicability

256. The WRA framework's strength lies in its structured, stepwise methodology for assessing threats, linking them to ecological impacts, and defining actionable monitoring strategies. Its global applicability is complemented by flexibility for regional and habitat-specific adaptation, making it highly suitable for Mediterranean ecosystems.

257. Gaps include the need to calibrate certain indicators to local species and habitat conditions and to integrate emerging pressures such as climate change-driven impacts.

258. By combining predictive risk assessment with early warning monitoring, the framework enhances the effectiveness and cost-efficiency of restoration interventions, ensuring that resources are directed toward the most ecologically and socially valuable sites.

33) Principles and guidelines for wetland restoration (Resolution VIII.16, 2002)

259. The Principles and Guidelines for Wetland Restoration provides a global framework for planning, implementing, and monitoring wetland restoration. The document emphasizes evidence-based prioritization of sites with high ecological relevance and recovery potential, considering the multifunctional nature of wetlands, including biodiversity, freshwater provision, flood regulation, and other ecosystem services. Restoration planning is recommended at the catchment scale to ensure consideration of upstream-downstream interactions and long-term ecological sustainability. The framework favours ecological engineering and nature-based solutions to achieve resilient ecosystems, while long-term stewardship, monitoring, and adaptive management are integral to maintaining restoration outcomes.

260. The methodology is structured into three phases: initial catchment-scale analysis, evaluation of site-specific constraints, and prioritization of sustainable restoration projects. Performance standards are defined to

be observable and measurable, allowing assessment of restoration success and integration of adaptive management measures when targets are not met.

Strengths, Gaps, and Applicability

261. The strength of this framework lies in its integration of multifunctional objectives with practical, site-specific implementation criteria, ensuring that restoration contributes to multiple ecosystem services simultaneously.

262. Gaps include the need for standardized metrics for measuring multifunctional outcomes and guidance on incorporating emerging climate pressures.

263. By explicitly linking restoration planning, adaptive management, and performance-based evaluation, the framework increases the effectiveness and cost-efficiency of interventions, ensuring that resources are allocated to projects with the highest potential ecological and social benefits.

34) An Integrated Framework and guidelines for avoiding, mitigating and compensating for wetland losses (Resolution XI.9, 2012)

264. The Integrated Framework and Guidelines for Avoiding, Mitigating, and Compensating for Wetland Losses (Resolution XI.9, 2012) provides a global policy and technical framework for managing wetland loss. It establishes a sequential approach - avoidance, mitigation, compensation - positioning restoration as the primary response when residual impacts remain after avoidance and mitigation measures. The framework emphasizes the importance of establishing a robust baseline describing the ecological character of wetlands, guiding the selection of restoration actions in line with ecological, functional, and spatial criteria.

265. Compensation must follow type-for-type principles, ensuring that restoration actions replicate the ecological character and functional performance of the lost wetland. Restoration is considered successful only when it addresses both structural and functional aspects, including key ecosystem services such as carbon stock, coastal protection, and habitat provision. The location of compensatory actions should ideally fall within the same hydrological catchment or coastal zone as the impacted wetland, reinforcing ecological connectivity and functional relevance. A risk-based decision-making matrix informs the choice between avoidance, mitigation, and restoration, assessing both the likelihood and magnitude of impacts to prioritize interventions. The framework further emphasizes the need for long-term stewardship, encompassing technical, financial, management, and legislative support to secure sustainable outcomes.

Strengths, Gaps, and Applicability

266. The strength of this framework lies in its clear decision-making hierarchy, linking risk assessment with restoration action, and its emphasis on functional outcomes over mere area replacement. Its global applicability is reinforced by regional relevance, particularly for Mediterranean ecosystems.

267. A main gap is the lack of quantitative thresholds for assessing functional equivalence and ecosystem service delivery, making site-specific adaptation necessary.

268. By combining risk-based prioritization with type-for-type and function-focused criteria, the framework enhances the effectiveness and cost-efficiency of interventions, ensuring that Action 12 restoration projects maximize ecological benefits while minimizing unintended trade-offs.

35) Guidelines on biodiversity-inclusive environmental impact assessment and strategic environmental assessment (Resolution X.17, 2008)

269. Resolution X.17 (2008) provides a global framework for incorporating biodiversity and wetland values into both strategic and project-level decision-making. It reinforces the Avoid-Mitigate-Compensate sequence described in Resolution XI.9 (2012). Mitigation measures may involve adjustments to scale, design, location, sequencing, or management of proposed activities. Restoration or rehabilitation is considered only when impacts cannot be avoided, applying the type-for-type principle noted in the previous framework.

Certain habitats are recognized as potentially irreplaceable, justifying rejection of proposals that would result in irreversible loss.

Strengths, Gaps, and Applicability

270. The strength of this framework lies in its systematic integration of biodiversity considerations into both strategic and project-level planning, reinforcing the prevention-focused hierarchy outlined in Resolution XI.9. Its global scope and explicit reference to Mediterranean ecosystems make it applicable for regional planning contexts.

271. Gaps include limited quantitative guidance on cumulative impacts across multiple sites or precise measurement of biodiversity benefits from mitigation actions.

272. By linking SEA and EIA with the Avoid-Mitigate-Compensate hierarchy, the framework facilitates targeted, cost-effective interventions, enhancing the efficiency and ecological relevance of conservation and restoration measures.

36) Ramsar Site Management Effectiveness Tracking Tool (R-METT) (Resolution XII.15, 2015)

273. Resolution XII.15 (2015) represents a globally recognized and standardized methodology for evaluating the effectiveness of wetland management interventions. It integrates lessons and practices applicable across a wide range of ecological and administrative contexts, providing a robust framework. R-METT relies on baseline information from the Ecological Character Description (ECD) framework (Resolution X.15), ensuring assessments are grounded in a comprehensive, scientifically robust, and globally comparable dataset.

274. R-METT evaluates the status and trends of key ecosystem components, processes, and services using qualitative ratings such as “Good,” “Low Concern,” “High Concern,” “Critical,” or “Data Deficient,” alongside trend assessments indicating whether systems are “Improving,” “Stable,” or “Deteriorating.” Structural metrics are assessed alongside functional outcomes including primary production, carbon cycling, and resilience to environmental pressures.

275. The tool is closely linked to threat assessment frameworks, including the Wetland Risk Assessment (Resolution VII.10). Threat categories encompass hydrological alterations, nutrient enrichment, pollution, physical habitat changes, biological exploitation, and invasive species. Early warning indicators - ranging from laboratory toxicity tests to field observations and rapid remote sensing surveys - support proactive management by detecting potential degradation before significant ecological harm occurs.

276. Monitoring under R-METT is hypothesis-driven and explicitly designed to support adaptive management. Each intervention is evaluated against baseline conditions, with objectives linked to management decisions. Data collection, metrics selection, and reporting provide clear interpretation of trends, enabling adjustments to management strategies to enhance ecosystem recovery and maintain ecological character.

Strengths, Gaps, and Applicability

277. R-METT’s strengths lie in its standardized global criteria, integration with baseline ecological data, and structured link to threat assessment, facilitating adaptive and proactive management.

278. Its primary limitations include reliance on high-quality baseline data and the need for site-specific indicators for certain ecosystem processes, such as carbon cycling or nutrient fluxes.

279. The tool is particularly suited for Mediterranean ecosystems, supporting the measurement of both structural and functional restoration outcomes and ensuring scientifically robust evaluation of management effectiveness. It complements previous Ramsar guidance by operationalizing systematic monitoring and feedback for long-term conservation and restoration initiatives.

37) Mediterranean Wetland Inventory: A Reference Manual

280. The Mediterranean Wetland Inventory: A Reference Manual provides a regionally focused framework for the Mediterranean Basin, aimed at standardizing wetland inventories across Mediterranean countries. Endorsed by the Ramsar Convention, it provides a scientifically robust and flexible methodology for compiling, harmonizing, and disseminating information on wetlands and associated coastal dune systems.

281. The inventory process is structured into three sequential and scalable phases. The first phase compiles existing data from bibliographies, maps, and databases to generate baseline information and identify prior classifications. The second phase consists of simple inventories with limited field verification, producing sketch maps and basic delineations of wetland extent, area, and key attributes. The third phase delivers detailed inventories through intensive fieldwork, high-resolution GIS mapping, and photogrammetry, generating precise site-level and habitat-level datasets suitable for monitoring, management, and restoration planning. Data are organized hierarchically across three main sheets: Catchment Area Data, capturing hydrology, upstream processes, land use, and threats; Wetland Site Data, including location, physical description, ecological value, and status; and Habitat Data, detailing ecological units coded according to Ramsar or CORINE classifications, with parameters such as water permanency, salinity, area, depth, and condition.

282. The manual emphasizes standardized ecological criteria to ensure comparability across Mediterranean sub-regions. Hydrology is characterized by permanent or periodic flooding or saturation during the growing season; vegetation focuses on hydrophyte dominance as an indicator of condition; and soils are assessed for hydric characteristics, either organic with peat layers over 40 cm or mineral with anaerobic features. These criteria ensure meaningful delineation of wetlands and coastal dune systems. Functional attributes, including groundwater recharge, flood control, nutrient retention, and shoreline stabilization, are systematically recorded, linking inventory data to management and restoration priorities.

Strengths, Gaps, and Applicability

283. The manual’s strengths include its harmonized regional methodology, scalable inventory phases accommodating varying levels of resources, and integration of both structural and functional ecosystem parameters, supporting adaptive management and restoration planning.

284. Gaps include potential challenges in local implementation where data or field capacity are limited, and the need for specialized technical skills and equipment for high-resolution mapping.

285. The framework is broadly applicable across the Mediterranean Basin, providing standardized baseline data for monitoring ecological trends, assessing threats, and guiding management or restoration actions. It complements global Ramsar methodologies and provides a practical, regionally adapted tool for ecological characterization and systematic wetland management.

38) Valuing wetlands. Guidelines for valuing the benefits derived from wetland ecosystem services

286. This global guidance provides a standardized methodology for assessing the ecological, socio-cultural, and economic values of wetland ecosystems. It standardizes methodologies to support the integration of ecosystem service values into policy, planning, and management decisions. The guidance complements existing inventory and monitoring frameworks by linking ecosystem structure and function to quantitative and qualitative measures of benefit.

287. A five-step methodology structures the assessment process: (1) Policy Analysis, establishing the purpose and relevance of the valuation; (2) Stakeholder Analysis, identifying relevant users and beneficiaries; (3) Function Analysis, translating ecosystem structure and composition into quantifiable services; (4) Valuation, applying both ecological and economic measures, including Total Economic Value (TEV); and (5) Communication, ensuring results inform decision-making processes.

288. The framework emphasizes the comparative value of intact versus degraded ecosystems, highlighting that well-preserved wetlands typically provide higher ecological and economic returns than converted or heavily altered systems. This principle underlines the importance of maintaining ecosystem integrity,

particularly for fragile habitats. The guidance further addresses naturalness, diversity, uniqueness, and fragility as criteria for identifying high-value ecosystems and guiding resource allocation or management actions.

289. The methodology is adaptable to different scales and contexts, supporting the identification of ecosystems that deliver significant ecological services, including carbon storage, nutrient retention, flood mitigation, shoreline stabilization, and nursery functions. By integrating valuation with monitoring and inventory data, the framework provides a foundation for evidence-based management, enabling both ecological and economic considerations to inform restoration, conservation, and planning strategies.

Strengths, Gaps, and Applicability

290. Strengths include its global recognition, standardized valuation methodology, and integration of ecological, socio-cultural, and economic dimensions, which enhances the rigor and comparability of ecosystem assessments. The guidance links valuation to established inventory and monitoring frameworks, ensuring scientific consistency across regions.

291. Gaps involve the adaptation of the methodology to non-wetland coastal habitats and contexts where ecological or socio-economic data are scarce, as well as the challenge of quantifying difficult-to-measure services. Long-term monitoring of restoration effectiveness and the realization of economic benefits is also limited.

292. Overall, the framework provides a robust, flexible, and standardized approach for evaluating wetland ecosystem services, supporting evidence-based prioritization, management, and restoration decisions across Mediterranean and global contexts.

2.4 Coastal dunes

39) Assessing the potential for restoring mediterranean coastal dune under pressure from tourism

293. At the regional and national level, focusing on the Mediterranean Basin with a detailed case study in Sardinia (Italy), this study provides a robust methodological framework for assessing the environmental condition, vulnerability, and restoration potential of coastal dune systems. The study introduces two complementary indices: the Dune Restoration Potential Index (DPR) and the StaDun Index (Geomorphological and Ecological Status of Dunes), designed to quantify both the conservation state and management requirements of coastal dune ecosystems. The DPR is calculated as DPR = BeaPot (1 − CoMan), where BeaPot expresses the natural potential for beach and dune development, and CoMan quantifies conservation actions and management pressures. This structure allows distinguishing between dunes that require active restoration and those maintaining adequate ecological function. The StaDun Index integrates 11 environmental and geomorphological variables, enabling a standardized characterization of dune typology and structural development. Conversely, the CoMan Index assesses conservation and management pressures, integrating human use intensity and implemented protection measures.

294. Application of these indices in Sardinian dunes demonstrated that well-developed dune systems are generally associated with high management effort, highlighting the combined role of geomorphological potential and conservation interventions. Integration of DPR and StaDun provides a comprehensive measure of ecological condition and restoration feasibility, supporting the prioritization of dune ecosystems for management and protection.

Strengths, Gaps, and Applicability

295. Strengths of this approach include its fully quantitative and replicable methodology, integration of natural and anthropogenic components, and the standardized assessment of both ecological potential and management pressures.

296. Gaps include the need for broader validation across Mediterranean contexts beyond Sardinia, incorporation of climate change-related factors such as sea-level rise and storm frequency, and refinement of management indicators to reflect diverse governance situations.

297. Overall, the framework offers a robust operational tool for classifying, assessing, and prioritizing coastal dune ecosystems, providing spatially explicit information to support evidence-based management and monitoring in Mediterranean regions.

40) Coast dune management guide

298. At the European scale, with detailed application in Great Britain but broader relevance, this guide presents a comprehensive set of practical management strategies and physical restoration techniques for coastal dunes. It emphasizes minimizing human disturbance, promoting natural regeneration, and integrating restoration with long-term ecosystem sustainability.

299. Restoration measures include the establishment of new dunes in eroded areas through fencing and targeted planting. Fencing functions both as a stabilizing mechanism and as a deterrent against trampling and vehicle access, addressing the most common forms of mechanical disturbance. Complementary actions, such as controlled access paths, reduce erosion in recreational and tourist areas.

300. The guide identifies off-road vehicles (ORVs) and intensive recreational use as major threats to dune stability. Empirical studies indicate that strandline vegetation is highly sensitive to vehicle passage, with cumulative impacts from repeated use significantly altering dune topography and hydrology. Mitigation measures recommended include exclusion zones for vehicles, spatial zoning, and management of recreational activities to prevent physical degradation.

301. Public engagement and education are emphasized as essential tools. Signage and communication strategies are recommended to convey the fragility of dune ecosystems, explain restoration activities, and gain community support, thereby fostering compliance with protective measures.

302. Empirical benchmarks for vegetation recovery are provided to inform post-restoration monitoring. Fore-dune (strandline) vegetation typically requires a minimum of four years to re-establish, whereas back-dune vegetation recovery may extend from four to eight years. These timelines establish realistic monitoring baselines for assessing restoration success and for adaptive management planning.

Strengths, Gaps, and Applicability

303. Strengths of this guide include its operational focus and field-tested restoration techniques, its integration of biophysical interventions with socio-educational approaches, and its provision of empirically derived recovery timelines that can inform standardized monitoring.

304. Gaps include the lack of site-specific adaptation for Mediterranean dune systems, limited consideration of climate-driven processes such as sea-level rise or storm surges, and absence of quantitative ecological indicators or scoring systems for integration into broader inventory frameworks.

305. Overall, the guide offers transferable management strategies and practical benchmarks for restoration of Mediterranean coastal dunes and can serve as a reference framework for developing national and regional restoration protocols and post-restoration monitoring plans.

41) Development of a coastal dune vulnerability index for Mediterranean ecosystems- A useful tool for coastal managers?

306. Within the regional and national framework, focusing on Italian coastal dunes and the western Mediterranean Basin, the study introduces the Mediterranean Dune Vulnerability Index (MDVI), a multidisciplinary tool that synthesizes complex environmental and anthropogenic parameters into a single index to support evidence-based coastal management. The MDVI is specifically tailored to the semi-enclosed Mediterranean context, accounting for low tidal ranges, localized wave and storm regimes, and geomorphological variability, extending previous frameworks such as the generic Dune Vulnerability Index (DVI).

307. The MDVI incorporates five principal components: Geomorphological Conditions, Marine Influence, Aeolian Effect, Vegetation Condition, and Human Effect. Together, these dimensions capture the interplay between physical processes, biological stability, and human pressures that determine dune resilience. By generating a composite vulnerability score, the index identifies sites where ecological function is most compromised, and recovery potential is limited. For example, sites with pronounced Human Effect or degraded Vegetation Condition require targeted interventions, such as controlled access or reintroduction of native pioneer species to restore sand accumulation and structural stability.

308. The MDVI allows coastal managers to disaggregate vulnerability into component-specific drivers, enabling precise, factor-based restoration planning. Periodic reapplication of the MDVI supports adaptive monitoring, allowing managers to track ecological recovery and evaluate the long-term effectiveness of restoration interventions.

Strengths, Gaps, and Applicability

309. The MDVI's strengths lie in its regional adaptation to Mediterranean dune dynamics, its integration of biophysical and human dimensions into a single, interpretable metric, and its capacity to inform targeted, evidence-based management actions. Its methodology is both practical and repeatable, providing an operational framework for prioritizing restoration where vulnerability is highest.

310. Key gaps include the need for broader validation beyond Italian case studies, limited incorporation of socioeconomic feedback, and the sensitivity of some indicators to seasonal or interannual variability, which requires standardized sampling protocols.

311. The MDVI identifies priority dune systems, provides a diagnostic framework for restoration planning, and functions as a cost-efficient tool for monitoring long-term ecological change and restoration success across Mediterranean coastal ecosystems.

42) Results of the Providune project: restoration of the "Coastal dunes with *Juniperus* spp." priority habitat in Sardinia

312. This local and national project provides a comprehensive account of restoration actions for the coastal dune habitat with Juniperus spp. (2250*) in Sardinia, Italy, under the LIFE Providune initiative. The study demonstrates that coastal dunes with Juniperus spp. are highly endangered habitats, with unsatisfactory conservation status across most sites, and face multiple anthropogenic and environmental pressures including trampling, urbanization, erosion, and invasive alien plants. Analyses revealed significant negative effects of human disturbance on endemic and native plant richness, highlighting the urgent need for active restoration measures. The LIFE Providune project implemented integrated interventions encompassing both in situ and ex situ strategies, combining species reintroduction, bioengineering, invasive species control, and seed banking to enhance the structural and functional resilience of the habitat.

313. In situ restoration employed sand-trapping fences, coir mesh stabilization, and the planting of key structural species. Species-specific protocols addressed recruitment limitations, revealing that planting seedlings is more effective than sowing for certain species (e.g., Juniperus macrocarpa) due to low germination rates. Human impact mitigation included the installation of wooden walkways and fencing to control trampling and manage tourist access, demonstrating the importance of preventative measures alongside active restoration. Ex situ conservation involved germplasm collection for 12 key species, with seed banking and propagation protocols supporting both current and future restoration efforts.

314. Long-term monitoring and post-project conservation planning were integral to the Providune methodology, ensuring continued assessment of vegetation recovery and the viability of stored germplasm. The project also emphasized public engagement, enhancing awareness of the ecological importance of coastal dunes and their role in climate adaptation and ecosystem service provision.

Strengths, Gaps, and Applicability

315. The Providune project exemplifies a holistic and operationally robust approach to coastal dune restoration. Baseline data establish standardized monitoring benchmarks, while human impact mitigation strategies link ecological restoration with socio-environmental management.

316. Limitations include the geographic focus, which may require adaptation for other Mediterranean dune systems, as well as uncertainties regarding the long-term viability of J. macrocarpa populations under variable climatic conditions. Interactions with faunal communities and broader ecosystem services beyond vegetation were not fully addressed.

317. The project offers a tested, replicable framework for dune habitat restoration across Mediterranean sites. It demonstrates how preventative measures, species reinforcement, and habitat engineering can be combined effectively to restore degraded dunes, providing a scientifically grounded model for future Action 12 implementation, monitoring, and adaptive management within coastal dune ecosystems.

43) Morphology and composition of beach-cast *Posidonia oceanica* litter on beaches with different exposures

318. This local and regional study from Sardinia provides critical insights into the ecological and geomorphological role of Posidonia oceanica banquettes in Mediterranean coastal dune systems. The research demonstrates that banquettes act as active ecosystem engineers, directly contributing to foredune formation, sand stabilization, and nutrient cycling within dune habitats. Morphological attributes - including volume, thickness, and cross-shore extent - differ according to beach exposure: exposed beaches show larger and more continuous accumulations, whereas sheltered beaches display smaller, sediment-rich deposits. On exposed beaches, sediment deposition and erosion primarily shape banquette morphology, while on sheltered sites, litter deposition dominates dune geomorphology, highlighting the need for site-specific dune management strategies.

319. Banquettes stabilize beach-faces, trap sand, and enhance foredune vegetation growth, thereby playing a crucial role in maintaining coastal dune resilience. Anthropogenic removal, particularly using heavy machinery for tourism, disrupts these processes, reducing dune regeneration, nutrient availability, and natural sediment retention.

320. The study emphasizes preventative interventions over compensatory measures. Mitigating stressors is more effective than attempting sediment replacement through artificial nourishment.

Strengths, Gaps, and Applicability

321. The study provides strong empirical evidence linking Posidonia oceanica litter to coastal dune stability and regeneration, offering actionable, site-specific data for dune monitoring and management. Its clear identification of anthropogenic pressures, such as banquette removal, supports targeted conservation measures.

322. Limitations include the restricted geographic focus on Sardinia, as well as limited exploration of long-term litter dynamics and interactions with other dune ecosystem components, such as invertebrates and microbial processes.

323. In terms of applicability, the findings directly support coastal dune conservation planning, guiding preventative and nature-based interventions to maintain sediment dynamics, vegetation development, and ecosystem resilience. They are particularly relevant for prioritizing high-ecological-relevance dune systems.

2.5 Seagrass meadows

44) Guidelines for the standardization of mapping and monitoring methods of marine magnoliophyta in the Mediterranean

324. Within the regional Mediterranean context, the Guidelines for the Standardization of Mapping and Monitoring Methods of Marine Magnoliophyta (UNEP/MAP-SPA/RAC) provide a rigorous and harmonized framework for inventorying and monitoring seagrass beds, including Posidonia oceanica (1120*) and associated marine angiosperms. By providing precise and replicable methodologies for both mapping and assessing ecological status, the guidelines ensure that data collected across Mediterranean countries are comparable and suitable for prioritization and restoration planning.

325. The document emphasizes that high-quality distribution maps are a prerequisite for any conservation activity, and it prescribes technological and methodological standards to achieve this. Mapping combines remote sensing techniques with acoustic methods to generate reliable habitat maps. Maps are accompanied by a reliability index (0–10) reflecting acquisition method, geometrical correction, and the proportion of ground-truthing data, with highly reliable mapping requiring ≥10% field coverage of the study area.

326. For ecological assessment, the guidelines provide standardized descriptors that capture both structure and function. These include shoot density, lower limit type of the meadow (indicating colonization or regression dynamics), leaf epiphyte biomass, nitrogen content, and leaf necrosis percentage. Descriptors are selected to detect degradation, eutrophication, and environmental stress, providing quantitative evaluation of meadow health. These metrics inform conservation prioritization, support identification of ecosystems with high regeneration potential, and guide restoration planning.

Strengths, Gaps, and Applicability

327. The strength of the guidelines lies in their scientific rigor, regional harmonization, and clear methodology for both mapping and monitoring seagrass beds. By integrating structural, functional, and environmental indicators, the framework allows meaningful comparisons across sites and countries, supporting both inventory development and restoration planning.

328. Gaps include limited guidance on transitional habitats or mixed seagrass assemblages (e.g., Cymodocea or Zostera) and minimal integration of socio-economic pressures, such as anchoring or tourism, into the assessment.

329. Despite these limitations, the guidelines provide a robust basis for compiling coherent regional inventories, calibrating databases, and informing site selection by distinguishing between degraded and healthy meadows. They also contribute to the standardization of monitoring approaches across Mediterranean countries, facilitating consistent reporting and comparison of ecological status at both national and regional levels.

45) Management of Posidonia Beaches Examples from Mediterranean Destinations

330. The publication Management of Posidonia Beaches: Examples from Mediterranean Destinations (IUCN, 2023) provides a regional and local perspective on sustainable management of Posidonia oceanica beach-dune systems across Mediterranean countries. The booklet illustrates practical applications of Nature-based Solutions (NbS) to enhance coastal resilience, particularly by mitigating beach erosion through the preservation and restoration of Posidonia oceanica banquettes and associated dunes.

331. The case studies were selected through a structured methodology: identification of sustainable practices, categorization by site characteristics and management body, in-depth data collection via desk research and interviews, and summarization of lessons learned. The case studies span diverse management scenarios, highlighting the various stages and approaches toward sustainable Posidonia oceanica management.

332. Central to the management practices is balancing ecological conservation with recreational and tourism pressures. Seasonal, temporary removal and reintroduction of banquettes is paired with scientific

guidance to prevent sand loss. Dune restoration strategies include physical protection measures, active revegetation, and innovative local solutions such as using palm leaves to trap sand.

333. The booklet underscores that successful management requires coordinated governance, scientific backing, and proactive communication to shift public perception of Posidonia oceanica from “waste” to a valued ecological asset. Collaborative governance strengthens local commitment. Financial incentives and private-sector involvement further enhance sustainable practices.

334. Challenges include the persistent perception of banquettes as aesthetically undesirable, inter-administrative coordination difficulties, the need for scientific data to support management decisions, and securing funding for ongoing education and maintenance. Recommendations emphasize clearly defining objectives, leveraging scientific support, engaging communities, advocating for supportive policies, and promoting effective communication to ensure the recognition of Posidonia oceanica as a key component of coastal ecosystem resilience.

Strengths, Gaps, and Applicability

335. The publication offers concrete, field-tested examples of Nature-based Solutions for the management and restoration of Posidonia oceanica beach-dune systems across diverse Mediterranean contexts. It integrates ecological conservation measures with governance, community engagement, and scientific support, demonstrating how coordinated efforts can maintain dune stability and shore protection.

336. Limitations include the site-specific nature of the case studies, which may require adaptation for areas with different ecological, legal, or social contexts, as well as variable monitoring frameworks that may not easily scale regionally.

337. The lessons provided inform coastal conservation planning by guiding the implementation of adaptive, community-inclusive interventions that enhance dune resilience, stabilize sediments, and support vegetation development while promoting long-term ecosystem integrity.

46) Conservazione e gestione della naturalità negli ecosistemi marino-costieri. Il trapianto delle praterie di *Posidonia oceanica*

338. The ISPRA manual “Conservazione e gestione della naturalità negli ecosistemi marino-costieri. Il trapianto delle praterie di Posidonia oceanica” provides a national and regional reference framework for Italy and the wider Mediterranean, offering technical and methodological guidance on the transplantation of Posidonia oceanica. Developed in response to the widespread regression of P. oceanica meadows - particularly near urbanized and industrial coastal areas - the document positions transplantation as a compensatory measure to accelerate the recovery of degraded ecosystems. Given the extremely slow natural growth rate of the species, the manual emphasizes that transplantation must adhere to stringent scientific and monitoring standards to ensure ecological validity and long-term sustainability.

339. Posidonia oceanica is recognized as a protected species and habitat under multiple conventions: the Barcelona Convention, the Bern Convention, and the EU Habitats Directive, which lists Posidonia oceanica meadows as priority habitats requiring designation as Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs). The ISPRA manual serves as an operational reference for implementing conservation, mitigation, and restoration actions consistent with the obligations established by the Barcelona and Bern Conventions and the EU Habitats Directive.

340. Four main transplantation methods are presented and evaluated:

- Concrete modules – The most successful and replicable method at scale. Using 50×50 cm cement frames reinforced with metal mesh, it achieved exceptional outcomes.
- Metallic grids – A cost-efficient technique for mobile substrates or dead matte, shifting most labour to on-land assembly. The pilot site demonstrated moderate success but site stability is fundamental.

- Biodegradable supports – An innovative approach using Mater-Bi® bioplastic structures designed to degrade within 3–5 years, avoiding permanent residue and promoting natural integration. Early trials achieved ~80% survival after 20 months, highlighting promise for future application.
- Naturalistic engineering – These approaches use Reno mattresses or geomats stabilize sediment and protect transplanted cuttings. Field tests confirmed high physical resistance and anti-erosive effectiveness, particularly in high-energy environments.

341. The manual emphasizes the necessity of long-term monitoring, with initial assessments covering at least five years and extended observation spanning up to fifty years to evaluate full ecological recovery. Monitoring should track both short-term survival and new rhizome formation, as proliferation is considered the true indicator of restoration success. Furthermore, the ISPRA document mandates that compensatory interventions be supervised by public scientific institutions with recognized expertise, ensuring methodological rigor, data reliability, and compliance with conservation standards.

Strengths, Gaps, and Applicability

342. The ISPRA manual provides one of the most comprehensive and empirically grounded references for Posidonia oceanica transplantation in the Mediterranean, offering detailed, field-tested guidance that is adaptable to both compensatory and proactive restoration contexts. Its integration with legal frameworks ensures that restoration aligns with established conservation obligations, and its emphasis on scientific supervision and long-term monitoring establishes robust protocols for validating ecological recovery.

343. Limitations include the constrained applicability of certain techniques outside specific substrate or hydrodynamic conditions, the high technical complexity and cost of interventions, and the resource-intensive nature of long-term monitoring, which may exceed the capacity of some institutions.

344. The methodologies outlined support the development of standardized restoration practices, facilitate integration of compensatory measures into environmental assessments, and provide a framework for capacity building, methodological harmonization, and policy alignment in regional Mediterranean coastal management initiatives.

47) Guidelines for the active restoration of *Posidonia oceanica*

345. The Guidelines for the Active Restoration of Posidonia oceanica provide a Mediterranean-scale reference framework for restoration practices of this key species. The guidelines reaffirm the protected status of Posidonia oceanica under multiple international frameworks, emphasizing its role as a keystone species whose conservation requires a harmonized regional strategy.

346. A central element of the document is its strong policy orientation: it promotes a strict adherence to the mitigation hierarchy, in which avoidance and minimization of impacts take precedence over active restoration. Active restoration should only be undertaken after all major stressors are controlled and the site is sufficiently protected, reinforcing that transplantation is a complementary intervention rather than a substitute for conservation.

347. Before authorizing any active restoration project, the guidelines require that decision-makers verify several essential prerequisites. These include evidence of prior presence of Posidonia oceanica at the site, effective control of the original stressors, and sustained protection throughout the project's lifespan. Moreover, any large-scale operation must be preceded by a small-scale pilot experiment monitored for at least three years to validate site suitability.

348. The technical section of the guidelines details operational methodologies proven effective under Mediterranean conditions. Optimal transplanting depth ranges from 10 to 18 meters, balancing light availability and low hydrodynamic stress. The most suitable substrates are Cymodocea nodosa-colonized sands and dead matte, while bare sand should be avoided due to poor survival rates. Extraction from donor meadows must not exceed two cuttings per square meter to prevent habitat degradation, while drifting fragments may be used to avoid donor impact.

349. Finally, the document highlights several key research and development areas critical for future restoration strategies. These include identifying heat- and stress-resilient Posidonia oceanica genotypes, exploring assisted evolution techniques, developing biotechnological tools for large-scale propagation, and advancing ecological function assessment to measure true restoration success. Additionally, improved monitoring technologies - like underwater photogrammetry - are identified as essential to ensure accurate evaluation and reporting.

Strengths, Gaps, and Applicability

350. The strength of these guidelines lies in their combination of scientific rigor, ethical standards, and regionally harmonized methodologies, offering practical guidance on site assessment, transplantation techniques, and monitoring.

351. Limitations include the experimental status of large-scale restoration, absence of evidence for full ecological function recovery, reliance on donor material, and limited long-term monitoring data across the Mediterranean.

352. The document provides a robust framework for planning and executing restoration initiatives, informing site feasibility evaluation, technical implementation, and prioritization of research and monitoring. It supports the development of standardized, scientifically informed approaches to Posidonia oceanica restoration and offers guidance for harmonizing interventions with regional conservation obligations and long-term ecosystem management strategies.

48) Monitoring protocol for *Posidonia oceanica* beds

353. With a regional scope focused on the Adriatic and a national implementation in Croatia, this protocol represents one of the most structured and operationally applicable frameworks for seagrass monitoring in the Mediterranean. Its purpose is to standardize methodologies for assessing the conservation status of Posidonia oceanica meadows, thereby ensuring the comparability of data and the integration of national results within regional and European reporting frameworks. The document provides the scientific and logistical foundation needed to evaluate restoration progress and conservation effectiveness. The standardized monitoring structure supports the harmonized assessment of Posidonia oceanica status and trends across Mediterranean Member States, allowing data-driven management.

354. The monitoring protocol relies on SCUBA-based field surveys and incorporates standardized UNEP/MAP-SPA/RAC methodologies. Core descriptors include shoot density, substrate coverage, lower depth limits, and associated biota or pressures. The protocol also requires the classification of lower limits into regressive, stable, or progressive types, which serve as visual indicators of meadow health and dynamics. Additionally, the presence of Pinna nobilis and alien taxa such as Caulerpa cylindracea, as well as evidence of mechanical damage from anchors or debris, are systematically recorded to capture the influence of external pressures.

355. Status evaluation is based on quantitative thresholds, including a five-class scale (High, Good, Moderate, Poor, Bad) derived from combined metrics of lower limit depth, cover, and shoot density. A key metric, the Conservation Index, quantifies the ratio of living to dead matte, with $CI > 0.9$ indicating high conservation status. Temporal dynamics are assessed using the BACI (Before/After-Control/Impact) design, which allows for evaluating anthropogenic impacts and the success of management interventions.

356. Within the Croatian implementation framework, the protocol highlights significant baseline data gaps and the need to expand distribution mapping. It also recognizes the importance of validating descriptor thresholds developed in other Mediterranean sub-regions and exploring complementary monitoring tools such as videography for large-scale coverage assessment. Operational deployment foresees a nationally coordinated monitoring network, structured by site priority and supported by trained scientific diving teams, with repeated surveys conducted across multi-year reporting cycles to ensure temporal robustness.

Strengths, Gaps, and Applicability

357. The protocol's strength lies in its high level of methodological standardization, regulatory alignment, and operational clarity, providing reproducible procedures that link field data collection with ecological status classification and policy reporting requirements. Its integration of structural descriptors, pressure indicators, and multivariate indices enables comprehensive evaluation of meadow condition and temporal trends.

358. Constraints emerge from the limited availability of long-term baseline data, the need to calibrate certain classification thresholds to Adriatic ecological conditions, and the logistical intensity of dive-based monitoring, which may restrict scalability.

359. Nevertheless, the framework offers a solid basis for harmonized seagrass assessment, supporting coordinated monitoring networks, informing conservation status evaluation, and contributing to the development of consistent regional inventories and management responses for Posidonia oceanica ecosystems.

49) A biotic index using the seagrass *Posidonia oceanica* (BiPo), to evaluate ecological status of coastal waters

360. The document presents a regionally oriented framework with national-level applicability, particularly for Western Mediterranean countries, in line with the Water Framework Directive (WFD) and the Barcelona Convention. Developed within the broader scientific and policy context of Mediterranean seagrass conservation, the index responds to the need for harmonized tools capable of assessing ecological quality in coastal environments through standardized, comparable indicators.

361. A central premise of the framework is that spatial mapping constitutes an essential prerequisite for any conservation or monitoring activity. The document therefore establishes differentiated mapping precision standards according to management objectives, ranging from very high-resolution mapping for pilot or test areas to broader-scale inventories for regional planning. The protocol explicitly excludes destructive sampling for protected seagrass species and promotes non-invasive survey techniques integrated within GIS platforms, ensuring both habitat protection and data standardization. Cartographic outputs are harmonized through common graphical conventions capable of distinguishing continuous meadows, dead matte formations, and mixed assemblages.

362. Monitoring protocols rely on fixed reference stations derived from long-term seagrass observation networks and incorporates a suite of structural and ecological descriptors. Interpretation grids define ecological status through five quality classes, supported by quantitative thresholds for lower depth limits, lower limit dynamics, and shoot density at standardized depths. These metrics enable ecological quality evaluation consistent with European assessment systems while maintaining sensitivity to Mediterranean meadow dynamics.

363. Within this system, the BiPo index functions as a synthetic, non-destructive indicator specifically designed for long-term ecological assessment. Its reliance on structural meadow descriptors makes it particularly suitable for repeated monitoring in protected or sensitive areas. The framework also differentiates monitoring objectives across temporal scales, distinguishing long-term heritage monitoring, medium-term environmental quality assessments linked to coastal management, and short-term impact evaluations associated with development pressures.

Strengths, Gaps, and Applicability

364. The strength of the guidelines lies in their scientific rigor, regional harmonization, and clear methodology for both mapping and monitoring seagrass beds. By integrating structural, functional, and environmental indicators, the framework allows meaningful comparisons across sites and countries, supporting both inventory development and restoration planning.

365. Gaps include limited guidance on transitional habitats or mixed seagrass assemblages and minimal integration of socio-economic pressures, such as anchoring or tourism, into the assessment.

366. The index nevertheless provides a robust operational basis for evaluating ecological status, structuring long-term monitoring networks, and informing conservation and management prioritization within broader Mediterranean ecosystem assessment processes.

50) A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the water framework directive (WFD)

367. The study presents a regionally focused methodology developed for the Catalan coast in the northwestern Mediterranean, with clear applicability at the national scale for other Mediterranean EU Member States. The POMI (Posidonia oceanica Multivariate Index) was designed to operationalize ecological quality assessment through seagrass indicators and responds to the requirement to evaluate and maintain “good ecological status” using sensitive biological quality elements.

368. As a Mediterranean endemic species, Posidonia oceanica represents a key Biological Quality Element (BQE) for coastal monitoring: it is highly sensitive to disturbances, widely distributed, and extensively studied in terms of ecology and anthropogenic responses. The POMI approach leverages these characteristics to provide a practical, integrative tool capable of synthesizing large amounts of ecological data into a simplified yet robust evaluation of ecological status.

369. The POMI’s multivariate design is one of its main methodological strengths. It integrates fourteen metrics spanning physiological, individual, population, community, and pollution descriptors, and synthesizes them through Principal Component Analysis (PCA). The resulting EQR values show a significant negative correlation with anthropogenic pressures such as coastal development, urban sewage, beach regeneration, tourism, and harbour activity, confirming the index’s sensitivity to human impacts. An important methodological challenge addressed in the study concerns the definition of reference conditions in historically impacted Mediterranean coastal systems. Rather than relying on hypothetical pristine baselines, the authors adopt a pragmatic approach by constructing composite optimal references derived from the best-performing monitored sites. This solution enhances operational feasibility while maintaining ecological realism in regions where undisturbed benchmarks are no longer available.

Strengths, Gaps, and Applicability

370. The strength of the framework lies in its capacity to integrate complex ecological information into a statistically robust yet operationally interpretable assessment system. By combining physiological sensitivity with long-term structural indicators, the index enables the detection of both rapid environmental responses and slower ecosystem recovery dynamics.

371. Gaps remain in relation to its exclusive focus on Posidonia oceanica, which constrains direct transferability to other seagrass species or benthic habitats, and in the technical requirements associated with multivariate data processing and statistical interpretation.

372. Nonetheless, the index provides a coherent analytical structure for ecological status evaluation, supporting harmonized monitoring design, environmental diagnostics, and the interpretation of ecosystem condition trajectories within Mediterranean coastal management frameworks.

51) A new synthetic index and a protocol for monitoring the status of *Posidonia oceanica* meadows - A case study at Sanremo

373. This study presents a detailed methodological framework developed for the Ligurian Sea (Italy), with applicability extending from local to national and regional scales within the Mediterranean. This work introduces a protocol that integrates benthic mapping techniques and two synthetic indices to assess the ecological status of Posidonia oceanica meadows, offering valuable operational support for conservation and restoration programs.

374. The Sanremo study provides a clear methodological advancement by combining side-scan sonar mapping, scuba assessments, and the application of synthetic indices to produce high-resolution thematic maps. These maps delineate meadow extent, dead matte coverage, and the morphology of the lower limit—critical parameters for establishing conservation baselines and evaluating spatial dynamics. The indices

introduced in this study provide quantitative tools for evaluating the degradation and transformation of P. oceanica meadows. The Conservation Index (CI) quantifies the proportion of dead matte relative to live meadow, reflecting structural loss and degradation severity. The Substitution Index (SI) measures the replacement of Posidonia oceanica by Cymodocea nodosa, indicating a functional phase shift in the ecosystem. This substitution process highlights a severe form of degradation, as C. nodosa provides lower structural complexity, carbon storage capacity, and biodiversity support compared to P. oceanica. By distinguishing between sites dominated by dead matte and those undergoing substitution by C. nodosa, managers can tailor restoration strategies accordingly ranging from transplantation in highly degraded sites to targeted pressure mitigation in meadows showing partial resilience. Furthermore, both indices offer quantifiable and repeatable measures of restoration success.

Strengths, Gaps, and Applicability

375. A key asset of the framework lies in the combined use of high-resolution spatial mapping and synthetic ecological indicators, which together enable a spatially explicit and diagnostically robust evaluation of meadow condition.

376. Its empirical validation, however, remains confined to a single geographic case study, highlighting the need for calibration across a wider range of Mediterranean environmental settings. Further methodological constraints stem from the limited integration of complementary biological descriptors that could enhance ecological interpretation, alongside the logistical and technological requirements associated with advanced acoustic mapping systems.

377. The protocol constitutes a scientifically solid and operationally relevant contribution to the standardized monitoring of Posidonia oceanica meadows, underpinning habitat assessment, degradation analysis, and restoration planning within Mediterranean coastal management frameworks.

52) Descriptors from *Posidonia oceanica* (L.) Delile meadows in coastal waters of Valencia, Spain, in the context of the EU Water Framework Directive

378. Developed within a local and national framework - specifically in the coastal waters of Valencia (NW Mediterranean, Spain) - this study evaluates 21 biological descriptors of Posidonia oceanica meadows to identify the most appropriate indicators for assessing the ecological status of coastal waters under the European Water Framework Directive (WFD). By establishing scientifically robust and operationally feasible descriptors, it contributes directly to Mediterranean-scale efforts for habitat conservation, monitoring, and restoration. From an initial suite of 21 parameters, nine key metrics were retained for their demonstrated responsiveness to a range of anthropogenic disturbances, including shoot density, dead-matte cover, meadow cover, shoot foliar surface, and foliar necrosis. Moreover, the application of class boundaries derived from the MedGIG (Geographical Intercalibration Group of the Mediterranean Coastal Waters) reinforces the regional harmonization effort essential for integrated monitoring systems.

379. Among the selected metrics, dead-matte cover emerged as the most sensitive indicator of irreversible structural damage. Its correlation with coastal constructions and beach replenishment underscores its utility in identifying areas of critical degradation, where natural regeneration is minimal and targeted restoration interventions are most urgently required. Other descriptors, such as foliar necrosis and variations in shoot foliar surface, capture physiological stress responses linked to chronic pollution or eutrophication, highlighting sites where functional recovery is still feasible if pressures are mitigated.

380. The use of Principal Component Analysis (PCA) to classify ecological status into five categories (High, Good, Moderate, Poor, and Bad) based on an EQR offers a quantitative foundation for defining both baseline conditions and restoration targets. Achieving or maintaining GES as defined by the WFD becomes the explicit benchmark for evaluating restoration success. Furthermore, the capacity to link specific descriptors to distinct degradation drivers enables managers to tailor restoration strategies: high dead-matte cover values may guide physical restoration or transplantation measures, while increased epiphyte biomass may direct efforts toward pollution reduction. The suite of nine descriptors also ensures cost-effectiveness, allowing for long-term, scalable monitoring programs.

Strengths, Gaps, and Applicability

381. The framework is strengthened by the scientific reliability and practical feasibility of the selected descriptor set, which allows consistent monitoring of Posidonia oceanica meadows within the WFD assessment context. The use of the EQR supports coherent ecological status classification across sites, while the clear relationship established between specific descriptors and anthropogenic pressures improves the ability to interpret degradation patterns and orient restoration responses. Its coherence with MedGIG intercalibration processes further reinforces regional comparability and methodological alignment among Mediterranean monitoring systems.

382. The validation of descriptors remains geographically concentrated in Spanish coastal waters, indicating the need for broader testing across different Mediterranean environmental conditions. Certain physiological parameters, including foliar necrosis, may be influenced by seasonal variability, requiring harmonized sampling timing to ensure comparability. In addition, the limited inclusion of faunal components reduces the ecological breadth of the assessment, as these elements could provide complementary insight into ecosystem condition.

383. From an operational perspective, the descriptor framework offers concrete support for ecosystem assessment and restoration planning by providing measurable indicators capable of identifying degradation levels and tracking recovery trends. It also represents a useful reference for the development of comparable monitoring approaches in other Mediterranean subregions, while supporting adaptive management processes that link ecological evaluation with restoration prioritization and effectiveness over time.

53) Ecosystem functions and economic wealth- Trajectories of change in seagrass meadows

384. Developed within the Ligurian Sea in the northwestern Mediterranean, this study investigates the long-term ecological and economic dynamics of Posidonia oceanica. The analysis provides a comprehensive framework for understanding the loss of ecosystem functionality, its economic implications, and its relevance to monitoring and restoration.

385. The study confronts the widespread issue of sliding baselines in ecological assessment, reconstructing historical reference conditions through predictive modelling and 19th-century cartographic data. Moreover, by employing a biophysical emergy accounting method, the study translates ecological functions into equivalent economic values, quantifying the “invisible capital” provided by P. oceanica and strengthening the policy case for its conservation and restoration.

386. Historical reconstruction reveals that P. oceanica meadows in Liguria have undergone a “huge regression,” with over 50% of their original area lost by 1990. This loss represents a dramatic decline in a habitat with exceptionally high ecological and functional value. The study also identifies a phase shift in degraded systems, where P. oceanica is replaced by Cymodocea nodosa, leading to reduced biomass and species richness.

387. The primary drivers of degradation are identified as physical and environmental alterations caused by coastal development, tourism infrastructure, and declining water quality, compounded by climate warming. While protection measures implemented since the 1990s have halted further decline and stabilized P. oceanica coverage, the extent remains only about one-third of its historical level. Emergy-based valuation further demonstrates that cumulative ecosystem function losses outweigh the economic gains generated by coastal development over the same period. Importantly, the stabilization of meadow extent in recent decades has occurred alongside continued economic growth, illustrating that coastal ecosystem protection and economic prosperity are not mutually exclusive but can evolve synergistically.

Strengths, Gaps, and Applicability

388. A major asset of the framework is its capacity to connect ecological change with economic valuation through the integration of historical reconstruction and emergy accounting. This combined perspective provides a robust quantitative basis for assessing long-term habitat loss while simultaneously translating ecosystem degradation into socio-economic terms that are directly relevant for policy and investment

decisions. The methodological approach also offers a valuable pathway for defining historical reference conditions in monitoring contexts where empirical baselines are incomplete or fragmented, thereby strengthening restoration target setting and strategic planning.

389. The geographic concentration on the Ligurian Sea constrains the immediate transferability of quantitative results to other Mediterranean subregions characterized by different environmental pressures and geomorphological settings. Elements of uncertainty are also inherent in the reconstruction of historical baselines, given the reliance on archival cartographic material with variable spatial resolution and interpretative accuracy.

390. The study delivers a solid diagnostic foundation for conservation and restoration planning by identifying degradation trajectories, functional losses, and their economic implications. Its findings reinforce the prioritization of P. oceanica, while the valuation of ecosystem services strengthens the strategic justification for protection and recovery investments. The analytical structure proposed by the study offers a replicable model for integrating ecological monitoring, ecosystem service assessment, and management planning across Mediterranean seagrass conservation initiatives.

54) Lepidochronological analysis of the seagrass *Posidonia oceanica* (L.) Delile: a standardized approach

391. The document provides a regional methodological framework that establishes a standardized and scientifically validated approach to lepidochronology - the analysis of cyclic variations in leaf scale thickness in Posidonia oceanica - that enables consistent and comparable assessments of seagrass growth dynamics, historical baselines, and ecological responses across the region.

392. Lepidochronology provides a unique long-term historical baseline for ecological assessment, allowing researchers to reconstruct annual and multi-annual growth cycles through the analysis of preserved rhizome scales, which can remain within the matte structure for several millennia. This unprecedented temporal resolution allows for the identification of pristine environmental conditions, effectively mitigating the sliding baseline syndrome that often obscures the interpretation of current ecological states in highly altered Mediterranean coastal systems.

393. Moreover, the method allows for the quantification of key ecological functions by determining annual leaf production rates, rhizome elongation, and the processes governing matte development. Cyclic variations in scale thickness correspond to environmental drivers such as light availability, hydrodynamics, and temperature, transforming the plant into a biological recorder of environmental history. This diagnostic capacity extends even to the detection of major anthropogenic and climatic events, demonstrating the method's ability to integrate ecological, temporal, and stress-related information within a single analytical framework.

394. The method provides a direct means of quantifying the extremely slow dynamics of matte formation and recovery, thus justifying the habitat's prioritization for protection and restoration. It also enables the assessment of reproductive capacity through the identification of paleoflowering events, revealing patterns in flowering frequency that are essential for evaluating the long-term regenerative potential of meadows, particularly under increasing climatic stress. Lepidochronology serves as an essential diagnostic and evaluative tool across all restoration phases.

395. By detecting variations in annual scale thickness, the method enables the dating of specific degradation events and their correlation with historical anthropogenic or climatic pressures. This capability allows for precise attribution of observed stress signals to events.

Strengths, Gaps, and Applicability

396. The main strength of the lepidochronological approach lies in its ability to provide standardized, long-term ecological baselines for P. oceanica meadows across the Mediterranean. By linking biological growth patterns with environmental and anthropogenic drivers, it enables a high degree of diagnostic precision that is unmatched by other monitoring methods. The temporal depth of the data allows managers to reconstruct

historical conditions, assess long-term regeneration potential, and evaluate the effectiveness of restoration interventions with unprecedented clarity.

397. Certain limitations are inherent to the methodology. The technique requires specialized expertise and laboratory capacity for rhizome sampling and scale measurement, which may limit its routine application. It is currently specific to P. oceanica, so direct application to other seagrass species would require adaptation. Additionally, interpretation of cyclic variations must account for local environmental conditions, necessitating site-specific calibration for accurate assessment.

398. In practical terms, lepidochronology provides essential chronological and functional metrics for evaluating restoration outcomes. By integrating these long-term ecological insights into regional monitoring frameworks, the approach enhances cross-country comparability, strengthens the scientific basis for restoration planning, and contributes directly to the sustainable management of Mediterranean seagrass ecosystems.

55) MANAGEMENT of Natura 2000 habitats *Posidonia* beds (Posidonion oceanicae) 1120

399. Within a regional and national context, this technical report provides comprehensive guidance for the management, conservation, and restoration of Posidonia oceanica meadows. The document stresses that the core environmental conditions required by the species - clear, oligotrophic waters and stable, oxygenated sediments - are increasingly threatened by human activities, necessitating standardized and enforceable management actions. Monitoring is described as “fundamental” for assessing both the conservation status and the effectiveness of protective or recovery initiatives, specifying protocols for monitoring using in situ mapping and remote-sensing techniques, complemented by quantitative indicators such as shoot density, rhizome elongation, and the oxic front depth in sediments. It further recommends long-term observation networks using permanent quadrats to account for the species’ intrinsic slow growth and natural patchiness.

400. The report further stresses the need for regulatory reinforcement, proposing specific thresholds for nutrient sedimentation and minimum buffer distances from aquaculture operations. Legal protection of individual plants is noted as particularly effective, providing clarity in management compared with habitat-level regulations. Posidonia oceanica meadows are recognized for their ecological significance as nursery habitats, carbon sinks, and natural coastal defenses. However, the species’ inherently slow growth renders recovery processes extremely gradual, with full regeneration occurring over centuries once stressors are removed. The report identifies major degradation drivers, including eutrophication, organic enrichment, trawling, anchoring, coastal infrastructure, and invasive algae, and it emphasizes that preventative measures and protection strategies are the most effective management tools given the ecosystem’s slow dynamics. While transplantation is addressed, it is presented as a limited and high-maintenance option, with cost and success constraints that reduce its practical applicability.

Strengths, Gaps, and Applicability

401. The report offers a harmonized and science-based framework for the management of Posidonia oceanica meadows, integrating monitoring protocols, regulatory guidance, and practical conservation measures. It provides clear thresholds and measurable indicators that can be directly applied to track ecosystem status and evaluate management outcomes.

402. At the same time, it presents limited consideration of climate change impacts, and the feasibility of transplantation at large scales remains unproven. Economic and governance dimensions, such as enforcement strategies and stakeholder engagement, are only briefly discussed.

403. Despite these limitations, the guidance establishes a solid operational basis for conservation planning, enabling Mediterranean countries to align monitoring and management actions with EU Habitat Directive objectives and to prioritize effective protection and restoration interventions.

56) The value of the seagrass *Posidonia oceanica*: A natural capital assessment

404. This study presents a comprehensive assessment of the ecological and economic significance of Posidonia oceanica meadows in the Ligurian Sea, employing Emergy Analysis to quantify the services

provided by this keystone habitat. By converting ecological functions into a standardized measure of natural capital, the research highlights the intrinsic value of seagrass meadows beyond direct human use, offering an objective perspective on their conservation importance. Posidonia oceanica is recognized for its role in sediment retention, shoreline stabilization, oxygen production, nursery provision, and primary productivity, with sediment retention representing the most substantial contribution to overall ecosystem value.

405. The study also documents substantial meadow regression over recent decades, exemplified by the case of the Bergeggi Marine Protected Area, where coverage decreased significantly, illustrating the tangible loss of ecological and natural capital. The species' extremely slow growth and infrequent sexual reproduction underline its limited regenerative capacity, emphasizing that large-scale losses are effectively irreversible on human timescales. The research concludes that while active restoration is technically possible, it is expensive and complex, and the mitigation of human impacts emerges as the most practical and efficient pathway to maintain ecological function.

406. Overall, the work provides a rigorous framework linking ecological function to economic valuation, reinforcing the critical importance of Posidonia oceanica in coastal ecosystem integrity. Its approach offers transferable insights for conservation planning, highlighting the necessity of preventative management to safeguard these slow-recovering habitats.

Strengths, Gaps, and Applicability

407. The study's main contribution lies in offering a robust, standardized method for valuing the ecosystem services of Posidonia oceanica, integrating ecological and economic perspectives in a single framework. It establishes clear evidence of the consequences of habitat loss, underlining the irreplaceable role of sediment retention and coastal protection.

408. At the same time, the regional focus limits the direct transferability of specific monetary values, and further work would be required to adapt the approach to other Mediterranean contexts. The methodology does not directly incorporate biological monitoring or spatially explicit planning, instead focusing on valuation metrics, which may constrain its application in highly detailed restoration strategies.

409. Nevertheless, the research provides a strong conceptual and practical foundation for assessing the ecological and functional importance of seagrass meadows, offering decision-makers a compelling rationale for prioritizing protective and preventative management over costly and uncertain restoration efforts.

2.6 Bioconstructions

57) Monitoring and assessment of the ecological status of coralligenous habitat

410. In the context of Italy and the broader Western Mediterranean sub-region, the ISPRA manual establishes a standardized, scientifically robust methodology for inventorying, monitoring, and assessing coralligenous cliff assemblages. Developed by a consortium of experts this methodological guide aligns with European legislative requirements, including the Habitats Directive, Water Framework Directive (WFD), and Marine Strategy Framework Directive (MSFD), as well as regional obligations under the Barcelona Convention.

411. Coralligenous habitats are biogenic hard substrates formed primarily through the accumulation of calcareous encrusting algae, such as Mesophyllum alternans and Lithophyllum stictiforme. These assemblages constitute biodiversity hotspots, offering high structural complexity and spatial heterogeneity that support diverse communities. The manual focuses on coralligenous cliffs, the most widespread shallow sub-habitat (typically 15-40 m depth), which serve as sensitive indicators of anthropogenic and climate-related pressures. Threats include mechanical destruction (trawling, anchoring), eutrophication and sedimentation, mass die-offs from climate anomalies, ocean acidification, and invasive species (e.g., Womersleyella setacea, Caulerpa cylindracea).

412. The STAR (STAndaRdized coralligenous evaluation) protocol is the manual's core methodological contribution. It ensures harmonized data collection across sites, enabling comparability at large spatial and

temporal scales. The protocol specifies fixed sampling parameters, including depth (approximately 35 m ±3 m), slope (vertical, 85–90°), seasonal timing (April–June), and replication (minimum three 4 m² plots per site, with ten photographic sub-samples per plot). STAR integrates non-destructive photographic methods within situ visual assessment (RVA), collecting descriptors relevant to both biodiversity (D1) and seafloor integrity (D6). Key parameters include consistency of the calcareous matrix, necrosis and epibiosis on erect anthozoans, stress from thermal events, mucilage, or mechanical impacts, α- and β-diversity.

413. Data collected feed into complementary Ecological Quality Indices, including ESCA, COARSE, and ISLA, which collectively evaluate species composition, structural integrity, disturbance sensitivity, and stress impacts. Reference conditions established for the Western Mediterranean provide a baseline for assessing ecological status and require adaptation for other sub-regions to ensure broader comparability.

Strengths, Gaps, and Applicability

414. The manual's primary strength lies in providing a standardized and scientifically validated approach for assessing coralligenous habitats, integrating structural, compositional, and vitality parameters to deliver a comprehensive evaluation of ecological condition and sensitivity. It enables comparability across scales and supports identification of sites with high ecological relevance and restoration potential.

415. Key gaps include the need to recalibrate reference conditions beyond the Western Mediterranean, potential limitations in detecting cryptic or early-stage stressors due to reliance on visual and photographic sampling, and limited integration of socio-economic pressures.

416. Nevertheless, the methodology establishes a solid foundation for characterizing habitat condition, informing ecological assessment, and guiding restoration prioritization, supporting the identification of sites with significant biodiversity, structural complexity, and bioconstruction value.

58) Standard methods for inventorying and monitoring coralligenous and rhodoliths populations

417. The Standard Methods for Inventorying and Monitoring Coralligenous and Rhodoliths Assemblages (UNEP-MAP-RAC/SPA, 2015) provides a regionally focused technical framework. It addresses the critical methodological gaps that have historically impeded standardized assessment and long-term conservation of coralligenous bioconstructions and maërl/rhodolith beds.

418. Coralligenous assemblages are defined as complex underwater landscapes dominated by coralline algae in low-light, low-disturbance conditions, while maërl/rhodolith beds consist of carpets of free-living calcareous algae on sedimentary substrates. Both are highly vulnerable to fishing, diving, sedimentation, and climate change-related impacts.

419. Inventory methodology is structured around two complementary objectives: locating assemblages (Range/Area) and detailed characterization. Locating assemblages integrates technological and field-based approaches, including Side Scan Sonar, Multi-Bundle Sounders, ROVs/dragged cameras, and scuba surveys, with trade-offs between spatial coverage, precision, and operational constraints. Characterization requires specialist expertise for taxonomic identification and assessment of vitality, including structural integrity, necrosis, epibiont presence, and associated ichthyofauna. Detailed species lists provided in the manual define characteristic native biota, bioeroders, and relevant species for monitoring purposes, facilitating RLE Criterion D proxies.

420. Monitoring methods emphasize reproducibility and long-term tracking of ecological status. For coralligenous habitats, non-destructive techniques (photographic quadrats) are recommended to maintain ecosystem integrity, while maërl beds require a combination of ROV, acoustic mapping, and occasional grab sampling due to hydrodynamic mobility. Cross-team calibration is necessary to standardize descriptors across projects, ensuring comparability.

421. The manual concludes with recommendations for regional strategy, highlighting the need for coordinated data sharing, development of a minimal set of validated descriptors, capacity building for technical skills (ROV operation, high-precision acoustic mapping), and integration of ecosystem services assessments.

Strengths, Gaps, and Applicability

422. This manual provides a robust, regionally relevant methodology for assessing coralligenous and rhodolith habitats, enabling both broad-scale mapping and fine-scale ecological characterization.

423. Key limitations include the high technical and operational requirements, potential variability in descriptors between teams, and incomplete baseline mapping across the Mediterranean, particularly outside the North-Western sector.

424. Overall, the framework offers a scientifically defensible basis for inventorying, monitoring, and restoring these priority habitats, supporting identification of sites of high ecological relevance, facilitating harmonized monitoring across Mediterranean countries, and underpinning conservation and restoration planning.

59) The coralligenous in the Mediterranean Sea

425. The report "The coralligenous in the Mediterranean Sea" (SAP BIO Project, 2001-2003) provides a regionally focused scientific review of coralligenous assemblages across the Mediterranean, establishing ecological baseline, structural components, biodiversity metrics, and threat assessment necessary to guide strategic conservation actions.

426. Due to its structural complexity and high microspatial variability, the coralligenous is considered a mosaic or "submarine landscape" rather than a single homogeneous community. Abiotic parameters critical for RLE Criterion C include light (0.05–3% surface irradiance), low nutrient concentrations, and relatively stable temperatures, though anomalous summer and autumn heat events have caused mass mortality in suspension feeders.

427. Algal builders such as Mesophyllum alternans, Lithophyllum stictaeforme, and Peyssonnelia squamaria provide the main biogenic framework. Animal contributors include bryozoans and serpulid polychaetes. Bioeroders, including excavating sponges, Lithophaga lithophaga, and sea urchins, significantly influence carbonate dynamics, with total carbonate production reaching up to 1000 g $CaCO_3$ m^{-2} $year^{-1}$. Accretion rates are extremely low, reflecting the habitat's slow-growth, long-lived characteristics.

428. The coralligenous supports exceptionally high species richness. Endangered and commercially valuable species serve as proxies for ecological integrity and highlight sites of maximum ecological relevance. Functional dynamics demonstrate low spatial turnover, emphasizing vulnerability to anthropogenic disturbances. Major threats include trawling, destructive harvesting, invasive species (Womersleyella setacea), diver impacts, and wastewater/sedimentation. Measures include prohibiting trawling in coralligenous areas, regulating coastal activities to reduce sedimentation, introducing legislation against alien species, and managing recreational diving to minimize damage.

Strengths, Gaps, and Applicability

429. The report delivers a comprehensive regional synthesis of coralligenous structure, biodiversity, and ecological function, providing essential baseline data to inform inventory, assessment, and restoration planning.

430. Key limitations include incomplete cartographic coverage, limited understanding of resilience and recovery, and some historical data requiring validation through current field surveys.

431. Despite these constraints, the document offers a robust scientific foundation for prioritizing sites of maximum ecological relevance, supporting the design of monitoring programs, and guiding restoration and management strategies to mitigate principal anthropogenic threats.

60) Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-concretions in the Mediterranean Sea

432. The "Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea" represents a regional framework that provides the principal strategic and operational

foundation for the conservation and restoration of coralligenous and other calcareous bioconstructions in the Mediterranean.

433. Its functions encompass data collection, validation, and dissemination, the promotion of transboundary cooperation, and the development of monitoring networks for coralligenous and maërl assemblages. Operational tasks include maintaining a database of specialists, preparing environmental impact assessment guidelines, standardizing assessment and monitoring protocols, and integrating coralligenous/maërl status evaluation into the regional Integrated Monitoring and Assessment Programme (IMAP).

434. Coralligenous habitats are identified as key conservation priorities. The Action Plan underscores their vulnerability: recovery following destructive impacts may require several decades to centuries. Consequently, the coralligenous is a model of both ecological richness and fragility. This framework provides a detailed assessment of anthropogenic and natural pressures that necessitate restoration. Trawling is identified as the most destructive activity, while climate change - especially recurrent thermal anomalies - is predicted to cause mass mortalities among key suspension feeders. Pollution and eutrophication are shown to reduce coralline algal growth and biodiversity, while artisanal fishing, anchoring, and unregulated diving physically damage fragile species. These threats highlight the need for site-specific restoration planning and regulation of human activities.

435. The Plan emphasizes the need to develop standardized protocols, indicators, and quality indices for assessing the conservation status of coralligenous assemblages. It mandates the creation of such indices and the initiation of intercalibration efforts among Mediterranean countries. Long-term monitoring through sentinel or reference sites, preferably located within marine protected areas, is also recommended. This approach ensures the generation of consistent temporal datasets capable of tracking ecological trends and restoration outcomes over extended periods, in line with the slow natural dynamics of these assemblages.

Strengths, Gaps, and Applicability

436. The Action Plan's principal strengths lie in its regionally endorsed mandate, integration of restoration and monitoring within a single operational framework, recognition of coralligenous as high-biodiversity, low-regeneration habitats, and promotion of harmonized assessment protocols for regional comparability.

437. Limitations include incomplete development and application of standardized indices, limited temporal datasets and monitoring frequency, and underdeveloped restoration methodologies relative to ecological complexity and slow recovery rates.

438. Overall, the Action Plan provides a scientifically robust foundation for prioritizing conservation and restoration efforts, monitoring ecosystem condition, and supporting informed management of Mediterranean coralligenous and calcareous bioconstructions.

61) Coralligenous reefs state along anthropized coasts: Application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach

439. This study represents a regional and national framework applied to the French Mediterranean, with relevance to the broader northwestern Mediterranean context. It introduces and validates the COARSE (COralligenous Assessment by ReefScape Estimate) index, a standardized monitoring tool designed to evaluate the integrity of coralligenous reefs subjected to varying levels of anthropogenic pressure. The COARSE index combines quantitative assessment with a Rapid Visual Assessment (RVA) approach, providing a field-based method to characterize sea-floor integrity in complex biogenic habitats such as coralligenous reefs.

440. The COARSE index directly responds to the need for harmonized monitoring and assessment methodologies. These frameworks emphasize the importance of developing regional tools for evaluating the conservation status of priority habitats, and COARSE represents one of the few operational instruments fulfilling this requirement. The index addresses the absence of standardized indices capable of quantifying the degree of physical and biological degradation in coralligenous systems. COARSE aligns with the Marine Strategy Framework Directive by focusing explicitly on the descriptor of "sea-floor integrity."

441. The RVA component of COARSE - based on direct SCUBA diving observations - enables immediate, practical, and repeatable assessments, making it particularly suited for large-scale application across Mediterranean coastal monitoring networks.

442. The COARSE index contributes by quantifying the level of degradation and identifying areas where restoration actions are most urgent. Its sensitivity to anthropogenic pressure allows for differentiation among high-, moderate-, and low-impact areas. The index's focus on the three-dimensional structure of the reefs - an essential determinant of ecological integrity - addresses a critical gap in previous assessment methods. Since coralligenous frameworks are built by long-lived bioconstructors and recover extremely slowly from physical damage, the capacity of COARSE to detect structural degradation is vital for restoration planning.

443. Furthermore, the study demonstrates that the coralligenous state primarily responds to physical pressures rather than to changes in water quality alone. This aligns with the known vulnerability of coralligenous assemblages and reinforces the role of COARSE as a suitable instrument for tracking ecosystem integrity. Furthermore, the index supports restoration planning by providing robust baseline data for degraded areas, especially along anthropized coasts where pristine reference sites are lacking. Through its capacity to generate a reliable current baseline, COARSE enables the definition of realistic restoration targets and progress evaluation benchmarks. Importantly, the methodology disaggregates quality assessments by three structural layers (basal, intermediate, and upper), reflecting differential sensitivities and degradation patterns within the assemblage. This stratified analysis allows to identify which structural components or faunal groups require the most urgent restoration measures, such as the protection of gorgonian-dominated upper layers from mechanical stress. The identification of impoverished facies and poor-quality sites provides spatially explicit evidence for prioritizing intervention efforts and for integrating local results into regional restoration programs.

Strengths, Gaps, and Applicability

444. Strengths include the provision of one of the first standardized, field-tested indices for coralligenous reef integrity, integration of structural complexity into assessment, and combination of scientific rigor with practical feasibility for rapid visual assessments.

445. Gaps concern the current validation being limited to specific northwestern Mediterranean regions, reliance on expert judgment for pressure gradients that may affect reproducibility, and the absence of long-term temporal or recovery metrics.

446. Applicability lies in its capacity to generate reliable baselines, identify priority areas for intervention, and provide a scalable monitoring protocol compatible with regional assessment needs, supporting evidence-based conservation and restoration planning for coralligenous reefs.

62) Development of a new biotic index for ecological status assessment of Italian coastal waters based on coralligenous macroalgal assemblages

447. This study, conducted within the regional-national scope of Italian coastal waters in the northwestern Mediterranean, presents the Ecological Status of Coralligenous Assemblages (ESCA) index, a biotic index specifically designed for assessing the ecological quality of coralligenous macroalgal communities. This index represents a major advancement in standardizing and operationalizing monitoring protocols for one of the Mediterranean's most complex and ecologically valuable habitats. The ESCA index introduces a scientifically sound method for evaluating deep-water macroalgal communities, harmonizing the WFD's structural framework with the more functional approach required under the Marine Strategy Framework Directive (MSFD).

448. Methodologically, the index is designed to be cost-effective and regionally replicable. It is based on non-destructive photographic sampling, allowing for extensive spatial coverage while maintaining compliance with monitoring protocols in Marine Protected Areas (MPAs). Classification relies on the Ecological Quality Ratio (EQR), which compares observed data with Reference Conditions (RC) established at Montecristo Island - one of the Mediterranean Geographical Intercalibration Group (GIG) reference sites.

449. The ESCA index provides strong evidence of coralligenous vulnerability to anthropogenic pressures. Testing along environmental gradients revealed significant negative correlations between EQR and stressors such as invasive species, nutrient enrichment, and sedimentation. Moreover, the index captures declines in structural complexity - measured as β-diversity - associated with the replacement of perennial, structure-forming species by opportunistic turf algae. Since the recovery of biogenic structures in coralligenous habitats can take decades or centuries, this diagnostic capacity makes ESCA a valuable tool for identifying areas requiring urgent restoration.

Strengths, Gaps, and Applicability

450. Strengths include the first standardized, non-destructive index specifically for deep coralligenous habitats, harmonization of structural and functional assessment objectives, use of validated reference conditions, and clear diagnostic capacity to detect anthropogenic stress and structural degradation.

451. Main limitations include calibration limited to the northwestern Mediterranean, focus primarily on macroalgal assemblages with limited integration of sessile fauna, and restricted temporal validation that may affect predictive capacity.

452. Applicability lies in its ability to provide a replicable, policy-relevant framework for monitoring, evaluating ecological status, and guiding restoration prioritization in Mediterranean coralligenous systems.

63) Mediterranean coralligenous assemblages: a synthesis of present knowledge

453. This regional and global synthesis provides a comprehensive overview of Mediterranean coralligenous assemblages, highlighting their ecological significance, structural complexity, and vulnerability. The source functions as a critical scientific reference for standardizing regional monitoring and guiding restoration efforts. The document confirms that coralligenous assemblages' relevance is reflected in both structural and functional complexity: biogenic concretion formed by encrusting calcareous algae under low light supports diverse trophic networks and habitat-forming invertebrates. The synthesis emphasizes the need for standardization in monitoring, noting that existing data are fragmentary, geographically biased, and insufficient for basin-wide assessments, particularly in the Eastern Mediterranean.

454. The framework identifies principal threats: trawling, wastewater and pollution, extreme warming events result in mass mortality of key suspension feeders, invasive species and recreational diving. The document recommends comprehensive management strategies, including complete trawling prohibition in coralligenous areas, strict wastewater controls, mitigation of physical disturbances from coastal works, fisheries management to protect slow-growing target species, and legislation to prevent invasive species introduction. Recovery monitoring must consider the extreme longevity and slow dynamics of the biogenic structure, with full ecosystem recovery potentially requiring decades or centuries, while fish populations can respond more rapidly to protection.

Strengths, Gaps, and Applicability

455. Strengths include providing the most comprehensive synthesis of Mediterranean coralligenous biodiversity, structure, and function; quantifying vulnerability and low regenerative potential to guide prioritization; identifying key threats and actionable management measures; and highlighting knowledge gaps that inform future research needs.

456. Despite its breadth, the study highlights some limitations. Basin-wide quantitative data on habitat extent and biomass remain scarce, understanding of community resilience to climate change and mass mortality events is limited, and standardized methodologies for long-term recovery monitoring are still insufficiently developed.

457. The findings offer a solid foundation for the characterization, inventory, and monitoring of coralligenous habitats, supporting the development of harmonized Mediterranean protocols, and providing scientific justification for regulatory and restoration priorities in vulnerable, slow-recovering ecosystems.

64) Assessment of the *Sabellaria alveolata* reefs' structural features along the Southern coast of Sicily (Strait of Sicily, Mediterranean Sea)

458. This regional-scale study focuses on three Sabellaria alveolata reefs distributed along the southern coast of Sicily (Italy). These biogenic formations, built by the honeycomb worm S. alveolata, are key marine habitats. By analysing the structural attributes and developmental stages of these bioconstructions, the research advances the understanding of their ecological dynamics, conservation status, and role within coastal ecosystems. Additionally, it highlights the potential facilitating role of Posidonia oceanica meadows in the vicinity of the study sites, suggesting a link between seagrass presence and enhanced Sabellaria larval settlement and sediment capture.

459. This study directly supports the assessment, inventory, and monitoring components related to bioconstructions such as polychaete, serpulid, and vermetid reefs. The study addresses one of the key limitations hindering the inclusion of S. alveolata reefs in Mediterranean habitat assessments: the lack of consistent data on their extent, dynamics, and structural condition. Through the combined application of field-based macroscale and laboratory-based microscale analyses, the work establishes a replicable framework for identifying the developmental phases of Sabellaria reefs (progradation, stagnation, retrogradation). Monitoring these features over time provides a sound basis for evaluating reef health, persistence, and vulnerability to disturbance. Although not focused on active restoration, understanding these natural phases is crucial for developing conservation and management strategies, as well as for informing potential restoration actions aimed at enhancing habitat resilience and continuity.

460. A dual-scale methodology was implemented to capture structural and demographic characteristics. At the macroscale, measurements of reef diameter and thickness provide direct indicators of habitat extent and growth stage, with compact, large formations indicative of progradation and reduced dimensions suggesting retrogradation. Fragmentation was categorized as Low, Moderate, or High, reflecting structural stability, natural heterogeneity, and potential recruitment zones. At the microscale, opercular length and its coefficient of variability (CoV) serve as proxies for population age structure and recruitment potential. Sand porch presence further provides a qualitative indicator of reef conservation status. Additional features, such as erosion, crevices, and epibiont colonization, complement the assessment by describing reef persistence and resilience.

Strengths, Gaps, and Applicability

461. This study introduces a comprehensive, two-tiered methodology that integrates macroscale and microscale parameters for assessing and monitoring Sabellaria alveolata reefs. It provides the first structured approach to overcome the "Data Deficient" status of these habitats, producing consistent and objective data for inclusion in regional and European inventories. The defined indicators allow clear determination of developmental phase and structural integrity, supporting effective ecological evaluation and management decisions.

462. The framework is limited to polychaete bioconstructions and does not encompass other reef-forming taxa such as Cladocora caespitosa, oysters, serpulids, vermetids, or rhodolith beds. The study focuses primarily on natural growth cycles and structural patterns, with limited assessment of anthropogenic pressures or active restoration feasibility. No operational protocols for habitat enhancement, outplanting, or artificial reef creation are provided.

463. The outlined parameters offer practical tools for the assessment and monitoring of polychaete and similar biogenic reefs throughout the Mediterranean. This approach enables managers to identify developmental stages, distinguish between natural dynamics and external impacts, and quantify reef extent, persistence, and structural integrity. These metrics inform ecological evaluation, highlight contributions to coastal protection, and provide a basis for prioritizing conservation and restoration initiatives.

65) Do *Sabellaria alveolata* reefs act as nursery areas for juvenile fish? First evidence from the integration of drone-based imagery and underwater visual census data

464. This source provides a regional-national perspective focused on the central Tyrrhenian coast of Italy. It examines the ecological structure and functional role of Sabellaria alveolata, reefs along Atlanto-Mediterranean coastal areas. These reefs act as ecosystem engineers by consolidating soft-sediment environments into rigid bioconstructions, thereby altering local hydrodynamics, sediment retention, and resource availability. Functionally, they represent biodiversity hotspots that support high faunal diversity and perform key ecological services related to nursery provision and coastal protection. The study provides robust evidence supporting the nursery role of S. alveolata reefs.

465. Within this framework, the research tests the Nursery Role Hypothesis (NRH; Beck et al., 2001), demonstrating that S. alveolata reefs serve as preferential juvenile habitats for several coastal fish species, including Diplodus sargus, D. vulgaris, D. puntazzo, and Dicentrarchus labrax. Quantitative analyses confirm that these reefs act as essential nursery grounds supporting fish recruitment and survival.

466. The study introduces a novel integrated approach combining high-resolution drone-based mapping (UAV) and Underwater Visual Census (UVC) techniques for the spatial characterization and temporal monitoring of reef ecosystems. This approach enables non-destructive, high-accuracy quantification of reef extent and structure, even in shallow or turbid coastal waters where traditional in situ methods are limited. UAV-derived orthophoto mosaics, processed through Structure from Motion and Object-Based Image Analysis (OBIA), allow detailed mapping of Sabellaria reef cover and its spatial dynamics. Such data are essential for developing an inventory of ecosystem extent (expressed as surface area or percentage cover) and for detecting seasonal changes linked to natural accretion and erosion cycles, which reflect the ecosystem's regeneration potential.

467. An important structural indicator, the Compactness Ratio (CR), is proposed as a metric of reef integrity, derived from GIS-based analysis of the ratio between area and perimeter of mapped polygons. The CR provides a proxy for habitat fragmentation and complexity. The study reveals a non-linear relationship between CR values and juvenile fish density, with highest densities recorded both in massive, compact reefs ($CR > 0.5$) and in smaller, highly fragmented ones ($CR < 0.3$). This dual pattern highlights the ecological importance of even small, discontinuous bioconstructions, which offer increased refuge opportunities. Monitoring CR over time thus provides a powerful means of assessing reef stability and transitions between accretional and degraded phases.

468. To assess ecological function, the study applies standardized measures of juvenile fish density and condition, derived from UVC surveys and biometric analyses. Juvenile density serves as a quantitative criterion for evaluating nursery capacity. Results indicate a strong habitat association between juvenile fish and Sabellaria reefs compared with adjacent rocky substrates, confirming their key role in early life stages of commercially relevant species.

469. The Relative Condition Factor (Kn) is used to evaluate fish health and growth, integrating biometric data to assess habitat quality independent of body length. Higher Kn values and steeper length-weight regression slopes were observed for juveniles on Sabellaria reefs than on rocky habitats, suggesting enhanced food availability and overall better physiological condition. This metric provides a direct indicator of the ecosystem's contribution to recruitment and long-term population sustainability.

Strengths, Gaps, and Applicability

470. The document presents an innovative and replicable methodology that integrates remote sensing, spatial analysis, and ecological monitoring to quantify the structure and function of Sabellaria alveolata reefs. It establishes explicit links between habitat integrity and nursery performance using standardized, measurable indicators. The application of the Nursery Role Hypothesis provides a strong scientific rationale for the inclusion of these reefs in ecosystem inventories.

471. The scope is limited to bioconstructional systems, with no methodological adaptation or data applicable to other target ecosystems. Although the study informs prioritization for restoration, it does not include active restoration techniques.

472. The proposed UAV-UVC integrated framework and associated indicators should be adopted as a reference methodology for mapping and assessing Sabellaria reefs and analogous Mediterranean bioconstructions (e.g., serpulid or vermetid reefs). The derived parameters are critical for defining ecosystems of highest ecological and regeneration potential, ensuring that the 2027 inventory captures both the spatial extent and the functional quality of these habitats.

66) Feasibility of the Sabellarid Reef Habitat Restoration

473. This source provides a regional–national perspective based on a pilot restoration experiment conducted at Falconara Marittima, along the western coast of the central Adriatic Sea (Marche region, Italy). The study focuses on Sabellaria spinulosa, a sabellarid polychaete forming biogenic reefs that are restricted to the Adriatic coastline of the Italian Peninsula. These reefs represent shallow-water bioconstructions analogous to other Mediterranean engineer habitats. Sabellaria reefs, owing to their ecological importance and vulnerability, are designated as “Special Areas of Conservation” under Annex I of the EU Habitats Directive.

474. This source addresses the restoration feasibility of fragile bioconstructions when natural recovery capacity is limited. In this study a transplantation protocol for S. spinulosa reefs was tested. Quantitative evaluation of survival and attachment provided clear criteria for assessing the short-term persistence and regeneration potential of transplanted units, while confirming the ecological functions of Sabellaria reefs in coastal protection and juvenile habitat provision.

475. The restoration protocol developed involves the collection of small S. spinulosa reef fragments, which are embedded into terracotta vases using bicomponent epoxy putty. Once hardened, these “translocation units” are affixed to natural rocky substrates, providing a stable interface between the transplanted biogenic material and the substrate. This method minimizes fragment loss during initial stabilization and is well suited for dynamic shallow-water environments. The success of this low-cost, scalable approach demonstrates its potential as a regional guideline for the restoration of brittle bioconstructions in the Mediterranean.

476. To assess restoration performance, several quantitative indicators were defined. The Fragment Survival Rate, calculated as the proportion of translocated fragments hosting live worms at successive monitoring times (T1-T4) relative to those initially deployed (T0), represents the primary measure of restoration feasibility. Over 17 months, an overall survival of 54.2% was recorded, rising to 75% at the best-performing site (Site A), demonstrating high tolerance to manipulation and suggesting that S. spinulosa is a suitable candidate for restoration initiatives. The Vase Persistence parameter, quantifying the percentage of translocation units remaining attached to the substrate throughout the monitoring period, reached 83.3%, confirming the effectiveness of the fixation method under coastal hydrodynamic stress.

477. A third variable, Fragment Surface Area, measured from orthogonal photographs using ImageJ software and a metric reference grid (1 cm mesh), was used as a two-dimensional proxy for growth. Although initial surface reduction occurred during the first months post-translocation (T0-T2), the area stabilized in later stages (T3-T4), suggesting adaptation and structural equilibrium. However, no significant net growth was detected, indicating that microscale environmental conditions likely constrained further development.

478. This finding underscores the need to integrate microscale environmental parameters - including sediment granulometry, organic matter load, and hydrodynamic regime - into restoration planning. These variables are critical for site selection and for assessing regeneration potential, as they directly influence the worms’ ability to construct and maintain their tubes. Sediment grain size determines material availability for tube building, while water movement must balance sediment suspension and structural stability. Incorporating these parameters into future monitoring and assessment frameworks will enhance the reliability of restoration outcomes and help identify the most suitable locations for large-scale interventions.

Strengths, Gaps, and Applicability

479. This source provides the first tested and validated transplantation protocol for Sabellaria spinulosa reefs in the Mediterranean. The use of terracotta-based translocation units offers a practical and effective solution to the mechanical fragility of sabellarid structures. The study establishes clear, quantitative indicators that can serve as reference benchmarks for regional restoration projects. Furthermore, it explicitly reinforces the dual ecological role of sabellarid reefs in coastal protection and as nursery habitats.

480. Despite demonstrating transplantation feasibility, this study did not achieve measurable growth, highlighting the need for refined techniques and inclusion of environmental micro-parameters. Additionally, growth was evaluated using a two-dimensional area proxy rather than three-dimensional photogrammetry, potentially underestimating volumetric expansion.

481. The methodologies and quantitative criteria developed in this study offer a replicable framework to the restoration and monitoring of sabellarid reefs across the Mediterranean. The terracotta transplantation protocol and the baseline survival thresholds can serve as operational standards in future restoration guidelines.

67) Serpulid reefs and their role in aquatic ecosystems: A global review

482. This document presents a global review on Serpulid reefs worldwide, with significant Regional and National relevance for the Mediterranean context due to its extensive coverage of species (e.g. Protula tubularia, Hydroides dianthus, Ficopomatus enigmaticus, and Serpula vermicularis), all occurring in Italian, Greek, and Cypriot coastal waters.

483. The review provides a detailed framework for understanding the ecosystem functioning and services delivered by Serpulid reefs. Their ecological importance stems from the stabilization of sediments, water filtration, and carbon sequestration through calcium carbonate deposition, in addition to their role as habitat-forming species supporting diverse assemblages of associated invertebrates and fishes. The source explicitly highlights their nursery function and emphasizes their contribution to coastal protection by dampening wave energy and reducing shoreline erosion. The inclusion of Ficopomatus enigmaticus reefs in brackish and lagoonal environments extends the discussion to the interface between marine bioconstructions and coastal wetlands, providing a cross-ecosystem linkage.

484. The review defines a set of measurable parameters that include geochemical, biomechanical, and biological criteria that collectively capture their functional role and resilience capacity. The document distinguishes between two adaptive strategies among Mediterranean serpulids: the “hard” (resistance-based) strategy, characterized by compact, dense, and low-porosity tubes, and the “soft” (resilience-based) strategy, which alternates phases of rapid growth and structural collapse.

485. The review identifies several quantitative parameters: the Carbonate Deposition Rate provides a robust metric for estimating carbon storage capacity and comparing bioconstruction productivity with other calcifying systems. Tube mineralogy serves as a proxy for dissolution resistance and resilience under acidification scenarios, analogous to metrics applied for crustose coralline algae. The review further recommends structural descriptors such as wall thickness, bulk density, and porosity as key indicators of mechanical strength and stability. Reefs with high-density, low-porosity tubes should be prioritized in areas where coastal protection is a management objective. Biological parameters such as tube elongation rate and life span are also highlighted as essential indicators of growth performance and long-term stability, guiding the duration and temporal resolution of monitoring programs.

486. Finally, the source discusses mapping and classification methodologies relevant for the Inventory. The vertical development of Ficopomatus reefs in lagoons allows the use of aerial or UAV-based photography for spatial quantification, while a habitat-type classification facilitates standardized reporting and cross-regional comparisons.

Strengths, Gaps, and Applicability

487. This global synthesis provides a comprehensive framework for understanding the ecological, structural, and geochemical dynamics of Serpulid bioconstructions, with detailed Mediterranean case studies. It identifies quantitative indicators and defines the dual “hard–soft” strategy model.

488. While methodologically rich, the review is a synthesis rather than a field-based operational guide. It does not provide standardized restoration or monitoring protocols for non-polychaete bioconstructions. Moreover, it outlines the biophysical criteria for site selection but lacks an integrated site suitability model that combines environmental drivers (e.g., sediment dynamics, hydrodynamics, water chemistry) with reef persistence data.

489. The document presents data and classifications relevant to the understanding of Serpulid reef dynamics, including growth, resilience, and ecological function. Indicators such as carbonate deposition, tube mineralogy, and structural characteristics provide measurable information for research and inventory purposes, supporting comparative studies across Mediterranean regions.

68) New opportunities for conservation of a threatened biogenic habitat- a worldwide assessment of knowledge on bivalve-reef representation in marine and coastal Ramsar Sites

490. This document provides a global framework and assessment of the current state of knowledge concerning bivalve reefs within marine and coastal Ramsar Sites worldwide, with direct regional relevance for the Mediterranean context through the integration of data from the European Nature Information System (EUNIS). The focus is on bioconstructions formed by reef-building bivalves, such as oyster reefs and mussel beds, which act as essential ecosystem engineers by creating complex three-dimensional habitats that enhance biodiversity, stabilize shorelines, and contribute to water quality improvement. These habitats are frequently associated with coastal wetland systems, given their prevalence in intertidal and lagoonal environments, and thus represent a critical ecological interface between marine and terrestrial systems. Bivalve reefs provide multiple ecosystem services of high ecological and socio-economic relevance, including shoreline protection, water filtration, and nursery functions for marine organisms.

491. The study highlights that approximately 85% of oyster reefs have been lost globally and emphasizes that existing reporting systems are insufficient to map bivalve reefs comprehensively. To overcome this, it proposes a multi-source approach integrating GIS databases, expert and local ecological knowledge, and internet-based data searches. This integrated method enables a more accurate identification of existing and potential reef locations, a crucial step for building the Mediterranean ecosystem inventory and overcoming the limitations of official datasets alone.

492. The document specifies that a habitat must exhibit at least 25% live shell cover to be considered a true reef, ensuring that only ecologically functional structures are included in the inventory. Reefs must cover sufficiently large areas, typically including multiple patches in order to ensure the capacity to sustain key ecosystem services and the persistence of the community through time is recognized as an essential criterion for assessing regeneration potential, as reefs must demonstrate temporal stability over decadal scales to be considered resilient systems.

493. The methodological framework proposed also includes multi-source data integration as a practical approach to overcome the lack of spatial and ecological data. By combining public databases, expert input, and local ecological knowledge, the study demonstrates that no single information source provides sufficient coverage and that integrating heterogeneous data is essential to capture the true distribution of bivalve reefs.

494. Another relevant aspect is the use of harvesting pressure as a proxy for monitoring habitat condition. The study reports that bivalve species are mentioned in approximately 20% of Ramsar Sites, often in the context of being harvested, and that unsustainable extraction leads to degradation of the reef structure itself. In this sense, harvest intensity can be used as an indirect but critical indicator of habitat status, with high exploitation rates signalling immediate threats to reef integrity and coastal protection functions. Furthermore, the presence of reef-forming species such as Ostrea and Mytilus, even in the absence of a fully developed reef, is identified as an indicator of restoration potential. Sites where these species persist should be prioritized for

restoration actions, as they retain the biological foundation for natural recovery and recruitment compared to areas where reef-forming species are completely absent.

Strengths, Gaps, and Applicability

495. This document offers a rigorous and globally consistent framework for the assessment of bivalve reef habitats, grounded in quantifiable and operational criteria. It introduces a solid multi-source methodology that integrates centralized databases with expert and local ecological knowledge to address the widespread data deficiencies that hinder the recognition of these habitats. The approach is particularly valuable in the Mediterranean context, where information is often fragmented.

496. The source focuses exclusively on bivalve reefs and, to a lesser extent, coastal wetlands, without addressing other ecosystems. It does not provide specific methodological guidance for active restoration, including site-scale interventions, material selection, or outplanting protocols.

497. The definitional criteria and multi-source methodology are suitable for standardizing the Mediterranean inventory of bivalve reefs, allowing for verification of ecological functionality and resilience. The multi-source verification approach - combining public datasets, expert consultation, and local ecological knowledge - provides a replicable approach for consistent regional assessment.

69) Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management

498. This source represents a global review and assessment synthesizing quantitative data on the condition of native oyster reefs across more than 140 bays and 44 ecoregions worldwide. It holds direct significance particularly for Ostrea edulis reefs, which are among the most degraded biogenic habitats in European waters. The document highlights specific regional examples in Greece and the historical presence of extensive natural beds in Mar Menor, Spain.

499. The ecosystem focus is strictly on bivalve bioconstructions formed by reef-building oyster species that act as ecosystem engineers, creating complex three-dimensional habitats supporting entire communities. The document defines quantitative criteria for assessing ecological relevance through ecosystem services. It details how oyster reefs contribute to coastal protection, improve water quality through filtration and denitrification processes, and provide essential nursery habitats.

500. The source introduces quantitative condition ranks based on comparisons between current and historical abundance data derived from surveys and fisheries landings over timeframes of up to 130 years. These ranks - Functionally Extinct (>99% loss), Poor (90–99% loss), Fair (50–89% loss), and Good (<50% loss) - allow standardized, objective classification of reef condition, ensuring comparability across regions. Restoration efforts should focus on reefs in “Fair” or “Poor” condition, where regeneration potential remains viable, before they decline into the functionally extinct category.

501. The study stresses the need for realistic restoration goals, aiming to restore reef abundance to at least 10% of historical levels, and emphasizes the use of modern mapping technologies such as side-scan sonar, multibeam sonar, and LIDAR for spatial planning and long-term monitoring.

502. The document underlines the role of watershed-based management, addressing land-derived inputs of sediment, nutrients, and pollutants that undermine reef recovery, and highlights the use of oysters as bioindicators for monitoring environmental improvements.

Strengths, Gaps, and Applicability

503. This document provides a scientifically rigorous and globally recognized framework for assessing the condition and prioritization of oyster reef ecosystems. The quantitative thresholds allow for a consistent classification of habitat condition and facilitate prioritization of restoration actions. The source explicitly links oyster reefs to key ecological functions, providing a robust justification for their inclusion among priority ecosystems. It also offers concrete and technically sound recommendations for management and restoration, including technological, ecological, and governance aspects.

504. Despite its methodological robustness, the document does not include localized Mediterranean restoration guidelines. Its scope remains restricted to bivalve reef ecosystems. Furthermore, while it emphasizes restoration planning and threat mitigation, it does not provide cost analyses, governance models, or monitoring indicators adapted to national or subregional scales.

505. The Condition Rank classification offers a transparent, data-driven basis for prioritizing restoration sites, focusing resources on reefs in "Fair" or "Poor" condition to maximize regeneration success and avoid functional extinction. The integration of mapping technologies such as side-scan sonar and LIDAR should be embedded within regional inventory protocols to ensure accurate spatial coverage. This framework effectively acts as a triage system, distinguishing between critically degraded reefs requiring long-term recovery and those where immediate, targeted interventions can yield rapid ecological returns, thereby optimizing restoration outcomes across the region.

70) Site selection for European native oyster (*Ostrea edulis*) habitat restoration projects/ An expert-derived consensus

506. This source provides a regional framework built on a European process that involved experts from twenty different locations, including several Mediterranean countries such as Spain, Greece, Croatia, and France. The consensus reached ensures that the resulting criteria for site selection are broadly applicable across Europe, with particular relevance to the Mediterranean basin, where native oyster habitats have been nearly extirpated.

507. The ecosystem focus is on bivalve reefs, specifically those formed by the European native oyster (Ostrea edulis). This species, historically widespread, acted as a keystone biogenic engineer. Today, O. edulis is recognized as a threatened species, and its recovery is regarded as a key step in restoring lost ecosystem functions in European coastal and estuarine environments.

508. The source addresses what is described as the "essential first step in long-term project success" - the selection of ecologically and socio-economically suitable restoration sites. Through an expert-derived consensus, the document provides a structured checklist of sixty-five factors that influence restoration success. These factors encompass abiotic, biotic, logistical, socio-economic, and threat-related dimensions, offering a comprehensive approach to site selection.

509. With respect to the restoration objective, the document provides the ecological and environmental foundations required to ensure the long-term survival, fitness, and reproductive success of O. edulis. It directly responds to the high historical failure rate of marine restoration projects caused by poor site selection and inadequate implementation frameworks, thereby contributing indispensable guidance for effective project planning and execution. The document's structured criteria provide measurable and scientifically robust indicators for evaluating the regeneration potential of sites prior to restoration interventions. The inclusion of socio-economic and governance-related factors further ensures that selected sites will benefit from local support and institutional feasibility, which are key to long-term viability.

510. The value of this framework lies in its capacity to serve as a consensus-based reference for habitat suitability modelling and site assessment. It organizes all factors into two primary categories: essential (mandatory for all site selection exercises) and desirable (beneficial for enhancing restoration success and long-term ecosystem stability).

511. Among the essential abiotic factors determining the regeneration potential of O. edulis reefs, the document identifies several key parameters, such as salinity, water temperature, substrate suitability and stability, dissolved oxygen.

512. Beyond environmental parameters, the study emphasizes essential logistical and socio-economic factors necessary for long-term project sustainability: availability of source oysters, the incorporation of Local Ecological Knowledge (LEK), and stakeholder engagement and regulatory support.

513. The document also identifies a suite of threat and environmental risk factors that must be assessed prior to restoration. Destructive fishing, dredging, and seabed extraction activities are categorized as essential considerations, as they can completely undermine restoration success by destabilizing substrates and

damaging benthic communities. Disease prevalence and invasive non-native species (INNS) are designated as desirable monitoring parameters; while total exclusion of disease is unrealistic, robust biosecurity and regulatory coordination are mandatory to limit spread and mitigate impacts. Water quality parameters such as low sedimentation, low pollution, and limited sewage discharge are desirable factors that enhance oyster viability and growth, and their evaluation should include tidal dynamics and flushing capacity, which affect both salinity and oxygenation.

Strengths, Gaps, and Applicability

514. This document is a scientifically rigorous and operationally applicable regional frameworks for the restoration planning and ecological assessment of European native oyster reefs. Its primary strength lies in the expert consensus approach which integrates multidisciplinary expertise, ensuring both scientific robustness and geographical representativeness. The explicit definition of quantitative abiotic thresholds provides clear, measurable parameters that can be directly incorporated into habitat suitability models. Additionally, the recognition of Local Ecological Knowledge as an essential factor represents an innovative advancement, particularly for Mediterranean regions where ecological datasets are fragmented or absent.

515. Despite its methodological depth, the framework remains limited to Ostrea edulis reefs and cannot be directly applied to other ecosystem types. The document focuses on site selection and pre-restoration assessment but does not detail the subsequent stages of restoration implementation. Furthermore, while it highlights threats and socio-economic conditions, it lacks standardized quantitative methodologies for assessing their relative weight or influence on site prioritization, leaving room for variability among national applications. The absence of explicit consideration for cumulative pressures under future climate projections represents another limitation, particularly relevant for the Mediterranean context where multiple stressors interact.

516. From an applied perspective, the expert-derived checklist of sixty-five site-selection criteria provides a structured reference tool for evaluating ecological suitability, feasibility conditions, and long-term persistence potential of native oyster reef restoration sites. The subset of seventeen essential factors - spanning abiotic thresholds, threat mitigation requirements, and socio-economic preconditions - functions as an effective pre-screening mechanism for identifying locations with the highest probability of ecological recovery and structural stability. The framework's integrated consideration of environmental conditions, governance capacity, and community engagement further enhances its practical relevance, supporting restoration planning processes that are both ecologically grounded and operationally feasible within complex coastal management settings.

71) The Native Oyster Restoration Alliance (NORA) and the Berlin Oyster Recommendation- bringing back a key ecosystem engineer by developing and supporting best practice in Europe

517. The document is classified as regional, focusing on the development and support of best practices for oyster restoration across European seas, including the North Sea and the Atlantic. It was produced by the Native Oyster Restoration Alliance (NORA), a collaborative network of experts from 11 European countries, under the framework of the Berlin Oyster Recommendation (BOR). The initiative aims to guide and harmonize restoration actions for the native European flat oyster (Ostrea edulis) in alignment with EU-level obligations, including the Habitats Directive and OSPAR recommendations.

518. The Berlin Oyster Recommendation provides a structured and scientifically grounded framework for restoration planning, ensuring that restoration initiatives achieve ecological significance, robustness, and long-term sustainability. The ecological rationale for restoration is clearly articulated, emphasizing the wide range of ecosystem services provided by oyster reefs. The document highlights that in many areas, passive recovery is not feasible due to the scarcity of remaining broodstock and substrate, making active restoration a necessity for the achievement of the 2030 restoration target.

519. The operational structure of the framework is articulated through six core recommendations addressing site identification, seed supply, genetic integrity, disease management, monitoring, and ecosystem service evaluation. A central methodological component is the classification of restoration sites into three

functional categories: reintroduction areas where the species is absent but habitat suitability persists; reinforcement areas where remnant populations survive at densities insufficient for natural recruitment; and conservation areas hosting viable, self-sustaining populations that function as genetic reservoirs. This categorization supports a gradient-based prioritization of interventions according to ecological condition and recovery potential.

520. Genetic management constitutes a further pillar of the framework. The recommendations stress the necessity of establishing diversified seed production systems through hatcheries, spatting ponds, and collector devices, while safeguarding local adaptations via broodstock sanctuaries. The use of geographically appropriate broodstock is prioritized to avoid genetic homogenization and to maintain resilience to disease and environmental variability. Monitoring guidance calls for standardized and comparable protocols capable of assessing not only survival and recruitment, but also the progressive recovery of ecosystem functions, including biodiversity support and water filtration capacity.

521. Threat mitigation measures are also extensively addressed. Substrate limitation is identified as a major bottleneck for larval settlement, leading to recommendations for shell retention policies and active substrate enhancement. Disease risk is treated as a critical management dimension requiring strict procedures, controlled translocations, and precautionary approaches in pathogen-free zones. Collectively, the framework integrates ecological, genetic, and operational considerations into a cohesive model for large-scale oyster reef restoration planning.

Strengths, Gaps, and Applicability

522. The document constitutes the most comprehensive and scientifically consolidated European framework for the restoration of biogenic bivalve reefs. Its strengths lie in the systematic structure that integrates ecological, genetic, and biosecurity principles with explicit criteria for site categorization (reintroduction, reinforcement, conservation). The inclusion of standardized monitoring and the emphasis on assessing ecosystem services ensure that restoration outcomes are measurable, comparable, and directly linked to biodiversity enhancement, coastal protection, and carbon and nutrient cycling functions.

523. While comprehensive within its scope, the document focuses exclusively on Ostrea edulis and does not address other types of Mediterranean bioconstructions. Moreover, it offers a strategic and conceptual framework rather than a detailed operational manual, lacking precise methodological protocols for field implementation, deployment design, or cost assessment.

524. Despite these constraints, the integrated approach to site categorization, genetic management, substrate enhancement, and biosecurity establishes a transferable conceptual and procedural model for guiding oyster reef recovery initiatives across diverse European marine settings.

72) Restoration of the endemic hermatypic coral *Cladocora caespitosa* in the Mediterranean Sea- coral gardening based on micro-fragmentation

525. This document, of regional and national scope, presents a pioneering study on the active restoration of the endemic zooxanthellate coral Cladocora caespitosa, based on coral gardening and micro-fragmentation techniques. Donor material was collected from two Adriatic sites to develop a restoration protocol that minimizes impact on natural colonies while generating new coral stock ex-novo. The study focuses on Cladocora bioconstructions, which form reef-building coral structures in the Mediterranean, significantly contributing to habitat complexity, biodiversity, and carbon sequestration. Given its slow growth, longevity, low dispersal capacity, and vulnerability to heatwave-induced mortality, C. caespitosa is listed as Endangered on the IUCN Red List. The coral gardening approach consists of two phases: ex-novo stock generation through the collection of “corals of opportunity” (naturally detached fragments that would otherwise be lost) and subsequent micro-fragmentation to stimulate asexual growth. Fragments of 1–20 polyps were produced, fixed on ceramic supports using cyanoacrylate and epoxy, and maintained under controlled aquarium conditions before outplanting. Two structural designs were tested - nursery modules (aluminium frames elevated from soft substrates) and restoration modules (smaller netted frames secured to rocky substrates) - both demonstrating resistance to hydrodynamic stress and suitability for long-term maintenance and larval

replenishment. The study provides a detailed methodological framework including measurable biological indicators for monitoring regeneration and ecological performance. Budding frequency (extra-tentacular budding rate per initial polyp) is proposed as a direct regeneration potential metric; results showed that micro-fragmented colonies reached higher budding frequencies than naturally occurring juveniles, confirming accelerated regeneration. Growth rate demonstrated structural expansion and carbonate accretion consistent with enhanced carbon stock potential. Thermal resistance tests showed 80% survival of bleached fragments and full recovery in most cases. This result supports site-specific donor selection based on local thermal adaptation, essential for developing climate-resilient restoration strategies. The study further quantifies the ecological relevance of C. caespitosa through its calcification rate, providing a quantitative metric for carbon stock assessment.

Strengths, Gaps, and Applicability

526. This source represents a critical advancement in Mediterranean restoration science, delivering a fully tested, ethically sound, and replicable methodology for the active restoration of Cladocora caespitosa bioconstructions. The experimental results demonstrate the strong regenerative capacity of micro-fragmented colonies, validated by measurable indicators. The approach provides standardized metrics for carbon stock, regeneration rate, resilience, scalable coral gardening and outplanting. Moreover, its emphasis on the use of "corals of opportunity" ensures minimal ecological disturbance and compliance with conservation ethics for an endangered species.

527. The study's taxonomic scope is limited to C. caespitosa, offering no methodological transferability to other key ecosystems. The monitoring period, although methodologically rigorous, was limited to a few months, which constrains long-term validation of survival, growth, and reproductive success. Additionally, the study does not provide economic or logistical guidance for scaling the methodology across multiple Mediterranean countries.

528. The protocol establishes a reproducible framework for designing restoration interventions targeting Cladocora reefs. The proposed indicators - such as budding frequency, linear growth, and calcification rates - offer measurable benchmarks for evaluating regeneration performance at both donor and recipient sites. Furthermore, the documented thermal tolerance gradient observed between northern and southern Adriatic populations introduces a relevant ecological variable for site selection and climate-adapted restoration planning, particularly under scenarios of increasing marine heatwave frequency.

73) Population structure change in a temperate reef coral after a quarter of century

529. At the national level, this work presents a long-term reassessment of the population structure and bioconstructional potential of Cladocora caespitosa. The study focuses on the Eastern Ligurian Sea (NW Mediterranean, Italy), revisiting a coral bed 25 years after the first survey (1994-2019). While primarily local in scope, the findings are framed within the broader Mediterranean context through the analysis of basin-wide mortality events associated with thermal anomalies, supported by global NOAA Sea Surface Temperature (SST) datasets.

530. The study demonstrates a marked reduction in mean colony diameter and the complete disappearance of large colonies, indicating a substantial decline in the reef's bioconstructional capacity. This change, combined with a strong positive correlation between colony size and necrosis/epibiosis rate, highlights the species' high vulnerability and the need for targeted restoration and monitoring strategies.

531. The methodological framework proposed is grounded in quantifiable and replicable field parameters suitable for comparative assessment across Mediterranean bioconstructions. Colony density is used to measure abundance and spatial coverage, yet in this case an apparent density increase masked an underlying structural decline-highlighting the necessity of pairing abundance metrics with size-based indicators. Colony size structure, assessed through size-frequency distributions spanning six classes (<5 cm to 25-30 cm), emerged as a key diagnostic variable: the shift from dominance of medium-sized colonies (10-15 cm in 1994) to small colonies (<5 cm in 2019) provides a rapid proxy for reduced reef accretion capacity. Mortality rates, calculated as the percentage of necrosis and epibiosis coverage, function as direct colony-health indicators and confirm size-dependent susceptibility. Environmental stress proxies, derived from annual SST maxima, show

correspondence between mortality peaks and documented thermal anomaly years (1997, 1999, 2003, 2012, 2015), quantitatively linking demographic change to climate forcing.

532. From a field-design perspective, the sampling configuration, four replicate 5 × 5 m quadrats per site, covering a total of 100 m², constitutes a standardized and reproducible protocol for both inventory and long-term monitoring applications. The revisitation of historically surveyed locations demonstrates the analytical value of integrating legacy datasets into contemporary ecological assessments, enabling the detection of structural trajectories that would otherwise remain obscured. Moreover, the statistical correlation between colony size and necrosis prevalence provides an operational basis for identifying sites exhibiting heightened ecological vulnerability.

Strengths, Gaps, and Applicability

533. A primary strength of the study resides in the provision of long-term, statistically validated ecological data for Cladocora caespitosa. The work establishes a suite of fully quantifiable structural and health indicators that can be consistently replicated in comparative assessments. The integration of in situ demographic observations with thermal anomaly records further strengthens causal interpretation by linking local degradation patterns to broader climatic drivers. In addition, the revisitation approach underscores the operational importance of historical baselines in detecting ecosystem change.

534. The investigation is restricted to a single site and species, reducing extrapolative capacity across other Mediterranean bioconstruction systems. While the temporal comparison spans 25 years, it is based on two principal survey points, limiting the resolution of intermediate recovery or decline dynamics.

535. The assessment framework offers a transferable model for evaluating structural condition in sessile bioconstructor habitats. The combined use of density, size-frequency structure, and colony health indicators provides an integrated lens through which reef functionality and degradation status can be interpreted. The quadrat-based sampling design and revisitation logic are particularly suited to the establishment of permanent monitoring sites, supporting the long-term tracking of structural recovery, vulnerability gradients, and climate-driven change within temperate reef environments.

2.7 Comparative analysis and identification of strengths, gaps, and applicability

536. The following Table 1 consolidates all 74 previously reviewed sources, detailing their identified strengths, gaps and their applicability to the development of harmonized national inventories, monitoring programs, and restoration prioritization in the Mediterranean region. The sources have been classified with a high or moderate score based on their level of applicability to Action 12 objectives, reflecting guidance for inventory, monitoring, and restoration planning. Within the sources classified as having high applicability, specific criteria, indices, conceptual frameworks, and habitat codes were extracted as methodological references to inform the development of criteria and indicators for assessing ecological relevance and regeneration potential.

Table 1. Summary of the 74 reviewed sources, detailing strengths, gaps, applicability, and overall score. Sources are classified as “high” or “moderate” based on their level of applicability for supporting harmonized Mediterranean inventories, monitoring programs, and restoration prioritization.

Source name	Strengths	Gaps	Applicability	Score
REGULATION (EU) 2024/1991 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on nature restoration and amending Regulation (EU) 2022/869 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401991	-Legally binding and standardised EU framework -Clear, time-bound restoration targets -Harmonised ecosystem classification (EUNIS-HD consistency) -Supports spatially explicit assessment through GIS and remote sensing	-EU-level framework with limited adaptation to regional Mediterranean contexts and monitoring needs - Limited operational guidance for non-coded or complex bioconstructions (e.g., vermetid and serpulid reefs)	Provides fully transferable legislative and methodological standards, enabling direct adoption of EU-aligned inventory, assessment, and restoration protocols.	**High**
Nature Restoration Plan Development Process in EU Member States (WWF/BirdLife, 2025) https://www.birdlife.org/wp-content/uploads/2025/12/RestoreNature-NRP_mid-term-assessment.pdf	-Clear operationalization of FRA and FRV concepts - Benchmarking of Mediterranean EU Member States - Strong linkage between science, governance, and legal compliance - Identification of best practices from frontrunner countries	- Limited transparency in national scientific baselines - Uneven stakeholder engagement across Member States - Insufficient data availability for independent technical validation	Supports the translation of ecosystem inventories into legally robust restoration plans, informing prioritization, governance readiness, and alignment with NRL requirements under Action 12.	**High**
IUCN Red List of Ecosystems Categories and Criteria Guidelines https://iucnrle.org/	-Global recognition -Standardised methodology adaptable to all Mediterranean ecosystems -Quantitative indicators -Criteria on ecosystem status assessment -Collapse thresholds	-Ecosystem services not considered -Lack of Mediterranean case studies -Lack of region-specific calibration	Offers directly operational quantitative criteria and thresholds, making it highly usable for ecosystem characterization, assessment, and monitoring under Action 12.	**High**

IUCN Global Ecosystem Typology 2.0 (GET) https://portals.iucn.org/library/sites/library/files/documents/2020-037-En.pdf	-Universal, scalable framework -Strong methodological rigour -Enables harmonized classification and assessment across all levels -Integrates with RLE for ecosystem status evaluation -Focuses on ecosystem functional attributes	- Requires Mediterranean specific calibration and mapping at finer ecosystem levels - Lacks prescribed indicators and quantitative monitoring thresholds - Methodological difficulties in aligning (cross walking) global and national classification systems	Provides a solid global reference framework, supporting harmonized Mediterranean inventories and restoration prioritization.	**High**
Guidelines for using a Global Standard for the Identification of Key Biodiversity Areas (Version 1.2) https://portals.iucn.org/library/node/49979	-Rigorous, quantitative, repeatable, transparent methodology -Links ecosystem science with spatial prioritization -Aligned with GET and RLE (A2, B4) -Considers "restoration dependency" principle	- Limited high-resolution data for sublittoral habitats - Criteria C and D thresholds need Mediterranean adaptation - Crosswalks with national habitat mapping (EUNIS, HD) not formalized	Supports site-level, evidence-based inventories and monitoring for Mediterranean ecosystem conservation and restoration.	**High**
IUCN Mediterranean blue carbon strategy (2025-2030) https://portals.iucn.org/library/sites/library/files/documents/2025-015-En.pdf	-Integrates ecological, policy, financial perspectives -Clearly aligns with SAPBIO Action 12 objectives -Promotes harmonization across Mediterranean countries	- Primarily conceptual, offering limited operational guidance - Uneven spatial and temporal data coverage, especially in southern countries - Restoration methodologies referenced but not detailed	Provides regional guidance for Action 12 prioritization but operational detail and data coverage are limited.	**Moderate**
The Ecosystem Approach: Foundational Framework (CBD guidelines) https://www.cbd.int/doc/publications/ea-text-en.pdf	-Integrative and flexible, supporting adaptive management and harmonized conservation-use strategies -Promotes ecosystem-based management of land, water, and living resources	-Broad and largely conceptual -Lacks quantitative metrics or standardized protocols (requires integration with RLE/GET) -Requires institutional alignment and data harmonization	Strong conceptual guidance for Action 12; limited by lack of standardized metrics and need for regional adaptation.	**Moderate**
Considerations on ecosystem restoration for the Post-2020 Global Biodiversity Framework (CBD)	-Promotes outcome-focused restoration using functional and spatial indicators	-Limited guidance for marine/coastal ecosystems, especially sublittoral habitats -Regional adaptation of indicators required	Conceptually strong for Action 12 but needs regional adaptation and	**Moderate**

https://www.cbd.int/doc/c/fcd6/bfba/38ebc826221543e322173507/post2020-ws-2019-11-03-en.pdf	-Frames restoration as improvement of ecological integrity	-Socio-economic trade-offs not always explicitly quantified	habitat-specific calibration.	
UN Decade on Ecosystem Restoration Strategy (2021–2030) https://globalseaweed.org/wp-content/uploads/2024/12/UN-Decade-on-Ecosystem-Restoration-Strategy.pdf	-Provides coherent goals and standardized restoration methodologies (SER standards, ROAM) -Explicit guidance for marine, coastal, and terrestrial habitats. -Links restoration to multiple SDGs (14 and 15)	-Global tools (e.g., ROAM) require local scale operationalization -Reference ecosystem parameters need adaptation for Mediterranean contexts	Guides Action 12 implementation but requires local adaptation and ecosystem-specific calibration.	**Moderate**
UN Ecosystem Restoration for People, Nature and Climate (UNEP report) https://wedocs.unep.org/bitstream/handle/20.500.11822/36251/ERPNC.pdf	-Quantifies restoration benefits (economic returns, climate mitigation) -Highlights coastal wetlands and seagrass beds as efficient carbon sinks. -Links restoration to coastal protection (wave attenuation)	-Global estimates need regional adaptation for Mediterranean ecosystems -Requires localization to Mediterranean biophysical and socio-economic contexts	Provides foundational guidance for Action 12 but needs regional adaptation and context-specific calibration.	**Moderate**
A metric for spatially explicit contributions to science-based species targets (STAR metric - Nature) https://www.nature.com/articles/s41559-021-01432-0	-Rigorous, quantitative, globally consistent prioritization framework -Spatially explicit design targets high-impact restoration actions -Supports prioritization using ecological relevance and restoration potential (STARR score)	-Limited marine and Mediterranean data -Needs integration with IMAP/Barcelona Convention data	Supports Action 12 prioritization and monitoring but requires Mediterranean-specific data integration.	**Moderate**
Scientific Foundations for an IUCN Red List of Ecosystems, Keith at al. (2013) https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0062111	-Globally recognized, standardized, theoretically grounded -Integrates spatial, compositional, and functional metrics (A–E) -Supports forward-looking evaluations for restoration prioritization	-High-quality spatial and functional data may be limited in some Mediterranean areas -Predictive modelling depends on scenario assumptions and local validation	Directly operational for Action 12, providing fully standardized, science-based metrics for Mediterranean ecosystems.	**High**
Manuale di interpretazione habitat Natura2000	-Harmonizes terminology and habitat codes for EU-wide application	-Some habitat types need regional adaptation	Provides valuable guidance on	**Moderate**

https://www.mase.gov.it/portale/documents/d/guest/int_manual_eu28-pdf	-Explicitly identifies priority habitats -Supports integration with regional monitoring protocols (Barcelona Convention)	beyond CORINE interpretation	habitats codes and contributes to regional harmonization of inventories and monitoring but includes less updated coding compared to other high applicability references.	
The ecosystem approach (CBD Secretariat, 2004) https://www.cbd.int/doc/publications/ea-text-en.pdf	-Global framework promoting adaptive, multi-scale, participatory management -Integrates ecological, socio-economic, and governance principles	-Requires localization and adaptation to regional Mediterranean ecosystems -Needs operational protocols and sufficient monitoring/coordination capacity	Supports Action 12 planning and adaptive management but needs regional adaptation and operational protocols.	**Moderate**
International principles and standards for the practice of ecological restoration. Second edition (SER) https://research.fs.usda.gov/treesearch/60367	-Scientifically validated framework with measurable criteria -Globally applicable and aligned with UN Decade and SDGs -Provides standardized assessment via six attributes and five-star recovery scale	-Limited habitat-specific guidance for marine systems -Bias towards terrestrial and freshwater examples -Implementation constrained by scarce baseline data and long-term monitoring capacity	Conceptually robust framework for restoration and monitoring but limited habitat specificity and dependent on baseline data.	**Moderate**
The value of the world's ecosystem services and natural capital https://www.nature.com/articles/387253a0	-Provides globally recognized, quantitative valuation (TEV) -Quantifies economic value of coastal and marine ecosystems per hectare -Highlights the importance of natural capital and its scarcity	-Global scale estimates need regional calibration and contextualization -Limited consideration of spatial heterogeneity and connectivity -Lacks site-specific management applicability	Provides quantitative, policy-relevant guidance, but requires regional calibration and site-specific adaptation.	**Moderate**
The cost and feasibility of marine coastal restoration	-Integrates ecological, technical, and economic analysis within a global framework	-Lacks Mediterranean-specific methodologies for target ecosystems	Offers standardized feasibility and monitoring guidance but limited by	**Moderate**

https://esajournals.onlinelibrary.wiley.com/doi/10.1890/15-1077	-Provides quantitative survival benchmarks for key habitats -Demonstrates the influence of site conditions and methodology on restoration success	-Data biased toward temperate and more developed regions -Short monitoring duration limits evaluation of long-term recovery	regional specificity and short-term data.	
Agenda item 4- Assessment methodologies, assessment criteria and thresholds for biodiversity common indicators CI1 and CI2 https://spa-rac.org/uploads/CKFiles/files/25_wg_606_5_en.pdf	- Regionally standardized with clear indicators and thresholds - Defines Common Indicators for habitat inventory and condition - Provides specific metrics for major benthic habitats	-Inconsistent and incomplete monitoring of habitat extent across Contracting Parties -Lack of standardized indices for certain habitats -Persistent challenges in data harmonization and intercalibration	Directly operational for Action 12; standardizes Mediterranean monitoring and supports multi-ecosystem assessment integration.	**High**
A Meta-Review on New Technologies for Marine Biodiversity Monitoring and Assessment (IEEE, 2025) https://ieeexplore.ieee.org/abstract/document/11245732	- Non-extractive, high-resolution monitoring technologies - Integration of remote sensing, robotics, eDNA, and AI - Applicable to complex and sensitive benthic habitats - Quantitative support for carbon stock and regeneration potential	- No standardized decision framework for method selection - Limited guidance for Mediterranean-specific environmental variability - Cost and technology readiness not systematically addressed	Provides advanced methodological tools for ecosystem characterization, inventory, and monitoring, supporting the scientific basis required for Action 12 implementation.	**High**
Integrated Meetings of the Ecosystem Approach Correspondence Groups on IMAP Implementation (CORMONs) – Update of Monitoring Protocols on Benthic Habitats (UNEP/MED WG.482/20) https://rac-spa.org/cormon1/docs/20wg482_20_eng.pdf	-Authoritative, regionally relevant guidance for benthic habitat -Standardized methodologies for habitat distribution (CI1) and condition (CI2) -Provides specific metrics for *Posidonia*, Coralligenous, and Rhodolith beds	-Challenges in scaling intensive local measurements to larger spatial assessments	Fully transferable for Action 12; enables standardized inventory, assessment, and restoration across Mediterranean benthic habitats.	**High**

Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes (M. SALOMIDI et al.) https://ejournals.epublishing.ekt.gr/index.php/hcmr-med-mar-sc/article/view/11996/12005#:~:text=The%20relative%20value%20of%20seabed,threats%20to%20European%20seabed%20biotopes	-Integration of ecosystem goods and services, vulnerability, and conservation status -Linkage between biotopes and ecological functions -Aligned with EUNIS classifications and MSFD criteria	-Limited spatial resolution in some EUNIS assessments	Supports Action 12 prioritization and parameter selection, though limited spatial resolution constrains full regional applicability.	**Moderate**
Best practices, measures and lessons learnt for biodiversity restoration, ensuring carbon sink optimization and buffering resilience to climate extremes (UNEP/MAP-SPA/RAC, 2024) https://spa-rac.org/en/publication/1760/best-practices-measures-and-lessons-learnt-for-biodiversity-restoration-ensuring-carbon-sink-optimization-and-buffering-resilience-to-climate-extremes	-Detailed synthesis of Mediterranean restoration experiences -Links restoration techniques to measurable outcomes (survival rates, carbon fixation potential) -Emphasizes carbon sink optimization and resilience	-Limited scale of some interventions (e.g., Coralligenous full habitat restoration) -Relatively short monitoring periods for assessing long-term ecosystem service recovery	Offers regionally validated restoration protocols but limited spatial scale and short monitoring reduce full regional transferability.	**Moderate**
Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region https://www.rac-spa.org/sites/default/files/doc_fsd/habitats_list_en	-Standardized Mediterranean benthic classification -Aligns with IMAP/MAP -Covers key ecosystems -Authoritative reference for Action 12	-No field protocols or active restoration guidance -Limited socio-economic integration -Scaling requires adaptation	Provides a robust baseline for identifying priority habitats, designing monitoring programs and supporting Action 12 restoration planning and evaluation.	**High**

Updated Reference List of Marine Habitat Types for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest in the Mediterranean https://www.rac-spa.org/sites/default/files/doc_fsd/reference_list_en.pdf	-Definitive, legally binding regional framework -Standardized, EUNIS-compatible codes -Uses a quantitative scoring system (8 traits, score ≥ 16) for transparent prioritization	-Lacks detailed methodological guidance on field data collection and analytical protocols -Scoring thresholds are uniform and may not account for local variability	Core reference for inventory, restoration prioritization, codes, and harmonized Mediterranean monitoring.	**High**
A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean https://www.sciencedirect.com/science/article/abs/pii/S0141113621001434	-Standardized regional classification -Comprehensive coverage of Mediterranean benthic habitats -Directly linked to IMAP/MAP objectives -Supports inventory, monitoring, and restoration planning	-No operational field protocols -Limited socio-economic integration -Scaling local data to regional assessments may require adaptation	Enables consistent habitat identification and prioritization, supporting scientifically defensible monitoring program design, and guiding restoration planning to achieve Action 12 targets.	**High**
Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE e Direttiva 09/147/CE) in Italia: ambiente marino https://www.isprambiente.gov.it/files2019/pubblicazioni/manuali-linee-guida/MLG_190_19.pdf	-Standardized national guide (Italy) -Integrates EU directives and RAC/SPA guidelines -Includes both habitat-level and indicator-species-level monitoring	-Requires adaptation for use outside Italy -Some deep-sea habitats need specialized equipment (ROVs, high-resolution mapping)	Supports Action 12 inventory and restoration but limited by geographic scope and technical requirements.	**Moderate**
Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural	-Harmonized, region-wide classification framework -Serves as an operational bridge between regional (SPA/RAC) and EU (NATURA 2000) conservation systems	-Does not incorporate recent ecological monitoring innovations (e.g., remote sensing, functional metrics)	Standardized guidance for inventory, monitoring, and prioritization of high-	**High**

sites of conservation interest (RAC/SPA) https://www.researchgate.net/publication/278773393_Handbook_for_Interpreting_Types_of_Marine_Habitat_for_the_Selection_of_Sites_to_be_Included_in_the_National_Inventories_of_Natural_Sites_of_Conservation_Interest	-Offers clear diagnostic and management guidance for key habitats	-Qualitative descriptions may need quantitative thresholds -Limited inclusion of emerging threats (e.g., climate change impacts)	relevance, low-regeneration habitats.	
An introduction to the Ramsar convention https://www.ramsar.org/sites/default/files/documents/library/handbook1_5ed_introductiontoconvention_final_e.pdf	-Comprehensive framework for diverse wetland types -Broad ecological scope encompassing seagrass, dunes, bioconstructions -Regional applicability strengthened through the MedWet initiative	-Uneven monitoring implementation among Parties -Limited resolution of data for certain coastal/marine wetland types -Monitoring not fully aligned with restoration-oriented metrics (e.g., carbon stock recovery)	Provides useful inventory and assessment guidance but constrained by uneven monitoring and limited metric alignment.	**Moderate**
Inventory, assessment, monitoring - An Integrated Framework for wetland inventory, assessment and monitoring (HBK 13, 2010) https://www.ramsar.org/sites/default/files/documents/pdf/lib/hbk4-13.pdf	-Scientifically coherent framework integrating multiple assessment tools (EIA, SEA, RA, VA) -Ensures consistency and applicability across spatial scales	-Inconsistent implementation among Contracting Parties -Ongoing data gaps for marine and coastal wetlands	Supports standardized inventory and monitoring but limited by uneven implementation and remaining data gaps.	**Moderate**
A Conceptual Framework for the wise use of wetlands and the maintenance of their ecological character (Resolution IX.1 Annex A, 2005) https://www.ramsar.org/sites/default/files/documents/pdf/guide/guide-wise-use-2005-e.pdf#:~:text=A%20Conceptual%20Framework%20for%20wetland%20wise%	-Globally recognized framework defining ecological character through structure, function, services -Establish a solid baseline for restoration planning -Ensures interventions focus on functionality and benefits	-Needs operational guidance to translate high-level principles into site-specific metrics -Limited focus on underrepresented habitats	Provides conceptual and methodological guidance but requires site-specific adaptation and broader habitat coverage.	**Moderate**

20use,well%20as%20human%20well%2Dbeing%20and%20poverty%20alleviation				
A Framework for Wetland Inventory (Resolution VIII.6, 2002) https://www.ramsar.org/sites/default/files/documents/pdf/guide/guide-inventory-framework-e.pdf	-Detailed operational guidance for conducting inventories -Advocates GIS/remote sensing integration for spatial delineation -MedWet highlighted as a standardized regional guide	-Operational challenges for complex or small-scale habitats where fine-scale mapping is critical	Strong methodological foundation but limited for small-scale or complex habitats requiring fine-scale mapping.	**Moderate**
Describing the ecological character of wetlands, and data needs and formats for core inventory: harmonized scientific and technical guidance (Resolution X.15, 2008) https://www.ramsar.org/sites/default/files/documents/pdf/res/key_res_x_15_e.pdf	-Global framework, provides harmonized and technical guidance -Integrates ecosystem components, processes, and services relevant to Action 12	-Translation of measures to fine-scale, patchy habitats requires field validation	Provides solid baseline guidance but requires field validation for fine-scale, patchy habitats.	**Moderate**
Wetland Risk Assessment Framework (Resolution VII.10, 1999) https://www.ramsar.org/sites/default/files/documents/pdf/guide/guide-risk-e.pdf	-Six-step methodology for threat assessment -Prioritization of restoration -Prescribes early warning indicators	-Need to calibrate indicators to local species and habitat conditions -Limited integration of emerging pressures (climate change-driven impacts)	Useful for identifying degradation and guiding restoration but requires local calibration and climate adaptation.	**Moderate**
Principles and guidelines for wetland restoration (Resolution VIII.16, 2002) https://www.ramsar.org/sites/default/files/documents/pdf/guide/guide-restoration.pdf	-Global framework for planning, implementation, and monitoring restoration activities -Emphasizes national prioritization and multifunctionality -Promotes ecological engineering solutions	-Need for standardized metrics for measuring multifunctional outcomes -Limited guidance on incorporating emerging climate pressures -Performance standards must be clearly defined and measurable	Provides technical foundation for Action 12 restoration but requires standardized metrics and climate adaptation.	**Moderate**
An Integrated Framework and guidelines for avoiding, mitigating and	-Clear decision-making hierarchy (Avoidance → Mitigation → Compensation)	-Limited quantitative thresholds for functional equivalence and	Guides Action 12 restoration, emphasizing functional	**Moderate**

compensating for wetland losses (Resolution XI.9, 2012) https://www.ramsar.org/sites/default/files/documents/pdf/guide/guide-losses-e.pdf	-Emphasizes type-for-type and function-focused compensation -Uses a risk-based decision-making matrix	ecosystem service outcomes -Needs adaptation to local contexts	outcomes but requires local adaptation and lacks quantitative thresholds.	
Guidelines on biodiversity-inclusive environmental impact assessment and strategic environmental assessment (Resolution X.17, 2008) https://www.ramsar.org/sites/default/files/documents/pdf/res/key_res_x_17_e.pdf	-Integrates biodiversity considerations into both strategic (SEA) and project-level (EIA) planning -Reinforces the Avoid-Mitigate-Compensate sequence -SEA frameworks addresses indirect drivers of ecosystem degradation	-Lacks quantitative guidance for cumulative impacts and measuring biodiversity outcomes	Useful for Action 12 planning and prioritization but lacks quantitative biodiversity and cumulative impact metrics.	**Moderate**
Ramsar Site Management Effectiveness Tracking Tool (R-METT) (Resolution XII.15, 2015) https://www.ramsar.org/sites/default/files/documents/library/guide_r-mett_e.pdf	-Global, standardized methodology for assessing management effectiveness -Tracks trends in ecological character using ECD baselines -Integrates with Wetland Risk Assessment (WRA)	-Dependent on high-quality baseline data -Some functional services may require additional site-specific indicators	Supports Action 12 restoration assessment but relies on site-specific data and additional indicators.	**Moderate**
Mediterranean Wetland Inventory: A Reference Manual https://www.medwet.org/codde/OtherResources/ReferenceManual.pdf	-Ramsar-endorsed, regionally harmonized methodology -Scalable inventory approach from rapid assessment to detailed GIS mapping -Integrates functional and structural parameters	-Requires adaptation for local contexts with limited data/field capacity -Detailed inventory requires specialized skills and equipment	Guides Action 12 inventory and restoration but dependent on local adaptation and technical capacity.	**Moderate**
Valuing wetlands. Guidelines for valuing the benefits derived from wetland ecosystem services (Ramsar/CBD) https://www.researchgate.net/publication/40110849_Valuing_Wetlands_Guidance_for_Valuing_the_Be	-Standardized globally recognized, methodology for ecosystem valuation -Links valuation to inventory, monitoring, and policy frameworks -Offers practical tools for prioritization of high ecological relevance habitats	-Quantitative valuation is limited by data availability	Supports Action 12 valuation and prioritization but constrained by limited data and regional adaptation needs.	**Moderate**

nefits_Derived_from_Wetland_Ecosystem_Services				
Assessing the potential for restoring mediterranean coastal dune under pressure from tourism (DPR/StaDun Index) https://link.springer.com/article/10.1007/s11852-022-00860-9	-Quantitative and replicable methodology -Introduces the Dune Restoration Potential Index (DPR) and StaDun Index -Integrates natural and anthropogenic components	-Requires calibration for broader Mediterranean contexts -Does not incorporate climate change–related pressures	Useful for Action 12 inventory and prioritization but needs regional calibration and climate integration.	**Moderate**
Coast dune management guide (NERC) https://nora.nerc.ac.uk/id/eprint/5233/1/Coast_dune_management.pdf	-Operational and field-tested restoration practices -Provides empirically derived recovery timelines for monitoring	-Lacks site-specific adaptation for Mediterranean -Limited consideration of climate-driven processes -Does not include quantitative indicators or scoring systems	Transferable for Action 12 restoration but limited by climate and site-specific adaptation.	**Moderate**
Development of a coastal dune vulnerability index for Mediterranean ecosystems- A useful tool for coastal managers? (MDVI) https://www.researchgate.net/publication/311807835_Development_of_a_coastal_dune_vulnerability_index_for_Mediterranean_ecosystems_A_useful_tool_for_coastal_managers#:~:text=2014)%20or%20by%20analyzing%20specific,Liyun%20et%20al	-Provides a regionally adapted, multidisciplinary index (MDVI) -Integrates geomorphological, marine, aeolian, biological, anthropogenic factors -Practical, repeatable diagnostic tool	-Requires validation across broader Mediterranean contexts	Provides practical guidance for Action 12, though broader regional validation is needed.	**Moderate**
Morphology and composition of beach-cast Posidonia oceanica litter on beaches with different exposures https://www.researchgate.net/publication/233812015_Morphology_and_composition_of_beach-cast_Posidonia_oceanica_litter_on_beaches_with_di	-Demonstrates the functional role of banquettes in coastal protection and dune regeneration -Offers quantitative, site-specific data on banquette morphology and composition -Links human activities (removal) with ecosystem degradation	-Limited to Sardinia sites -Long-term dynamics under varying climatic or human pressures remain underexplored	Useful for inventory and management but limited geographic and long-term scope.	**Moderate**

fferent_exposures#:~:text=The%20results%20of%20the%20study,the%20size%20and%20overtopping%20capacity				
Results of the Providune project: restoration of the "Coastal dunes with Juniperus spp." priority habitat in Sardinia (LIFE Providune) https://www.scienzadellavegetazione.it/wp-content/uploads/2023/07/522.pdf	-Combines in situ and ex situ restoration techniques -Provides quantitative baseline data -Demonstrates effective mitigation of human impacts	-Limited to Sardinia sites -Long-term success of reintroduced populations under variable climate is uncertain	Provides tested restoration guidance but geographic and climatic scope is limited.	**Moderate**
Guidelines for the Standardization of mapping and monitoring methods of marine magnoliophyta in the Mediterranean https://www.rac-spa.org/sites/default/files/doc_mkh/vegetation/algue_eng_bd_cover.pdf	-Harmonized and scientifically robust framework -Prescribes technological standards (remote sensing, acoustic methods) with a reliability index -Standardizes descriptors	-Some assessment parameters are destructive, limiting repeated monitoring	Directly operational for seagrass inventory, monitoring and restoration; ensures regional standardization and comparability.	**High**
Management of Posidonia Beaches Examples from Mediterranean Destinations https://iucn.org/sites/default/files/2024-07/posbemed-booklet-examples-from-mediterranean-destinations_compressed.pdf	-Provides concrete Nature-based Solutions -Integrates governance, communication, and collaboration	-Local solutions may lack direct transferability due to diverse legal, ecological, or social contexts -Monitoring frameworks are often site-specific and may require scaling up	Provides practical, site-tested guidance but limited transferability across diverse Mediterranean contexts.	**Moderate**
Conservazione e gestione della naturalità negli ecosistemi marino-costieri. Il trapianto delle praterie di *Posidonia oceanica* (ISPRA)	-Comprehensive and empirically grounded methodological references for *P. oceanica* transplantation -Aligns with international legal	-Limited applicability of certain techniques outside specific substrate conditions -High cost and technical complexity -Requires long-term monitoring	Offers tested restoration methods but constrained by cost, technical demands and site specificity.	**Moderate**

https://www.academia.edu/57470906/Il_trapianto_delle_praterie_di_Posidonia_oceanica	frameworks (Barcelona, Bern, EU HD) -Offers field-tested technical guidance			
Guidelines for the active restoration of *Posidonia oceanica* (MPN, 2024) https://bluedotassociates.com/downloads/EN-Guidelines-for-Posidonia-oceanica-restoration-2024.pdf	-Comprehensive, regionally harmonized framework aligned with RAC/SPA strategy -Emphasizes the mitigation hierarchy (avoidance > restoration) -Offers technical guidance (optimal depth, substrate, biodegradable fixations)	-Acknowledges the absence of full ecological function recovery in restored meadows -Limited long-term monitoring data across Mediterranean sites	Provides practical restoration guidance, though limited by incomplete recovery data and short-term monitoring.	**Moderate**
Monitoring protocol for *Posidonia oceanica* beds (MedMPAnet/RAC/SPA, Croatia) https://www.rac-spa.org/sites/default/files/doc_medmpanet/monitoring_protocol_posidonia_croatia.pdf	-Standardized monitoring framework fully aligned with RAC/SPA, UNEP/MAP, and EU directives -Clear operational guidance -Establishes quantitative thresholds (e.g., Conservation Index CI > 0.9 for high status)	-Limited baseline data and long-term monitoring limits trend assessment -Current classification thresholds may require adaptation to local Adriatic conditions	Useful for inventory and restoration but constrained by limited baseline data and need for local adaptation.	**Moderate**
A biotic index using the seagrass *Posidonia oceanica* (BiPo), to evaluate ecological status of coastal waters https://www.sciencedirect.com/science/article/abs/pii/S1470160X0900123X	-Scientifically validated, standardized framework directly linked to RAC/SPA -Harmonized classification thresholds and non-destructive methods -Promotes long-term, multi-scale monitoring	-Uneven implementation among Contracting Parties due to capacity gaps -High-precision mapping and long-term data continuity are resource-intensive -Focuses primarily on *P. oceanica*	Supports standardized assessment and restoration but limited by uneven implementation and resource intensity.	**Moderate**
A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the water framework directive (WFD) https://www.sciencedirect.com/science/article/abs/pii/S0025326X06003225	-Fully compliant with WFD and directly applicable to Mediterranean monitoring -Integrates multiple ecological levels into a single index (PCA) -High sensitivity to anthropogenic pressures	-Reference condition approach may limit cross-regional comparability -Application is restricted to *P. oceanica* -Requires specialized data collection and statistical expertise	Operational and robust for *P. oceanica* but limited cross-regional transferability and requires technical expertise.	**Moderate**

	-Pragmatic approach for data-limited or degraded areas			
A new synthetic index and a protocol for monitoring the status of *Posidonia oceanica* meadows - A case study at Sanremo https://www.researchgate.net/publication/229563360_A_new_synthetic_index_and_a_protocol_for_monitoring_the_status_of_Posidonia_oceanica_meadows_A_case_study_at_Sanremo_Ligurian_Sea_NW_Mediterranean	-Introduces two synthetic indices (CI and SI) quantifying structural degradation and functional phase shift -Integrates advanced mapping (side-scan sonar) with *in situ* monitoring -Clear, quantifiable metrics for assessing restoration effectiveness	-Requires regional calibration -Biotic descriptors (e.g., species diversity) not fully integrated -Technological and logistical costs may limit replication	Scientifically robust and transferable but requires calibration and may face logistical constraints.	**Moderate**
Descriptors from *Posidonia oceanica* (L.) Delile meadows in coastal waters of Valencia, Spain, in the context of the EU Water Framework Directive https://academic.oup.com/icesjms/article/65/8/1492/714280	-Scientifically validated set of nine descriptors for WFD monitoring -Integrates quantitative classification (EQR) supporting consistent ecological status assessment -Links specific descriptors to distinct anthropogenic pressures	-Requires further validation for broader Mediterranean application -Some descriptors may vary seasonally -Limited integration of faunal components	Provides measurable indicators for assessment but limited spatial/temporal scope and faunal integration.	**Moderate**
Ecosystem functions and economic wealth- Trajectories of change in seagrass meadows (Emergy Analysis) https://www.researchgate.net/publication/319575824_Ecosystem_Functions_and_Economic_Wealth_Trajectories_of_Change_in_Seagrass_Meadows#:~:text=oceanica%20meadows%20are%20reported%20to,%2C%202019).%20	-Integration of ecological reconstruction, emergy accounting, and economic valuation -Clear quantitative basis for historical loss and ecological degradation -Offers a transferable framework for defining reference conditions	-Geographically limited to the Ligurian Sea -Emergy valuation approach requires local calibration	Quantifies losses and supports prioritization but geographically limited and requires local calibration.	**Moderate**
Lepidochronological analysis of the seagrass *Posidonia oceanica* (L.)	-Standardized, regionally validated methodology	-Currently specific to *P. oceanica*	Provides essential baselines and functional	**Moderate**

Delile: a standardized approach https://www.researchgate.net/publication/248197127_Lepidochronological_analysis_of_the_seagrass_Posidonia_oceanica_L_Delile_a_standardized_approach	-Temporal resolution for reconstructing historical baselines -Links biological, physical, and environmental data	-Interpretation can be influenced by local conditions	metrics but limited to *P. oceanica* and local conditions.	
MANAGEMENT of Natura 2000 habitats * Posidonia beds (Posidonion oceanicae) 1120 (EC) https://op.europa.eu/en/publication-detail/-/publication/c9f3ee20-d98f-4cfe-9067-b9834a00a5a1/language-en	-Harmonized, science-based framework aligned with EU/Mediterranean policies -Quantitative environmental thresholds -Emphasizes protection and prevention due to species' slow recovery dynamics	-Limited consideration of climate change impacts -Transplantation methodologies remain experimental/discouraged as compensatory measures	Supports Action 12 restoration and monitoring but limited by experimental methods and climate-change considerations.	**Moderate**
The value of the seagrass *Posidonia oceanica*: A natural capital assessment (Emergy) https://www.sciencedirect.com/science/article/abs/pii/S0025326X13004311	-Objective, standardized valuation of ecosystem services using Emergy accounting -Quantifies the financial consequences of habitat loss	-Focuses on the Ligurian Sea -Long-term effectiveness under climate change scenarios needs validation -Focuses on valuation rather than biological monitoring	Informs Action 12 prioritization and management but geographic and functional scope is limited.	**Moderate**
Monitoring and assessment of the ecological status of coralligenous habitat (ISPRA STAR Protocol) https://www.isprambiente.gov.it/files2021/pubblicazioni/manuali-e-linee-guida/mlg-191bis-2020.pdf	-Provides a scientifically validated, standardized protocol -Integrates structural, compositional, and vitality parameters -Uses Italian-developed Ecological Quality Indices	-Requires recalibration for sub-regions beyond the Western Mediterranean -Reliance on visual assessment may limit detection of cryptic stressors	Provides standardized assessment for coralligenous habitats but regional calibration and detection limits reduce transferability.	**Moderate**
Standard methods for inventorying and monitoring coralligenous and rhodoliths populations	-Standardized, regionally relevant methodology for complex Coralligenous and Rhodolith assemblages	-High technical and operational demands may limit use in resource-constrained areas -Limited baseline cartographic	Fully supports inventory, monitoring, and restoration of Coralligenous and Rhodolith	**High**

https://www.rac-spa.org/sites/default/files/doc_mkh/coralligenous/corail_bd_cover.pdf	-Integrates technological and field-based approaches -Emphasizes long-term monitoring and reproducibility	coverage across the Mediterranean	habitats across the Mediterranean.	
The coralligenous in the Mediterranean Sea (SAP BIO Project, Ballesteros) https://www.rac-spa.org/sites/default/files/doc_spabio/b1eng.pdf	-Comprehensive regional scientific review -Establishes ecological baseline, structural components, and biodiversity metrics -Quantifies vulnerability and low regenerative potential	-Near-total absence of cartography across the Mediterranean -Insufficient knowledge on resilience and recovery dynamics -Some historical data may be outdated	Essential for Action 12 inventory and prioritization but limited by sparse cartography and incomplete resilience data.	**Moderate**
Action Plan for the Conservation of the Coralligenous and Other calcareous Bio-concretions in the Mediterranean Sea (RAC/SPA) https://www.rac-spa.org/sites/default/files/action_plans/pa_coral_en.pdf	-Clear, regionally endorsed strategic framework under the Barcelona Convention -Integrates restoration, monitoring, and management	-Incomplete development and application of standardized indices and protocols -Restoration methods are underdeveloped given habitat's complexity	Supports Action 12 guidance and national harmonization, but protocols and restoration methods remain partially developed.	**Moderate**
Coralligenous reefs state along anthropized coasts: Application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach https://www.sciencedirect.com/science/article/abs/pii/S1470160X14006025	-One of the first standardized, field-tested indices for assessing coralligenous reef integrity -Aligns with MSFD Descriptor 6 and IMAP objectives -Combines scientific robustness with operational feasibility	-Currently validated only in specific regions of the northwestern Mediterranean -Relies partly on expert judgment for defining anthropogenic pressure gradients -Does not yet incorporate long-term temporal dynamics or direct recovery metrics	Provides standardized baseline and site prioritization tools but regionally limited and lacking long-term recovery data.	**Moderate**
Development of a new biotic index for ecological status assessment of Italian coastal waters based on coralligenous macroalgal assemblages (ESCA)	-Standardized, non-destructive, and cost-effective ecological index (ESCA) -Harmonizes WFD structural assessment with MSFD functional objectives	-Currently calibrated for the northwestern Mediterranean -Focuses primarily on macroalgal assemblages -Limited validation across temporal scales	Supports regional monitoring and restoration prioritization but limited to NW Mediterranean and macroalgae.	**Moderate**

https://www.tandfonline.com/doi/full/10.1080/09670262.2014.918657	-Uses validated reference conditions and intercalibrated methods			
Mediterranean coralligenous assemblages: a synthesis of present knowledge (Ballesteros, 2006) https://www.cigesmed.eu/wp-content/uploads/2021/07/2006_Ballesteros_Oceanography-and-Marine-Biology-An-Annual-Review_Mediterraneous-coralligenous-assemblages-a-synthesis-of-present-knowledge_xs.pdf	-Comprehensive scientific synthesis of coralligenous structure, biodiversity, and function -Quantifies vulnerability and low regenerative potential -Provides actionable management recommendations (e.g., trawling prohibition)	-Scarcity of basin-wide quantitative data on biomass and habitat extent -Limited information on resilience to climate change and mass mortality events	Provides strong scientific basis for inventory and restoration but limited spatial coverage and climate-resilience date.	**Moderate**
Assessment of the *Sabellaria alveolata* reefs' structural features along the Southern coast of Sicily https://ejournals.epublishing.ekt.gr/index.php/hcmr-med-mar-sc/article/view/30434	-Comprehensive, two-tiered methodology (macro and microscale) for *S. alveolata* assessment -Defines objective indicators for developmental phase and structural stability -Provides the first structured framework for this data deficient habitat	-Limited to polychaete bioconstructions -Limited consideration of anthropogenic drivers or restoration feasibility	Useful for inventory and assessment of polychaete reefs, though restricted to natural dynamics and not restoration planning.	**Moderate**
Do *Sabellaria alveolata* reefs act as nursery areas for juvenile fish? First evidence from the integration of drone-based imagery and underwater visual census data https://iris.uniroma1.it/bitstream/11573/1710281/1/Ventura_Do-Sabellaria-alveolata_2024.pdf	-Innovative and replicable integrated methodology for structural and functional quantification -Links habitat integrity with nursery performance -Standardized, measurable indicators (Compactness Ratio, juvenile density, Relative Condition Factor)	-Lacks active restoration techniques	Directly applicable for structural and functional assessment of Sabellaria reefs but limited by absence of active restoration guidance.	**Moderate**
Feasibility of the Sabellarid Reef Habitat Restoration (*Sabellaria spinulosa*)	-First tested and validated transplantation protocol for sabellarid	-Focuses exclusively on *S. spinulosa*	Directly usable for sabellarid reef assessment,	**Moderate**

https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2022.854986/full	reefs in the Mediterranean -Low-cost, scalable approach -Clear, quantitative survival indicators	-Need for refined techniques and micro-parameters	though species-specific focus and need for fine-scale parameters limit broader regional application.	
Serpulid reefs and their role in aquatic ecosystems: A global review https://www.sciencedirect.com/science/article/abs/pii/S0065288122000025	-Comprehensive framework integrating ecological, structural, and geochemical dynamics of Serpulid bioconstructions -Identifies quantitative indicators -Defines a dual "hard–soft" strategy model (resistance vs. resilience)	-Functions as a synthesis rather than an operational field-based guide -Lacks an integrated site suitability model -Does not provide standardized protocols for non-polychaete bioconstructions	Provides a solid conceptual and assessment basis for Action 12 but limited operational guidance for field implementation and site suitability.	**Moderate**
New opportunities for conservation of a threatened biogenic habitat- a worldwide assessment of knowledge on bivalve-reef representation in marine and coastal Ramsar Sites https://www.researchgate.net/publication/273140889_New_opportunities_for_conservation_of_a_threatened_biogenic_habitat_a_worldwide_assessment_of_knowledge_on_bivalve-reef_representation_in_marine_and_coastal_Ramsar_Sites	-Rigorous and globally consistent framework for inventory and assessment of bivalve reefs -Quantifiable and operational criteria -Solid multi-source methodology (GIS + expert/local knowledge) to address data deficiencies	-Does not provide specific methodological guidance for active restoration	Supports Mediterranean bivalve reef inventories with multi-source verification but lacks active restoration protocols.	**Moderate**
Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management https://academic.oup.com/bioscience/article-	-Scientifically rigorous and globally recognized framework -Introduces the Condition Rank system -Explicitly links oyster reefs to key ecological functions	-Does not include localized Mediterranean restoration guidelines -Scope remains restricted to bivalve reef ecosystems	Provides structured assessment for oyster reefs but limited to bivalves and lacks Mediterranean-specific	**Moderate**

abstract/61/2/107/242615?redirectedFrom=fulltext			restoration guidance.	
Site selection for European native oyster (Ostrea edulis) habitat restoration projects/ An expert-derived consensus (Delphi) https://onlinelibrary.wiley.com/doi/full/10.1002/aqc.3917	-Scientifically rigorous, consensus-based framework -Comprehensive checklist (65 factors) for site suitability evaluation -Explicit definition of quantitative abiotic thresholds -Recognizes Local Ecological Knowledge (LEK) as an essential factor	-Limited to *Ostrea edulis* reefs -Focuses on site selection and pre-restoration assessment (not implementation protocols) -Lacks quantitative methodologies for weighting cumulative pressures	Useful as a standardized pre-screening tool for *O. edulis* site selection but limited to one species and lacks full implementation protocols.	**Moderate**
The Native Oyster Restoration Alliance (NORA) and the Berlin Oyster Recommendation- bringing back a key ecosystem engineer by developing and supporting best practice in Europe https://www.alr-journal.org/articles/alr/full_html/2019/01/alr190016/alr190016.html	-Most comprehensive and scientifically consolidated European framework for bivalve reef restoration -Introduces a tripartite site categorization (reintroduction, reinforcement, conservation) for inventory -Emphasis on ecosystem services monitoring	-Focuses exclusively on *Ostrea edulis* -Lacks detailed operational manuals/cost assessment -Requires calibration for Mediterranean hydrographic and thermal regimes	Directly supports Action 12 but limited to *O. edulis* and requires regional adaptation.	**Moderate**
Restoration of the endemic hermatypic coral *Cladocora caespitosa* in the Mediterranean Sea- coral gardening based on micro-fragmentation https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2025.1605099/full	-Fully tested, ethically sound, replicable methodology for the active restoration of *C. caespitosa* -Demonstrates accelerated regeneration potential -Provides standardized metrics for assessment and restoration	-Geographic and taxonomic scope limited to *C. caespitosa* -Monitoring period was short, constraining long-term validation -Does not provide economic or logistical guidance for regional scaling	Quantitative for *C. caespitosa* assessment but limited by narrow taxonomic/geographic scope and short-term validation; not fully scalable regionally.	**Moderate**
Population structure change in a temperate reef coral after a quarter of century	-Long-term, statistically validated data for *C. caespitosa* -Fully quantifiable parameters directly applicable to inventory and assessment	- Focuses on a single site and species - Does not include detailed restoration or intervention methodologies	Provides transferable metrics for *Cladocora* and similar bioconstructions, but limited	**Moderate**

https://www.sciencedirect.com/science/article/abs/pii/S027277142200110X	-Integrates field ecology with climate data -Demonstrates the operational value of site revisitation for long-term ecosystem trend analysis	- Short-term revisit (two time points) limits temporal resolution of recovery trajectories	by single-site focus, short-term data, and absence of full restoration guidance.	

3. Criteria and indicators to evaluate ecological relevance and regeneration potential of marine ecosystems (phase 2)

537. The development of criteria and methodology for inventory and assessment builds directly upon the outcomes of the desk review and the comparative analysis of the available scientific and technical literature. From the full corpus of 74 analysed sources, a subset of 15 documents was identified as having the highest applicability for supporting the identification of ecosystems with high ecological relevance and regeneration potential. These sources were selected because they provide particularly robust, operational, or conceptually mature contributions - whether in the form of well-defined ecological criteria, habitat-specific indicators, updated classification codes, or methodological frameworks directly relevant to ecosystem assessment.

538. Together, these 15 high-applicability sources offer the most substantive and scientifically defensible basis for defining criteria related to ecological relevance and regeneration potential. They contain key elements that support the identification of criteria for ecological relevance and regeneration potential, as well as insights essential for determining which Mediterranean ecosystems should be prioritised in national and regional inventories. Their methodological inputs also contribute to the structuring of assessment procedures, including the identification of habitat attributes, functional traits, and pressure-response relationships relevant for evaluating ecosystem condition and restoration potential.

539. Accordingly, Table 2 synthesizes the principal conceptual and methodological inputs extracted from this selected group of high-applicability sources. The aim is to derive a coherent set of assessment criteria, methodologies, and codes for identifying ecosystems of high ecological relevance and regeneration potential, while ensuring methodological consistency and compatibility with regional standards (IMAP, EUNIS, Barcelona Convention).

Table 2. List of 15 high-applicability sources and their key contributions, summarizing the specific concepts, indicators, and methodological elements identified as relevant for the development of criteria and the design of the ecosystem inventory.

High applicability source	**Key contributions**
REGULATION (EU) 2024/1991 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869	- Establishes binding EU-level restoration obligations and temporal targets - Provides mandatory ecological objectives to inform target-state definitions - Highlights priority ecosystem functions to integrate into the scoring system - Ensures alignment with EU habitat classifications through explicit links to Habitat Directive codes
Nature Restoration Plan Development Process in EU Member States (WWF/BirdLife, 2025)	- Operationalizes FRA and FRV concepts for translating inventories into restoration targets - Identifies governance and scientific criteria required for legally robust Nature Restoration Plans - Supports integration of ecological, socio-economic, and feasibility considerations into restoration scoring frameworks
IUCN Red List of Ecosystems Categories and Criteria Guidelines	- Provides the globally accepted quantitative framework for assessing ecosystem risk and vulnerability - Ensures methodological coherence through mandatory alignment with the IUCN Global Ecosystem Typology (GET) - Supplies risk categories and quantitative criteria (A-E) that support weighting of ecological relevance and assessment of degradation - Introduces standardized spatial (EOO, AOO) and functional metrics directly applicable to habitat distribution and condition assessments - Offers a structured approach for handling uncertainty and support expert-based inference where data are limited
IUCN Global Ecosystem Typology 2.0 (GET)	- Provides a coherent, scalable global framework for structuring ecosystem inventories - Harmonizes ecosystem identification across Mediterranean and regional datasets - Supplies hierarchical nomenclature for organizing ecological relevance - Supports integration of ecological constraints into assessment design

IUCN Global Standard for the Identification of Key Biodiversity Areas (Version 1.2): A Framework for Site-Level Biodiversity Prioritization	- Provides globally consistent criteria and quantitative thresholds for identifying priority biodiversity sites across species, genetic, and ecosystem levels - Offers explicit benchmarks for selecting nursery areas based on key life-stage population proportions - Provides metrics to assess ecological integrity and functional role of coastal ecosystems in delivering coastal protection services - Establishes data quality standards favouring Area of Occupancy (AOO) or Extent of Suitable Habitat (ESH) for precise inventory and assessment - Introduces the principle of restoration potential to guide prioritization of sites capable of recovery
Scientific Foundations for an IUCN Red List of Ecosystems (Keith et al., 2013)	- Provides quantitative criteria for assessing ecosystem vulnerability - Maps habitat-specific degradation metrics to standardized risk assessment - Introduces functional decline concepts to quantify severity beyond mere area loss
Agenda item 4 - Assessment methodologies, assessment criteria and thresholds for biodiversity common indicators CI1 and CI2	- Establishes quantitative thresholds to guide the scoring of the habitat status - Defines reference states for habitat condition, supporting baseline-based assessment and restoration targets
A Meta-Review on New Technologies for Marine Biodiversity Monitoring and Assessment (IEEE, 2025)	- Defines state-of-the-art, non-extractive methodologies for ecosystem characterization and assessment - Enables high-resolution spatial and structural mapping of marine habitats relevant to carbon stock and coastal protection - Provides data-rich inputs for quantifying regeneration potential and informing restoration prioritization
Guidelines for the Standardization of mapping and monitoring methods of marine magnoliophyta in the Mediterranean	- Provides standardized methods for mapping and monitoring *P. oceanica* across the Mediterranean - Specifies inventory technologies, combining Remote Sensing, Side Scan Sonar, and field ground-truthing integrated into GIS

	- Defines condition metrics for assessing habitat status - Introduces Lepidochronological analysis to quantify past growth and regeneration potential over time
Integrated Meetings of the Ecosystem Approach Correspondence Groups on IMAP Implementation (CORMONs) - Update of Monitoring Protocols on Benthic Habitats (UNEP/MED WG.482/20)	- Defines quantitative thresholds and classification schemes for coralligenous habitats using different indices - Provides harmonized and validated monitoring protocols within the EcAp/IMAP framework
Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region	- Establishes the official EUNIS-based classification and nomenclature for Mediterranean benthic habitats, ensuring standardized inventory and monitoring across Contracting Parties - Provides specific codes for habitats - Guides the selection of mapping methodologies (GIS protocols, software) capable of accurately delineating priority habitats for carbon stock, coastal protection, regeneration potential
Updated Reference List of Marine Habitat Types for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest in the Mediterranean	- Provides the official prioritization framework for Mediterranean habitats, based on 8 ecological traits - Defines a scoring mechanism where habitats scoring ≥16 are considered of high ecological relevance - Designates mandatory priority habitats - Offers a clear, quantitative basis for integrating ecological relevance into inventory and assessment criteria
A review of the classification systems for marine benthic habitats and the new updated Barcelona Convention classification for the Mediterranean (Montefalcone et al., 2021)	- Provides scientific and strategic rationale for regional habitat prioritization - Guides inventory methodology by promoting a physiognomic approach for non-destructive habitat classification - Ensures nomenclature stability
Standard methods for inventorying and monitoring coralligenous and rhodoliths populations	- Provides standardized protocols for surveying coralligenous and rhodolith habitats, including structural and species composition

	- Defines operational limits and precision of inventory methods - Identifies habitat-forming species and associated megafauna as core indicators
Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest	- Provides foundational biocenotic and functional context for Mediterranean habitats, supporting ecological relevance assessment - Highlights *P. oceanica*'s functional roles (coastal protection, biodiversity support, carbon sequestration) - Emphasizes preventive management approaches for fragile habitats to maintain regeneration potential - Recommends classification by bathymetric stage and substrate type to structure assessment criteria appropriately

3.1 Criteria and scoring system for habitat prioritisation

540. While the desk review encompassed the full range of habitats under consideration - including coastal dunes, wetlands, coralligenous assemblages, and seagrass systems - the subsequent methodological development has been intentionally focused on marine habitats, in line with the knowledge and experience of the experts that have been involved. The methodological approach followed during the phase 2 ensured a more robust, coherent, and technically grounded elaboration of criteria and scores for the assessment of habitats with high ecological relevance and regeneration potential.

541. The inventory and assessment frameworks were developed using habitat typologies and classification codes derived from the main European and regional reference systems, namely the Habitats Directive, EUNIS system, and the SPA/RAC classification framework (SPA/RAC-UN Environment/MAP, 2019a). A total of 287 marine benthic habitats were considered across all bathymetric levels, including littoral, infralittoral, circalittoral, offshore circalittoral, upper bathyal, lower bathyal, and abyssal zones, ensuring a comprehensive representation of Mediterranean benthic ecosystems (Annex I).

542. To support the identification of ecosystems with high ecological relevance and regeneration potential, eight biological criteria were defined and applied to each habitat type in order to evaluate their ecological value and their potentiality to recover following perturbations. This biologically based assessment approach follows the methodology previously used to identify “Reference Habitats” - those with high ecological and conservation value (SPA/RAC-UN Environment/MAP, 2019b) - from the comprehensive list of benthic habitats (SPA/RAC-UN Environment/MAP, 2019a), and also incorporates additional initiatives and criteria developed to identify priority habitats for conservation (Ballesteros, 2017). A semi-quantitative scoring system based on three classes was applied to each criterion: score 1 (low), score 2 (medium), score 3 (high). In cases where information is insufficient or unavailable for a specific habitat type under a given criterion (i.e., data deficient), a score of 0 can be assigned to account for uncertainty and data gaps within the assessment framework.

543. The selected criteria include:

1. Uniqueness
2. Significance
3. Species diversity
4. Structural complexity
5. Vulnerability
6. Modifying capacity
7. Resilience
8. Regeneration potential

544. Each criterion was designed to capture complementary ecological and functional dimensions of habitat relevance, combining biodiversity value, ecosystem functioning, resistance to pressures, recovery capacity, and restoration feasibility.

545. Uniqueness is defined as the degree to which a habitat is considered ecologically important because it is rare at the Mediterranean scale or because it hosts species that are rare, protected, endemic, keystone, threatened, or endangered, thereby contributing to the region’s unique biodiversity and ecological functioning. The score 1 is assigned when the habitat is not rare and does not host any endemic, rare, keystone, threatened, or endangered species. The score 2 is assigned when the habitat is not rare or is relatively rare and hosts at least one endemic, rare, keystone, threatened, or endangered species. The score 3 is assigned when the habitat is rare and/or hosts several endemic, rare, keystone, threatened, or endangered species. Intermediate situations, particularly habitats that are not rare but host species of high conservation relevance, are therefore included within the score 2 class to maintain methodological simplicity and consistency.

546. Significance refers to the role of a habitat in supporting the survival, reproduction, or spawning of species that may not be typical of that habitat throughout their life cycle, such as nursery habitats, as well as in providing essential ecosystem services, with particular emphasis on biomass production, carbon sequestration, water filtration, and coastal protection. The score 1 indicates that the habitat has a limited role in these functions. The score 2 indicates a

significant role in at least one of these ecosystem services. The score 3 indicates a significant role in several of these ecosystem services.

547. Species diversity is defined as the level of biodiversity within a habitat, evaluated based on the order of magnitude of species richness it can typically support. This criterion does not rely on the absolute number of species, but rather on a comparative assessment of whether a habitat hosts relatively low, moderate, or high levels of biodiversity in relation to other habitats. The score 1 corresponds to low species diversity, the score 2 to medium species diversity, and the score 3 to high species diversity, assigned when the habitat represents a biodiversity hotspot. No specific biodiversity indices or threshold values are applied to this criterion, as biodiversity patterns are highly variable depending on habitat type and geographical context. The assessment is therefore based on comparative analyses among habitats, based on experts' evaluation rather than on absolute quantitative values.

548. Structural complexity is defined as the extent of complexity in the physical structures formed by biotic and abiotic elements, including the habitat's role as a corridor or stepping stone that facilitates species migration and genetic exchange, reflecting the degree of ecological connectivity. The score 1 corresponds to low structural complexity and low ecological connectivity. The score 2 corresponds to medium structural complexity and moderate to high connectivity, or other intermediate situations such as high complexity with low connectivity, or vice versa. The score 3 corresponds to high structural complexity and moderate to high degree of connectivity. As for species diversity, this criterion is scored through a comparative and semi-quantitative assessment rather than through fixed quantitative thresholds.

549. Vulnerability is defined as the extent to which a habitat is susceptible to degradation, in terms of maintaining its structural and functional integrity, when exposed to natural or anthropogenic disturbances, essentially representing the inverse of resistance. The score 1 indicates low vulnerability and high degree of resistance to pressures. The score 2 indicates medium vulnerability and moderate degree of resistance. The score 3 indicates high vulnerability and low degree of resistance. Pressures include all types of stressors and disturbances, both natural and anthropogenic, and resistance is evaluated comparatively by considering the timeframe required for the habitat to lose its main functions and potentially shift towards an alternative ecosystem state.

550. Modifying capacity refers to the habitat's ability to alter the physical environment and influence ecosystem processes, hosting species that act as ecosystem engineers, as reflected in geomorphological traits, matter and energy fluxes, and bioconstruction potential. The score 1 indicates low modifying capacity, when the habitat hosts neither an ecosystem engineer nor a bioconstructor. The score 2 indicates medium modifying capacity, when the habitat host species that act as ecosystem engineers but are not bioconstructors, or vice versa. The score 3 indicates high modifying capacity, when the habitat hosts species that function both as ecosystem engineers and bioconstructors. This criterion is assessed at the habitat level, considering the main typical and characteristic structuring species and, when several species coexist, focusing on the most representative ones.

551. Resilience is defined as the ability of the habitat to rapidly recover following a perturbation, typically linked to the life-history traits of its constituent species that enable fast recovery, as well as to its adaptive capacity, including rapid growth rates, early maturity, predictable recruitment, and short lifespan. The score 1 corresponds to fast recovery, due to rapid growth rates, early maturity, high and predictable recruitment, and short-lived species. The score 2 corresponds to moderate recovery, due to intermediate growth rates, moderate age at maturity, low or unpredictable recruitment, and long-lived species. The score 3 corresponds to slow recovery, due to inherently slow growth rates, late maturity, low or unpredictable recruitment, and the predominance of long-lived species.

552. Regeneration potential is defined as the capacity of a habitat to recover once disturbances have ceased, through either active or passive restoration, taking into account the feasibility of restoration under the prevailing pressure regime and current state of knowledge. The score 1 indicates low feasibility of restoration, when the habitat can hardly be restored even after the elimination of all local pressures, including situations where damage is irreversible compared with reference conditions and habitats with non-deterioration potential. The score 2 indicates medium feasibility of restoration, when the habitat can be restored after the elimination of local pressures, but recovery requires very long periods due to limited natural regeneration potential. The score 3 indicates high feasibility of restoration, when the habitat can be effectively restored once local pressures are removed, damage is reversible, and recovery can occur within a reasonable timeframe based on natural regeneration potential or evidence from restoration interventions, protection measures, or other comparable habitats.

3.2 Habitat scoring

553. Following the definitions of the eight criteria described above, the scoring system was applied to the full list of 287 marine benthic habitats (see Annex III). Based on current knowledge and experts' judgment, each habitat received a cumulative final score derived from the sum of the eight criteria, generating values ranging from the minimum value of 8 (score 1 to all criteria) to the maximum value of 24 (score 3 to all criteria). The final score allowed for the comparative prioritisation of the habitats and for the definition of an initial list of 176 valuable ecosystems that been prepared for experts' evaluation (see Annex I).

554. The first draft of the document (Annex I) containing the 176 valuable ecosystems with their proposed scores, as well as the proposal of the scoring system based on the eight biological criteria, was provided to Focal Points for their evaluation and revision. This Excel file supported a collaborative expert consultation on the proposed criteria, scoring system, and the related standardized methodologies for data collection and assessment (see the following Section 4), for identifying Mediterranean ecosystems (i.e., habitats) with high ecological relevance and/or regeneration potential. Experts were asked to indicate whether each criterion, definition, score, and methodology (for both inventory and assessment) is appropriate (Yes/No) and to add brief comments when relevant or necessary. The Excel file is composed by five main sections:

1) CRITERIA & SCORING — Proposed biological criteria and scoring (with their definition) designed to support the identification of ecosystems (i.e., habitats) with high ecological relevance and/or regeneration potential. How to read the criteria definitions: each definition is placed in the row immediately below its name. These rows are grouped: click the + symbol on the left side of the sheet to expand the group and view the full definition. Click – to collapse it again.
2) HABITATS — List of valuable ecosystems (i.e., habitats) emerging from the scoring. This section lists the habitats that obtained a score equal to or higher than 16 (maximum score = 24). For each habitat, the corresponding codes for Habitats Directive, EUNIS classification, and SPA/RAC (2018) classification are reported. All the habitats listed in the Nature Restoration Law (EU 2022/869) have been included.
3) INVENTORY — List of the most relevant and applicable methodologies for ecosystem inventory. Inventory refers to the identification and mapping of the spatial distribution and configuration of a given ecosystem.
4) ASSESSMENT — List of the most relevant and applicable methodologies for ecosystem condition assessing. Assessment refers to the evaluation of the ecological condition and functional integrity of the ecosystem.
5) BIBLIOGRAPHIC REFERENCES in alphabetical order (the hyperlink at the published article online is provided when available). Add any additional bibliographic reference that might be useful.

555. An accompanying letter was also provided to outline the commitment to collaborative input from national and regional experts (Annex II). The proposed scoring system identified an initial set of valuable ecosystems, defined as those habitats achieving a final score of 15 or higher. This threshold was established based on the frequency distribution of final scores across all 287 habitats (Figure 1). The frequency values showed a non-uniform pattern, with a marked concentration of habitats within the intermediate-to-high score classes and a visible separation between lower-scoring and higher-scoring groups. The histogram and fitted distribution curves highlighted the score 15 as a transition point between these two clusters, supporting the adoption of a data-driven threshold. On this basis, habitats with a final score ≥15 were classified as critical valuable ecosystems, resulting in the identification of 176 valuable and 111 non-valuable habitats. The threshold therefore provided an operational basis for selecting the habitats requiring priority attention for the subsequent inventory and assessment.

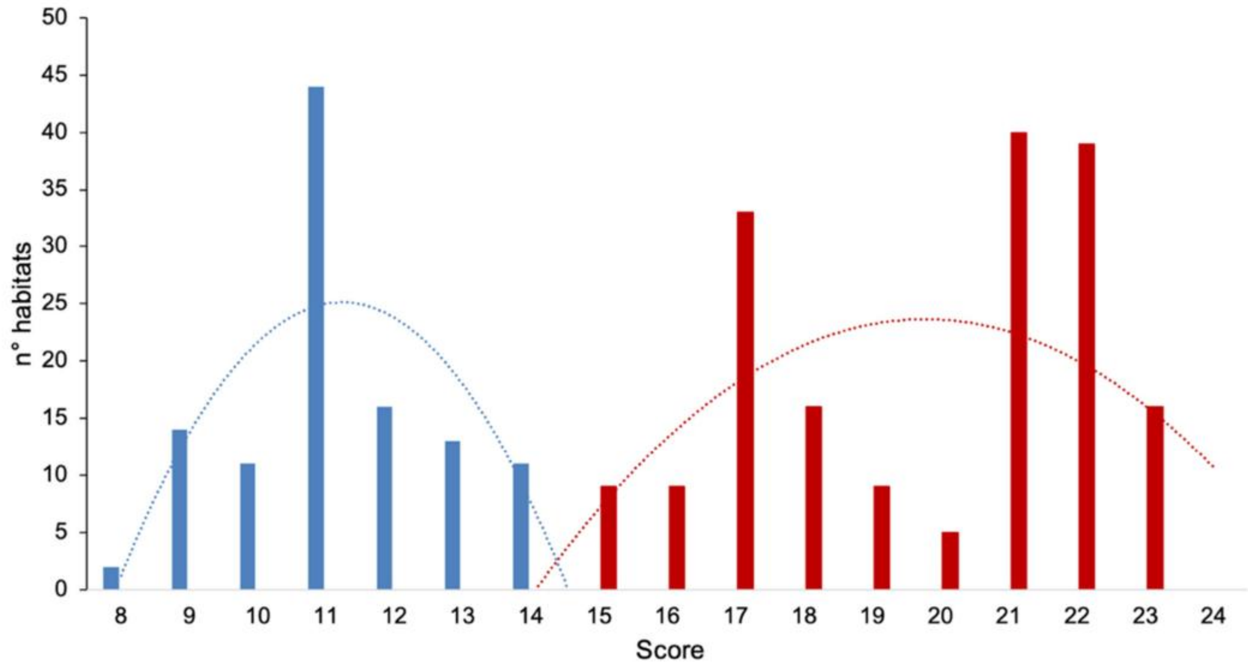

Figure 1. Frequency distribution of the final scores for the 287 benthic habitats assessed and the two fitted distribution curves.

556. The comparison of the mean score values for each criterion between valuable and non-valuable habitats (Figure 2) showed consistently higher values across all eight criteria for the valuable group, confirming that the classification did not depend on a single dominant parameter but reflected a broader ecological and functional differentiation. In particular, the highest mean values for valuable habitats were observed for Significance, Vulnerability, and Modifying Capacity, indicating that these habitats tend to play a stronger role in supporting essential ecosystem services and ecological functions, while also being more exposed to degradation and structural loss. Structural Complexity, Regeneration Potential, and Uniqueness also showed substantial differences between the two groups, reinforcing the interpretation that valuable habitats represent systems of great ecological importance and high strategic relevance for restoration planning.

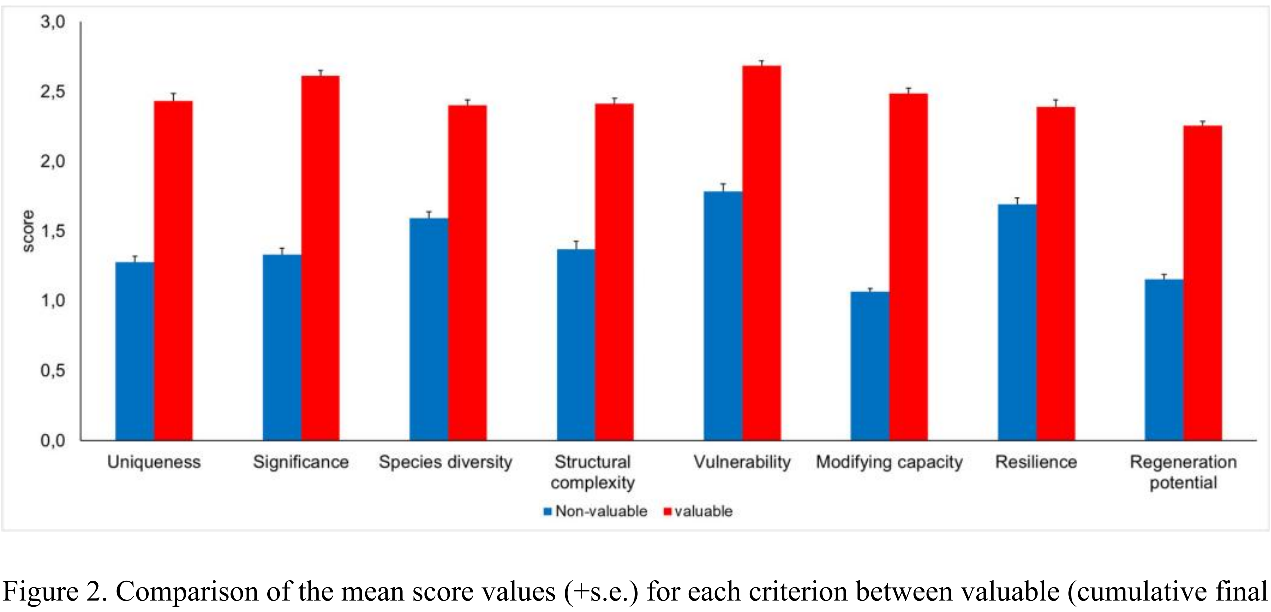

Figure 2. Comparison of the mean score values (+s.e.) for each criterion between valuable (cumulative final score ≥15; red bars) and non-valuable (cumulative final score <15; blue bars) habitats.

557. To further identify which criteria contributed mostly to the segregation between valuable and non-valuable habitats, the delta values (Δ) were calculated as the difference between the mean scores of the two groups for each criterion (Figure 3). The highest delta was recorded for Modifying Capacity (1.43), showing that the strongest distinction concerns the ability of valuable habitats to function as ecosystem engineers and influence ecosystem processes through bioconstruction, geomorphological influence, and matter and energy fluxes. This was followed by Significance (1.28), confirming the central role of nursery function and ecosystem service provision in determining habitat priority. High delta values were also observed for Uniqueness (1.15), Regeneration Potential (1.10), and Structural Complexity (1.05), highlighting the importance of rarity, restoration feasibility, ecological connectivity, and habitat architecture in the prioritisation process. Vulnerability (0.90) and Species Diversity (0.81) remained relevant but were comparatively less discriminant, while Resilience showed the lowest delta (0.70), suggesting that the selection of valuable habitats was mostly driven by their ecological relevance and functional role than by recovery potential alone.

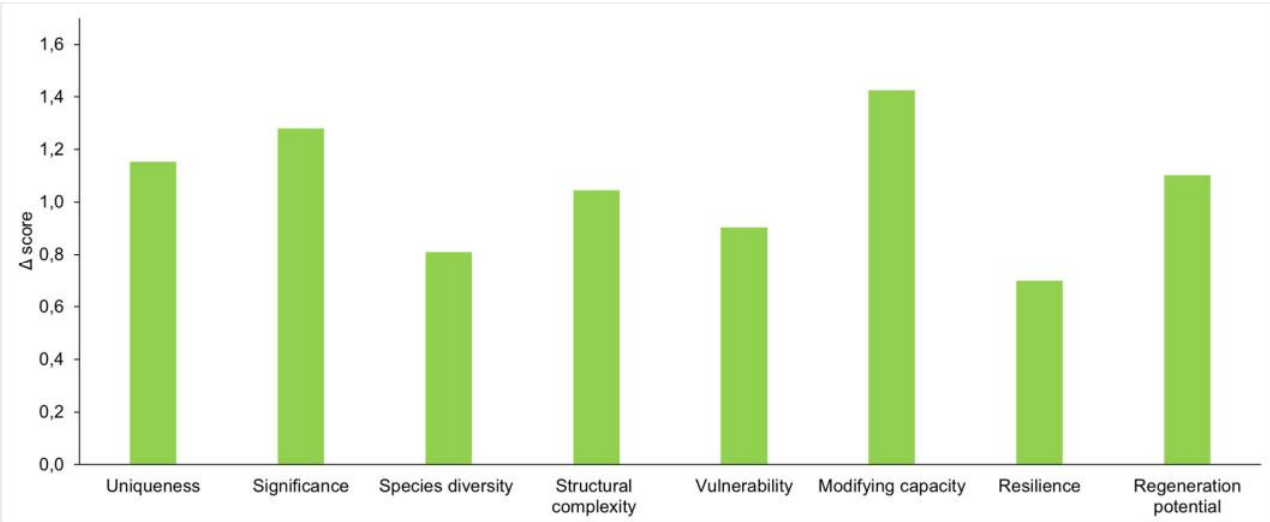

Figure 3. Δ values of the mean scores between valuable and non-valuable habitats, computed for each criterion.

558. The application of the proposed scoring system showed that the vast majority of habitats classified as "valuable" (cumulative final score ≥ 15; see Annex III) correspond to structurally complex and functionally significant ecosystem types. These include bioconstructions, seagrass meadows, as well as both algal and animal forests, occurring across a wide bathymetric range from the littoral and infralittoral zones to the circalittoral, and extending into bathyal and abyssal environments. Notably, all these habitats have already been identified as key Mediterranean ecosystem types, recognized for their outstanding ecological importance, their substantial contribution to ecosystem services, and their high potential for natural regeneration or active restoration. These habitats should therefore be considered priority targets in the planning of future ecological restoration actions.

4. Standardized methodology for inventory of marine ecosystems with high ecological relevance and regeneration potential (phase 3)

559. This section reports the methodological review (phase 3) of the main approaches currently available for inventory and assessment of all the habitats identified as valuable through the scoring process of the phase 2. In order to support the subsequent development of a coherent and standardised restoration framework, the analysis focused specifically on those habitats that reached a final score ≥15, i.e. those defined as valuable habitats.

560. Table 3 summarises the main methodologies used for habitat inventory, organised by habitat type, also reporting the corresponding survey techniques and the reference sources (see also Annex I for the full list of References). These approaches include mapping, detection, spatial delimitation, and habitat characterisation methods aimed at identifying the distribution, extent, and structural presence of the target ecosystems. Table 4 follows the same structure and reports the main methodologies used for habitat assessment and their reference sources (see also Annex I for the full list of References), including approaches designed to evaluate ecological condition, conservation status, functional integrity, and degradation levels. Both tables provide a technical overview of the existing methodological frameworks available for the valuable habitats across the Mediterranean context. These proposed standardised methodologies for data collection and assessment have been identified following the experts' consultation of the data included in the Annex I.

Table 3. Overview of the main standardised inventory methodologies available for the valuable habitats (final score ≥15), organised by habitat type, survey techniques, and supporting references.

Habitat	Inventory methodology	References
Marine angiosperms	Satellite images	Kenny et al., 2003
	Multispectral and/or hyperspectral images	Mumby and Edwards, 2002; Mumby et al., 2004; Dekker et al., 2006; Gagnon et al., 2008
	Aerial images	Kenny et al., 2003; Diaz et al., 2004; Frederiksen et al., 2004
	Drone images (UAVs)	Ventura et al., 2017, 2018; Rende et al., 2020
	Side scan sonar	Paillard et al.,1993; Kenny et al., 2003; Clabaut et al., 2006
	Single-beam acoustic sonar (SSS)	Kenny et al., 2003; Riegl and Purkis, 2005
	Multi-beam acoustic sonar (MBES)	Kenny et al., 2003; Komatsu et al., 2003
	Transect or permanent square frames (quadrates)	Pergent et al., 1995a; Montefalcone et al., 2006
	Video camera (ROV or towed camera)	Kenny et al., 2003; Diaz et al., 2004
	Laser-telemetry	Descamp et al., 2005
	GIB (GPS intelligent buoy)	Descamp et al., 2005
	LiDAR	Rende et al., 2025
Reefs of Vermetidae	Drone images UAVs	Donnarumma et al., 2021
Reefs of Sabellaria spp.	Line transects	Gravina et al., 2018
	Photogrammetry	Brunier et al., 2022
	Drone images (UAVs)	Ventura et al., 2025
Platforms of encrusting Corallinales	CAT-LIT	Mariani et al., 2014
Reefs of *Cladocora caespitosa*	In situ transects (line, radial, line-intercept)	Kersting et al., 2017; Chimienti et al., 2025
	Photographic transects, photogrammetry	Azzola et al., 2022; Chimienti et al., 2025
	Frame-based mapping and colony outlining	Pons-Fita et al., 2020; Chimienti et al., 2025
	Interpolation mapping (IDW, kriging, etc.)	Kersting and Linares, 2012
	Satellite imagery (WV-2, multispectral, pansharpened)	Quintano et al., 2025
	Compilation of occurrence records (GBIF, literature, data series, etc.)	Chefaoui et al., 2017
Algal forests (i.e., Fucales and Laminariales)	Catenas for GIS-based habitat mapping	Mariani et al., 2014
	Linear photographic transects, depth transects	Gatti et al., 2017; Savin et al., 2023
Bivalvia (Oysters/Mussels reefs)	Visual underwater surveys	Papadakis et al., 2023
	Side scan sonar (SSS)	Beck et al., 2011
	Multi-beam acoustic sonar (MBES)	Beck et al., 2011
	LiDAR	Beck et al., 2011
Coralligenous/maërl/rhod-oliths	Underwater visual surveys	Gatti et al., 2012
	Photographic quadrats	Piazzi et al., 2019; Astruch et al., 2023

	Sampling from vessels with blind grabs, dredges, or box corers	UNEP/MAP-RAC/SPA, 2015
	Side scan sonar (SSS)	Cánovas-Molina et al., 2016b
	Multi-beam acoustic sonar (MBES)	Cánovas-Molina et al., 2016b
	Remote Operating Vehicle (ROV)	Bo et al., 2014; Cánovas-Molina et al., 2016b
	Towed camera	UNEP/MAP-RAC/SPA, 2015
Sponge ground	Multi-beam acoustic sonar (MBES)	Neves et al., 2014
	Remote Operating Vehicle (ROV)	Bo et al., 2011
	Species Distribution Models	Azzola et al., 2021
	Photographic transects	Gerovasileiou et al., 2017
	Photo-quadrats	Gerovasileiou et al., 2017
	Visual underwater surveys	UNEP/MAP-RAC/SPA, 2015
	Towed camera Video Transects	UNEP/MAP-RAC/SPA, 2015; Stamouli et al. 2023, 2025
Animal forests in offshore circalittoral and bathyal	Multi-beam acoustic sonar (MBES)	Suke et al., 2017
	Side scan sonar (SSS)	Prada et al., 2008
	Autonomous Underwater Vehicle (AUV)	Bo et al., 2014; Enrichetti et al., 2019
	Remote Operating Vehicle (ROV)	Bo et al., 2014; Enrichetti et al., 2019

Table 4. Overview of the main standardised assessment methodologies available for the valuable habitats (final score ≥15), organised by habitat type, assessment approaches, and supporting references.

Habitat	**Assessment methodology**	**References**
Marine angiosperms	Meadow extent (i.e. surface area)	Foden and Brazier, 2007
	Bathymetric position of the meadow upper limit (in m) and its morphology	Pergent et al., 1995; Montefalcone, 2009
	Bathymetric position of the meadow lower limit (in m)	Pergent et al., 2008; Montefalcone et al., 2009; Vacchi et al., 2012
	Meadow lower limit morphology	Boudouresque and Meinesz, 1982; Pergent et al., 1995; Montefalcone, 2009
	Density (shoots · m^{-2})	Duarte and Kirkman, 2001; Pergent-Martini et al., 2005; Pergent et al., 2008; Bacci et al., 2015
	Percent cover	Buia et al., 2004; Pergent-Martini et al., 2005; Boudouresque et al., 2006; Romero et al., 2007; Montefalcone, 2009

	Percentage of plagiotropic rhizomes	Boudouresque et al., 2006
	Leaf surface area (cm² · shoot), and other phenological measures	Giraud 1977, 1979; Lopez y Royo et al., 2010; Orfanidis et al., 2010
	Necrosis on leaves (in %)	Romero et al., 2007
	State of the apex	Boudoresque and Meinesz, 1982
	Foliar production (in mg dry weight · $shoot^{-1}$ yr^{-1})	Pergent, 1990; Gaeckle et al., 2006; Pergent et al., 2008
	Rhizome production (in mg dry weight · $shoot^{-1}$ yr^{-1}) or elongation (in mm yr^{-1})	Pergent et al., 2008
	Burial or baring of the rhizomes (in mm)	Boudoresque et al., 2006
	Nitrogen and phosphorus content (in % dry weight) in plant tissues	Romero et al., 2007
	Carbohydrate content (in % dry weight) in plant tissues and sediments	Alcoverro et al. 1999, 2001; Romero et al., 2007
	Trace metal content (in µg · g^{-1})	Salivas-Decaux, 2009
	Nitrogen isotopic relationship (δ15N in ‰)	Romero et al., 2007
	Sulphur isotopic relationship (δ34S in ‰)	Romero et al., 2007
	Epiphytes biomass (in mg dry weight · $shoots^{-1}$ or % dry weight · $shoots^{-1}$) and epiphytes cover (in %) on the leaves	Pergent-Martini et al., 2005; Romero et al., 2007; Fernandez-Torquemada et al., 2008; Giovannetti et al. 2008, 2010
	POSWARE index	Buia et al., 2005
	POMI index	Romero et al., 2007
	POSID index	Pergent et al., 2008
	Valencian CS	Fernandez-Torquemada et al., 2008
	PREI index	Gobert et al., 2009
	BiPo index	López y Royo et al., 2010
	Conservation Index - CI	Moreno et al., 2001
	Substitution Index - SI	Montefalcone et al., 2007
	Phase Shift Index - PSI	Montefalcone et al., 2007
	Patchiness Index - PI	Montefalcone et al., 2010
	RESQUE index	Oprandi et al., 2021
	EBQI index	Personnic et al., 2014
Reefs of Vermetidae	LUSI index (Land Use Simplified Index)	Badreddine et al., 2019
	Compilation of occurrence records (GBIF, literature, data series, etc.)	Ingrosso et al., 2018; Badreddine et al., 2019
Reefs of Sabellaria spp.	Compilation of occurrence records (GBIF, literature, data series, etc.)	Bertocci et al., 2017; Gravina et al., 2018
Platforms of encrusting Corallinales	Percentage cover	Mariani et al., 2014
Reefs of *Cladocora caespitosa*	Necrosis evaluation (extent, recent vs old)	Rodolfo-Metalpa et al., 2005; Kersting et al., 2013; Chimienti et al., 2025
	Injury type recording (burial, breakage, tissue loss)	Quintano et al., 2025
	Percentage of necrosis relative to living area	Chimienti et al., 2025; Quintano et al., 2025
	Sphericity index (Is-index)	Kružić & Benković, 2008

	Size-frequency structure	Kersting and Linares, 2012; Chimienti et al., 2025; Quintano et al., 2025
	Compilation of occurrence records (GBIF, literature, data series, etc.)	Chefaoui et al., 2017
	Colony health assessment (healthy/bleached/damaged/ dead/epibionted)	Chimienti et al., 2025
Algal forests (i.e., Fucales and Laminariales)	CARLIT index	Blanfuné et al., 2017; Orlando-Bonaca et al., 2021; Jacob et al., 2024
	EBQI index	Personnic et al., 2014
	Canopy cover	Pons-Fita et al., 2020; Orlando-Bonaca et al., 2021
	Canopy height	Pons-Fita et al., 2020; Monfort et al., 2021
	Photogrammetry-based descriptors (3D structure)	Monfort et al., 2021
	Ecological Evaluation Index (EEI / EEI-c)	Orfanidis et al., 2001; Orfanidis et al., 2003; Orfanidis et al., 2011
	LUSI index (Land Use Simplified Index)	Flo et al., 2011
	MA-LUSI-WB index (population pressure + artificialization rate)	Blanfuné et al., 2016
	Macrophyte Quality Index (MaQI) and Rapid MaQI (R-MaQI)	Sfriso et al., 2014
	QISubMac (Quality Index of Subtidal Macroalgae)	Le Gal and Derrien-Courtel, 2015
	M-ALEX (ecological quality in relation to alien species)	Piazzi et al., 2015
	ECOfast-m (sub-index of EBQI for macroalgae)	Kytinou et al., 2023; Jacob et al., 2024
	Quality of Rocky Bottoms index (CFR)	Guinda et al., 2014
	Assessment of grazing effects on phytobenthic community structure	Guidetti, 2006; Tsirintanis et al., 2018
Bivalvia (Oysters/Mussels reefs)	Species abundance with underwater visual surveys (divers)	Papadakis et al., 2023
	Recent Mortality Rate Calculation	Papadakis et al., 2023
	Shell Width Measurement	Papadakis et al., 2023
Coralligenous/maërl/ rhodoliths	Remote Operating Vehicle (ROV) or towed camera	Cánovas-Molina et al., 2016b; Enrichetti et al., 2019; Piazzi et al., 2019
	Underwater visual observation	Gatti et al. 2012, 2015; Piazzi et al., 2019
	Underwater sampling by scraping or collection	Bianchi et al., 2004
	Underwater photography or video recording	Gatti et al., 2015; Montefalcone et al., 2017; Piazzi et al. 2017, 2019; Çinar et al., 2020
	Photo-quadrats	Astruch et al., 2025
	Sampling from vessel with blind grabs, dredges, or box corers	UNEP/MAP-RAC/SPA, 2015
	STAR index	Piazzi et al., 2019

	ESCA index	Piazzi et al., 2015
	ISLA index	Montefalcone et al., 2017
	CAI index	Deter et al., 2012
	EBQI index	Ruitton et al., 2014
	COARSE index	Gatti et al., 2012
	INDEX-COR index	Sartoretto et al., 2014
	Cor-EBQI index	Astruch et al., 2025
	Overall Complexity Index - OCI	Paoli et al., 2016
Sponge ground	Percentage cover with photo-quadrats	Strano et al., 2020
	Structure from motion photogrammetry	Pulido Mantas et al., 2024
Animal forests in offshore circalittoral and bathyal	Mesophotic Assemblages Ecological Status - MAES	Cánovas-Molina et al., 2016a
	Coralligenous Bioconstructions Quality Index - CBQI	Ferrigno et al., 2018
	Mesophotic Assemblages Conservation Status - MACS	Enrichetti et al., 2019

5. Conclusions

561. Developing criteria for a full inventory of marine ecosystems with the highest ecological relevance and/or regeneration potential (as nursery areas, carbon stocks, avoiding coastal erosion, preventing or reducing the impact of natural disasters) is crucial to support restoration of those ecosystems that provide key services, that are degraded, and that are expected to become increasingly affected in a changing climate. In this context, the Contracting Parties to the Barcelona Convention requested to develop the criteria for the full inventory of marine ecosystems necessary to start restoration activities and favouring nature-base solutions between the identified priority areas.

562. This document (Deliverable 3) provides a structured and comparative framework for the prioritisation of Mediterranean marine benthic habitats based on a transparent, criteria-driven scoring system. By systematically applying the identified criteria for the full inventory (revised and approved after the experts' consultation) across the full set of marine benthic habitats, the adopted approach ensures consistency across Mediterranean countries in evaluation while capturing key ecological dimensions, including conservation relevance, functional importance, and potential for restoration. The visual outputs and comparative analyses further support the interpretability of the results, facilitating their use in decision-making processes. Overall, the developed criteria and indicators can be used to evaluate ecosystem functions and services - such as biodiversity support, carbon storage, coastal protection, and nursery provision - within a standardized scoring structure. These criteria will contribute to operationalising the full inventory and prioritisation of valuable ecosystems (i.e., those with high ecological relevance and/or regeneration potential) under Action 12 by providing a replicable and scalable methodology. It lays a solid foundation for guiding restoration planning and supporting the identification of priority areas where interventions can maximise ecological benefits in terms of biodiversity conservation, carbon storage, and coastal protection.

563. The results of the scoring process highlight a clear differentiation among habitats, allowing the identification of those with the highest ecological relevance and/or regeneration potential, in line with the objectives of Action 12 of post-2020 SAPBIO framework. In particular, the integration of multiple habitat typologies across depth zones ensures a comprehensive perspective that reflects the ecological heterogeneity of Mediterranean marine systems. The proposed list of valuable ecosystems (with score ≥ 15) spans all marine zones, from the littoral to the abyssal, highlighting the need to conserve and restore not only well-known systems (e.g., seagrass meadows and algal forests) but also less-studied habitats, such as animal forests in circalittoral and bathyal zones. These ecosystems play a crucial role in the functioning of deeper Mediterranean environments, despite being increasingly affected by human pressures and exploitation. Importantly, many of these valuable ecosystems retain a strong capacity for regeneration when effectively protected, making them fundamental for maintaining marine ecosystem health, enhancing resilience to climate change, supporting biodiversity, providing coastal protection, and contributing to carbon sequestration.

564. The restoration of Mediterranean marine ecosystems is essential for preserving biodiversity, ensuring human well-being, and maintaining the planet's ecological balance. Restoration is one of the nature-based solutions essential to ensure more resilient ecosystems capable of providing ecosystem services and goods across the Mediterranean. The criteria, methodologies and indicators here proposed for the full inventory will serve as a reference for Contracting Parties under the Barcelona Convention to compile their national inventories of priority ecosystems, enabling comparison, integration, and harmonization at the regional scale. They also will support the implementation of Action 12 of the Post-2020 SAPBIO related to ecosystem health, where the Target T.1.6 on ecosystem restoration states "By 2027 develop the full inventory of ecosystems with the highest ecological relevance and/or regeneration potential (as nursery areas and/or carbon stocks), and by 2030, complete the restoration of most of those selected". They will also contribute to the broader goals of the UNEP/MAP ecosystem-based approach, in alignment with international commitments such as the Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework (target 2), the Ramsar Convention, and the EU Nature Restoration Law.

6. References

Alcoverro T., Manzanera M., Romero J. 2001. Annual metabolic carbon balance of the seagrass *Posidonia oceanica*: the importance of carbohydrate reserves. Marine Ecology Progress Series 211, 105-116. https://doi.org/10.3354/meps

Alcoverro T., Zimmerman R.C., Kohrs D.G., Alberte R.S. 1999. Resource allocation and sucrose mobilization in light-limited eelgrass Zostera marina. Marine Ecology Progress Series 187, 121-131. https://doi.org/10.3354/meps

Astruch P., Boudouresque C.-F., Cabral M., Schohn T., Ballesteros E., Bellan-Santini D., Belloni B., Bianchi C.N., Cassetti O., Chevaldonné P., Fourt M., Guidetti P., Hartmann V., Jacob É., Le Diréach L., Michez N., Montefalcone M., Morri C., Nérini D., Pérez T., Pibot A., Poggiale J.-C., Reveret C., Valance F., Ruitton S., Sartoretto S., Blouet S., Ricquiers L., Thibaut T., Vacelet J., Verlaque M. 2025. An ecosystem-based index for Mediterranean coralligenous reefs: A protocol to assess the quality of a complex key habitat. Marine Pollution Bulletin 220, 118375. https://doi.org/10.1016/j.marpolbul.2025.118375

Astruch P., Orts A., Schohn T., Belloni B., Ballesteros E., Bănaru D., Bianchi C.N., Boudouresque C.-F., Changeux T., Chevaldonné P., Harmelin J.-G., Michez N., Monnier B., Morri C., Thibaut T., Verlaque M., Daniel B. 2023. Ecosystem-based assessment of a widespread Mediterranean marine habitat: The Coastal Detrital Bottoms, with a special focus on epibenthic assemblages. Frontiers in Marine Science, 10. https://doi.org/10.3389/f

Azzola A., Bavestrello G., Bertolino M., Bianchi C.N., Bo M., Enrichetti F., Morri C., Oprandi A., Toma M., Montefalcone M. 2021. You cannot conserve a species that has not been found: the case of the marine sponge *Axinella polypoides* in Liguria, Italy. Aquatic Conservation: Marine and Freshwater Ecosystems 31, 737-747. https://doi.org/10.3389/fmars.2023.1130540

Azzola A., Bianchi C.N., Morri C., Oprandi A., Peirano A., Montefalcone M. 2022. Population structure change in a temperate reef coral after a quarter of century. Estuarine, Coastal and Shelf Science 270, 107851. https://doi.org/10.1016/j.ecss.2022.107851

Bacci T., Rende S.F., Rocca D., Scalise S., Cappa P., Scardi M. 2015. Optimizing *Posidonia oceanica* (L.) Delile shoot density: Lessons learned from a shallow meadow. Ecological Indicators 58, 199-206. https://doi.org/10.1016/j.ecolind.2015.05.054

Badreddine A., Milazzo M., Abboud-Abi Saab M., Bitar G., Mangialajo L. 2019. Threatened biogenic formations of the Mediterranean: Current status and assessment of the vermetid reefs along the Lebanese coastline (Levant Basin). Ocean & Coastal Management 169, 137-146. https://doi.org/10.1016/j.ocecoaman.2018.12.019

Ballesteros E., Aguilar R., Bazairi H., Evans D., Gerovasileiou V., Jeudi De Grissac A., Marin P., Del Mar Otero M., Ouerghi A., Pergent G., Ramos A., Ramz Sghaier Y., Tunesi L. 2017. Draft updated reference list of marine habitat types for the selection of sites to be included in the national inventories of natural Sites of Conservation Interest in the Mediterranean. Thirteenth meeting of focal points for Specially Protected Areas, Alexandria, Egypt, 9-12 May 2017. UNEP (DEPI)/MED WG.431/6, 17 pp.

Bianchi C.N., Pronzato R. Cattaneo-Vietti R., Benedetti-Cecchi L., Morri C., Pansini M., Chemello R. Milazzo M., Fraschetti S., Terlizzi A., Peirano A., Salvati E., Benzoni F., Calcinai B., Cerrano C., Bavestrello G. 2004. Hard bottoms. Biologia Marina Mediterranea 10 (Suppl.), 185-215.

Blanfuné A., Boudouresque C.-F., Verlaque M., Beqiraj S., Kashta L., Nasto I., Ruci S., Thibaut T. 2016. Response of rocky shore communities to anthropogenic pressures in Albania (Mediterranean Sea): Ecological status assessment through the CARLIT method. Marine Pollution Bulletin 109(1), 409-418. https://doi.org/10.1016/j.marpolbul.2016.05.041

Bo M., Bava S., Canese S., Angiolillo M., Cattaneo-Vietti R., Bavestrello G. 2014. Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biological Conservation 171, 167-176. https://doi.org/10.1016/j.biocon.2014.01.011

Bo M., Bertolino M., Bavestrello G., Canese S., Giusti M., Angiolillo M., Pansini M., Taviani M. 2011. Role of deep sponge grounds in the Mediterranean Sea: A case study in southern Italy. Hydrobiologia 680, 1-15. https://doi.org/10.1007/s10750-011-0964-1

Boudouresque C.-F., Bernard G., Bonhomme P., Charbonnel E., Diviacco G., Meinesz A., Pergent G., Pergent-Martini C., Ruitton S., Tunesi L. 2006. Préservation et conservation des herbiers à *Posidonia oceanica*. RAMOGE publ., Monaco, 202 pp.

Boudouresque C.-F., Meinesz A. 1982. Découverte de l'herbier de Posidonie. Cahiers du Parc National de Port-Cros 4, 1-79. https://www.researchgate.net/publication/284682314_Decouverte_de_l'herbier_de_Posidonies

Brunier G., Oiry S., Gruet Y., Dubois S.F., Barillé L. 2022. Topographic analysis of intertidal polychaete reefs (*Sabellaria alveolata*) at a very high spatial resolution. Remote Sensing 14(2), 307. https://doi.org/10.3390/rs14020307

Buia M.C., Gambi M.C., Dappiano M. 2004. Seagrass systems. Biologia Marina Mediterranea 10 (Suppl.), 133-183.

Buia M.C., Silvestre F., Iacono G., Tiberti L. 2005. Identificazione delle biocenosi di maggior pregio ambientale al fine della classificazione della qualità delle acque costiere. Metodologie per il rilevamento e la classificazione dello stato di qualità ecologico e chimico delle acque, con particolare riferimento all'applicazione del decreto legislativo 152/99. APAT, Rome, 269-303.

Burgos E., Montefalcone M., Ferrari M., Paoli C., Vassallo P., Morri C., Bianchi C.N. 2017. Ecosystem functions and economic wealth: Trajectories of change in seagrass meadows. Journal of Cleaner Production 168, 1108-1119. https://doi.org/10.1016/j.jclepro.2017.09.046

Cánovas-Molina A., Bavestrello G., Cau A., Montefalcone M., Bianchi C.N., Morri C., Canese S., Bo M. 2016a. A new ecological index for the status of deep circalittoral Mediterranean megabenthic assemblages based on ROV photography and video footage. Continental Shelf Research 121, 13-20.

Cánovas-Molina A., Montefalcone M., Bavestrello G., Cau A., Bianchi C.N., Morri C., Canese S., Bo M. 2016b. A new ecological index for the status of mesophotic megabenthic assemblages in the Mediterranean based on ROV photography and video footage. Continental Shelf Research 121, 13-20. https://doi.org/10.1016/j.csr.2016.01.008

Chefaoui R.M., Casado-Amezúa P., Templado J. 2017. Environmental drivers of distribution and reef development of the Mediterranean coral *Cladocora caespitosa*. Coral Reefs 36, 1195-1209. https://doi.org/10.1007/s00338-017-1611-8

Chimienti G., Tursi A., Logrieco A., et al. 2025. Corallith bed of the endangered coral *Cladocora caespitosa* in the South Adriatic Sea. Scientific Reports 15, 16690. https://doi.org/10.1038/s41598-025-01554-6

Çinar M.E., Féral J-P., Arvanitidis C., David R., Taşkin E., Sini M., Dailianis T., Doğan A., Gerovasileiou V., Evcen A., Chenuil A., Dağli E., Aysel V., Issaris Y., Bakir K., Nalmpanti M., Sartoretto S., Salomidi M., Sapouna A., Açik S., Dimitriadis C., Koutsoubas D., Katağan T., Öztürk B., Koçak F., Erdogan-Dereli D., Önen S., Özgen Ö., Türkçü N., Kirkim F., Önen M. 2020. Coralligenous assemblages along their geographical distribution: testing of concepts and implications for management. Aquatic Conservation: Marine and Freshwater Ecosystems 30, 1578-1594. https://doi.org/10.1002/aqc.3365

Clabaut P., Augris C., Morvan L., Pasqualini V., Pergent G., Pergent-Martini C. 2006. Les fonds marins de Corse. Cartographie bio-morpho-sédimentaire par sonar à balayage latéral - Atlas de sonogrammes. Rapport Ifremer & Univ. Corse, N°GM 06-01, 78 pp.

Convention on Biological Diversity. 2019. Considerations on ecosystem restoration for the Post-2020 Global Biodiversity Framework, including on a possible successor to Aichi Biodiversity target 15. cbd/post2020/ws/2019/11/3

Costanza R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P., van den Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260. https://doi.org/10.1038/387253a0

Descamp P., Pergent G., Ballesta L., Foulquié M. 2005. Underwater acoustic positioning systems as tool for *Posidonia oceanica* beds survey. C.R. Biologies 328, 75-80. 10.1016/j.crvi.2004.10.007

Ramsar, 10th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971). Resolution X.15- Describing the ecological character of wetlands, and data needs and formats for core inventory- harmonized scientific and technical guidance, 2008.

Deter J., Descamp P., Ballesta L., Boissery P., Holon F. 2012. A preliminary study toward an index based on coralligenous assemblages for the ecological status assessment of Mediterranean French coastal waters. Ecological Indicators 20, 345-352. https://doi.org/10.1016/j.ecolind.2012.03.001

Diaz R.J., Solan M., Valente R.M. 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. Journal of Environmental Management 73, 165-181. https://doi.org/10.1016/j.jenvman.2004.06.004

Donnarumma L., D'Argenio A., Sandulli R., Russo G.F., Chemello R. 2021. Unmanned aerial vehicle technology to assess the state of threatened biogenic formations: The vermetid reefs of Mediterranean intertidal rocky coasts. Estuarine, Coastal and Shelf Science 251, 107228. https://doi.org/10.1016/j.ecss.2021.107228

Duarte C.M., Kirkman H. 2001. Methods fort the measurement of seagrass abundance and depth distribution. In: Global Seagrass Research Methods, Short F.T., Coles R.G. (Eds), Elsevier publ., Amsterdam, 141-153.

Enrichetti F., Bo M., Morri C., Montefalcone M., Toma M., Bavestrello G., Tunesi L., Canese S., Giusti M., Salvati E., Bertolotto R.M., Bianchi C.N. 2019. Assessing the environmental status of temperate mesophotic reefs: A new, integrated methodological approach. Ecological Indicators 102, 218-229. https://doi.org/10.1016/j.ecolind.2019.02.028

Fernandez-Torquemada Y., Diaz-Valdes M., Colilla F., Luna B., Sanchez-Lizaso J.L., Ramos-Espla A.A. 2008. Descriptors from *Posidonia oceanica* (L.) Delile meadows in coastal waters of Valencia, Spain, in the context of the EU Water Framework Directive. ICES Journal of Marine Science 65 (8), 1492-1497. https://doi.org/10.1093/icesjms/fsn146

Ferrigno F., Russo G.F., Sandulli R. 2017. Coralligenous Bioconstructions Quality Index (CBQI): A synthetic indicator to assess the status of different types of coralligenous habitats. Ecological Indicators 82, 271-279. https://doi.org/10.1016/j.ecolind.2017.07.020

Flo E., Garcés E., Camp J. 2019. Land Uses Simplified Index (LUSI): Determining land pressures and their link with coastal eutrophication. Frontiers in Marine Science 6, 18. https://doi.org/10.3389/fmars.2019.00018

Foden J., Brazier D.P. 2007. Angiosperms (seagrass) within the EU water framework directive: A UK perspective. Marine Pollution Bulletin 55 (1-6), 181-195. https://doi.org/10.1016/j.marpolbul.2006.08.021

Frederiksen M., Krause-Jensen D., Holmer M., Laursen J.S. 2004. Long-term changes in area distribution of eelgrass (Zostera marina) in Danish coastal waters. Aquatic Botany 78, 167-181. https://doi.org/10.1016/j.aquabot.2003.10.002

Gaeckle J.L., Short F.T., Ibarra-Obando S.E., Meling-Lopez A.E. 2006. Sheath length as a monitoring tool for calculating leaf growth in eelgrass (*Zostera marina* L.). Aquatic Botany 84 (3), 226-232. https://doi.org/10.1016/j.aquabot.2005.10.006

Gagnon P., Scheibling R.E., Jones W., Tully D. 2008. The role of digital bathymetry in mapping shallow marine vegetation from hyperspectral image data. International Journal of Remote Sensing 29 (3), 879-904. https://doi.org/10.1080/01431160701311283

Gatti G., Bianchi C.N., Montefalcone M., Venturini S., Diviacco G., Morri C. 2017. Observational information on a temperate reef community helps understanding the marine climate and ecosystem shift of the 1980-90s. Marine Pollution Bulletin 114, 528-538. https://doi.org/10.1016/j.marpolbul.2016.10.022

Gatti G., Montefalcone M., Rovere A., Parravicini V., Morri C., Albertelli G., Bianchi C.N. 2012. Seafloor integrity down the harbour waterfront: first characterisation and quality evaluation of the coralligenous rocky shoals of Vado Ligure (NW Mediterranean Sea). Advanced in Oceanography and Limnology 3, 51-67. https://doi.org/10.1080/19475721.2012.671190

Gerovasileiou V., Dimitriadis C., Arvanitidis C., Voultsiadou E. 2017. Taxonomic and functional surrogates of sessile benthic diversity in Mediterranean marine caves. PLoS ONE 12(9), e0183707. https://doi.org/10.1371/journal.pone.0183707

Giovannetti E., Montefalcone M., Morri C., Bianchi C.N., Albertelli G. 2008. Biomassa fogliare ed epifita in una prateria di *Posidonia oceanica* (Prelo, Mar Ligure): possibilità di determinazione tramite un metodo indiretto. Proceedings of the Italian Association of Oceanology and Limnology 19, 229-233.

Giovannetti E., Montefalcone M., Morri C., Bianchi C.N., Albertelli G. 2010. Early warning response of *Posidonia oceanica* epiphyte community to environmental alterations (Ligurian Sea, NW Mediterranean). Marine Pollution Bulletin 60, 1031-1039.

Giraud G. 1977. Essai de classement des herbiers de *Posidonia oceanica* (Linné) Delile. Botanica Marina 20 (8), 487-491.

Giraud G. 1979. Sur une méthode de mesure et de comptage des structures foliaires de *Posidonia oceanica* (Linnaeus) Delile. Bulletin de Musée Histoire naturelle Marseille 39, 33-39.

Gobert S., Sartoretto S., Rico-Raimondino V., Andral B., Chery A., Lejeune P., Boissery P. 2009. Assessment of the ecological status of Mediterranean French coastal waters as required by the Water Framework Directive using the Posidonia oceanica Rapid Easy Index: PREI. Marine Pollution Bulletin 58 (11), 1727-1733. https://doi.org/10.1016/j.marpolbul.2010.01.024

Gravina M.F., Cardone F., Bonifazi A., Bertrandino M.S., Chimienti G., Longo C., Nonnis Marzano C., Moretti M., Lisco S., Moretti V., Corriero G., Giangrande A. 2018. *Sabellaria spinulosa* (Polychaeta, Annelida) reefs in the Mediterranean Sea: Habitat mapping, dynamics and associated fauna for conservation management. Estuarine, Coastal and Shelf Science 200, 248-257. https://doi.org/10.1016/j.ecss.2017.11.017

Guidetti P. 2006. Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs. Ecological Applications 16, 963-976. https://doi.org/10.1890/1051-0761(2006)016[0963:MRRLPI]2.0.CO;2

Guinda X., Juanes J.A., Puente A. 2014. The Quality of Rocky Bottoms index (CFR): A validated method for the assessment of macroalgae according to the European Water Framework Directive. Marine Environmental Research 102, 3-10. https://doi.org/10.1016/j.marenvres.2014.06.002

Jacob É., Cabral M., Schohn T., Belloni B., Boudouresque C.-F., Thibaut T., Ruitton S., Astruch P. 2024. Understanding the ecosystem quality of Mediterranean shallow rocky reefs: Insights from the application of ecosystem-based indices. Marine Pollution Bulletin 209 (Part A), 117050. https://doi.org/10.1016/j.marpolbul.2024.117050

Kenny A.J., Cato I., Desprez M., Fader G., Schuttenhelm R.T.E., Side J. 2003. An overview of seabed-mapping technologies in the context of marine habitat classification. ICES Journal of Marine Science 60 (2), 411-418. https://doi.org/10.1016/S1054-3139(03)00006-7

Kersting D.K., Bensoussan N., Linares C. 2013. Long-term responses of the endemic reef-builder *Cladocora caespitosa* to Mediterranean warming. PLoS ONE 8(8), e70820. https://doi.org/10.1371/journal.pone.0070820.

Kersting D., Linares C. 2012. *Cladocora caespitosa* bioconstructions in the Columbretes Islands Marine Reserve (Spain, NW Mediterranean): Distribution, size structure and growth. Marine Ecology 33. https://doi.org/10.1111/j.1439-0485.2011.00508.x

Kersting D., Cebrian E., Verdura J., Ballesteros E. 2017. A new *Cladocora caespitosa* population with unique ecological traits. Mediterranean Marine Science 18, 38-42. 10.12681/mms.1955

Komatsu T., Igarashi C., Tatsukawa K., Sultana S., Matsuoka Y., Harada S. 2003. Use of multi-beam sonar to map seagrass beds in Otsuchi Bay on the Sanriku Coast of Japan. Aquatic Living Resources 16 (3), 223-230. http://dx.doi.org/10.12681/mms.1955

Kružić P., Benković L. 2008. Bioconstructional features of the coral *Cladocora caespitosa* (Anthozoa, Scleractinia) in the Adriatic Sea (Croatia). Marine Ecology 29, 125-139. https://doi.org/10.1111/j.1439-0485.2008.00220.

Convention on Biological Diversity (2022). Kunming-Montreal Global Biodiversity Framework. CBD/COP/15L.25

Kytinou E., Issaris Y., Sini M., Salomidi M., Katsanevakis S. 2023. ECOfast – An integrative ecological evaluation index for an ecosystem-based assessment of shallow rocky reefs. Journal of Environmental Management 344, 118323. https://doi.org/10.1016/j.jenvman.2023.118323

Le Gal A., Derrien-Courtel S. 2015. Quality Index of Subtidal Macroalgae (QISubMac): A suitable tool for ecological quality status assessment under the scope of the European Water Framework Directive. Marine Pollution Bulletin 101(1), 334-348. https://doi.org/10.1016/j.marpolbul.2015.10.053

Lopez y Royo C., Casazza G., Pergent-Martini C., Pergent G. 2010. A biotic index using the seagrass *Posidonia oceanica* (BiPo), to evaluate ecological status of coastal waters. Ecological Indicators 10 (2), 380-389. https://doi.org/10.1016/j.ecolind.2009.07.005

Lopez y Royo C., Pergent G., Alcoverro T., Buia M.C., Casazza G., Martínez-Crego B., Pérez M., Silvestre F., Romero J. 2010. The seagrass *Posidonia oceanica* as indicator of coastal water quality: experimental intercalibration of classification systems. Ecological Indicators 11 (2), 557-563. https://doi.org/10.1016/j.ecolind.2010.07.012

Lopez y Royo C., PergentG., Pergent-Martini C., Casazza G. 2010. Seagrass (*Posidonia oceanica*) monitoring in western Mediterranean: implications for management and conservation. Environmental Monitoring and Assessment 171, 365-380. 10.1007/s10661-009-1284-z

Mariani S., Cefalì M.E., Terradas M., Chappuis E., Ballesteros E. 2014. Using catenas for GIS-based mapping of NW Mediterranean littoral habitats. Estuarine, Coastal and Shelf Science 147, 56-67. https://doi.org/10.1016/j.ecss.2014.05.030

Monfort T., Cheminée A., Bianchimani O., Drap P., Puzenat A., Thibaut T. 2021. The three-dimensional structure of Mediterranean shallow rocky reefs: Use of photogrammetry-based descriptors to assess its influence on associated teleost assemblages. Frontiers in Marine Science 8, 639309. https://doi.org/10.3389/fmars.2021.639309.

Montefalcone M. 2009. Ecosystem health assessment using the Mediterranean seagrass *Posidonia oceanica*: a review. Ecological Indicators 9, 595-604. https://doi.org/10.1016/j.ecolind.2008.09.013

Montefalcone M., Albertelli G., Bianchi C.N., Mariani M., Morri C. 2006. A new synthetic index and a protocol for monitoring the status of *Posidonia oceanica* meadows: a case study at Sanremo (Ligurian Sea, NW Mediterranean). Aquatic Conservation: Marine and Freshwater Ecosystems 16, 29-42. https://doi.org/10.1002/aqc.688

Montefalcone M., Morri C., Bianchi C.N., Bavestrello G., Piazzi L. 2017. The two facets of species sensitivity: stress and disturbance on coralligenous assemblages in space and time. Marine Pollution Bulletin 117, 229-238. https://doi.org/10.1016/j.marpolbul.2017.01.072

Montefalcone M., Morri C., Peirano A., Albertelli G., Bianchi C.N. 2007. Substitution and phase-shift in *Posidonia oceanica* meadows of NW Mediterranean Sea. Estuarine, Coastal and Shelf Science 75 (1), 63-71. https://doi.org/10.1016/j.ecss.2007.03.034

Montefalcone M., Parravicini V., Vacchi M., Albertelli G., Ferrari M., Morri C., Bianchi C.N. 2010. Human influence on seagrass habitat fragmentation in the NW Mediterranean Sea. Estuarine, Coastal and Shelf Science 86(2), 292-298. https://doi.org/10.1016/j.ecss.2009.11.018

Moreno D., Aguilera P.A., Castro H. 2001. Assessment of the conservation status of seagrass (*Posidonia oceanica*) meadows: implications for monitoring strategy and the decision-making process. Biological Conservation 102, 325-332. https://doi.org/10.1016/S0006-3207(01)00080-5

Mumby P., Hedley J., Chisholm J., Clark C., Ripley H., Jaubert J. 2004. The cover of living and dead corals from airborne remote sensing. Coral Reefs 23, 171-183. https://doi.org/10.1007/s00338-004-0382-1

Mumby P.J., Edwards A.J. 2002. Mapping marine environments with IKONOS imagery: enhanced spatial resolution can deliver greater thematic accuracy. Remote Sensing of Environment 82 (2-3), 248-257. https://doi.org/10.1016/S0034-4257(02)00041-X

Neves B.M., Du Preez C., Edinger E. 2014. Mapping coral and sponge habitats on a shelf-depth environment using multibeam sonar and ROV video observations: Learmonth Bank, northern British Columbia, Canada. Deep Sea Research Part II: Topical Studies in Oceanography 99, 169-183. https://doi.org/10.1016/j.dsr2.2013.05.026

Oprandi A., Bianchi C.N., Karayali O., Morri C., Rigo I., Montefalcone M. 2021. RESQUE: A novel comprehensive approach to compare the performance of different indices in evaluating seagrass health. Ecological Indicators 131, 108118. https://doi.org/10.1016/j.ecolind.2021.108118

Orfanidis S., Papathanasiou V., Gounaris S., Theodosiou T. 2010. Size distribution approaches for monitoring and conservation of coastal *Cymodocea* habitats. Aquatic Conservation: Marine and Freshwater Ecosystems 20 (2), 177-188. https://doi.org/10.1002/aqc.1069

Orfanidis S., Panayotidis P., Stamatis N. 2001. Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model. Mediterranean Marine Science 2, 45-65.

Orfanidis S., Panayotidis P., Stamatis N. 2003. An insight to the ecological evaluation index (EEI). Ecological Indicators 3, 27-33. https://doi.org/10.1016/S1470-160X(03)00008-6

Orlando-Bonaca M., Pitacco V., Lipej L. 2021. Loss of canopy-forming algal richness and coverage in the northern Adriatic Sea. Ecological Indicators 125, 107501. https://doi.org/10.1016/j.ecolind.2021.107501

Paillard M., Gravez V., Clabaut P., Walker P., Blanc J., Boudouresque C.F., Belsher T., Ursheler F., Poydenot F., Sinnassamy J., Augris C., Peyronnet J., Kessler M., Augustin J., Le Drezen E., Prudhomme C., Raillard J., Pergent G., Hoareau A., Charbonnel E. 1993. Cartographie de l'herbier de Posidonie et des fonds marins environnants de Toulon à Hyères (Var - France). Reconnaissance par sonar latéral et photographie aérienne. Notice de présentation. Ifremer & GIS Posidonie Publ., 36 pp.

Paoli C., Morten A., Bianchi C.N., Morri C., Fabiano M., Vassallo P. 2016. Capturing ecological complexity: OCI, a novel combination of ecological indices as applied to benthic marine habitats. Ecological Indicators 66, 86-102. https://doi.org/10.1016/j.ecolind.2016.01.029

Papadakis O., Mamoutos I.G., Ramfos A., Catanese G., Papadimitriou E., Theodorou A.J., Batargias C., Papaioannou C., Kamilari M., Tragou E., Zervakis V., Katsanevakis S. 2023. Status, distribution, and threats of the last surviving fan mussel populations in Greece. Mediterranean Marine Science 24(3), 679-708. https://doi.org/10.12681/mms.35384

Pergent G. 1990. Lepidochronological analysis of the seagrass *Posidonia oceanica* (L.) Delile: a standardised approach. Aquatic Botany 37, 39-54. https://doi.org/10.1016/0304-3770(90)90063-Q

Pergent G., Leonardini R., Lopez Y Royo C., Mimault B., Pergent-Martini C. 2008. Mise en œuvre d'un réseau de surveillance Posidonies le long du littoral de la Corse - Rapport de synthèse 2004-2008. Contrat Office de l'Environnement de la Corse et GIS Posidonie Centre de Corse. GIS Posidonie Publ., Corte, France, 273 pp.

Pergent G., Pergent-Martini C. 1995. Mise en œuvre d'un réseau de surveillance de la végétation marine en Méditerranée - Synthèse. Contract RAC/SPA N°10/94, 25 pp. + 10 Annexes.

Pergent-Martini C., Leoni V., Pasqualini V., Ardizzone G.D., Balestri E., Bedini R., Belluscio A., Belsher T., Borg J., Boudouresque C.F., Boumaza S., Bouquegneau J.M., Buia M.C., Calvo S., Cebrian J., Charbonnel E., Cinelli F., Cossu A., Di Maida G., Dural B., Francour P., Gobert S., Lepoint G., Meinesz A., Molenaar H., Mansour H.M., Panayotidis P., Peirano A., Pergent G., Piazzi L., Pirrotta M., Relini G., Romero J., Sanchez-Lizaso J.L., Semroud R., Shembri P., Shili A., Tomasello A., Velimirov B. 2005. Descriptors of *Posidonia oceanica* meadows: use and application. Ecological Indicators 5, 213-230. https://doi.org/10.1016/j.ecolind.2005.02.004

Personnic S., Boudouresque C.F., Astruch P., Ballesteros E., Blouet S., Bellan-Santini D., Bonhomme P., Thibault-Botha D., Feunteun E., Harmelin-Vivien M., Pergent G., Pergent-Martini C., Pastor J., Poggiale J.-C., Renaud F., Thibaut T., Ruitton S. 2014. An ecosystem-based approach to assess the status of a Mediterranean ecosystem, the *Posidonia oceanica* seagrass meadow. PLoS ONE 9(6), e98994. https://doi.org/10.1371/journal.pone.0098994.

Piazzi L., Gennaro P., Montefalcone M., Bianchi C.N., Cecchi E., Morri C., Serena F. 2019. STAR: An integrated and standardized procedure to evaluate the ecological status of coralligenous reefs. Aquatic Conservation: Marine and Freshwater Ecosystems 29, 189-201. https://hdl.handle.net/11567/957891

Piazzi L., Kaleb S., Ceccherelli G., Montefalcone M., Falace A. 2019. Deep coralligenous outcrops of the Apulian continental 1 shelf: biodiversity and spatial variability of sediment-regulated assemblages. Continental Shelf Research 172, 50-56. https://doi.org/10.1016/j.csr.2018.11.008

Piazzi L., Gennaro P., Ceccherelli G. 2015. Suitability of the ALien Biotic IndEX (ALEX) for assessing invasion of macroalgae across different Mediterranean habitats. Marine Pollution Bulletin 97(1-2), 234-240. https://doi.org/10.1016/j.marpolbul.2015.06.011

Pons-Fita A., Verdura J., Santamaría J., Kersting D., Ballesteros E. 2020. Coexistence of the reef-building coral *Cladocora caespitosa* and the canopy-forming alga *Treptacantha ballesterosii*: Description of a new Mediterranean habitat. Scientia Marina 84. https://doi.org/10.3989/scimar.05018.11B

Prada M., Appeldoorn R., Rivera J. 2008. Improving coral reef habitat mapping of the Puerto Rico insular shelf using side scan sonar. Marine Geodesy 31, 49-73. https://doi.org/10.1080/01490410701812170

Pulido Mantas T., Roveta C., Calcinai B., Benelli F., Coppari M., Di Camillo C.G., Pantaleo U., Puce S., Cerrano C. 2024. Structure from Motion photogrammetry as an effective nondestructive technique to monitor morphological plasticity in benthic organisms: the case study of *Sarcotragus foetidus* Schmidt, 1862 (Porifera, Demospongiae) in the Portofino MPA. Diversity 16(3), 175. https://doi.org/10.3390/d16030175

Quintano N., Sini M., Topouzelis K., Tsirintanis K., Katsanevakis S. 2025. First record of a remarkable *Cladocora caespitosa* bank in Aristotle's Lagoon (N Aegean Sea): Structure and health status. Mediterranean Marine Science 26, 903-920. https://doi.org/10.12681/mms.40108

Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869.

Rende S.F., Bosman A., Di Mento R., Bruno F., Lagudi A., Irving A.D., ... Cellini E. 2020. Ultra-high-resolution mapping of *Posidonia oceanica* (L.) Delile meadows through acoustic, optical data and object-based image classification. Journal of Marine Science and Engineering 8(9), 647. https://doi.org/10.3390/jmse8090647

Rende S.F. et al. 2025. Large-scale seafloor mapping of the Italian coasts using multi-sensor surveying to characterise *Posidonia oceanica* and seafloor morphology in shallow waters. GEOmedia 29(3).https://www.mediageo.it/ojs/index.php/GEOmedia/article/view/2101

Riegl B.M., Purkis S.J. 2005. Detection of shallow subtidal corals from IKONOS satellite and QTC View (50, 200 kHz) single-beam sonar data (Arabian Gulf; Dubai, UAE). Remote Sensing of Environment 95 (1), 96-114. https://doi.org/10.1016/j.rse.2004.11.016

Rodolfo-Metalpa R., Bianchi C.N., Peirano A., Morri C. 2005. Tissue necrosis and mortality of the temperate coral Cladocora caespitosa. Italian Journal of Zoology 72, 271-276. https://doi.org/10.1080/11250000509356685.

Romero J., Martinez-Crego B., Alcoverro T., Pérez M. 2007. A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the water framework directive (WFD). Marine Pollution Bulletin 55, 196-204. https://doi.org/10.1016/j.marpolbul.2006.08.032

Ruitton S., Personnic S., Ballesteros E., Bellan-Santini D., Boudouresque C.-F., Chevaldonné P., Bianchi C.N., David R., Féral J.-P., Guidetti P., Harmelin-Vivien J.-G., Montefalcone M., Morri C., Pergent G., Pergent-Martini C., Sartoretto S., Tanoue H., Thibaut T., Vacelet J., Verlaque M. 2014. An ecosystem-based approach to assess the status of the Mediterranean coralligenous habitat. In C. Bouafif, H. Langar & A. Ouerghi (Eds.), Proceedings of the 2nd Mediterranean Symposium on the Conservation of Coralligenous and others Calcareous Bio-Concretions (pp. 153–158). RAC/SPA. https://hal.science/hal-01790546v1

Salivas-Decaux M. 2009.Caractérisation et valorisation des herbiers à *Posidonia oceanica* (L.) Delile et à *Cymodocea nodosa* (Ucria) Ascherson dans le bassin Méditerranéen. Thèse Doctorat in Ecologie Marine, Université de Corse, France, 168 pp.

Salomidi M., Katsanevakis S., Borja A., Braeckman U., Damalas D., Galparsoro I., et al. 2012. Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem-based marine spatial management. Mediterranean Marine Science 13(1), 49.

Savin A., Sini M., Xynogala I., Lioupa V., Vougioukalou K., Stamatis K., Noè S., Ragkousis M., Gerovasileiou V., Dailianis T., Katsanevakis S. 2023. Assessment of macroalgal communities on shallow rocky reefs in the Aegean Sea indicates an impoverished ecological status. Mediterranean Marine Science 24(2), 241-258. https://doi.org/10.12681/mms.31034

Sfriso A., Facca C., Bonometto A., Boscolo R. 2014. Compliance of the macrophyte quality index (MaQI) with the WFD (2000/60/EC) and ecological status assessment in transitional areas: The Venice lagoon as study case. Ecological Indicators 46, 536-547. https://doi.org/10.1016/j.ecolind.2014.07.012

SPA/RAC-UN Environment/MAP, 2019a. Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region. UNEP/MAP-SPA/RAC publ, Tunis.

SPA/RAC-UN Environment/MAP, 2019b. Updated Reference List of Marine Habitat Types for the Selection of Sites to Be Included in the National Inventories of Natural Sites of Conservation Interest in the Mediterranean. UNEP/MAP-SPA/RAC publ, Tunis.

Stamouli C., Gerovasileiou V., Voultsiadou E. 2023. Sponge community patterns in mesophotic and deep-sea habitats in the Aegean and Ionian seas. Journal of Marine Science and Engineering 11(11), 2204. https://doi.org/10.3390/jmse11112204

Stamouli C., Gerovasileiou V., Voultsiadou E. 2025. Sponges as habitat formers on mesophotic, soft-substrate seafloors of the eastern Mediterranean. Journal of Marine Science and Engineering 13(11), 2132. https://doi.org/10.3390/jmse13112132

Strano F., Micaroni V., Costa G. et al. 2020. Shallow-water sponge grounds along the Apulian coast (central Mediterranean Sea). Marine Biodiversity 50, 7. https://doi.org/10.1007/s12526-019-01026-x

Suke R., Rooney J. 2017. Acoustic characterization of mesophotic coral reef ecosystems of West Hawaii. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-61, 31 p. https://doi.org/10.7289/V5/TM-PIFSC-61

Tsirintanis K., Sini M., Doumas O., Trygonis V., Katsanevakis S. 2018. Assessment of grazing effects on phytobenthic community structure at shallow rocky reefs: An experimental field study in the North Aegean Sea. Journal of Experimental Marine Biology and Ecology 503, 31-40. https://doi.org/10.1016/j.jembe.2018.01.008

UNEP/MAP-RAC/SPA. 2015. Standard methods for inventorying and monitoring coralligenous and rhodoliths populations. Monaco: RAC/SPA. https://www.rac-spa.org/sites/default/files/doc_mkh/coralligenous/corail_bd_cover.pdf

UNEP/MAP-SPA/RAC. 2021. Post-2020 Strategic Action Programme for the Conservation of Biodiversity and Sustainable Management of Natural Resources in the Mediterranean Region.

United Nations Environment Programme (UNEP). 2021a. State of the Environment and Development in the Mediterranean (SoED) 2020. United Nations, Erscheinungsort nicht ermittelbar.

United Nations Environment Programme (UNEP). 2021b. Ecosystem Restoration for People, Nature and Climate: Becoming #GenerationRestoration. United Nations, Erscheinungsort nicht ermittelbar.

Vacchi M., Montefalcone M., Bianchi C.N., Ferrari M. 2012. Hydrodynamic constraints to the seaward development of Posidonia oceanica meadows. Estuarine, Coastal and Shelf Science 97, 58-65. https://doi.org/10.1016/j.ecss.2011.11.024

Ventura D., Bonifazi A., Gravina M., Belluscio A., Ardizzone G. 2018. Mapping and classification of ecologically sensitive marine habitats using unmanned aerial vehicle (UAV) imagery and Object-Based Image Analysis (OBIA). Remote Sensing 10 (9), 1331. https://doi.org/10.3390/rs10091331

Ventura D., Bonifazi A., Gravina M.F., Ardizzone G.D. 2017. Unmanned aerial systems (UASs) for environmental monitoring: A review with applications in coastal habitats. Aerial Robots-Aerodynamics, Control and Applications, 165-184. 10.5772/intechopen.69598