D3.1 Critical review on multilevel ecological processes to improve systemic biodiversity protection and restoration strategies in Europe

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Abstract	The need to conserve and restore ecological

	functioning, i.e the set of processes that biotic and abiotic components perform within ecosystems, is universally recognized as vital to preserve and rebuild the health of ecosystems and sustain the flow of the services they provide. However, the designation and management of area-based management tools for conservation is still generally based on criteria related to the conservation status of single species, the use of taxonomic diversity indices and the physical characteristics of habitats, overlooking their ecological roles and contributions to key processes in marine ecosystems. Whilst the need for ecologically coherent networks of Marine Protected Areas (MPAs) and Ecologically or Biologically Significant Marine Areas (EBSAs) is recognized, effective conservation strategies must ensure that species remain not just extant, but able to maintain key functional roles in marine ecosystems. Such ecological functions, however, have so far not been well incorporated into management or policy. To understand which functional criteria have been suggested in the specialized bibliography before their use for marine conservation and restoration, we perform a systematic review considering different ecological and biological levels, from single species to communities up to ecosystems (e.g., focusing on species traits and interactions, functional groups, ecological processes, among others). Connectivity and animal movements are treated separately as these are supported by several systematic reviews recently published. The present systematic review will provide information to build a portfolio of improved ecological criteria for prioritization and designation of MPAs and EBSAs and for identification and improvement of MPA networks to effectively catalyse actions for systematic biodiversity protection and effective restoration, and to support nature-

	based solutions to be used and applied to MSP4BIO test sites. This portfolio of criteria will be presented in D3.2.
Keywords	systematic review, functional criteria, ecosystem functioning, ecosystem processes, conservation, restoration, area-based managment tools, marine protected areas, networks
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HISTORY OF CHANGES		
VERSION	PUBLICATION DATE	CHANGE
1.0	31.08.2023	Initial version.
2.0	31.08.2024	Revised version: modified after comments from the reviewers. Chapter 1. “Introduction” includes clarifications regarding the scope of the analysis, links with T6.3 Science Policy Dialogues and collaboration with parallel projects. Chapter 5. “Linking functional criteria to priority areas for marine conservation” provides a detailed description of the functional criteria linkages with EBSAs. The contribution of this deliverables’ systematic review as the groundwork for T3.1 and D3.1 of the Horizon Europe project Blue4All is described in Chapter 6. “Conclusions and food-for-thought”.

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Glossary

Area-based Management Tools (ABMTs): Instruments that entail "*the implementation of a system of rights and duties in a particular management area, under the responsibility of a designated authority, and ABMTs tend to afford high levels of protection*" (definition from Gissi et al., 2022, based on UNGA, 2007; Prior et al. 2010). ABMTs include Marine Protected Areas (MPAs) and Other Effective area-based Conservation Measures (OECMs).

Biological organizational levels: These are defined on the basis of how living organisms are classified in a hierarchical and orderly manner according to their level of complexity (from molecules to single organisms, from species to communities and ecosystems). The level of biological organization has been defined by several studies such as Scheffers et al. (2016) to address climate change impacts and responses.

Criterion/criteria: In the frame of the present document, a criterion is defined as a standard or principle for prioritizing and managing conservation areas and designing and evaluating the effectiveness of conservation measures. Particular requirements must be met to be considered and qualified as criteria in conservation. Those criteria must address the protection and conservation of keystone, emblematic, vulnerable species (e.g. addressed to ensure their survival and healthy status), ecosystems structure as well as ecosystems‘ functioning. Some examples of criteria can be the protection of feeding grounds for endangered predators, areas/habitats essential for the development of the life cycle of keystone species, or the maintenance of genetic diversity hotspots essential to ensure adaptation in the context of climate change, among others.

Ecologically or Biologically Significant Marine Areas (EBSAs): EBSAs are defined as geographically or oceanographically discrete areas that need protection since they provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics, or otherwise meet the EBSA criteria (Secretariat of the Convention on Biological Diversity, 2008). There are seven scientific criteria to identify EBSAs in the marine realm: (1) uniqueness or rarity, (2) special importance for life history of species, (3) importance for threatened, endangered or declining species and/or habitats, (4) vulnerability, fragility, sensitivity, slow recovery, (5) biological productivity, (6) biological diversity, and (7) naturalness. Further details can be found in Secretariat of the Convention on Biological Diversity (CBD) (2008) and Ardron et al. (2009)." Differently from other ABMTs, EBSAs are not legally binding (Roe et al. 2022).

Ecosystem function and functioning: Refers to the set of ecological and biogeochemical processes that defined the cycle of matter and flow of energy in marine ecosystems (Groot et al. 2002).

Functional diversity: Diversity metric based on organismal traits (attributes and functions), —that influence one or more aspects of the functioning of an ecosystem (e.g its dynamics, stability, productivity, nutrient balance, and other aspects) (Mouchet et al. 2010). Measuring functional diversity is quantifying the distribution of functional units in a multidimensional space (Villéger, et al 2008https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2435.2010.01695.x), with functional diversity (i.e. the functional component of biodiversity) as the distribution of species in a functional space whose axes represent functional features (Mouchet et al. 2010).

Functional group: A collection of functionally similar species that have a similar functional role in a system regardless of morphological or behavioural characteristics, or taxonomic affinity. (from Table S2, supplement material in Bellwood et al. 2018).

Functional role: The importance or function that something, usually an organism, plays in an ecosystem.

Functional trait: Features measurable at the individual level, without reference to the environment or any other level of organisation, and which impact fitness indirectly via their effects on growth, reproduction and survival. A trait is considered a variable measured on an organism at any scale, from gene to whole organism and which can be scaled up from individuals to genotype, population, species, or community (Volaire et al., 2020 and literature therein).

Indicator: Direct measurement or proxy of relevant biotic or abiotic components/processes used to implement and assess the defined criteria.

Life-history: Pattern of survival and reproduction events that define the lifecycle of the members of a species. Life history patterns evolve by natural selection, and they represent an "optimization" of tradeoffs between growth, survival, and reproduction. Examples of life history traits are: age at first reproductive event, reproductive lifespan and ageing, number and size of offspring, age at first reproductive event, etc. (Stearns, 2000).

Marine Protected Area: Is defined by the IUCN as a “clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (IUCN-WCPA, 2008).

Other Effective area-based Conservation Measures: Geographically defined area other than a protected area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity. There are four criteria for identifying these measures: the area is not currently recognized as a protected area; the area is governed and managed; the area achieves sustained and effective contribution to *in situ* conservation of biodiversity; associated ecosystem functions and services and cultural, spiritual, socio-economic and other locally relevant values are conserved and respected (Convention of Biological Diversity, 2018).

Significant Areas: Are defined as those that host an outstanding proportion of a biodiversity element (e.g. a species, habitat or ecosystem), this(definition is based on definition of 'significant' by IUCN (IUCN, 2016).

Executive Summary

The need to conserve and restore ecosystem functioning i.e, “the set of processes that biotic and abiotic components perform within ecosystems”, is universally recognized as vital to preserve and rebuild the health of ecosystems and sustain the flow of the services they provide. However, the designation and management of area-based management tools (ABMTs) for conservation is still generally based on criteria related to the conservation status of single species, the use of taxonomic diversity indices and the physical characteristics of habitats, overlooking their ecological roles and contributions to key processes in marine ecosystems. Whilst the need for ecologically coherent networks of Marine Protected Areas (MPAs) and Ecologically or Biologically Significant Marine Areas (EBSAs) is recognized, effective conservation strategies must ensure that species remain not just extant, but able to maintain key functional roles in marine ecosystems. Such ecological functions, however, have so far not been well incorporated into management or policy. To understand which functional criteria have been suggested in the specialized literature before their use for marine conservation and restoration, we perform a systematic review considering different ecological and biological levels, from single species to communities up to ecosystems (e.g., focusing on species traits and interactions, functional groups, ecological processes, among others). Connectivity and animal movements are treated separately as these are supported by several systematic reviews recently published. The present systematic review will provide information to build a portfolio of improved ecological criteria for MPAs and EBSAs identification and for the improvement of MPA networks to effectively catalyze actions for systematic biodiversity protection and effective restoration, and to support nature-based solutions to be used and applied to test study cases. This portfolio of criteria will be presented in D3.2.

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1. Introduction

The designation and management of area-based conservation measures is still generally based on criteria related to the conservation status of single species, the use of taxonomic diversity indices and the physical characteristics of habitats, overlooking their ecological roles and contributions to key processes in marine ecosystems. However, the diversity of life histories and functional groups are responsible for the healthy functioning of marine ecosystems and, therefore, are characteristics that should be included and integrated in virtue of biodiversity conservation, beside species numbers (Levin & Levin 2002). For example, life-history diversity in salmon populations makes them more resilient to climatic and human perturbations (Hilborn et al. 2003), and diversity of functional groups may mediate ecosystem-level processes (Duffy et al. 2007). Thus, although the conservation of species richness is undoubtedly an important management issue, a detailed understanding of species functional attributes (their functional role) is essential for the success of conservation efforts.

Changes in biodiversity can affect ecosystem processes and functioning in different ways, for example, they can lead to changes in the community structure, resource uses and food web structure, as well as the loss of keystone species (e.g, Gray 1997; Hooper et al. 2002; Paine 2002). Effective conservation strategies thus must ensure that species remain not just extant, but able to maintain key roles in species interactions and in the maintenance of communities and ecosystems processes. As such the need to conserve and restore ecosystem functioning, i.e., the set of processes that biotic and abiotic components perform within ecosystems (de Groot et al. 2002), is becoming universally recognized as vital to preserve and rebuild the health of ecosystems and sustain the flow of the services they provide (Bennet et al 2009). Moreover, functional diversity can be monitored to measure resource use and predict changes in ecosystem processes (Gray 1997; Tilman 2001). Thus, conservation can be more effective if ecosystem processes are considered (Klein et al. 2009; Bennett et al. 2009; Magris et al. 2014; Watson et al. 2016).

Functional processes include climatic processes, primary productivity, carbon (C) flow through food webs, hydrological processes, intra- and inter-specific interactions, movements of organisms, (connectivity at different life-history stages, from larvae to adults) and others. Conceptual frameworks, criteria and associated indices that consider functional dimensions have been suggested and used in the scientific literature to inform the identification and prioritisation of EBSAs, MPAs and Other Effective area-based Conservation Measures (OECMs) in marine ecosystems. However, no effort has been made to systematically screen, assess and integrate existing approaches and criteria to generate a coherent framework that explicitly considers functional diversity and ecosystem functioning in marine conservation and to provide an implementation protocol that guides under different data realities the implementation of functional dimensions into management or policy (Brodie et al. 2018).

In this systematic review we aim to cover the main ecological attributes/processes and functional criteria that can be considered, proposed, tested or can improve the criteria currently in use for the designation, prioritisation and management of area-based management tools for conservation, to come up with new useful criteria for the planning of MPAs and MPA networks and restoration initiatives. The analysis considers different ecological and biological levels, from single species to communities up to ecosystems and their correlation (e.g., focusing on species traits and interactions, functional groups, ecological processes, and connectivity aspects) and wide ecological processes that have not been systematically considered so far. Criteria and functional attributes are then linked to areas important for achieving biodiversity protection and restoration goals (e.g., ecological corridors, fish spawning- and recruitment- areas etc).

This analysis relies on the Science Policy Dialogues (T6.3) and collaboration with relevant parallel projects, as well as with the GOBI and Biodiversity Partnership, to integrate the best available knowledge.

2. Methods

The general goal of a systematic review is to provide a valid summary of primary research findings through a pre-planned and explicit procedure. We specified our research question using the PICO/PECO framework, a clear frame for formulating good questions, formulating search and eligibility criteria, presenting outcomes, and the wording in guidelines of final recommendations (Foo et al. 2021). Regardless of the methods of synthesis, all systematic reviews need to find an unbiased sample of available evidence to accurately reflect the state of our knowledge on a topic, through planned and logical steps (Foo et al. 2021):

1. Framing appropriate questions

2. Identify term search and combine them in search strings with Boolean search operators

3. Run search on literature databases

4. Refine search by excluding duplicates

5. Define exclusion criteria

6. Screen documents at the title, abstract and full-text levels

7. Exclude articles not responding to the framing questions

8. Define extraction criteria for the collection of information

9. Define criteria for the extraction of the needed information

These are the main steps for a review procedure where each step must be validated and criteria homogenised among reviewers (see Figure 1 for a full description of the process).

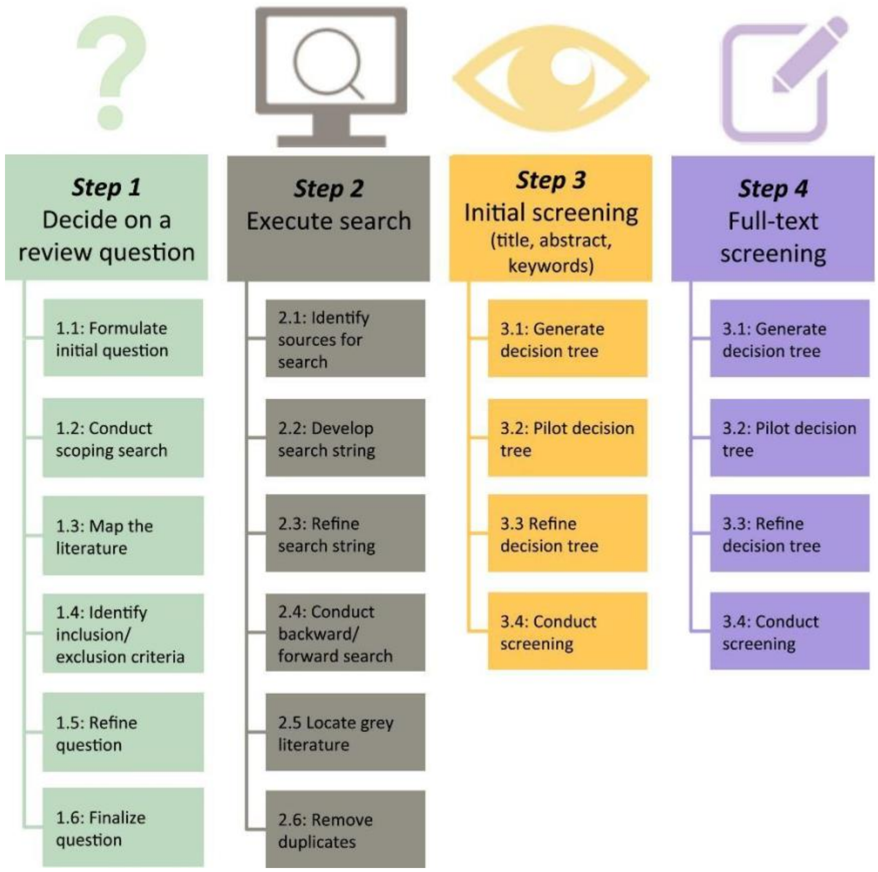

Figure 1 *Literature review steps (from Foo et al., 2021) adopted in this deliverable*

2.1 Framing questions

This review is intended to provide hints on functional attributes that might improve systemic biodiversity protection and restoration strategies in Europe; however, most of the studies have been carried out overseas (USA, Australia etc.). Therefore, in this review we did not exclude any geographical area and we provide a global analysis.

To guide the systematic review, we focused on two main questions:

1. What are the main ecological attributes, associated criteria and indicators, based on the best ecological knowledge, currently used or considered (a) in the designation and prioritisation and (b) in setting conservation, restoration and management targets of MPAs and EBSAs and OECMs worldwide?

2. In this context, are there critical ecological and functional attributes that have been systematically overlooked but have been shown to indicate changes in the integrity and functioning of marine ecosystems and provide quantifiable information on the status of habitats and biodiversity?

2.2 Setting the structure and terms of the search string, and performing the search

Searches should capture as many relevant studies as possible while reducing the number of irrelevant ones. To achieve this goal, there are sub-steps to consider when identifying the most appropriate literature sources, generating the search string for database/platform searches, and refining the search strings.

Division of the search string into different parts/blocks has been recommended for an improved structuring of research questions and associated searches in the context of systematic reviews. Therefore, we divide our search string into three main parts:

i) Systems/environments/realms of interest for our search and, therefore, include almost all terms that we usually use to refer to them.

ii) Different spatial management measures applied worldwide and the different names they receive.

iii) Comprehensive set of structural and functional attributes (and potential associated ecological criteria and indicators) that consider both what has been done up to now in the context of conservation and management and what can be done when developing innovative frameworks.

When defining the terms related to functional attributes, we consider the generally applied scheme "*Ecosystem processes => Ecosystems functions => Ecosystem Services*" (Snelgrove et al. 2014).

Strings were built by selecting very structured search terms (keywords) depicting the aforementioned topics and considering the terminology used in the specialized bibliography (see references list Annex A), and combining them with Boolean search operators, thus increasing the efficiency and reproducibility of searches (Foo et al. 2021).

Once search strings were refined, the search of scientific articles was carried out using two specific platforms for the search of scientific literature, Scopus and Web of Science (WoS) that are linked to the journal impact rankings SCImago Journal & Country Rank (SJR) and Journal Citation Reports (JCR), respectively. These databases are commonly

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used in ecology and evolution and are considered the largest online databases of scientific literature (Gusenbauer & Haddaway, 2020 for a more complete list of potential platforms).

We included in the search the entire Scopus and WoS collections (search was finalised on the 13th of March 2023). After removing several non-specific terms, the number of publications obtained significantly decreased. As we need to find indicators of processes that are useful for conservation but also not yet routinely used in conservation, we made an additional search in which we skip Part II, i.e., the one related to the spatial management measures used worldwide (i.e., we only use Part I and Part III).

<u>The final search string used for the search was the following</u>:

(ocean* OR sea OR marine OR brackish OR estuar* OR coast* OR benth* OR pelagic)

AND

("marine spatial planning" OR "maritime spatial planning" OR "spatial planning" OR "spatial management" OR "marine directive*" OR "integrated coastal zone management" OR "marine protected area*" OR "protected area*" OR "marine protected area network*" OR "marine reserve*" OR "marine reserve network*" OR "marine park*" OR "marine park network*" OR "marine sanctuary*" OR "protected seascape*" OR "marine conservation area" OR "special area* of conservation" OR "conservation unit*" OR "other effective area-based conservation measures" OR "special protection area*" OR "special protection zone*" OR "buffer zone*" OR "closed area*" OR "restricted area*" OR "no take zone*" OR "no take zone network*" OR "no take area*" OR "no take area network*" OR "site* of community importance" OR "site* of community interest" OR "site* of special scientific interest" OR "partial protection" OR "temporal protection" OR "permanent protection" OR "fully protected" OR "highly protected" OR "lightly protected" OR "minimally protected" OR "active* manage*")

AND

("functional diversity" OR "functional richness" OR "functional divergence" OR "functional evenness" OR "functional redundancy" OR "functional group*" OR "biological trait*" OR "life history trait*" OR "functional trait*" OR "phenological trait*" OR "ecosystem function*" OR "ecosystem process*" OR "ecosystem metabolism" OR "energy flow*" OR "flow* of energy" OR "energy flux*" OR "flux* of energy" OR "energy transfer" OR "transfer of energy" OR "matter cycl*" OR "cycl* of matter" OR "nutrient cycl*" OR "cycl* of nutrient*" OR "nutrient uptake" OR "uptake of nutrient*" OR "nutrient capture" OR "capture of nutrient*" OR "nutrient assimilation" OR "assimilation of nutrient*" OR "nutrient storage" OR "storage of nutrient*" OR "nutrient sequestration" OR "sequestration of nutrient*" OR "nutrient fixation" OR "fixation of nutrient*" OR "nutrient transfer" OR "transfer of nutrient*" OR "nutrient flow*" OR "flow* of nutrient*" OR "nutrient flux*" OR "flux* of nutrient*" OR

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"carbon cycl*" OR "cycl* of carbon" OR "carbon uptake" OR "uptake of carbon" OR "carbon capture" OR "capture of carbon" OR "carbon assimilation" OR "assimilation of carbon" OR "carbon storage" OR "storage of carbon" OR "carbon sequestration" OR "sequestration of carbon" OR "carbon transfer" OR "transfer of carbon" OR "carbon flow*" OR "flow* of carbon" OR "carbon flux*" OR "flux* of carbon" OR "primary product*" OR "secondary product*" OR "photosynthesis" OR "oxygen production" OR "production of oxygen" OR respiration OR "oxygen consumption" OR "consumption of oxygen" OR growth OR calcification OR "habitat form*" OR "trophic transfer" OR “trophic role” OR “food web” OR “trophic interaction*” OR “intra-specific interaction*” OR “inter-specific interaction*” OR deposition OR biodeposition OR "benthic-pelagic coupling" OR decomposition OR connectivity OR corridors OR meta-population OR meta-community OR meta-ecosystems OR dispers* OR migrat* OR immigration OR emigration).

2.3 Exclusion/ inclusion criteria

The aim of this exclusion step was to define *a priori* a clear set of criteria for the inclusion/exclusion of publications derived from the search, considering the framing questions and the three topics included in the search string. This phase was performed by a core team of four reviewers of institutions collaborating in WP3 who coordinated and continuously cross-checked the results of the inclusion/exclusion processed, crossed their analysis on a subset of exclusion results to homogenise as much as possible the exclusion criteria (see *kappa* test explained below).

In exclusion step 1 (see Fig 2), the list of papers collated from the systematic search of literature databases were screened and their exclusion decided based on the criteria listed below. All documents were initially evaluated at the title and abstract levels by the core team, and those retained were assessed at the full-text level (the inclusion/exclusion process at this level was performed by all the participants during the process of extraction of information, see below section 2.4 for further information). A document was excluded if it would have fulfilled at the title, abstract at least one of the following exclusion criteria:

- Not about marine systems: documents on terrestrial or inland aquatic ecosystems were excluded. An exception was made in case of species migrating between marine and other systems.
- Language: documents were excluded if not written in English.
- Not about EBSAs or area-based management tools: documents were excluded if they did not provide meaningful conceptual or procedural insights regarding the identification or prioritisation of EBSAs or the design, implementation, assessment and management of ABMT from an ecological perspective. In this sense, documents that only referred marginally to or speculate about EBSAs or area-based protection measures, e.g., in the concluding remarks of the abstract or the full text, were not considered.

- Not about functional dimensions: documents were excluded if they did not address or provide any insights regarding the use of functional dimensions of marine ecosystems for area prioritization or the design of conservation measures. Functional dimensions here refer to the consideration of: (i) biological traits and associated functional diversity measures across organisation levels and (ii) ecosystem functioning and relevant processes such as productivity, carbon sequestration, and nutrient cycling, among others, for the identification, prioritization and management of EBSAs or ABMTs in marine ecosystems. We decided to exclude papers dealing mainly with animal movements, connectivity, and migrations.
- Type of research: documents were excluded if the research outputs could not provide any practical *in situ* approach for ABMTs in marine ecosystems. Therefore, any document that focused on laboratory experimental designs without the possibility to translate/upscale the research results for their meaningful use in the prioritization of areas or the design of conservation measures in marine ecosystems were excluded. Papers without DOI were excluded.
  Type of document: documents were excluded if they were not original research articles or narrative/systematic reviews (with or without meta-analysis) and opinion papers published in peer-reviewed journals or as book chapters. Documents written in the form of comments and letters to the editor were also excluded.

Criteria were screened in the following order: 1) Language, 2) “Marine” criteria; 3) functional dimension; 4) conservation aspects and 5) type of paper. At the title level, a precautionary approach was followed only excluding papers when the search results were clearly spurious. This is because the title usually does not contain enough information to review perform an in-detail assessment of the overall content of a document. A detailed screening and a more informed decision were made at the abstract and full-text level.

Generally, when there was insufficient information at the title and/or abstract levels to make a decision, such articles were included and later evaluated at the full-text level. However, this led to a large number of articles being retained. Therefore, when an article was included due to insufficient information, the reviewer was asked to highlight this in the “Comments” column, to later facilitate the extraction process.

Documents that include both climate change and MPAs and/or climate change and prioritization/designation scenarios were listed apart (Exclusion Step 2, Fig 2). We excluded papers not simply mentioning climate change but that included this aspect as an integral part of the introduction and discussion. This list was provided to T3.2, i.e., the task dedicated to climate change. In addition, we excluded all the papers dealing mainly with connectivity criteria which included for example species’ movements or migrations. Connectivity was treated apart in a separate paragraph and not included in the review analyses, as criteria related to connectivity are already well represented in the literature in comparison to other functional criteria.

The level of agreement between reviewers for the screening process was tested using a Kappa test. Fifty papers were randomly selected from the overall set of papers gathered from the search in Scopus and WoS (following the removal of duplicates). The same set of papers was distributed between reviewers, who were requested to perform the inclusion/exclusion processes using the criteria listed above. For this purpose, the reviewers screened the 50 documents only at the title and abstract level. The results of all reviewers were chosen to be tested using a Cohen's kappa test as it is a statistical method frequently applied to validate the inter-rater reliability. The test was performed in R programming language (R 3.4.0) using the R package *psych*.

2.4 Extraction Guidelines

The papers retained after the inclusion/exclusion processes at the title and abstract levels (722) were divided in 13 blocks of 48 articles and 2 blocks of 49 articles to be screened at full-text level, for the extraction of the information by 15 volunteering reviewers selected among T3.1 participants. Reviewers were trained to perform the inclusion/exclusion process at the full-text level and to extract the requested information (see details below).

Reviewers were provided with an ***Extraction Guideline*****,** which listed again the exclusion criteria (see above) and detailed the extraction fields (Annex B). A spreadsheet was also provided to each reviewer with the list of papers to be screened. The spreadsheet was organised in rows corresponding to the documents to be evaluated at the full-text level and to be extracted (each document associated to and identifiable with an ID number), while columns corresponded to different fields of information to be extracted (Fig B1 in Annex B).

Drop-down lists were included in the columns and where fixed levels were reported. In "free text" columns, the table fields were left empty for reviewers to freely describe/explain the answer to the relevant query. A note column titled "Notes" was provided at the end of the fields of information to be extracted, allowing the addition of any additional and explanative information that reviewers considered relevant and that could not be included in the information fields. 'NA' (not available) was used when information could not be provided.

For each spreadsheet field (columns), a clear explanation and a description of the type of information required was provided.

The following 21 fields (Queries; Q) were used for full-text extraction (details provided by the guideline, are listed in Appendix A):

Q1. Functional process/criteria: Which functional criteria is the study focusing on?
Q2. Ecoregions and province: Which ecoregion/provinces is the study focusing on?
Q3. Article type:
Q4. Country: Which country is the study focusing on?
Q5. Marine domain: Which marine domain is the study focusing on?
Q6. Marine habitats: Which habitat is the study focusing on?

Q7. Bio-Ecological organisation level: What level of biological organisation is the study/criterion focusing on?
Q8. Taxon specific (optional): Which specific taxa are the focus of the study/criterion?
Q9. Area-based conservation typology: Which conservation typology is the study focusing or mentioning?
Q10. Inclusion of area-based conservation: At which level is the area-based conservation measure considered in the study?
Q11. Potential contribution of criteria: How do criteria contribute to area-based conservation?
Q12. Human activities: What are the main human activities mentioned to affect or potentially affect criteria?
Q13. Human pressures: What are the main human pressures mentioned to affect or potentially affect criteria?
Q14. Spatial scale: At what spatial scale does the criterion/criteria occur?
Q15. Temporal scale: At what temporal scale does the criterion/criteria occur?
Q16. Variables/indicators supporting criteria: Which are the variables used for measuring the criteria?
Q17. What data on the criterion/criteria is available?
Q18. Integration into Decision Support Tool (DSTs): Has the criteria been integrated in a DST?
Q19. Link to ecosystem services: Does the criteria link to specific ecosystem services and if so which ones?
Q20. Criteria constraints: Is the criterion/criteria limited by factors such as data unavailability, time or other constraints? If so, which ones are pertinent?
Q21. Notes

3. Results

3.1 Literature search

Searches combining Scopus and WoS, after removing duplicates, provided a total of 6,497 documents.

3.2 Exclusion process

Documents were checked for double entries and 0.65% (42 entries) were excluded for this reason. Additional 184 articles were excluded based on language (i.e., the documents were not written in English). From the resulting entries (6,271) 1,424 and 2,704 papers were excluded after reading the title and abstract, respectively.

In the first exclusion step 2,143 documents were retained. From the papers retained, those referring to climate change were referred to Task 3.2 since this other task aims at exploring climate change in defining and identification of ABMTs, and those referring to connectivity/mobility aspects, although fundamental to ecosystem functioning, were keep apart and have been thoroughly addressed and reported in dedicated and separate section of this deliverable. This decision was made based on the amount of reviews and scientific papers addressing this issue and for leaving the main focus on the analysis of the other functional criteria that have not been fully and systematically addressed/reviewed in the scientific literature.

In total 1,377 articles referred to climate change and connectivity. An additional 44 papers were excluded due to missing DOIs. At the end of the exclusion process at the title and abstract levels, and after removing papers referring to climate change and connectivity aspects (and missing DOIs), 722 documents were retained for the screening at the full-text level. In total 283 documents were excluded at the full-text level for different reasons such as not being focused on conservation aspects, mainly concerned with aspects of connectivity or climate change or because their conclusions were too general (this category included papers focusing more on fisheries rather than conservation, and papers dealing with monitoring methodologies or similar and, therefore, of general interest). A summary of the main reasons for excluding documents at the full-text level is reported in Fig 2. Additional exclusions were made for documents that could not be downloaded (see section 2.2 of this deliverable).

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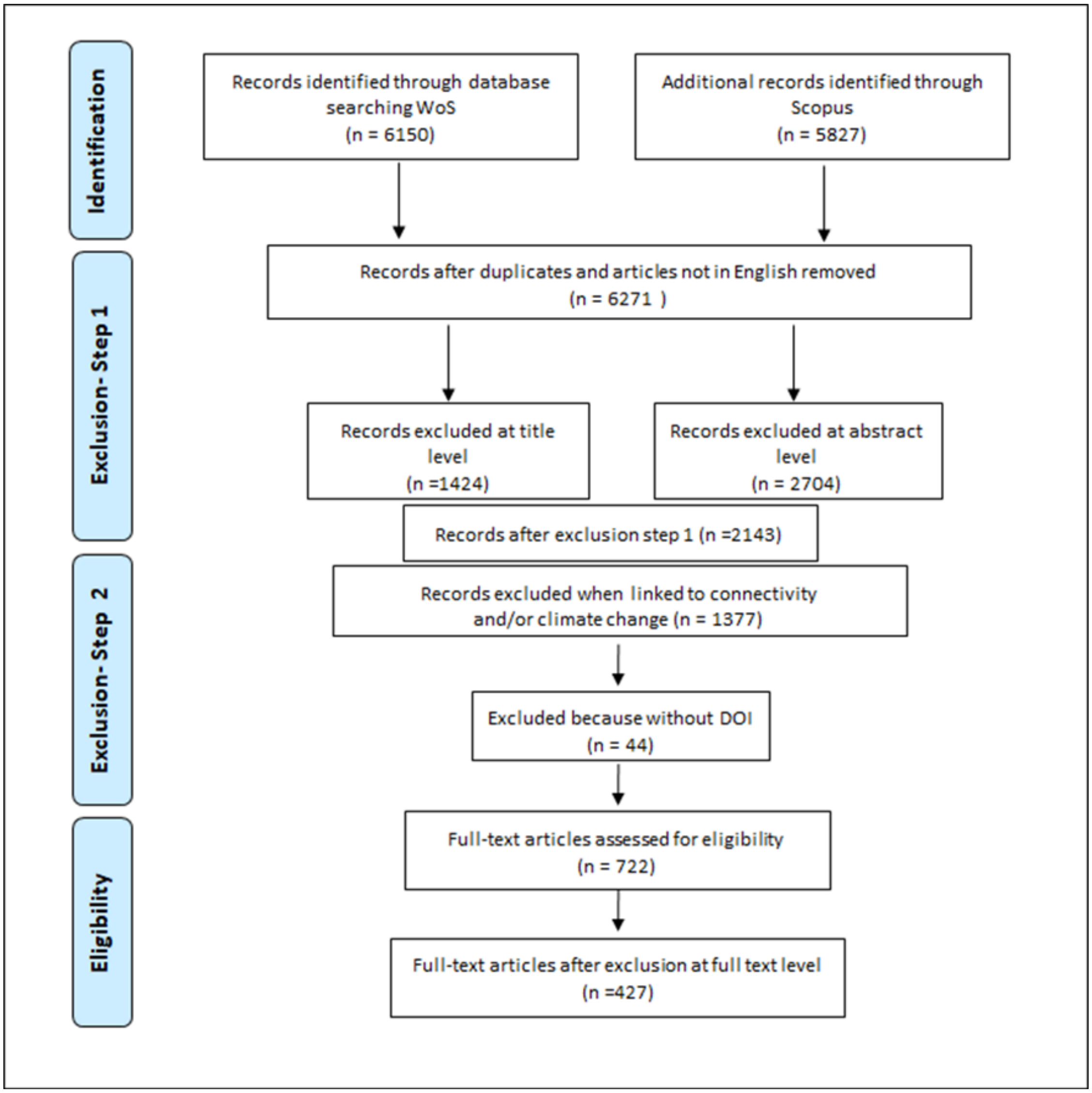

Figure 2 *Scheme showing the results of the literature search in Scopus and WoS and of the inclusion/exclusion process at the title, abstract and full-text level*

3.3 Extraction of information at full text level

The results from the fifteen reviewers were collated. When screening the documents at the full-text level, 59% of papers out of the 722 were included for the extraction of information while 41% were discarded for the following reasons: not sufficiently considering ABMTs; not considering functional criteria; focusing on fisheries management or only providing general recommendations; mainly focusing on ecological connectivity and animal movements or mainly addressing climate change (Fig. 3).

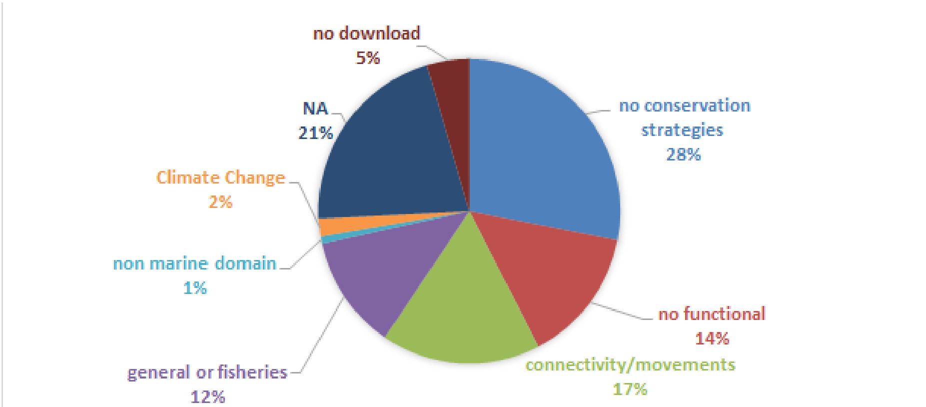

Figure 3 *Percentage of reasons to exclude papers at full text level*

Most of the included and reviewed articles fell in the category of research papers (97.26%) followed by reviews (around 5.72%) and meta-analysis (2.24%). The majority of included studies were carried out in the Temperate North Atlantic region (107 studies, which include most of European seas, Northern European Seas; Lusitanian, Mediterranean, Cold Temperate Northwest Atlantic, Warm Temperate Northwest Atlantic, and Black Sea). This was followed by the Tropical Atlantic and Central Indo-Pacific (51 and 48 studies, respectively, Fig 4).

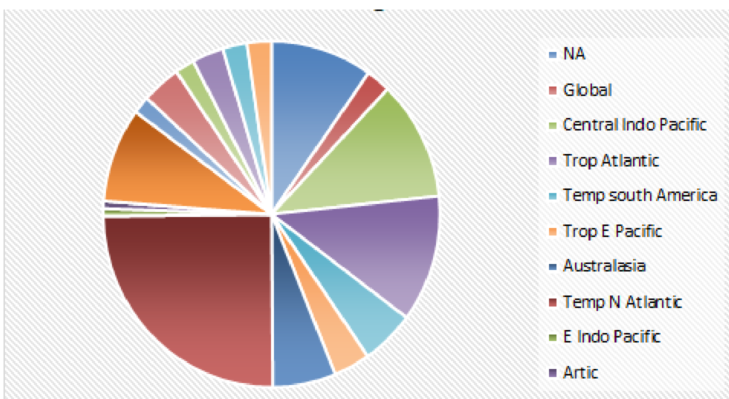

Figure 4 *Overview of screened documents by ecoregion*

Regarding conservation typologies taken into consideration, single MPAs were the primary focus of most documents, followed by Marine Reserves and networks of MPAs (Fig. 5). The rest of the area-based protection measures considered in this review were far less represented in the bibliography (< 40%).

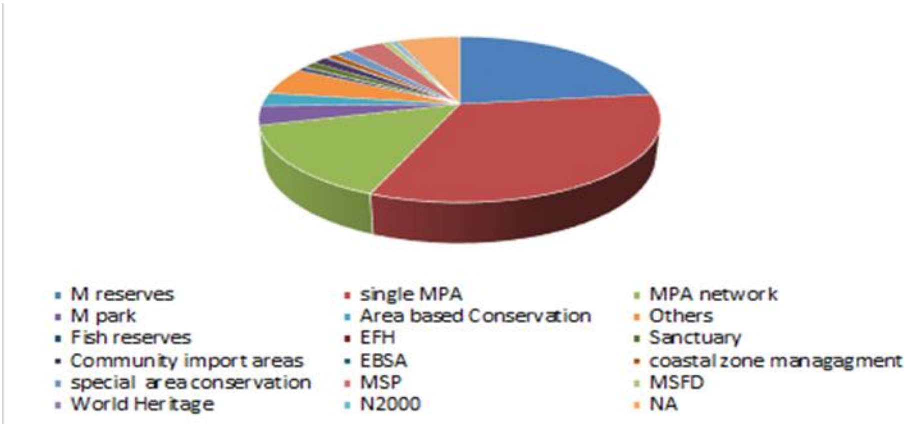

Figure 5 *Typologies of area-based management tools for conservation reported from the review search*

Overall, 51.5% of the ABMTs were classified as experimentally and extensively tested/measured, 29.7% as proposed/suggested (to reach some conservation goals), and 14.3% and 4.4% as mentioned or NA, respectively.
The most represented marine domains were the coastal benthic (82.3 %) and pelagic (7.6 %) ones (Fig 6). Regarding habitats, corals (coral reefs) and rocky benthic habitats such as boulder fields and bedrock (coralligenous) or patches of sand were the most represented. Other targeted habitats included mixture of habitats e.g., boulder fields and bedrock, corals, soft-substrates, macroalgae/kelp forests, seagrass meadows, and transitional habitats; mangrove forests, mudflats, swamps and salt marshes, estuaries, and coastal lagoons; intertidal rocky boulders/rock platforms). Entries showed a remarkable number of studies addressing studies at community level, followed by population and species (Fig 7). The community and population were the most represented organizational levels in the reviewed literature (Fig 8).

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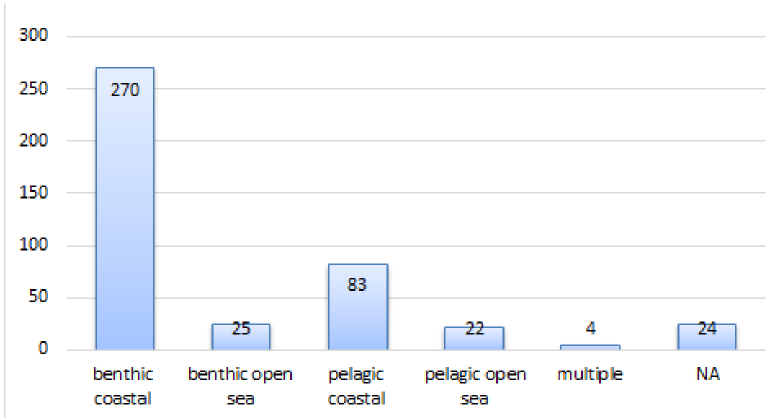

Figure 6 *Marine domains reported in the reviewed articles*

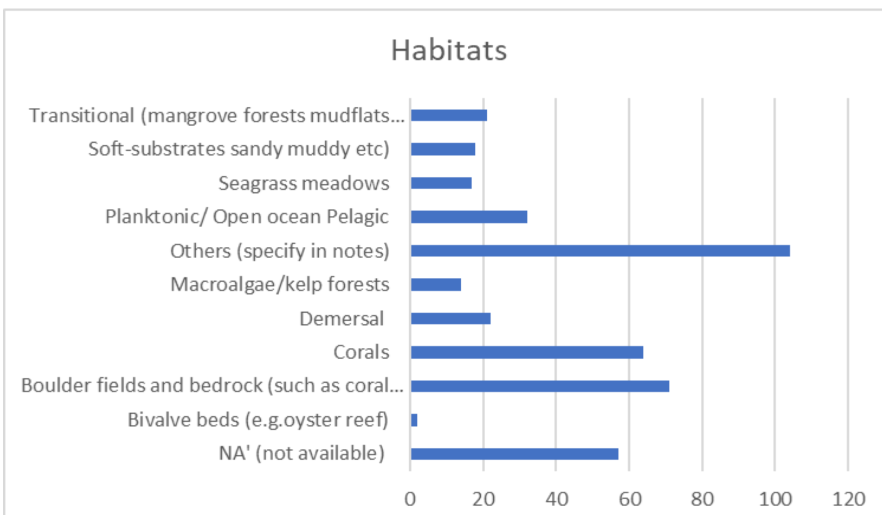

Figure 7 *Habitat types reported from studies in the literature review*

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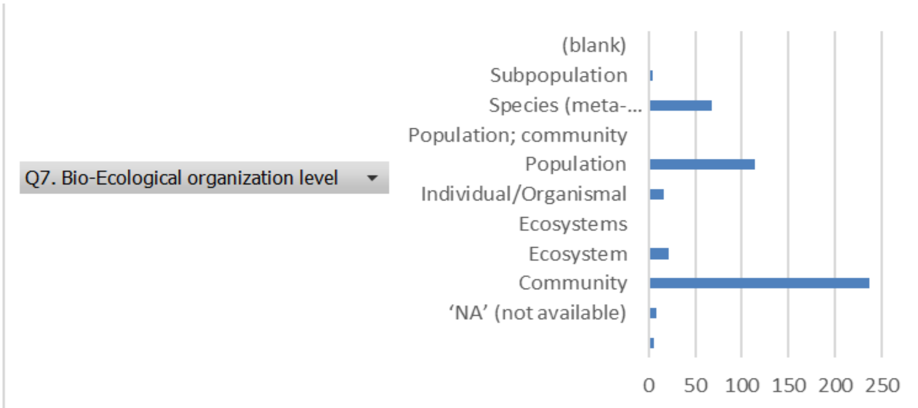

Figure 8 *Bioecological organization level reported from the literature review*

Based on word cloud analysis on the ecological criteria listed by the reviewers, the most reported criteria were functional diversity and life history traits, followed by foraging and refuge areas, trophic interactions, food web structure, biomass, size and feeding modes (Fig 9).

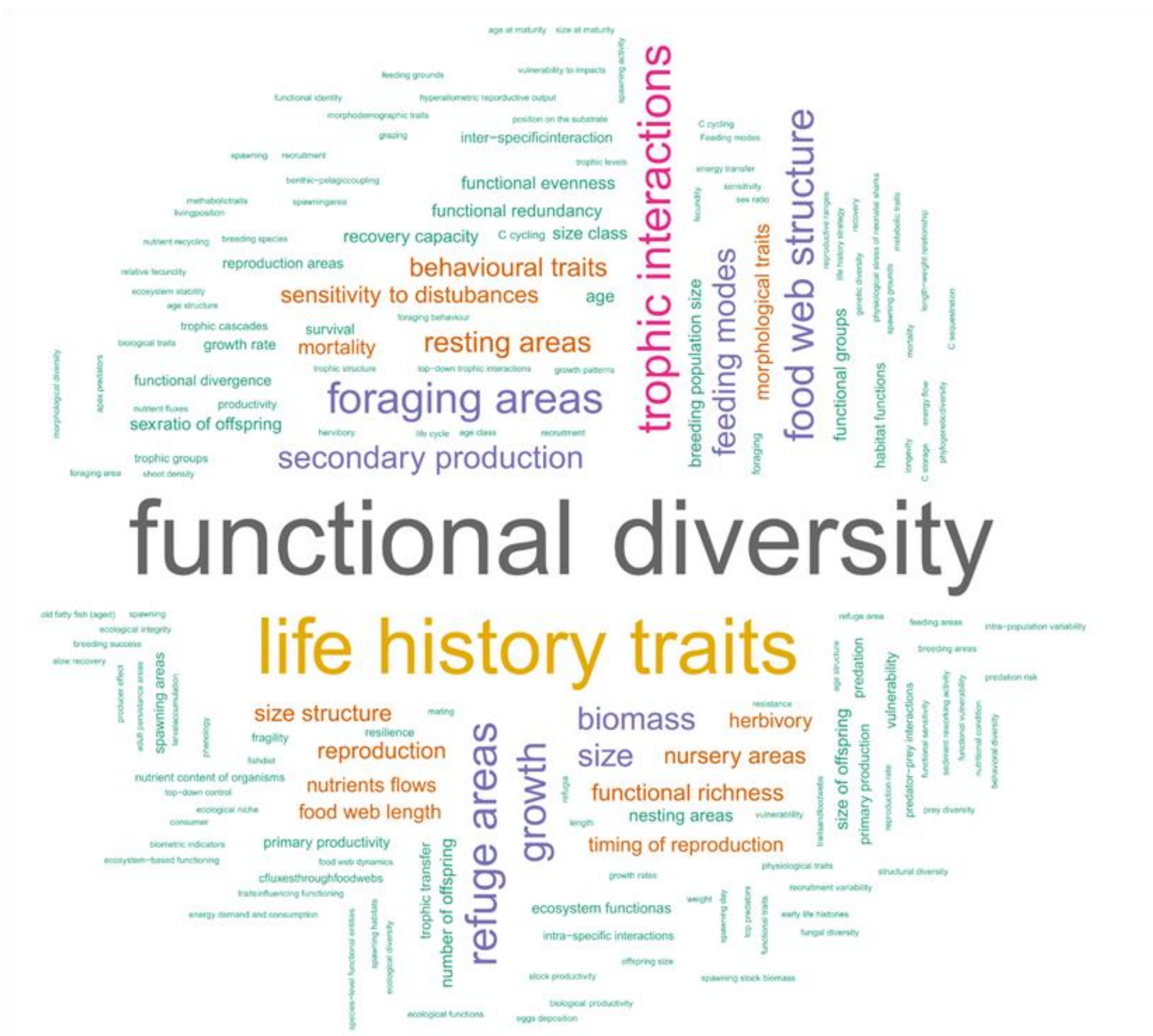

Figure 9 *Word cloud showing the main ecological criteria highlighted by the reviewers based on the screening of the specialized bibliography. The size of the terms refers to the frequency with which the terms were reported by the reviewers*

3.3.1 Functional diversity

Functional diversity (see also definition in Glossary) refers to the variety of biological processes functions or characteristics/traits expressed of a particular ecosystem; as such functional diversity reflects the biological complexity of an ecosystem (Thorne-Miller Boyce 1999). Researchers have for long focused on species diversity as a measure of ecosystem integrity and the success of conservation initiatives. However, the ecology of a species is determined by its functional traits and not necessarily by its taxonomy (Lefcheck et al. 2015). Traits such as body size, feeding behavior/diet, and mobility broadly determine what, how, and where resources are acquired, consumed, and transported. In turn, the diversity of traits (functional diversity) in a community dictates the ability of communities to fill diverse niches, assimilate energy, and transfer it within and across ecosystems, and enhance and stabilize ecosystem processes (Lefcheck et al. 2015; Gagic, et al. 2015; Dee et al. 2016; Duffy et al. 2016). Therefore, changes in biodiversity can affect ecosystem processes and functioning, for example, they can lead to changes in the community structure, resource uses and food webs as well as the loss of keystone species (e.g., Hooper et al. 2002; Paine 2002). In this way, functional diversity can be monitored to measure resource use and predict changes in ecosystem processes (Tilman 2001). Moreover, functional traits differentiate species in terms of how ecologically redundant or unique they are (Mouillot et al. 2014). Hence, measuring functional diversity allows us to generalize the functional contributions of species to ecosystems and contemplate the potential ecological consequences of their extinction whilst providing criteria for protection and conservation of important functions and ecosystem services.This category included criteria such as functional richness; functional divergence; functional evenness; functional redundancy; functional groups (see also Mason et al. 2005).

Functional diversity has been reported to represent functional groups based on form, size, life-history, feeding and behavior (see for example table 2 included in Barbera et al 2012). Other research measured community-scale rarity, and functional structure metrics, as proxies of functional redundancy and functional specialization Functional traits were used to capture the ecological roles of species, whereas distinct population-level criteria can be used to assign species' extinction risk.

3.3.2 Life history traits

Life history traits (definition also included in the glossary) include phenotypic characters that affect fitness, and include size at birth, age or size at maturity, and the sex ratio of offspring, and age- or stage-specific rates of growth, reproduction, survival, and investment in offspring (Stearns,2000). All of these are heritable to some degree and thus subject to natural selection.

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In our categorization this included the number, size and sex ratio of offspring, seaweeds shoot density; timing of reproduction, breeding population size; breeding failures, age and size at sexual maturity; growth patterns, incl. growth rate; size classes, body length distribution; slow-growing species; flowering index, patterns of dormancy, longevity; mortality; survival rates, k-r-strategies, incl. long-living species (among others).

Life history traits have previously been utilised by researchers as a proxy of resistance to disturbance. Maximum body size (length), body growth rate, longevity, age or length at sexual maturity, and rate of natural mortality are the main life history parameters that have been shown to correlate with vulnerability (Absesamis et al. 2014, and literature therein). Recently Kindsvater et al. (2016) provided a framework POSE (Precocial–Opportunistic–Survivor–Episodic) for categorizing life histories. This illustrates how a species' life history traits determine a population's compensatory capacity. They suggest that considering where a species' life history falls on the POSE spectrum can therefore be used to go beyond the usual cast of stock-assessed species to diagnose vulnerability to human exploitation of data-poor species. Therefore, management accounting for life history traits can lead to recovery, and eventually to resilient populations that are better able to withstand further environmental change.
Interestingly, some studies have tried to determine which life history traits could favor species invasiveness as traits can be determinant for the success of different invasion stages, from non-native species spreading to their full establishment in native communities (Castles and Briski 2019).

3.3.3. Trophic interaction, feeding modes, food web structures:

Trophic ecology investigates how various organisms at different feeding (trophic) levels interact within an ecosystem. In general, feeding or trophic relationships are represented as a food web or as a food chain. In the literature screening, criteria often reported were food web length, structure and/or complexity; feeding modes (trophic structure) and energy flow inferred from Ecopath /Ecosym models based on length, abundance, weight, trophic groups, and stable isotopes/ niche, and biomass used to predict predator, prey, trophic level. For example, trophic interaction has been used to model community interactions and predict alternative stable states of these for reserve design (Baskett et al. 2011). In another study, fish stomach content data was investigated to see how this could contribute to the definition of EBSAs. Identifying EBSAs is 'fitness-consequences' which relates to areas important for key life history functions (Gaichas et al. 2012). Food webs are analysed in terms of structural and functional traits including trophic levels, transfer efficiency, trophic role of species and keystoneness, trophic spectra and other synthetic ecological indicator have been analysed in Lercari and Francisco (2009), and Libralato et al. (2010).

4. Connectivity

Papers dealing mainly with connectivity, animal movements and migrations were temporarily kept apart (excluded from the systematic review on functional criteria) as starting from 2010 connectivity aspects in MPAs have been largely documented in peer-reviewed publications and reviews. However, connectivity terms and keywords were included in the final search strings and provide a list of papers that will be retained for future analyses (see section 2.2 of this deliverable).
In this paragraph, we collect general information from some insightful, selected reviews and grey literature on connectivity to provide a general, although not exhaustive, framework for deriving this ecological property in the designation, prioritisation and management of ABMTs.
Ecological connectivity is defined by UNEP (2019) as "the degree to which landscapes and seascapes allow species to move freely and ecological processes to function unimpeded" (Fig. 10). This concept derived from the fact that most living organisms (populations, and that of individuals, genes, gametes, and propagules) are largely dependent on more than one habitat, and might need to freely move among communities, and ecosystems, to accomplish their vital functions (e.g. feeding and breeding), and as such can be a major determinant of marine community structure and ecosystem functioning (Hilty et al. 2020). Connectivity becomes even more important in the marine environment where processes are highly interlinked, the complex life histories of most species have evolved adapting to the marine habitats, and many species are widespread. Ecological connectivity in marine environments consists in:

Passive (oceanographic) connectivity, the incidental movement of organisms, nutrients, and materials through physical processes such as currents, sinking, or upwelling. An example of passive connectivity would be fish, shellfish, or coral larvae dispersing via ocean currents, or nutrients being moved to the surface by upwelled water.
Active (migratory) connectivity, is the purposeful, self-directed movement of organisms from place to place. Migrations of large animals such as whales and turtles are the most obvious example of active connectivity, but this category also includes other movements such as the daily vertical migrations of mesophotic species between the surface and deeper waters.
Habitat connectivity, is the linkage between discontinuous habitat patches of the same type, whilst lastly
Seascape connectivity, is defined as the linkage between habitats of differing types, such as a fish juvenile moving from mangroves to seagrasses and then as adults to coral reef (Cannizzo et al 2021 and literature therein).

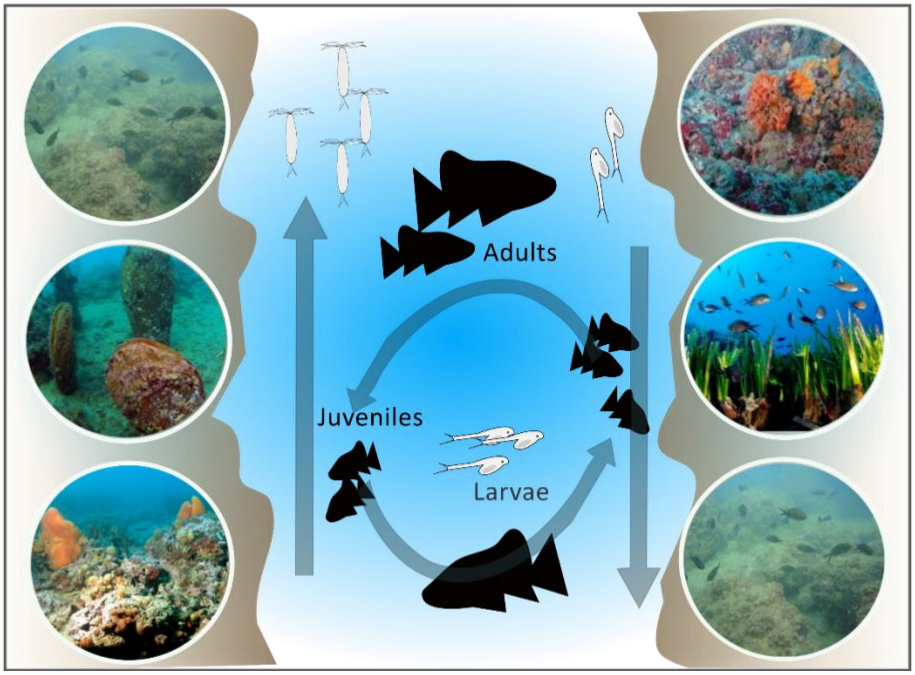

Figure 10 *Sketch showing species connectivity within a seascape (from Manea et al. 2020)*

To achieve the desirable 30% target of global conservation by 2030 there is an urgent need to upgrade management, conservation, and restoration strategies to maintain biodiversity and functioning of natural systems through connectivity (Hilty et al. 2020). The incorporation of connectivity criteria into MPA management is still in its early stages compared to its terrestrial counterparts. Balbar and Mataxas (2019) found that only 11% of the total 746 MPAs screened considered connectivity as an ecological criterion for their managment and improvement and out of these MPAs ca 71% were located mainly in California and Australia, indicating an important geographic bias.

Existing MPAs that have not incorporated connectivity may be ineffective in achieving the protection and persistence of biodiversity (Magris et al. 2018). This is especially the case for the decision-making processes of MPAs characterised by limited self-recruitment or where the size of the area required to maintain a viable population exceeds the size of the area proposed to receive protection, where as a result focusing also on connectivity can and should be essential (Marti-Puig et al. 2013). By prioritising connectivity, there is also a potential for both economic and social benefits to occur (e.g., spillover). When single protected areas cannot conserve marine ecological connectivity, a network of ecologically coherent marine protected areas is a promising alternative. In this case ecological connectivity becomes an essential tool for the designation of a networks of connected areas and their management, which might include protected areas, as well as other effective conservation measures, and other intact natural or semi-natural areas connected by ecological corridors, which have been established, restored, and maintained to conserve biodiversity in often fragmented systems (Hilty et al. 2020). Networks of MPAs should satisfy different connectivity-related objectives. In particular, MPAs should be strategically designed, placed and spaced to protect foraging movements in the home range of species and ontogenetic migrations between habitats for different life cycle stages (Grüss et al. 2011; D'Aloia et al. 2017). Therefore network design should incorporate connections between adjacent or continuous habitats, such as coral reefs and seagrass beds, or among mangrove and seagrass nursery areas and coral reefs; through regular larval dispersal in the water column between and within MPA sites; regular settlement of larvae from one MPA to another that promotes population sustainability; movements of mature marine life in animal home ranges from one site to another or because of regular or random spillover effects from MPAs (Cannizzo et al 2021).

The role of connectivity in the spatial prioritisation for conservation and management of both marine and terrestrial realms has been widely revised by Virtanen et al (2019). These authors identified several connectivity criteria/methods that were applicable to marine environments:

1. hydrodynamic modelling, to track larval movements,
2. knowledge on species traits,
3. information on species occurrences,
4. quality of habitats.

Sources and destinations of larvae or propagules can be identified as separate spatial layers and considered in full-scale spatial prioritisation, because involving data on population connectivity is an important determinant of meta-population persistence. However, the importance of marine connectivity vs other criteria depends on species traits and the marine environment studied. It depends on a range that goes on one hand from species that occupy isolated habitats and have long pelagic larval durations in deeper sea areas with strong directional currents, to the other end of the spectrum, where species with short pelagic durations, occupy fragmented habitats in shallow topographically complex sea areas with weak and variable currents (Virtanen et al. 2019).

Approaches and metrics:

Balbar and Metaxas (2019) reported that while managers mainly used seascape measures (e.g., habitat linkages) using tools such as Marxan, scientists have used more genetic and modelling approaches.

Methods to measure connectivity include modelling, tagging, genetics and simple observation (Bryan-Brown et al. 2017). Depending on the method used to collect connectivity data, various metrics can be used to elucidate connectivity patterns.

Modelling methods*:* In the scientific literature, individual-based modelling approaches yielding dispersal trajectories, connectivity matrices (i.e., source distribution matrix, e.g., through electronic or natural passive tagging methods) and dispersal kernels are

commonly used. Some authors have tailored metrics to taxa with different spawning and larval traits and have further combined them in a multi-species approach.
Other metrics involve local retention/population persistence in MPA (using fecundity or survival data, Burgess et al. 2012).
Genetic methods, on the other hand, have only been used in the management plans of only a few MPAs as they are more difficult to obtain. However, when available they can provide interesting information such as with regards to the genetic structure and diversity of metapopulations on scales of 1–100km (Beltrán et al. 2017). Inclusion of phylogenetic diversity, intraspecific genetic diversity and taxonomic diversity can increase the comprehensiveness of systems of marine conservation areas, while the characterization of taxonomic diversity, itself, will benefit from the rapid generation of complementary information from eDNA techniques. The integration of connectivity and adaptive genetic diversity can help create networks of MPAs that better satisfy the adequacy criterion, because they ensure greater long-term persistence of biodiversity (Andrello et al. 2023 and literature therein).
An overview of methods and metrics used to include connectivity in the designation and management of area-based protection measures is shown in the table below (Table 1).

Table 1 Examples of methods and metrics to include connectivity in marine conservation areas

Methods	Metrics	How	Description
Seascape approaches	Habitat linkage	tracking animals	linkage to other similar habitats through movements of adults, juveniles, seedlings
	Larval exchange		role in larval exchange with other marine habitats and for this reason a prioritisation for protection
Demographic approaches	Local Retention	biophysical model based on for example fecundity or survival	proportion of reproductive output (larvae) that recruits back into the donor population, provides details on replacement and therefore persistence of a population
Demographic approaches	Source		area of larval source for potential supply of nearby areas

Demographic approaches	Spillover	observation, visual census, video recording	e.g., supply of species adult and larvae that can disperse from one protected local area/community to other areas for fisheries harvest outside MPA, in which otherwise it would be excluded by local interactions
Demographic approaches	Stepping stone		e.g., small patches used by species to move between large patches, important in fragmented landscapes. Stepping stones facilitate the transport of biological material.
Genetic approaches	isolation by distance, gene flow, Intraspecific genetic diversity	haplotype diversity, nucleotide diversity, number of haplotype	e.g., parentage analysis, where juveniles can be assigned to their parents and the distance between them can be used to infer the dispersal larval capacities
	Intraspecific genetic diversity: genetic clusters, allelic richness, and local genetic differentiation. Dispersal		selection of planning units (PUs) that were not prioritised using habitat data only.
Genetic approaches	phylogenetic diversity	reconstruction of species-level phylogenetic trees	can be a proxy for functional diversity, and is therefore linked to ecosystem functioning and services

The inclusion and prioritization of connectivity in the design of a network of MPAs is particularly relevant to reach goals such as biodiversity conservation and sustainability, population persistence, resilience, and fisheries management of metapopulations. This approach is particularly important for species that move across different ecosystems or areas throughout their life cycle and as a means for achieving demographic persistence through MPAs and networking aspects particularly in the face of climate change (Magris et al. 2014).

For example, for fragmented populations key questions are:

- Is the habitat large enough for the population to be self-seeding?

- Are propagules from adjacent subpopulations needed for local population maintenance?
- What is the role played by the protected sub-populations with respect to the resilience of meta-population? (e.g. in Rozenfeld et al. 2008; Watson et al. 2011)

Several conservation objectives can be supported and guided by connectivity. A framework to facilitate its application of the best available information in the design and adaptive management of MPAs and networks of MPAs is report below:

Maintain population/community persistence: species/population that rely on different habitats for their life cycle or are characterised by low local retention may depend on connectivity to maintain persistence.
Siting and prioritisation of MPAs: setting sites for new MPA should be informed by data on individual passive and active dispersal that ensure connectivity and should attempt to improve persistence of populations or species that have to be protected.
Enlargement of MPAs networking: additional MPAs may need to be placed in areas recognized as being important for protecting genetic diversity, maintaining health of spawning stocks and creating stepping stones between existing MPAs.
Management plan adjustment: changes to the current MPA network such as rezoning, relocating or protecting adjacent habitats, have been proposed as a means to improve connectivity. Understanding the state of different sub-populations requires an adjustment in terms of monitoring and increasing knowledge of the current MPAs within their reference basin.

New tools are becoming accessible to managers to include connectivity in. The R toolbox 'best MPA' aims to explore alternative MPAs network designs and assess trade-offs of different ecological decisions. Marxan also allows for connectivity to be incorporated as a discrete feature and Zonation is another spatial planning tool, to optimise for connections through corridors or apply penalties based on boundary lengths. A newly developed tool, MarxanConnect, provides a graphical user interface to incorporate connectivity matrices and landscape connectivity data into Marxan. Simpler tools, such as a decision tree, can allow managers to incorporate size and spacing into MPA planning, if data on connectivity are limited (Balbar & Metaxas 2019 and literature therein).

5. Linking functional criteria to priority areas for marine conservation

Areas of priority for marine protection and conservation are those of particular ecological significance, where key functional processes take place, supporting species survival, the completion of species' life cycles, and population/community stability, and the healthy functioning of marine ecosystems. Additionally, areas that increase connectivity among other areas (ecological corridors), contribute to minimize the loss of biodiversity and support its conservation and protection. For example, the Convention on Biological Diversity (CBD, COP 9) proposed the Ecologically or Biologically Significant Areas (EBSAs) with regards to the marine environment as areas of priority, as those supporting the healthy functioning of oceans and the many services that it provides. To select EBSAs, seven scientific criteria have been conceived (defined in Annex I of CBD Decision IX/20, CBD, 2008; Johnson et al. 2018). The application of the EBSA criteria is an open and evolving process that should be continued to allow ongoing improvement and updating as improved scientific and technical information becomes available.

Here, we provide an exercise linking the EBSAs criteria with functional criteria-terms distilled from the scientific review and suggest methodologies to identify those areas for them to be included in conservation planning. Only EBSA criteria showing this kind of connection were taken into consideration. The information collated here can be further integrate existing guidance to identify sites to be included in a representative network of protected areas, addressing ecological coherence through representativity, connectivity, and replication and the adequacy and viability of the selected sites (Annex II of CBD Decision IX/20, CBD, 2008).

CBD scientific criteria for ecologically or biologically significant areas (EBSAs) (annex I, decision IX/20, (CBD, 2008)):

1. EBSA criterion / Special importance for life history stages of species: "Areas that are required for a population to survive and thrive" (CBD, 2008). Species are highly dependent on specific habitat and area types for population maintenance and survival. These areas correspond to the need for organisms to fulfil their vital functions, complete their life cycle and maintain population size. It therefore refers to areas supporting or suitable to important functions as spawning, breeding, growing, feeding and movements among vital areas. Relevant functional criteria: reproduction/breeding areas, spawning grounds, recruitment areas (larval sinks), nursery areas, feeding/foraging areas, corridors/migration routes, steppingstone areas, resting areas.

   Possible methodological strategies to address criteria is the full understanding of species life traits, modelling of species and habitat distributions (adults, juvenile larval distribution, dispersion, aggregation), ecological connectivity models, behavioural observations, assessing prey density and observing feeding rates, etc.

2. EBSA criterion / Importance for threatened, endangered or declining species and/or habitats are "areas containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species" (CBD, 2008).
   Related functional criteria: this EBSA criterion directly links to the functional criteria listed above that define the life history strategy of species. In addition, it relates to the criterion refuge areas (or refuges), defined as habitat features that provide protection or buffering to single organism or population against environmental, biotic or anthropogenic stressors (Bongaerts & Smith, 2019; Keppel et al., 2012; Pavey et al., 2015 cited in Boon et al. 2023).

   In addition to the above-mentioned identification methods for life history-related traits, those areas important for organisms survival can be defined with species dispersion models, assessing population sizes and persistence (e.g. sex ratio, reproductive rates, population dynamic models). Climate refugia can be identified by modelling the spatial distribution of species density under current environmental conditions and future climate change scenarios (habitat/species suitability models).

3. EBSA criterion / Vulnerability, Fragility, Sensitivity, or Slow recovery: "areas containing a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible, or unable to cope to degradation or depletion by human activity or by natural events) or with slow recovery" (CBD, 2008).
   Related functional criteria: vulnerability depends on the intrinsic characteristics of the system, criteria such as sensitivity, resistance, resilience/recovery and adaptivity which are in turn related to life traits and the magnitude and rate of pressure to which the system is exposed (IPCC, 2007; Foden et al., 2019).

   Methods to identify those areas depend on the biological targets, and can be assessed by using mechanistic models based on detailed information on the physiology of a species (if data are available) or by the trait-based methods that assess the sensitivity, adaptive capacity and exposure of a species, drawing on the biological traits of the species and their exposure to changes in climate (Foden et al, 2013).

4. EBSA criterion / Biological Productivity: "areas containing species, populations or communities with comparatively higher natural biological productivity. Examples Frontal areas, Upwelling zones, Hydrothermal vents, Seamounts, polynyas" (CBD, 2008).
   Related functional criteria: are those related to trophic ecology and linked to primary and/or secondary productivity, C production, C flux through food webs,

food webs stability and complexity). Those areas are identified by measuring C fluxes, primary and secondary C production, food webs structures and composition, etc

5. EBSA criterion / Biological Diversity: “areas containing comparatively higher diversity of ecosystems, habitats, communities, or species, or have higher genetic diversity” (CBD, 2008).
   Related functional criteria: Biological diversity is likely related to functional diversity, i.e. those areas providing high level of ecosystem functioning (e.g., Carbon storage, photosynthetic production) or areas where key ecological functions are concentrated (e.g., productivity). In particular, functional diversity is furthermore related to the presence of diverse functional groups, presence of key functional species (such as apex predators, primary producers, or other specific trophic group, functionally rare species, presenting peculiar/critical key functions, Grenié et al., 2018) and key functional areas (e.g., Carbon sink and source areas), functionally representative areas (areas with many critical/key functions) and food web structure (complexity, length, interactions).
   The strategy for addressing functional hotspots is mainly based on identifying and estimating number and intensity of species functional traits, metabolic functions, ecosystems processes, (such as energy flow and nutrient cycles etc.)

6. EBSA criterion / Naturalness: “Area with a comparatively higher degree of naturalness as a result of the lack of, or low level of, human-induced disturbance or degradation” (CBD, 2008).
   Related functional criteria: This EBSA criterion is principally related to ecosystem integrity, defined as an ecosystem in which dominant ecological characteristics occur within natural ranges of variation and are able to withstand and recover from most perturbations (Parrish et al., 2003). According to Foley et al. (2010) and de Juan et al. (2015) Indicators and metrics used for quantifying ecosystems integrity (and its inner criteria stability and resilience) can be based on their status (i.e. composition, functions and response to disturbances). Many of the indices currently available focus on structural rather than functional attributes therefore as already discussed, may be poor surrogates of the functional aspects of integrity. Species functional traits approach allow estimating the functioning and stability of communities and ecosystems and thus potentially offer useful surrogate variables for functional integrity (de Juan et al. 2015).

6. Conclusions and food-for-thought

MPAs have received significant attention and many studies have attempted to assess the effectiveness with respect to conservation targets set by management objectives (e.g., Giakoumi et al. 2018; Grorud-Colvert et al. 2021; Pendleton et al. 2017), but less attention has been devoted to identify and measure functional aspects that can be used to design new MPAs or redefine existing ones. This is especially critical in the context of a changing climate, with species that will potentially disappear or shift as a response to increasing temperature or ocean acidification (García-Molinos et al. 2015; Pinsky et al. 2020) thus reducing the benefits from MPAs (Bruno et al. 2018).

The aim of D3.1 was to apply a strict systematic approach for the revision of available bibliography to inform the definition of a portfolio of novel functional criteria to improve the way in which the designation of new MPAs and the planning of MPA networks is being done. Our results show that most of revised studies focused on single MPAs. We did not find many studies addressing functional aspects in identifying EBSAs, likely because, even when there has been a significant effort to identify EBSAs in national waters and in Areas Beyond National Jurisdiction (ABNJ), (Dunn et al. 2014; Johnson et al. 2018), in many cases there has not been any follow-up in terms of revising or effectively implementing protection measures for these areas (Harris et al. 2022), and indeed in assessing their relevance and effectiveness. We also found that even fewer studies were addressing the study of networks of MPAs. In addition, most of the studies were focused on well-established ABMTs (experimentally and extensively tested/measured) in comparison to newly proposed ones (proposed/suggested to reach some conservation goals). Most papers addressed coastal benthic domains and habitats such as coral reefs, coralligenous outcrops, rocky-shore or patchy soft sediments. As expected, our analyses suggested a paucity of information related to planktonic and deep-sea-habitats.

Based on the frequencies in which criteria-terms were reported by reviewers screening of the gathered documents, we were able to define an initial set of functional criteria highlighted in the specialized bibliography. Criteria-terms such as functional diversity, life history traits, foraging and refuge areas, trophic interactions, food web structure, biomass, size and feeding modes were among the most mentioned ones. Based on this information the following step will be the further harmonization and integration of extracted data. Furthermore, an in-detail analysis of the methods used for the estimation of described criteria will be performed. This would certainly help decision-makers and managers to rethink what data and methods are needed in order to include functional aspects in the design and management of area-based protection measures.

The information generated in this review will be compared with the list of criteria generated in WP2 in order to exactly define which criteria are already being used and which ones require further attention. This will allow us to propose a novel portfolio of functional criteria to be used in addition to relevant structural ones in order to improve the identification and designation of ABMTs, and the design of MPA networks. This information will be at the core of deliverable 3.2 (D3.2 *Portfolio of improved ecological criteria to be applied in systemic biodiversity protection and restoration for project testing sites*) and to the creation of the ESE 1 toolkit (D3.4). In addition, the systematic review and information extracted in this deliverable served as crucial groundwork for T3.1 and D3.1 of the Horizon Europe project Blue4All. The insights provided by T3.1 of MSP4BIO inspired and significantly contributed to the initial identification of key ecological aspects to be considered in D3.1 of Blue4All. This framing document developed in Blue4All will play a pivotal role in operationalizing ecological and environmental knowledge and data for its effective integration into the design and management of MPAs across European sea basins.

Our review poses the basis to list the functional aspects that will be critical to maintain, so that priority areas for conservation could be identified and their management improved in order to protect species and ecosystems providing essential functions. The whole information provided by this review constitutes the best available knowledge on functional aspects/criteria and it is the first step to upgrade the current prioritisation criteria, especially - when possible - focusing on EBSA criteria, ecological attributes associated to species and habitats listed as of priority for protection and those recognized as vulnerable and under threat in European basins (although our analysis covered the full globe). This will be done to effectively catalyze actions for systematic biodiversity protection and restoration, and to support nature-based solutions.

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Annex A – Literature that inspired the search string terms/keywords (not mentioned in the text)

Part II

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Annex B- Extraction of information Guideline

Instruction legend/format: **Extraction field name** (in bold**),** *Information on extraction field* (in italics)**,** categories of extracted information (in blue)

Q1. Functional process/criteria: ***Which functional criterion/a is the study focusing on?*** *Indicate and define in a few lines the target criteria/attributes/process mentioned in the article (Criteria that refer to processes and properties of ecosystems and their components, that relate to functioning, from ecosystem level to species level), indicate more than one if needed and separate with a*space if there is more than one with semicolon*. Insert one of the following fixed answers listed below (those merged from T2.2 criteria definition and from the review search string).*

Fixed answers:

Ecosystem functions/process:

- Food web length, structure and/or complexity (C fluxes through food webs; trophic transfer)
- Primary productivity (Phytoplankton bloom, bloom frequency, autotrophic processes);
- Secondary production (biomass production trough heterotrophic processes)
- Benthic-pelagic coupling
- Nutrient content of organism; nutrients flows
- C cycling (C storage, C uptake, C degradation)
- Carbonate deposition; biodeposition; calcification
- Trophic interaction; intraspecific interaction; inter-specific interaction
- Functional diversity; functional richness; functional divergence; functional evenness; functional redundancy; functional group

Species/population traits influencing functioning: *capture species/population characteristics and influence vulnerability to global impacts, e.g., having a large, fragile body and limited mobility, etc.):*

- Phenology (the study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life)

- Connectivity (such as migration, ecological connectivity= movement of animals/juveniles/gametes etc. among habitat) This includes dispersal capacity; migration capacity; immigration; emigration rates etc.)
- Physiological/metabolic traits (define energy storage, e.g., fatty acids or sterol composition; respiration; oxygen consumption; growth; degradation)
- Morphological traits (Size, structural morphological diversity, e.g., blubber thickness = layer of fat under the skin that prevents the animal's body from losing

heat, appendices for buoyancy etc.)

- Life history traits (Number, size and sex ration of offspring, incl. seaweeds shoot density; Timing of reproduction, Breeding population size; Breeding failures, Age and size at sexual maturity; Growth pattern, incl. growth rate; Size classes -, body length –distribution; Slow-growing species; Flowering index, Patterns of dormancy, Longevity-; Mortality -; Survival- rates, k-r-strategies, incl. long-living species, etc.)
- Behavioural traits (e.g., Foraging, Predation, Mating, Parental care, Defense behaviour etc.).
- Feeding modes (trophic groups, e.g., top predator, primary consumers, define a trophic level, and feeding strategy)
- Response of communities to the environments (role and adaptation in an ecosystem linking to functioning)
- Sensitivity to disturbance; Sensitive / tolerant species, Vulnerability; resilience e.g., communities associated with low oxygen, low light etc.;
- Opportunistic species, Pollution indicating species etc.

Habitat functions (*functions related to habitat structure*):

- Refuge areas; Resting areas; Foraging areas/Feeding grounds; Nursery areas and Nesting grounds; Reproduction areas, Spawning grounds; connectivity corridors

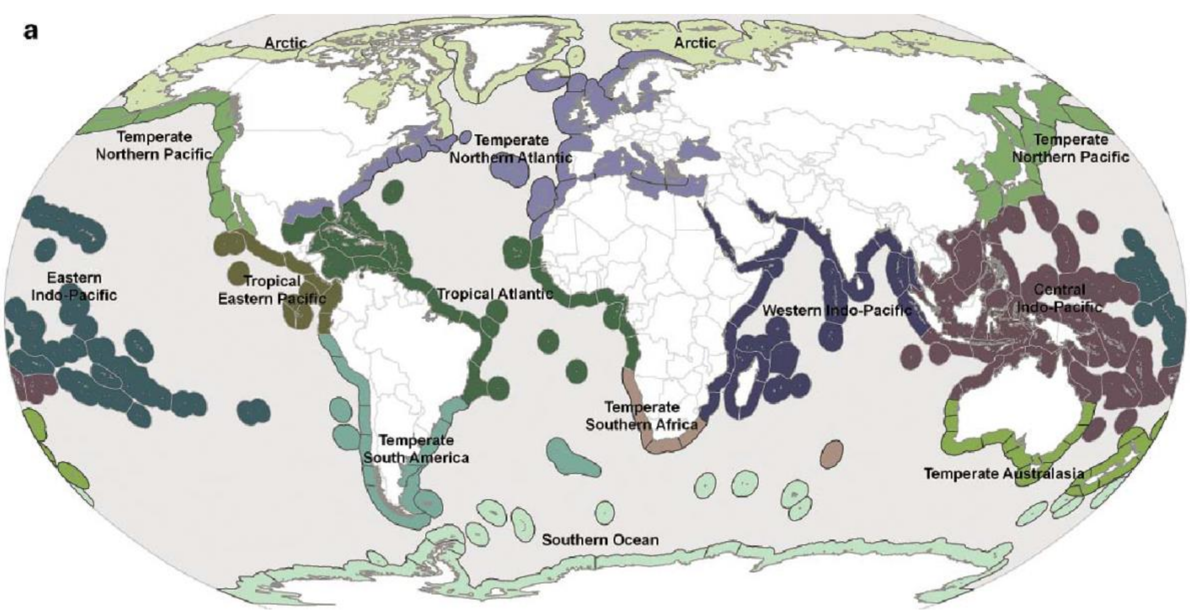
Q2. Ecoregions and province: *Which ecoregion/provinces is the study focusing on?*

Indicate the marine ecoregion and provinces for each ecoregion the province from which the criteria/attributes/process is described, following the Marine Ecoregions of the World (MEOW) of Spalding et al. (2007). Indicate the standard ocean and sea basin (please mind the spelling), NA in case the document is not referring to specific ecoregions.

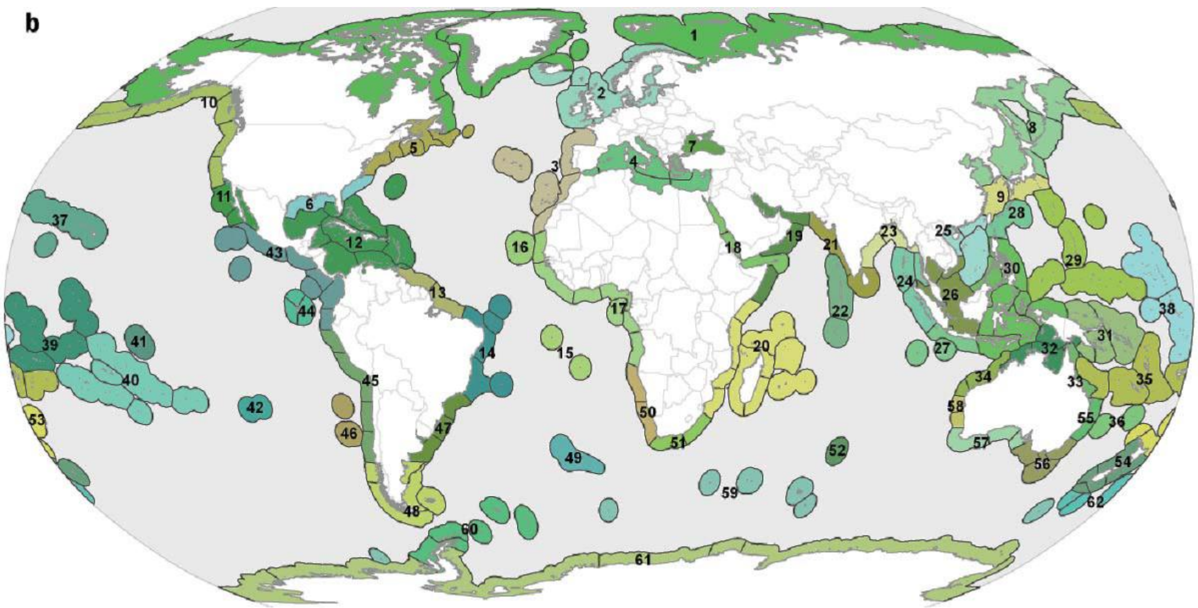
Fixed answers: Indicate Ecoregion in first column, and province in the second column; space with semicolon if more than one entry

- **Ecoregion:** Arctic ((1) on the map).
- **Ecoregion: Temperate Northern Atlantic** (Provinces: Northern European Seas (2); Lusitanian (3); Mediterranean (4); Cold Temperate Northwest Atlantic (5); Warm Temperate Northwest Atlantic (6); Black Sea (7)).
- **Ecoregion: Temperate Northern Pacific** (Provinces: Cold Temperate Northwest Pacific (8); Warm Temperate Northwest Pacific (9); Cold Temperate Northeast Pacific (10); Warm Temperate Northeast Pacific (11)).
- **Ecoregion: Tropical Atlantic** (Provinces: Northwestern Atlantic (12); North Brazil Shelf (13); Tropical Southwestern Atlantic (14); St. Helena and Ascension Islands (15); West African Transition (16); Gulf of Guinea (17)).
- **Ecoregion: Western Indo-Pacific (**Provinces: Red Sea and Gulf of Aden (18); Somali/Arabian (19); Western Indian Ocean (20); West and South Indian Shelf (21); Central Indian Ocean Islands (22); Bay of Bengal (23); Andaman (24)).

- **Ecoregion: Central Indo-Pacific (**Provinces: South China Sea (25); Sunda Shelf (26); Java Transitional (27); South Kuroshio (28); Tropical Northwestern Pacif (29); Western Coral Triangle (30); Eastern Coral Triangle (31); Sahul Shel; Northeast Australian Shelf (33); Northwest Australian Shelf (34); Tropical Southwestern Pacific (35); Lord Howe and Norfolk Islands (36)).
- **Ecoregion: Indo-Pacific** (Provinces: Hawaii (37); Marshall, Gilbert, and Ellis Island (38); Central Polynesia (39); Southeast Polynesia (40); Marquesas (41); Easter Island (42)).
- **Ecoregion: Tropical Eastern Pacific** (Provinces: East Pacific (43); Galapagos (44)).
- **Ecoregion: Temperate South America** (Provinces: Warm Temperate Southeastern Pacific (45); Juan Fernández and Desventuradas (46); Warm Temperate Southwestern Atlantic (47); Magellanic (48); Tristan Gough (49)).
- **Ecoregion: Southern Africa** (Provinces: Benguela (50); Agulhas (51); Amsterdam–St Paul (52));
- **Ecoregion: Australasia (**Provinces: Northern New Zealand (53); Southern New Zealand (54); East Central Australian Shelf (55); Southeast Australian Shelf (56); Southwest Australian Shelf (57); West Central Australian Shelf (58)).
- **Ecoregion: Southern Ocean** (Provinces: Subantarctic Islands (59); Scotia Sea (60); Continental High Antarctic (61); Subantarctic New Zealand (62)).



b



Q3. Article type: *Provide information if the article/study is an opinion paper proposing an ecosystem attribute/criteria/process, a research paper providing and analysing original data/indicators of the attribute/criteria, a review of attributes and criteria, a systematic review with meta-analysis re-analysing primary evidence.*

Fixed answers:

- opinion;
- research;
- review;
- metanalysis;
- OTHERS (specify if not included in the other categories)
- NA if not specified/available

Q4. Country: Which country is the study focusing on? *Report the location of the study/countries where criteria are studied /applied/ proposed (if any). NA in case the document is not referring to specific countries.*

Free answers: e.g., "Italy, France….can list more than one country if mentioned in the paper); separate if more than one with a semicolon; NA if not available

Q5. Marine domain: Which marine domain is the study focusing on? *provide the domain/realm to which the document refers to.*

Fixed answers: *separate if more than one with semicolon*
- benthic coastal
- benthic open sea
- pelagic coastal
- pelagic open sea

Q6. Marine habitats: Which habitat is the study focusing on? *provide name and combination of the habitat = physical and chemical environment in which a species lives, which refer to the attribute/criteria/process.*

Fixed answers: *separate if more than one with semicolon*
- Boulder fields and bedrock (such as coral reefs/coralligenous)
- Corals
- Bivalve beds (e.g., oyster reef),
- Soft substrates (sandy, muddy etc.)
- Macroalgae/kelp forests,
- Seagrass meadows,
- Transitional (mangrove forests, mudflats, swamps and salt marshes, estuaries, coastal lagoons),
- Planktonic/ Open ocean, Pelagic
- Demersal
- Ice cover bank
- OTHERS (please specify)
- 'NA' (not available).

Q7. Bio-Ecological organisation level: What level of biological organisation is the study/criterion focusing on? *Indicate at which level the attribute/process/criteria is referring to. (Reference: Scheffers et al. 2016, Science). If more than one, separate by semicolon.*

Fixed answers:
- Sub-organismal,
- Individual/Organismal,
- Subpopulation,
- Population,
- Species (meta-population),
- Community,

- ‘NA’ (not available).

Q8. Taxon specific (optional): Which specific taxa are the focus of the study/criterion? *Provide the name of a specific organism taxon reported to be linked to the attribute/criteria. Else, use ‘NA’ (not available).*

Free answers

Q9. Area-based conservation typology: Which conservation typology is the study focusing or speculating on? *Indicate for which spatial management typology the criteria are proposed, or tested/applied (choices refers to comprehensive list included in Part II of the review search string)*

Fixed answers:

- Marine spatial planning;
- Marine Strategy Framework directive;2008/56/EC;
- Integrated coastal zone management;
- Marine protected area (individual MPA);
- Marine protected area network;
- Marine reserve;
- Marine park;
- Marine sanctuary;
- Other effective area-based conservation measures;
- Special area of conservation;
- Special protection area;
- Site of community importance
- Other
- NA (not available, i.e. if no area-based conservation measure is mentioned in the study)

Q10. Inclusion of area-based conservation: At which level is the area-based conservation measure considered in the study? *Indicate if the measure is only mentioned, proposed/suggested to reach some goals; experimentally and extensively tested/measured*

Fixed answers:

- mentioned,
- proposed/suggested (to reach some conservation goals);
- experimentally and extensively tested/measured
- NA (information not available, i.e. if no area-based conservation measure is mentioned in the study)

Q11. Potential contribution of criteria*:* How criteria contribute to area-based conservation? *List how the attribute/criteria analysed or described can contribute in terms of conservation goals. This is an important section - define the purpose and provide more detailed information, if any, as it is useful to understand how authors contextualise the criteria for spatial prioritisation or other purposes).*

Fixed answers: *if more than one can be separated by semicolon*

- Designating (coherence, representativeness, vulnerable habitats, endangered species/habitat, preserve reproductive nursery area for commercial species etc.),
- Prioritising (coherence, representativeness, vulnerable habitats, endangered species/habitat, preserve reproductive nursery area for commercial species etc.),
- Setting management target (connectivity of network, increase spill over to fishing areas,), Restoring;
- Others (specify if other categories not included in the previous);
- NA (if not available)

Free answers: *add any additional comments regarding criteria purposes /aims/contribution*

Q12. Human activities: Which are the main human activities mentioned to affect or potentially affect criteria? *List if mentioned in papers human activities affecting the target attributes/processes/criteria. If more than one, separate each activity with a semicolon.*

Fixed answers: *defined according to list in annex III of MSFD.*

- Land claim;
- Canalization and other watercourse modifications;
- Coastal defence and flood protection;
- Semi-permanent restructuring of seabed morphology;
- Urban developments;
- Industrial developments;
- Transport infrastructure;
- Tourism & leisure infrastructure;
- Ports and other coastal constructions;
- Offshore marine infrastructure (including associated with mineral and energy extraction);
- Cables & pipelines;
- Extraction of oil and gas;
- Extraction of sand and gravel;
- Extraction of rock & minerals;
- Extraction of salt;
- Extraction of water;
- Renewable energy generation (wind, wave & tidal power;

- Non-renewable energy generation;
- Fish & shellfish harvesting (professional, recreational);
- Marine plant harvesting;
- Hunting and collecting (e.g., for non-food purposes);
- Aquaculture;
- Transport – shipping;
- Tourism and recreation;
- Research and survey;
- Military use;
- Waste and material disposal;
- Others (specify if not listed)
- None (no use)
- NA (if not clearly specified)

Q13. Human pressures: Which are the main human pressures that affect or potentially affect criteria? *List if mentioned in papers human pressures affecting the target attributes/ processes/criteria. If more than one, list and separate by semicolon.*

Fixed answers: *defined according to the list in MSFD annex III and integrated with threats mentioned in Bennet et al (2009).*

- Change of seabed substrate or morphology (~ physical loss);
- Disturbance or damage to seabed;
- Extraction of seabed or subsoil (e.g., sand, gravel, rock, oil, gas);
- Input of water;
- Changes to hydrological conditions (*this includes alterations to hydrological flows and reduction of aquatic connectivity e.g., water extraction, dams, breakwaters and artificial channels mentioned in Bennet et al 2009*), and *altered rainfall due to CC;*
- Input of sound;
- Input of electromagnetic and seismic waves;
- Change in water temperature (*this includes effects of global warming on regional temperature mentioned in Bennet et al 2009)*;
- Input of artificial light;
- Input of nutrients and organic matter (*this includes nutrient addiction mentioned in Bennet et al 2009);*
- Input of contaminants (synthetic substances, non-synthetic substances, radionuclides) - diffuse sources, point sources, acute events (*this includes chemical additions to ecosystems e.g., fertilisers, pesticides, insecticides mentioned in Bennet et al 2009*);
- Input of CO2 (and other greenhouse gases), *this includes change in pH/acidification*;
- Input of litter (solid waste matter, including micro-size litter);
- Extraction or, or mortality/injury to, species (targeted, non-targeted), (*this includes*

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unsustainable harvesting of natural resources e.g., exploitation of fish stocks, timber and other plant products beyond the rate of natural replacement mentioned in Bennet et al 2009)

- Disturbance of species;
- Translocation of (native) species;
- Introduction of genetically modified species;
- Introduction or spread of non-indigenous species;
- Introduction of microbial pathogens;
- Artificialisation of natural habitat (*this includes degradation, fragmentation and loss of habitats, e.g., forest destruction, draining wetlands mentioned in Bennet et al 2009*);
- Others (specify if not listed)
- None (no use)
- NA (not available)

Q14. Spatial scale: At what spatial scale do the criteria occur? Provide information (if mentioned in the paper) *on spatial scale at which the criteria/process occurs.*

Fixed answers:

- National (part of the marine waters of a country),
- Supranational (spans over more than one country),
- Continental,
- Global,
- NA, not applicable, in case of laboratory experiments

Q15. Temporal scale: At what temporal scales do the criteria occur? Provide information (if mentioned in the paper) *on temporal scale at which the criteria/process mentioned in the paper occurs.*

Fixed answers:

- Hourly;
- Daily,
- Seasonal,
- Yearly
- Others (specify if not listed)
- NA (not available)

Q16. Variables/indicators supporting criteria: Which are the variables used for measuring the criteria? *Provide indicators/variables* (if mentioned in the paper) *supporting the assessment of attributes/criteria/process.*

Free answers

Q17. Availability of data: What data on criteria is available? *Provide information on the data availability of the specific attribute/ criteria /process obtained e.g. from monitoring programme/ environmental policy etc.*

Fixed answers:

- MSFD (Marine Strategy Framework Directive);
- WD (Water directive);
- HD (Habitat directive);
- LTER (Long Term Ecological Research);
- Copernicus,
- GEO EV-Essential Variable,
- Other (specify if not listed),
- NA (if data are not available)

Q18. Integration into DSTs: *Indicate if criteria/process/attributes have been used in Decision Support Tools (DST) or other spatial, spatio-temporal, prevision tools (e.g., dispersion models).*

Free answers:

- specify tools (e.g. brief DST description, model description)
- NA (if any DST is mentioned)

Q19. Link to Ecosystem Services: *Indicate if the process/criteria/attributes are related/linked to the provision of ES (according to Common International Classification of Ecosystem Services, CICES v5.1 by EEA see Appendix Table B1 at the end of document).*

Fixed answers: *Provide ES from the list extracted from CICES v5.1 by EEA see Appendix; if more than one separate by semicolon*

Q20. Criteria constraints: *indicate (if mentioned in the paper) the time, cost, knowledge gaps, uncertainty, measurement gaps or other constraints relevant to the criteria analysed/used.*

Free answers: *write freely if mentioned*

NA, *if not available*

Q21. Notes: *add any notes/comments about the article that are of interest for interpretation.*

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Table B1. List of ecosystem services filtered for marine environments assets (from CICES v5.1)

Provisioning	Biomass	Cultivated aquatic plants for nutrition, materials or energy	B
	Biomass	Reared aquatic animals for nutrition, materials or energy	B
	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	B
	Biomass	Wild animals ((terrestrial and aquatic) for nutrition, materials or energy)	B
	Genetics (including seeds, gamete production)	Genetic material from plant, algae or fungi	B
	Genetics (including seeds, gamete production)	Genetic material from animals	B
Regulation & Maintenance	Transformation	Mediation of wastes or toxic substances of anthropogenic origin by living processes	B
	Transformation	Mediation of nuisances of anthropogenic origin	B
	Regulation	Regulation of baseline flows and extreme events (Control of erosion rates)	B
	Regulation	Regulation of baseline flows and extreme events,: Buffering and attenuation of mass movement	B
	Regulation	Regulation of baseline flows and extreme events: Hydrological cycle and water flow regulation (Including flood control	B
	Regulation	Regulation of baseline flows and extreme events, Storm protection	B
	Regulation	Lifecycle maintenance, habitat and gene pool protection: Pollination (or 'gamete' dispersal in a marine context)	B
	Regulation	Lifecycle maintenance, habitat and gene pool protection: Maintaining nursery populations and habitats (Including gene pool protection)	B
	Regulation	Pest control (including invasive species)	B
	Regulation	Disease control	B
	Regulation	Water conditions: Regulation of the chemical condition of salt waters by living processes	B
	Regulation	Atmospheric composition and conditions: Regulation of chemical composition of atmosphere	B
	Regulation	Atmospheric composition and conditions: Regulation of temperature and humidity, including ventilation and transpiration	B
Cultural	Direct, in-situ and outdoor interactions with living systems	Physical and experiential interactions with natural environment: Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	B
	Direct, in-situ and outdoor interactions with living systems	Physical and experiential interactions with natural environment: Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	B
	Direct, in-situ and outdoor interactions with living systems	Intellectual and representative interactions with natural environment: Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge	B
	Direct, in-situ and outdoor interactions with living systems	Intellectual and representative interactions with natural environment Characteristics of living systems that enable education and training	B
	Direct, in-situ and outdoor interactions with living systems	Intellectual and representative interactions with natural Environment: Characteristics of living systems that are resonant in terms of culture or heritage	B
	Direct, in-situ and outdoor	Intellectual and representative interactions with natural	B

	interactions with living systems	Environment: Characteristics of living systems that enable aesthetic experiences	
	Indirect, remote, often indoor interactions with living systems	Spiritual, symbolic and other interactions with natural environment: Elements of living systems that have symbolic meaning	B
	Indirect, remote, often indoor interactions with living systems	Spiritual, symbolic and other interactions with natural environment: Elements of living systems that have sacred or religious meaning	B
	Indirect, remote, often indoor interactions with living systems	Spiritual, symbolic and other interactions with natural environment: Elements of living systems used for entertainment or representation	B
	Indirect, remote, often indoor interactions with living systems	Other biotic characteristics that have a non-use value Characteristics or features of living systems that have an existence value	B
	Indirect, remote, often indoor interactions with living systems	Other biotic characteristics that have a non-use value Characteristics or features of living systems that have an bequest value	B

Guideline References

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