Deliverable D3.2- *Synthesis and detailed assessment of ecology-based tools to support MPA practitioners*

WP3 – Work Package 3

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Document History

Deliverable Title	Synthesis and detailed assessment of ecology-based tools to support MPA practitioners
Brief Description	This deliverable provides a detailed inventory and semi-quantitative assessment (considering the end users' perspective) of digital tools equipped with the analytical capabilities to support managers and decision-makers in integrating and analysing ecological and environmental data within MPA processes.
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Table of Contents

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1. Executive Summary

WORK PACKAGE 3 AIMS TO DEVELOP SCIENCE-BASED SOLUTIONS TO ENHANCE THE INTEGRATION OF ECOLOGICAL AND ENVIRONMENTAL DATA INTO THE DESIGN AND MANAGEMENT OF MARINE PROTECTED AREAS (MPAS). THIS DELIVERABLE PRESENTS A COMPREHENSIVE INVENTORY AND SEMI-QUANTITATIVE ASSESSMENT OF DIGITAL TOOLS EQUIPPED WITH THE NECESSARY ANALYTICAL CAPABILITIES TO SUPPORT MPA MANAGERS AND DECISION-MAKERS. THE IDENTIFICATION OF THESE TOOLS WAS BASED ON A SYSTEMATIC REVIEW, EXPERT CONSULTATION, AND THE INITIAL SCOPING CONDUCTED IN DELIVERABLE 1.3. ALL RELEVANT DIGITAL TOOLS WITH ANALYTICAL FUNCTIONALITIES FOR ADDRESSING KEY ECOLOGICAL AND ENVIRONMENTAL DIMENSIONS, AS PREVIOUSLY IDENTIFIED IN DELIVERABLE 3.1, WERE EVALUATED AGAINST A COMPREHENSIVE SET OF CRITERIA. BEYOND TECHNICAL AND DATA-RELATED ASPECTS, THE ASSESSMENT PLACED SPECIAL EMPHASIS ON USER EXPERIENCE AND THE CHALLENGES FACED BY END USERS WHEN INTERACTING WITH THESE TOOLS. TO ENSURE A HOLISTIC EVALUATION, CRITERIA RELATED TO USER-FRIENDLINESS AND ACCESSIBILITY WERE EXPLICITLY INCORPORATED. THE RESULTS OF THIS ASSESSMENT INFORMED RECOMMENDATIONS ON THE MOST SUITABLE AND USER-FRIENDLY TOOLS FOR ADDRESSING A BROAD RANGE OF ECOLOGICAL AND ENVIRONMENTAL DIMENSIONS, INCLUDING UNDERREPRESENTED ASPECTS SUCH AS CONNECTIVITY AND CLIMATE CHANGE, AS IDENTIFIED IN DELIVERABLE 3.1. ADDITIONALLY, THIS DELIVERABLE PROVIDES INSIGHTS INTO EXPANDING AND REFINING THE INTRODUCED ASSESSMENT METHODOLOGY AND EFFECTIVELY INTEGRATING IT INTO THE PROJECT'S PRIMARY OUTPUT, THE BLUEPRINT PLATFORM. FURTHERMORE, THE DELIVERABLE EXPLORES STRATEGIES FOR THE EFFECTIVE INTEGRATION OF DIGITAL TOOLS AND ADDRESSES CHALLENGES RELATED TO DATA AVAILABILITY THAT MAY IMPACT THEIR IMPLEMENTATION. THE INSIGHTS GAINED WILL ALSO CONTRIBUTE TO THE DEVELOPMENT OF SOLUTIONS FOR CHALLENGES ENCOUNTERED IN THE PROJECT'S LIVING LABS, FURTHER ENHANCING THE EFFECTIVENESS OF SCIENCE-BASED DECISION-MAKING IN MPA DESIGN AND MANAGEMENT.

2. Introduction

Decision-making in nature conservation faces several challenges, not the least of which is the complexity of ecological systems (Game et al., 2013). The structure and functioning of marine ecosystems combined with human activity leads to a myriad of interactions and responses (Solé & Levin, 2022). Traditionally, expert opinion has been relied on to untangle this complexity. Expert opinion, while valuable for providing insights and contextual understanding, is inherently subjective and often limited in its ability to disentangle the intricate interactions that characterise ecological systems. Moreover, it falls short in quantifying the uncertainties embedded within ecological responses, which are shaped by complex, dynamic, and often non-linear processes. As a result, relying solely on expert judgment can lead to oversimplified interpretations and a lack of transparency, potentially undermining the robustness of conservation and management decisions (Inácio et al., 2020). Decision-support tools (DSTs) based on scientific evidence have been developed in an effort to mitigate subjectivity in decision-making and systematically address the complexity of natural systems (McIntosh et al., 2011; Rose et al., 2017; Kotta et al., 2020).

DSTs are often developed in relative isolation within academia and shaped primarily by the perspectives of their scientifically minded developers. As a result, they frequently fail to account for the practical needs and expectations of the end users they are intended to support (McIntosh et al., 2011; Rose et al., 2017; Bolman et al., 2018). In addition, non-expert end users often struggle to locate and access available DSTs, as well as to determine whether a particular tool aligns with their specific needs. For DSTs to be effectively applied in spatial planning and conservation, they must bridge the gap between the scientific knowledge of their developers and the decision-making processes of managers. This requires translating expert scientific knowledge into accessible, user-friendly formats that accommodate the needs of non-specialist users (Kotta et al., 2020). DSTs are of no benefit if their use is stymied by a lack of expertise or arduous training demands.

In other words, DSTs need to be both usable and meaningful to their users, regardless of technical background. Meeting these challenges requires, first and foremost, a thorough and systematic assessment of available DSTs, encompassing not only technical characteristics but also their accessibility and ease of use. Ensuring that DSTs are both technically robust and aligned with user expectations is essential for their effective integration into spatial planning and conservation decision-making processes.

As part of Work Package 3, this deliverable aims to assess the current state of DSTs with the capability to integrate ecological and environmental knowledge and data into the design and management of Marine Protected Areas (MPAs). Following the PRISMA Protocol (Page et al., 2021), a systematic and comprehensive review of all relevant DSTs was conducted. The collected information was used to document and assess their applications, capabilities, and limitations, with a particular focus on their practical suitability for MPA managers and decision-makers. The review will ultimately lead to the amalgamation of suitable features to create DSTs that maximize the ability to meet the conservation and restoration objectives of MPAs, integrating the best available scientific knowledge and data through user-friendly applications.

2.1 Specific Aims

1. To compile a list of applicable DSTs to inform the design and management of MPAs and area-based conservation measures in general.

2. To perform a systematic and comprehensive assessment of the identified DSTs following a bottom-up approach, considering not only their technical features and data-related aspects but also their accessibility and ease of use for end users.

3. To leverage the review results to propose strategies for improving the integration of existing DSTs, ensuring they effectively address the practical needs of MPA managers and decision-makers. These recommendations will be also informed by the baseline and needs assessment conducted in WP4 across the 14 project Living Labs, as well as insights from the "Revision and Practical Guidelines for the Implementation of Innovative Ecological and Environmental Concepts in MPA Processes" (D3.1). Additionally, the assessment conducted in this deliverable is expected to aid future users of the project's Blueprint Platform (a user-friendly, web-based platform designed to assist managers in the planning and management of effective, efficient, and resilient MPAs and MPA network) in identifying the most suitable solutions for the challenges faced by MPAs.

3. Methodological approach

This deliverable presents a systematic review of existing DSTs with the capabilities to integrate ecological and environmental knowledge into MPA processes. Through the systematic review, additional online searches and expert consultation we aimed to improve the preliminary list of tools created in D1.3 (Lai et al., 2023). The information gathered and extracted through a comprehensive extraction guide (Appendix A) was used to evaluate the ability of each tool to address the needs and challenges of MPA managers and decision-makers, as well as to integrate the necessary knowledge, identified in D3.1 (Hoppit et al., 2024), into MPA processes.

The following sections outline the steps taken to identify available tools (section 3.1), describe the tool types and selection for in the final assessment (section 3.2), and the criteria developed and selection for the ecological and environmental tools assessment (section 3.3).

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3.1 Systematic review of science-based ecological and environmental tools

A systematic review of academic literature was conducted between June and July 2024 using Web of Science and Scopus. The search focused on keywords related to the marine realm, DSTs, and spatial planning and conservation measures. The search string, created by combining topic-related keywords using the Boolean search connectors was developed, refined, and optimized based on the expertise of Project Partners (Table 1). It was further shaped by adapting and building upon the preexisting search string from the systematic review protocol published by Mangano et al. (2015).

Table 1. Search string utilized for the systematic search conducted in Web of Science and Scopus.

Topic	Keywords
Sea-related	(sea OR marine OR brackish OR ocean* OR lagoon* OR coast* OR estuar* OR maritime OR "deep sea")
Tools-related	(tool* OR "decision support*" OR "decision mak*" OR "manager support" OR "management support" OR geo-platform*)
Spatial planning and conservation related	("spatial planning" OR "spatial management" OR "marine directive*" OR "integrated coastal zone management" OR "protected area*" OR "marine reserve*" OR "marine park*" OR "marine sanctuary*" OR "protected seascape*" OR "marine conservation area" OR "special area* of conservation" OR "conservation unit*" OR "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 area*" 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*")

Papers were screened following the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) protocol (Page et al., 2021). First, articles retrieved from Web of Science and Scopus were screened for duplicates. Second, a title and abstract screening was conducted, with multiple reviewers collaboratively verifying and agreeing on the selection of articles. Third, full-text screening and data extraction were performed by the co-authors of the deliverable.

A document was excluded if it fulfilled, either at the title, abstract or full-text, at least one of the following exclusion criteria:

1. *Realm:* the document does not refer to marine or related transitional environments.
2. *Minimum information provided*: publications that do not explicitly revise, assess and/or implement specific tools or address the more general topic of DSTs in marine spatial planning and conservation.
3. *Type of tool*: Tools that do not support the integration and analysis of ecological and environmental data to inform the planning, designation and management of area-based conservation measures.

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3.2 Tool typology

Within the scope of WP3, tools will be broadly categorized into two main classes:

A. Data collection and gathering

This category includes methods, approaches, and protocols designed to gather baseline information critical for planning, implementing, and evaluating area-based conservation measures. It encompasses a wide range of approaches, from purely scientific methods to participatory strategies, for generating relevant data. Examples include monitoring programs, expert-based assessments, systematic reviews (with or without meta-analysis), participatory mapping, and citizen science initiatives.

B. Integration and analysis to support planning

This category includes tools that facilitate the integration and analysis of ecological and environmental data to support the planning, implementation and assessment of area-based conservation measures. Examples include tools designed for identifying and prioritising Ecologically or Biologically Significant Areas (EBSAs), conducting (in-combination and cumulative) assessments of human pressures, spatial optimization of conservation measures, and analysing ecological connectivity.

While the initial systematic search focused primarily on digital tools capable of integrating and analysing ecological and environmental data within MPA processes (Class B), particularly to address persisting knowledge gaps identified in D3.1, tools for data collection and gathering (Class A) will be further explored in later stages of the project. These tools will be assessed for their potential integration into the Blueprint Platform.

3.3 Tools assessment criteria

3.3.1 Development of criteria to assess science-based tools

In alignment with the Blue4All project approach, the criteria for evaluating tools were developed using a bottom-up methodology that prioritizes end users' perspectives and needs. The qualities that make a tool effective for managers and decision-makers in supporting MPA processes are often overlooked by tool developers (McIntosh et al., 2011; Rose et al., 2017; Bolman et al., 2018). While analytical capabilities and complex models may appeal to scientific users, they frequently fail to engage those without a scientific background, leading to non-data-driven decision-making in MPA processes. Therefore, selecting tools that integrate and analyse data in a user-friendly and easily accessible manner is crucial to ensuring well-planned and effective conservation measures.

To establish a comprehensive set of criteria for assessing and scoring identified DSTs—helping decision-makers and MPA managers select the most suitable tool—a structured three-step process was followed:

Step 1: Brainstorming initial criteria and sub-criteria with a core team composed of partners from Work Packages 2 and 3.

Step 2: A workshop (including main partners in Blue4all and stakeholders from Living Labs) was held, to define a first comprehensive set of criteria. The participants were divided into five groups. Representation of the Living Labs was granted in all groups. Each group was given a board with the following six criteria (based on

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those introduced in step 1) written: 1) knowledge-related, 2) user-friendliness, 3) accessibility, 4) technical aspects, 5) social aspects, and 6) administrative aspects. Examples of sub-criteria were provided for each of the criteria. The activity was divided into three phases:

- Phase 1: Discuss the pre-proposed criteria and suggest additional ones (if needed).
- Phase 2: Suggested relevant dimensions (sub-criteria) for each criterion (including newly proposed ones, if any) considering the provided examples.
- Phase 3: Rank the criteria for ecological and environmental, and social, economic, and governance-related tools separately.

All groups discussed for 45 minutes and completed the three phases of the exercise.

Step 3: All groups' keywords combining and network analysis.

In general, all groups agreed on the suggested criteria. The additional criteria "transferability" and "legal aspects" were suggested. The groups suggested including the criterion "social aspects" into other criteria and not keeping it as an independent one and considering some of criteria and sub-criteria as pre-conditions that should be granted for the tool to be used (e.g., accessibility, Table 1, Figure 1).

Over 150 comments and keywords were suggested during the discussion of sub-criteria. After an initial cleaning, the provided information resulted in 23 sub-criteria (Table 1). Given the identified sub-criteria and the criteria in which the groups included them, a network analysis was performed to assess the links between criteria and the level of redundancy (Figure 1). A criterion was considered relevant if it included at least two sub-criteria not shared with other criteria.

The generated network (Figure 1) confirmed that "social aspects" was redundant, and the sub-criteria included in this criterion could be placed under other criteria. The only unique sub-criteria proposed under "social aspects" was "equity", but after a thorough discussion, the sub-criteria were put under the criterion "user-friendliness". In addition, the sub-criteria "transferability" and "legal aspects" did not contain any unique sub-criteria (Figure 1, Table 1) and, therefore, should not be considered as separate criteria in the tools assessment. In addition, none of the suggested sub-criteria under "administrative aspects" differed from those under other criteria.

As a result, four main criteria were derived from the analysis (Figure 2, Table 2):

a) User-friendliness: refers to the experience that users have when interacting and using the tools.

b) Knowledge-related: refers to the capacity of the tool to cover relevant ecological/environmental and social/economic/governance topics to be considered in the design and management of MPAs and MPA networks.

c) Accessibility: refers to how openly available the tool is and the technical demands that users must consider for its implementation.

d) Technical aspects: refers to the set of features of the tools that define their operability, stability and adaptability.

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It was made clear by the workshop participants that ranking criteria and tools based on their importance for the user is impossible at this stage. Such ranking should be considered in the development of the Blueprint Platform, where a ranking system based on the users' feedback could be included.

Table 1. Sub-criteria's general description and frequency in criteria groups based on the group discussions.

		Ecological and Environmental				**Social**		**Suggested**	
Sub-criteria	**General description**	Knowledge-related	User-friendliness	Accessibility	Technical aspects	Social aspects	Administrative aspects	Transferability	Legal aspects
Cocreation and communication	It evaluates the involvement of stakeholders in the development and updating of tools and the possibility of providing feedback and communicating the tool's value	4	3	1	2	8		1	
Transparency	It evaluates the tool's and tool outputs' transparency and reliability (e.g., detailed user guide, presence of meta-info, usage in examples)	5	4		2	6			
Open access	It evaluates the monetary cost of the tool (e.g., open/partially open/license required)			7		1	4		
Data input	It evaluates the possibility of inputting new data (e.g., data requirements and possible data types)	5			3	1	1		1
Level of expertise	It evaluates the expertise required to use the tool (e.g., complexity level, intuitiveness, technical background required)		6	3			1		
Legislation inclusion	It evaluates the tool's possibility of indicating local legislation criteria and national policies.	3	1		1		4	1	
Integrability	It evaluates the tool's potential to integrate available platforms/services and databases and services.	3	1	1	4				
Tool longevity	It evaluates the tool's age, updates and level of maintenance.	1			4		2		
Adaptability	It evaluates the tool's ability to adapt to different user types and needs.	2			2	1	1		
Language technicality	It evaluates the tool's user-interface language complexity level.		2	3					
Scalability	It evaluates the tool's usage in different scales and the	3						2	

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	spatial-temporal coverage (e.g., single MPAs, MPA networks, temporal scenarios, spatial coverage).						
User manual	It evaluates the presence and practicality of the tool's user manual.		4	1			
Local context inclusion	It evaluates the tool's ability to account for local and cultural contexts	1	1			1	1
Output complexity	It evaluates the tool's outputs practicality and visualization.		1		2	1	
Technical requirements	It evaluates the technical requirements of the system to use the tool.		3		1		
Usage time	It evaluates the time that users need to invest to use the tool.			2		1	
Data in tool	It evaluates the data included in the tool (e.g., inclusion of functioning data).	2		1			
Language inclusiveness	It evaluates if the tool uses gender-inclusive language.		1			1	1
Multilanguage	It evaluates if the tool supports different languages.		2				
Output downloading	It evaluates if the tool has options to download the outputs.				2		
Technical support	It evaluates if the tool offers technical support.				1	1	
Equity	It evaluates if equity is considered.					1	
Multi-platform support	Evaluates if the tool is supported in multiple platforms.		1				

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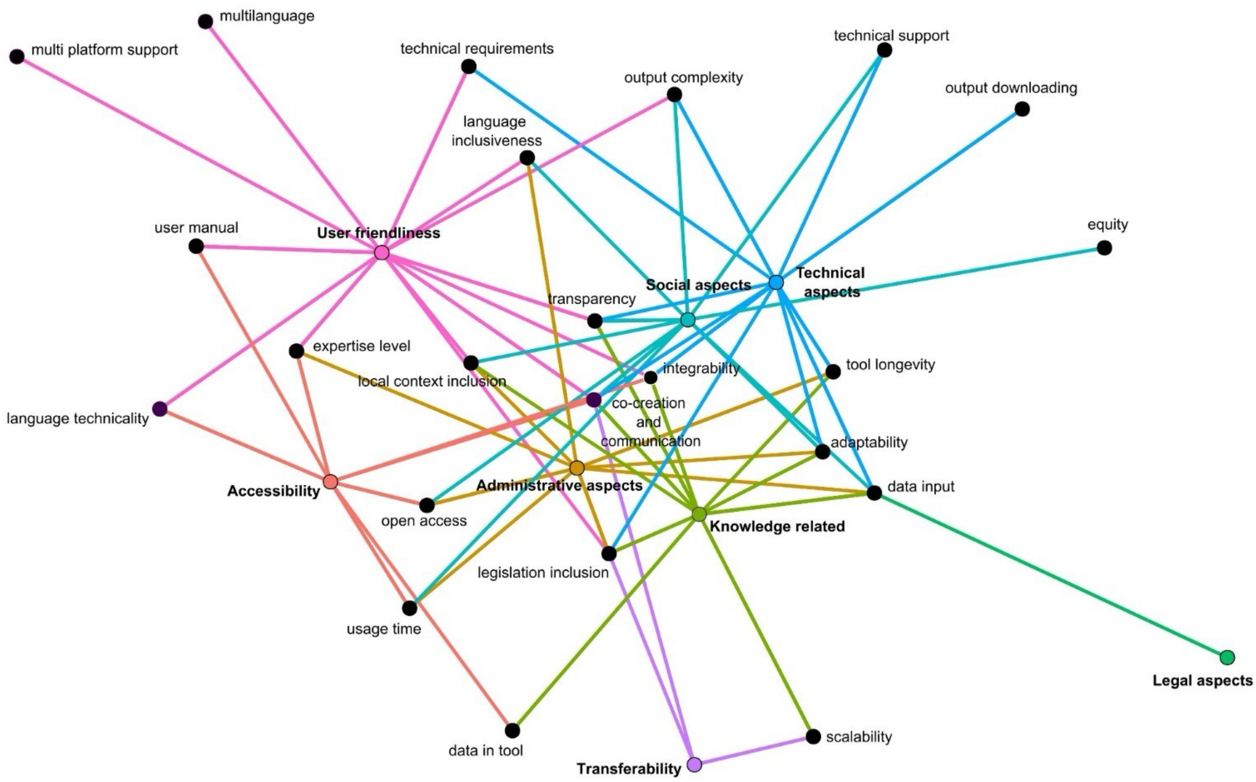

Figure 1. Network showing the links among all suggested criteria and associated sub-criteria.

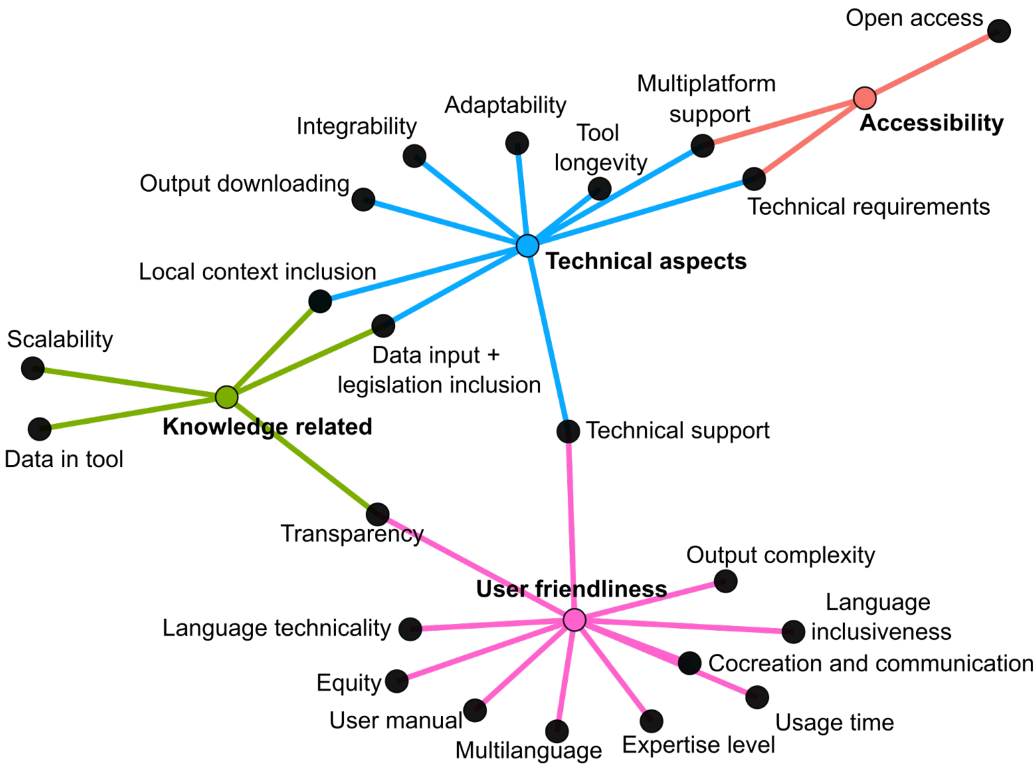

Figure 2. Network showing the categories and criteria after removing redundancies among groups. This information was used as the basis for the definition of the final set of criteria and sub-criteria for the assessment of tools.

3.2.2 Final set of criteria for the assessment of science-based ecological and environmental tools

The previously mentioned criteria and sub-criteria were ultimately organized into categories, criteria, and sub-criteria to enhance the structure and clarity of the assessment. The final set of categories, criteria and sub-criteria to be used in the semi-quantitative assessment of science-based ecological and environmental tools was refined by a Work Package 3 core team (Table 2). Some of the originally suggested criteria were excluded from the semi-quantitative assessment for multiple reasons. Some criteria were extremely difficult to translate into meaningful scores due to their highly context-dependent nature (e.g., dimensions reliant on the nature of the input data or the type of analysis performed). Others were heavily influenced by the reviewers' ability to assess them (e.g., multiplatform support, which depends on the reviewers' access to different devices). Additionally, some were deemed irrelevant for tools designed to analyse ecological and environmental data, particularly certain social dimensions.

After the final set of assessment criteria were selected, criteria describing the different dimensions of a single topic were combined as one criterion and sub-criteria. All criteria were combined into four main categories:

a. User-friendliness: Experience that end users have when interacting with and using the tools.
b. Data and outputs: Nature of data required or incorporated into the tool, the nature of the results it produces, and their potential implications for its implementation by end users.
c. Accessibility: How openly available the tool is in general and to different end users.
d. Technical aspects: refers to the set of features of the tools that define their technical demands, operability, stability and adaptability.

Table 2. Categories, criteria, and sub-criteria used for tool evaluation and their relative contributions to the overall criteria and main category.

Category	Criteria and Sub-criteria
1. User-Friendliness	1.a. User Interface (10%)
	1.b. Expertise Level Required (20%)
	1.c. Tool Language Complexity (10%)
	1.d. Time to Learn and Use (20%)
	1.e. General Info (20%)
	1.e.1. User Manual (80%)
	1.e.2. Tool's Purpose Description (10%)
	1.e.3. FAQ Section (10%)
	1.f. Co-Creation (20%)

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	1.f.1. User Co-Creation (30%)
	1.f.2. User Feedback (70%)
2. Data and outputs	2.a. Data in Tool (25%)
	2.b. Data Uploading (25%)
	2.c. Realms Coverage (10%)
	2.d. Outputs (30%)
	2.d.1. Complexity (25%)
	2.d.2. Confidence Estimates (25%)
	2.d.3. Downloading (25%)
	2.d.4. Transparency (25%)
	2.e. Applicability (10%)
3. Accessibility	3.a. Accessibility (80%)
	3.a.1. Open access (70%)
	3.a.2. Downloading/accessing effort (30%)
	3.b. Multilanguage Support (5%)
	3.c. User Support (5%)
	3.d. Aimed Users (10%)
4. Technical Aspects	4.a. Technical Requirements (50%)
	4.a.1. System Demands (30%)
	4.a.2. Platform type (70%)
	4.b. Integrability (20%)
	4.c. Tool Longevity (30%)

Given the varying importance of the criteria and sub-criteria, their overall contribution to the final scores for each category/criterion were evaluated from the perspective of end users. Greater weight was assigned to components deemed essential for facilitating ease of use and practicality. For example, within the "general information" criterion, a detailed user manual was prioritized as critical for effective tool usage, while the tool's purpose description and a FAQ section was considered less significant in contributing to the overall score. Similarly, within the "technical requirements" category, although system demands are important, web-based tools were deemed

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more convenient from an MPA manager's perspective due to their substantially lower usage effort and greater overall accessibility.

Reviewers evaluated each criterion according to the levels outlined in Appendix A. The number of levels varied across criteria. Each level was assigned a score, and the values were standardized (0-1) using min-max normalization. Tools integrated within a single platform were evaluated together. The assessment results for each tool were visualized in a radar plot, displaying the final scores across the four categories (i.e., user-friendliness, data and outputs, accessibility and technical aspects). An overview on each tool's or platform's analytical capacities to assist the incorporation of ecological and environmental data into MPA processes was provided.

4. Revision and assessment of science-based ecological and environmental tools

4.1 Results of the systematic search

The systematic searches conducted on Web of Science and Scopus (as of 1 July 2024) yielded 4,475 and 4,855 results, respectively. After removing duplicates, 5,693 publications were screened at the title-abstract level, 863 publications were reviewed at the full-text level and 155 mentioned a broad range of tools (Figure 3). Along with the tools identified in D1.3 and expert knowledge, the initial list of potential tools included 72 tools (Figure 3). The tools in the initial list were distributed among T3.2 partners with their relevant links and a set of tool-related publication provided for evaluation. While evaluating the tools, the reviewers conducted additional online searches to be able to consider all available info in their evaluations (webpages, user manuals, reports, etc.) and conducted a basic tool test, if the tool was accessible without reaching out to the developers.

Due to the broad scope of the systematic review, many of the initially identified tools were found to be outdated or discontinued, inaccessible beyond scientific publications, unrelated to the marine realm, or not focused on ecological or environmental aspects. The semi-quantitative assessment performed focused exclusively on digital application and platforms capable of analysing spatial data for the design and management of area-based conservation measures. While several mapping, data visualization, and monitoring tools were identified (e.g., MPA-FishMApp, Marine Planner, MANGLEE, STELLA, Google Earth Engine, etc.), they lacked the analytical capabilities necessary for processing data to inform MPA processes. Consequently, these tools were excluded from the assessment performed in the frame of this deliverable. While these platforms were not part of the quantitative assessment, they can effectively complement other tools by offering robust data and visualization support.

Several tools demonstrate significant potential for incorporating ecological and environmental data into MPA processes, with ongoing developments to expand their marine applications. For instance, ARIES is being enhanced through projects like MARBEFES to better address marine-specific needs. Tools such as ASSETS and NEAT, which focus on assessing ecosystem health and state, provide valuable insights for evaluating specific area conditions, contributing important pieces to the

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conservation puzzle. Additionally, certain tools originally designed for fisheries and aquaculture management, including FishRent, ISIS-FISH, MERA, SISAQUA, and DISPLACE, offer specialized functionalities that could complement broader area-based conservation efforts with further adaptation.

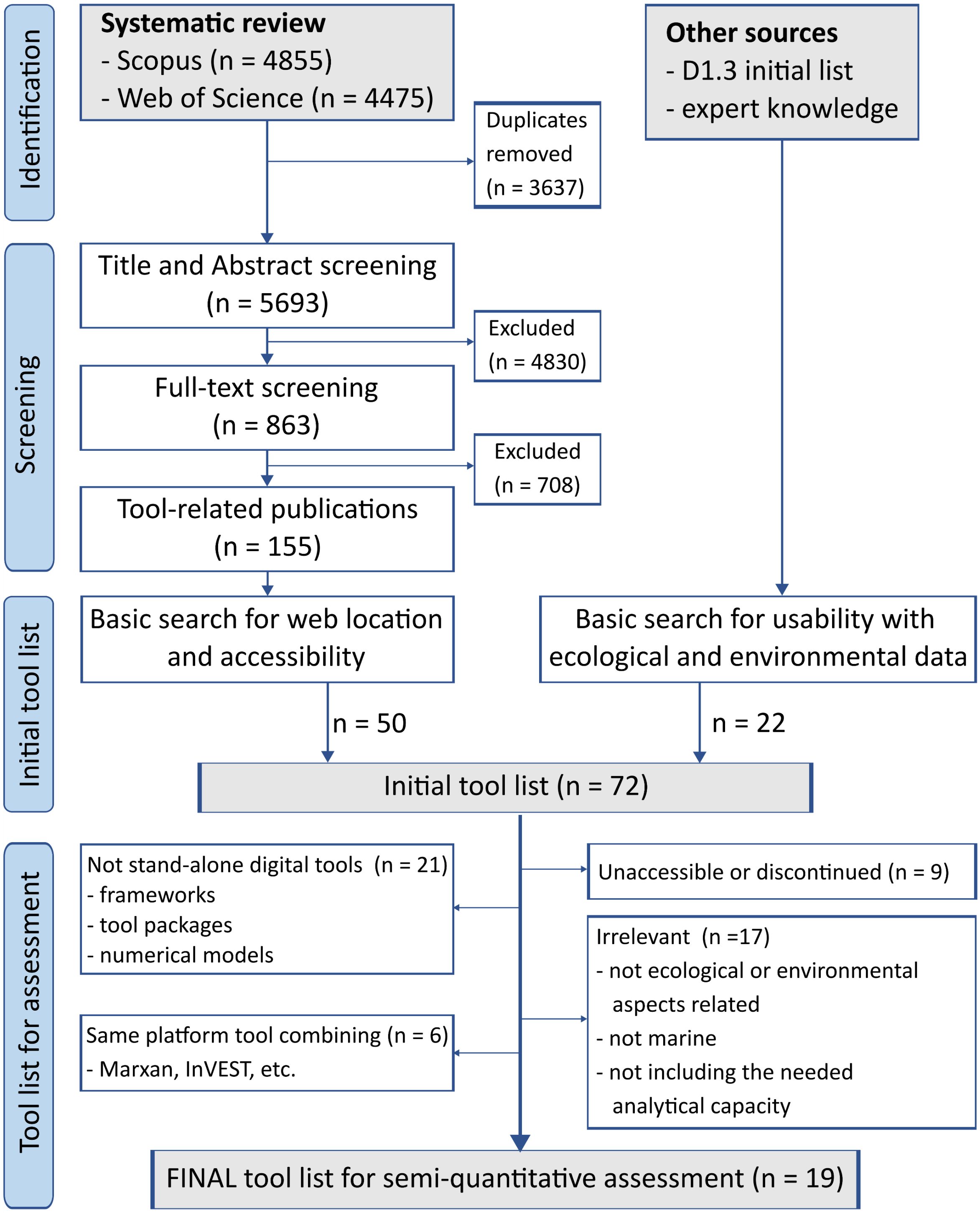

Figure 3. Flow diagram summarizing the systematic search and screening for all available ecological and environmental tools and tool list refinement for the semi-quantitative assessment of science-based ecological and environmental tools.

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Frameworks, approaches, and protocols were excluded from the semi-quantitative assessment due to the challenges of quantifying their dimensions. The evaluation focused solely on digital tools, applications, and platforms, as these are critical for MPA design, implementation, and management. Similarly, purely numerical and statistical models (e.g., R packages, ArcGIS tools) were excluded because they are not stand-alone tools and are often integrated into existing digital tools.

The final semi-quantitative assessment was conducted on 19 digital tools, with over half of them being web-based (Table 3, Figure 3). In general, the tools demonstrated eight distinct analytical capabilities:

1. **Cumulative and in-combination effects assessment of human activities and pressures** – This capability involves evaluating how various human activities and environmental pressures collectively impact ecosystems and conservation values. Tools with this feature can assess the combined impacts of different stressors, helping to identify critical areas under threat and inform strategies to mitigate these pressures.
2. **Identification and prioritization of ecologically and biologically significant areas** – Tools with this ability help to identify marine areas of high ecological or biological importance, such as habitats for endangered species or areas with exceptional biodiversity. Majority of them also are able to prioritize areas for conservation based on specific criteria.
3. **Zoning and spatial optimization** – This analytical function allows tools to allocate space for different uses—such as conservation, fisheries, or development—based on specified goals. Spatial optimization ensures that competing interests are balanced while maximizing ecological or economic benefits.
4. **Climate Change Vulnerability Evaluation** – Tools with this feature assess the vulnerability of ecosystems, species, or habitats to climate change. They analyse projected climate scenarios, such as temperature changes, sea-level rise, or shifting habitats, to identify areas at risk and guide adaptive management strategies.
6. **Structural connectivity** – Refers to the physical characteristics that shape the structure of marine environments, influencing the movement of organisms (e.g., currents, blue corridors, etc.).
7. **Functional connectivity** – Refers to all types of movements of organisms (dispersion, seasonal migrations, etc.) across and between marine habitats. Understanding and measuring these movements is crucial for designing effective conservation strategies that preserve the ecological viability and resilience of interconnected marine ecosystems.
8. **Ecosystem services assessment** – This capability involves evaluating the benefits that ecosystems provide to humans, such as carbon sequestration, water filtration, or food provision. Tools with this functionality help to quantify and map these services, supporting informed decision-making for sustainable development and conservation.

9. **Area-based conservation measures assessment** – Tools with this analytical ability assess the effectiveness of specific conservation measures, such as marine protected areas (MPAs). They evaluate how these measures contribute to biodiversity conservation, ecosystem resilience, or other management goals.

Table 3. Quantitatively evaluated DST, their acronyms and analytical capacities. CIA = Cumulative and in-combination effects assessment of human activities and pressures; IP = Identification and prioritization of ecological and biological significant areas; ZO = Zoning and spatial optimization; CCV = Climate Change Vulnerability Evaluation; SC = Structural connectivity; FC = Functional connectivity; ESA = Ecosystem services assessment; ACMA = Area-based conservation measures assessment

Tool/platform and integrated tools	Acronym	CIA	IP	ZO	CCV	SC	FC	ESA	ACMA
Blue Bio Sites (PlanWise4Blue and ABC-planner)	Blue Bio Sites	✓	✓	✓		✓		✓	
Tools4MSP with GAIR data platform	Tools4MSP	✓	✓			✓	✓	✓	
SeaSketch	SeaSketch		✓	✓				✓	
West Indian Ocean Symphony with Symphony	WIO Symphony	✓							
Marxan solutions (Marxan MAPP, Marxan with Connectivity, Marxan with Zones, Marxan with Probability)	Marxan		✓	✓	✓	✓	✓		
HELCOM Spatial Pressure and Impact Assessment tool	HELCOM SPIA	✓							
Feature Activity Sensitivity Tool	FeAST	✓							
Integarted valuation of ecosystem services and tradeoffs (InVEST Habitat Risk Assessment, InVEST Coastal Blue Carbon,	InVEST		✓		✓			✓	

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INVEST Wind Energy Production)									
Marine Reserve Evaluation App	MAREA								✓
The Conservation Planning System	C-Plan		✓	✓		✓			
Benthic Impact Tool	BIT	✓							✓
Ecopath w Ecosim (Ecopath, Ecospace, Ecotroph)	EwE	✓	✓	✓	✓		✓	✓	
Zonation 5	Zonation 5	✓	✓	✓		✓	✓	✓	
Digital Shoreline Analysis System	DSAS				✓				
Decision Support System for Environmental Impact Assessment	DESYCO				✓				
Atlantis	Atlantis	✓						✓	✓
Mytilus	Mytilus	✓							
Connectivity Modeling System	CMS					✓	✓		
Coastal Management Software	COMASO				✓				

4.2 Tools assessment results

The tools currently available to scientists, decision-makers, and Marine Protected Area (MPA) managers vary significantly in terms of accessibility, user-friendliness, technical aspects, data-handling capabilities, and their overall analytical scope for effectively incorporating scientific data into decision-making processes.

Among the web-based tools (Figure 4), Tools4MSP (https://geoplatform.tools4msp.eu/), Blue Bio Sites (https://gis.sea.ee/bluebiosites/), SeaSketch (https://www.seasketch.org/), and Marxan (https://marxansolutions.org/) emerge as top performers. These tools demonstrate strong technical capabilities, accessibility, and a broad analytical scope. However, limitations remain in certain areas: Marxan, for instance, performs well in analytical scope and accessibility but scores lower in user-friendliness and data-related aspects. As part of ongoing improvements, Marxan's recent release of a web environment will undergo reassessment during the development of the

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Blueprint Platform. Additionally, several easily accessible web-based tools, including WIO Symphony (https://www.nairobiconvention.org/wio-symphony/), HELCOM SPIA (https://maps.helcom.fi/website/bsii/), FeAST (https://feature-activity-sensitivity-tool.scot/), and MAREA (https://innovacionazul.shinyapps.io/marea/), score above average in all categories. However, these tools are often specialized for specific analyses in certain regions or rely heavily on user-provided data.

On the desktop-based side (Figure 5), tools such as InVEST (https://naturalcapitalproject.stanford.edu/software/invest), EwE (https://ecopath.org/), Zonation 5 (https://zonationteam.github.io/Zonation5/), and C-Plan (https://github.com/mattwatts/cplan) demonstrate high accessibility and robust data-handling capabilities. Nevertheless, they often require specialized knowledge and significant learning time, limiting their overall user-friendliness. For example, Zonation 5 offers a wide range of analytical functionalities but suffers from complex technical language and a lack of ease of use, reducing its overall potential for decision-making and MPA management. Some highly specialized desktop tools, such as DSAS (https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas) and CMS (https://github.com/beatrixparis/connectivity-modeling-system/blob/master/User-Guide-v2.pdf), would require substantial improvements in technical aspects and user-friendliness before they can be widely adopted by MPA managers and other relevant stakeholders. Similarly, while Atlantis (https://github.com/Atlantis-Ecosystem-Model/Atlantis_example_and_instructions) has been applied in multiple contexts, it's extremely low user-friendliness restricts its use primarily to scientists.

Some more specialized tools, such as BIT, DESYCO, Mytilus, and COMASO are challenging to access, often requiring direct contact with developers for downloading and use. This presents significant barriers for MPA managers and decision-makers, leading to these tools being evaluated based solely on available publications, user guides, and related documents (Figure 6). Consequently, their scores may require re-evaluation and adaptation upon proper access and more comprehensive assessments.

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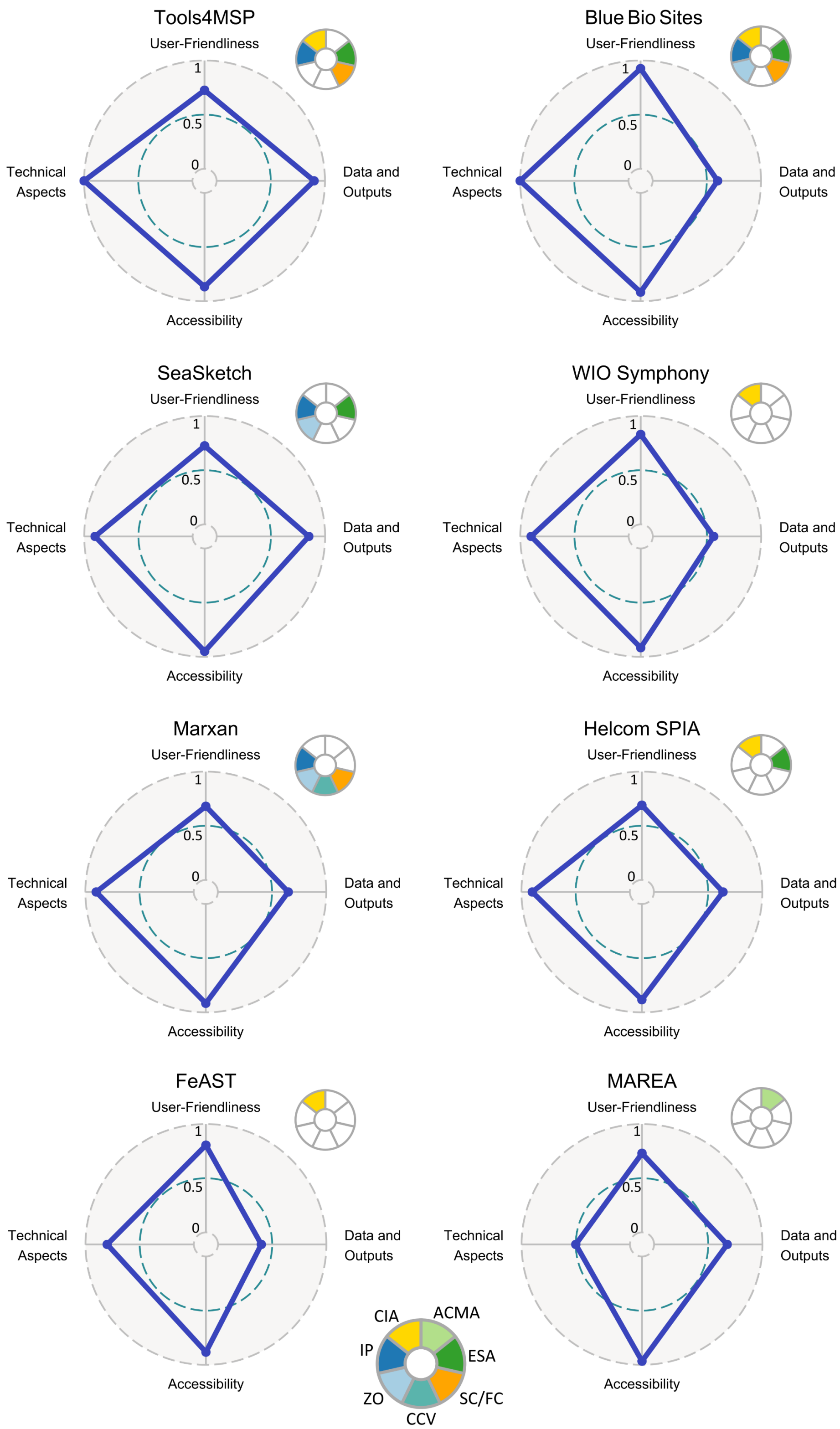

Figure 4. Best ranking easily accessible web-based DSTs. Pie charts indicate each tools analytical abilities. CIA = Cumulative and in-combination effects assessment of human activities and pressures; IP = Identification and prioritization of ecological and biological significant areas; ZO = Zoning and spatial optimization; CCV = Climate Change Vulnerability Evaluation; SC = Structural connectivity; FC = Functional connectivity; ESA = Ecosystem services assessment; ACMA = Area-based conservation measures assessment

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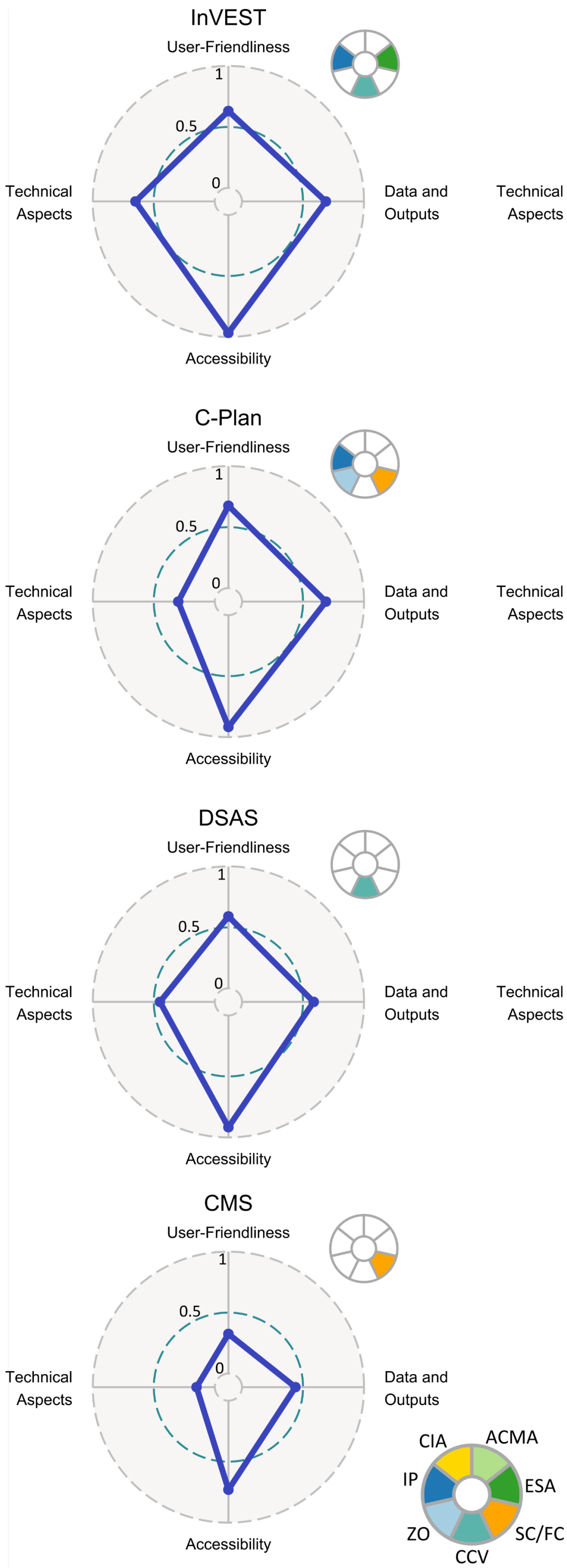

Figure 5. Best ranking accessible desktop-based DSTs. Pie charts indicate each tools analytical abilities. CIA = Cumulative and in-combination effects assessment of human activities and pressures; IP = Identification and prioritization of ecological and biological significant areas; ZO = Zoning and spatial optimization; CCV = Climate Change Vulnerability Evaluation; SC = Structural connectivity; FC = Functional connectivity; ESA = Ecosystem services assessment; ACMA = Area-based conservation measures assessment

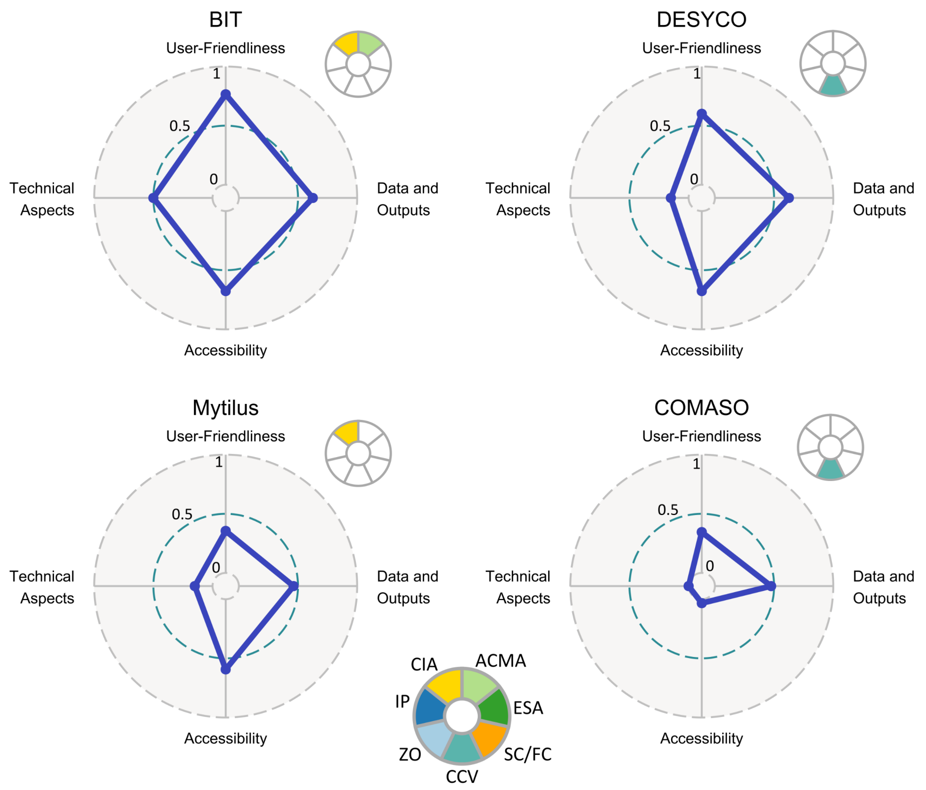

Figure 6. Very difficult to access web- and desktop-based tools. Pie charts indicate each tools analytical abilities. CIA = Cumulative and in-combination effects assessment of human activities and pressures; IP = Identification and prioritization of ecological and biological significant areas; ZO = Zoning and spatial optimization; CCV = Climate Change Vulnerability Evaluation; SC = Structural connectivity; FC = Functional connectivity; ESA = Ecosystem services assessment; ACMA = Area-based conservation measures assessment

4.3 Tools for the incorporation of under-addressed ecological and environmental dimensions in MPA processes

The lack of consideration for certain ecological and environmental dimensions in MPA processes, as identified in D3.1, highlights critical gaps in current practices in European MPAs. This deliverable compiled a comprehensive list of tools that can address these gaps. Among these dimensions, connectivity and climate change stand out as particularly pressing and under-addressed dimensions that can be tackled effectively using Decision Support Tools (DSTs).

4.3.1 Structural and functional connectivity tools

Connectivity is a key factor in maintaining the structure, functioning, and resilience of ecosystems, and its importance in MPA processes is widely acknowledged in the scientific literature. Both structural and functional connectivity are essential for ensuring ecological coherence and the long-term success of conservation measures. Despite this, European MPAs have yet to fully integrate these concepts into their design and management practices. Efforts have largely centred on structural connectivity, focusing on aspects such as habitat continuity and migration corridors. This is partly due to the relative simplicity of using readily available habitat distribution data. However,

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functional connectivity, which involves more complex dynamics like species movement, dispersal, and genetic flow, remains underrepresented. This gap exists because functional connectivity requires advanced methodologies, including genetic markers, chemical tags, tracking technologies, and hydrodynamic models, which are often resource-intensive and technically demanding.

DSTs offer an opportunity to address this gap by providing the necessary analytical frameworks to incorporate both structural and functional connectivity into MPA planning and management. This integration is particularly important for defining the spatial arrangements and ecological coherence of MPA networks, enabling conservation outcomes that go beyond local boundaries and take a network-based approach to marine protection. Among the identified tools, Tools4MSP and Marxan (specifically Marxan with Connectivity) stand out as user-friendly options capable of analysing both structural and functional connectivity. Additionally, the Blue Bio Sites platform includes a functionality within its Area-based Conservation Planner tool that enables the analysis of structural connectivity, with ongoing efforts to expand its capabilities to functional connectivity as part of the Blue Connect project. These advancements reflect the growing potential of DSTs to bridge critical gaps in connectivity within MPA processes.

4.3.2 Climate Change vulnerability consideration in MPA processes

Integrating climate change vulnerability assessment into MPA processes is vital for addressing the escalating impacts of global change on marine ecosystems. Climate change acts as a pervasive stressor, altering species distributions, increasing the frequency and intensity of extreme events, and exacerbating other pressures such as pollution and overfishing. Without explicitly incorporating these dynamics, MPAs risk becoming ineffective as conservation measures fail to account for shifting ecological baselines and the broader spatial and temporal scales of climate impacts.

Despite the importance of this issue, only a limited number of tools can analyse climate change vulnerability. Among those identified, Marxan (in particular Marxan with Probability) and Ecopath with Ecosim (EwE), specifically its Ecospace module, stand out as the most robust options available. These tools are capable of modelling and evaluating climate change scenarios, including shifts in species distributions and ecosystem dynamics. However, their application often requires significant expertise, time, and computational resources, making them less accessible for users without specialized training. Encouragingly, Marxan’s newer, web-based version has recently been introduced, offering a more user-friendly interface. Although it is still in the process of being fully adapted for marine applications, this updated version is expected to significantly enhance accessibility and usability, making it easier for a broader range of stakeholders to incorporate climate change considerations into MPA planning and management processes. By addressing climate change vulnerabilities with DSTs, decision-makers can ensure that MPAs remain resilient in the face of future uncertainties, helping to safeguard marine biodiversity and ecosystem services over the long term.

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4.4 Tools to address project Living Labs needs

The main ecological or environmental challenge identified in the Living Labs is assessing the cumulative effects of various human activities and pressures on conservation values. Over half of the evaluated tools are capable of assessing these impacts on natural values, providing spatially explicit outputs. Among these, user-friendly tools with excellent accessibility and technical features, such as Blue Bio Sites (specifically its PlanWise4Blue module), Tools4MSP, and HELCOM SPIA, are most effective for assessing cumulative effects. The final tools to be used in the tool testing phase will be selected collaboratively with the Living Labs during the project's tool-testing process.

5. Reflections on Developing Efficient Science-Based Tools and a Blueprint Platform to Support European Conservation Efforts

5.1 The need for a "bottom-up" assessment of science-based tools to guide MPA managers and decision-makers

The comprehensive review of science-based ecological and environmental tools conducted in Task 3.2 identified an extensive list of resources originating from academic research initiatives, the development of practical solutions in regional and national projects, and commercial products. The number of tools designed to analyse ecological and environmental processes and inform decision-making in spatial planning and conservation has grown rapidly over the past decade in Europe and globally (e.g., Pınarbaşı et al., 2019; Rafael et al., 2024). This growth has been driven by the urgent need for decision-makers to integrate an ever-growing body of ecological and environmental data, aiming to deliver timely, evidence-based solutions to complex environmental challenges and addressing the pressing targets set by sustainable development and conservation agendas (e.g., Depellegrin et al., 2021). New tools are continuously produced and published (Pınarbaşı et al., 2019), making it particularly challenging, even for experts directly involved in tool development, to stay updated on the latest advances. In Europe alone, the number of projects fully or partially funded by the European Commission that have led to or are in the process of developing tools with implications for spatial planning and conservation is enormous. For instance, this can be observed by visiting and exploring the European MSP Platform (https://maritime-spatial-planning.ec.europa.eu/), where many of the tools that were produced in European projects are currently listed. This multiplicity of often undercoordinated efforts has led to a diverse yet frequently redundant collection of tools, designed to operationally support many of the actions required by managers and decision-makers involved in MPA and MSP processes. However, most of these tools and operational solutions remain "buried" in detailed project deliverables or highly technical academic publications and, therefore, inaccessible to the very end users for whom they were initially designed.

Navigating this complex landscape of existing tools demands advanced digital platforms capable of smartly inventorying, classifying, and assessing them. These platforms must go beyond merely listing and describing tools by streamlining access, enhancing usability, and enabling MPA managers and decision-makers to identify and leverage the most suitable tools for their specific needs

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effectively. To achieve this, such platforms should incorporate a multidimensional, participatory ("bottom-up") approach to tool assessment, offering tailored guidance for end users to select tools. Incorporating the needs, expectations, and perspectives of end users, while fostering direct interaction with tool developers, is increasingly recognized as essential for developing fit-for-purpose solutions (Pınarbaşı et al., 2019). Consequently, this should be a core feature integrated into the Blue4All Blueprint Platform and be of significant value when including tools in the Work Package 3 toolkit to be developed in Task 3.3. With this vision in mind, we developed the comprehensive assessment approach presented in the previous sections of the deliverable. In our assessment, while technical aspects have been systematically evaluated, particular emphasis has been placed on the dimensions of user-friendliness and accessibility. These factors are critical for ensuring the effective adoption of tools by non-expert end users, as MPA managers and decision-makers frequently are. These users often encounter significant challenges when engaging with tools, as they may lack the necessary expertise or the time to navigate the complex processes involved in advanced coding, modelling, data preparation, and interpreting technical outputs. This issue is frequently rooted in the fact that many tools are developed within academic settings, where usability for non-expert end users is not always a primary consideration (McIntosh et al., 2011; Rose et al., 2017; Bolman et al., 2018). By prioritizing tools with intuitive designs and ease of use, the aim is to bridge the gap between complex tool functionality and the practical needs of MPA managers, enabling them to focus on decision-making rather than deciphering overly complicated systems.

While the criteria used in our assessment are comprehensive, they are by no means exhaustive. We acknowledge that the selected categories, criteria, and sub-criteria —developed through a dedicated workshop involving scientists and MPA managers during the 1st General Assembly of the project in Lecce— and their relative contributions will likely require future revisions, refinements and expansions. This process will occur not only within the framework of Work Package 3 but also as a continuous, iterative effort throughout the project's duration and beyond its conclusion, being a core component of the Blue4All Blueprint Platform's legacy. Potential improvements to the assessment approach that could be implemented in the development of the Blueprint Platform are:

- ***Feedback on and revision of included criteria***. The platform should allow end users to provide feedback on the value and clarity of assessment criteria and the possibility to recommend alternative ones.
- ***Adaptive prioritization of criteria and contributions***. During the tool search and selection process, end users should be able to perform assessments based on a tailored selection of criteria and relative contributions. The idea is to allow a dynamic assessment that fits the preferences and needs of different end users.
- **Assessment guided by the preferences of other platform end users**. New users, especially those with limited experience, should be able to perform an initial assessment of tools based on the most frequently selected criteria and central tendency measures of the contributions and feedback provided by other users.

It is worth noting that our assessment relied on information available in published papers, official tool web pages, and, whenever possible, direct interaction with the applications and platforms themselves. Consequently, the assessment presented in this deliverable, initially intended to select tools to be highlighted in the toolkit to be developed under T3.3, is likely to evolve and expand as users engage more deeply with the tools and share their experiences. This level of user participation, combined with the improvements previously outlined, represent essential steps to move beyond the static nature of the assessment approach described in this deliverable. By incorporating participatory, user-driven enhancements, the proposed assessment has the potential to evolve into a more adaptive and interactive system better suited to meet the diverse and dynamic needs of its end users.

5.2 Data demands and availability as primary barriers to the implementation of science-based ecological and environmental tools

Beyond the technical challenges a tool may present to users, the primary barrier to its practical implementation is frequently the availability and quality of the data it requires. While tools that rely on participatory approaches —such as SeaSketch, which draws directly on the knowledge and expertise of local actors, authorities, scientists, and other stakeholders— can somewhat bypass these challenges (these tools might encounter additional issues that exceed the scope of this deliverable), most of the promising tools examined in the deliverable are notably data-intensive. Even when some of these tools offer ready-to-use data, applying them to new contexts outside the geographic areas for which they were initially designed requires access to suitable data specific to those new regions or identifying adequate replacements and proxies.

In an era of rapid and continuous generation of ecological and environmental data (Hampton et al., 2013; Peters et al., 2014; Lausch et al., 2015), the open availability of an expanding volume of information provides unprecedented opportunities for the application of quantitative tools to inform decision-making in the design, implementation, assessment of MPAs and other area-based conservations measures. Data platforms such as Copernicus, EMODnet or HELCOM Map and Data Service, OBIS and GBIF, among many others, centralize access to comprehensive and reliable datasets encompassing biological, socio-economic, and environmental information. These repositories provide products that can overcome the data deficiencies that MPA managers and decision-makers usually face when implementing science-based ecological and environmental tools. They facilitate access to data at the regional scale, which is crucial for ensuring consistency and fostering cross-border collaboration, as is frequently the case when working with MPA networks. However, significant barriers remain. The processing of environmental data obtained from data infrastructure portals and its preparation to the specific scales at which MPAs are typically designed and implemented (when possible) requires advanced analytical skills that many MPA managers and decision-makers lack. Without this expertise, the full potential of these data platforms remains constrained, limiting their direct usability in spatial planning and conservation. To address this gap, it is essential for the tools outlined in this deliverable to not only offer direct integration with data platforms but also provide user-friendly applications that simplify the processing, harmonization, and visualization of the retrieved data. Incorporating features such as automated data pipelines for streamlined processing alongside intuitive, self-explanatory dashboards could significantly empower MPA managers and decision-makers to utilize data portals effectively without requiring advanced technical expertise. The Tools4MSP platform has begun exploring these solutions. However, current efforts are still in the early stages of development and require further refinement to fully meet the needs of MPA managers and decision-makers. The Tools4MSP platform has begun exploring these solutions. However, current efforts are still in the early stages of development and require further refinement to fully meet the needs of MPA managers and decision-makers. Furthermore, training programs and capacity-building initiatives tailored to MPA managers and decision-makers could complement these tools, enhancing their ability to use such platforms effectively.

Systematic reviews and meta-analyses (*sensu* Higgins et al., 2019; Nakagawa et al., 2023) play a unique and critical role in the current process of gathering and integrating information and data only provided in the academic and grey literature. By aggregating findings from multiple studies and sources, it is possible to access both qualitative and quantitative evidence generated in similar ecological and environmental contexts, which can help fill gaps in areas lacking the necessary information for the implementation of science-based ecological and environmental tools. However, the processes of implementing systematic reviews and metanalyses are often time-consuming and resource-intensive, requiring extensive literature screening, data extraction, and analysis. To overcome these challenges, several solutions could be implemented in existing digital applications and platforms:

- ***Automation and AI Integration***: Artificial intelligence and machine learning tools have the potential to significantly accelerate systematic reviews by automating labour-intensive tasks such as literature screening, keyword extraction, and data synthesis. These solutions could be implemented as supplementary features within some of the tools analysed in this deliverable. In fact, several development teams are already exploring these possibilities. For instance, the Blue Bio Sites development team is investigating AI-driven solutions for the automatic screening and integration of quantitative evidence from academic literature. This approach aims to streamline the quantitative definition of effects and sensitivities for cumulative impact assessments.
- ***Integration of Collaborative Web-Based Platforms into Science-Based Digital Ecological and Environmental Tools***: Incorporating direct links to open-access platforms designed for collaborative systematic reviews can facilitate workflows, allowing multiple team members to contribute to various stages of the review process. Open-access platforms designed to support systematic review and meta-analysis processes, such as CADIMA (https://www.cadima.info/index.php), could be integrated into science-based digital ecological and environmental tools to facilitate data synthesis and quantitative, evidence-based decision-making.

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5.3 The need for collaboration among tool developers and the seamless integration of their tools

As described in section 5.1, the rapid proliferation of tools designed to address ecological and environmental challenges in spatial planning and conservation has resulted in a fragmented landscape. While these independent efforts have produced a plethora of solutions, many overlap in functionality and remain hidden within specific research or project contexts. This lack of integration among tools forces MPA managers and decision-makers to navigate multiple platforms, formats, and methodologies without the needed expertise or guidance. This situation has created a highly inefficient environment in which MPA managers and decision-makers struggle to understand and stay informed about the latest developments. Consequently, they frequently rely on familiar, easy-to-implement solutions, such as expert-based approaches, which are not always appropriate for achieving the desired objectives. This reliance on suboptimal tools leads to ineffective outcomes and missed opportunities to adopt more impactful and innovative solutions. Furthermore, beyond the degree of overlap among existing DSTs, no single universal tool is capable of comprehensively addressing all the ecological and environmental topics necessary for designing effective and resilient MPAs and other area-based conservation measures. In this context, there is an urgent need to connect tools through interoperable systems and shared standards that allow MPA managers and decision-makers to leverage the strengths of multiple tools simultaneously, enabling more comprehensive and effective decision-making processes.

A platform, such as the Blueprint Platform to be designed within WP5, that centralizes and evaluates the most relevant tools and resources will not only facilitate the selection process for MPA managers and decision-makers but also create an integrative environment that encourages collaboration among tool developers. Within such a platform, tool developers will have the opportunity to identify persistent limitations in their tools compared to other available solutions. This will enable them to gain deeper insights into end user needs and requirements, fostering innovation and driving improvements in tool functionality and usability. In this context, tool developers will also be able to see the work done by other developers, allowing them to identify potential synergies, avoid redundant efforts, and build on existing innovations.

Addressing the fragmented landscape of digital tools for ecological and environmental spatial planning requires more than just a centralized platform; it demands the development of an integrated and interoperable ecosystem of DSTs. A key step toward this integration is the establishment of standardized protocols, data formats, and APIs that enable tools to communicate and share data seamlessly. Creating modular frameworks that allow tools to complement each other can ensure that users can leverage the strengths of combining multiple tools. Furthermore, as mentioned before, linking DSTs to centralized data platforms, such as EMODnet or Copernicus, through automated pipelines and real-time data updates can provide MPA managers and decision-makers with the most up-to-date and comprehensive information available. Opening the underlying code of tools can further enhance this integration by fostering transparency, encouraging collaboration among developers, and enabling customization to meet specific needs. EU

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transnational collaborative frameworks materialized trough the EU Mission: Restore our Ocean and Waters, the European Digital Twin of the Ocean (European DTO), and funding programmes such as the Horizon Europe, represent unique incubators where to start promoting such level of collaboration.

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Appendix A. Evaluation levels for each sub-category and criteria.

1. User-Friendliness

1.a. User Interface - User-friendliness of the tools interface.

a. Visually Appealing and Intuitive - The interface is attractive, with a clear, logical layout that makes it easy to navigate and understand. (3)

b. Visually Appealing but Complex to Navigate - The interface has an appealing design, but its structure or features may be challenging to follow or require time to learn. (2)

c. Unattractive and Difficult to Navigate - The interface lacks visual appeal and has a confusing layout, making it hard to use effectively. (1)

1.b. Expertise Level Required – The technical expertise requirement level for using the general functions of the tool.

a. Intuitive Use - The tool is designed to be user-friendly, requiring only general logical understanding or intuitive use. (5)

b. Basic Digital Literacy - Only general computer skills are needed, such as using software interfaces and navigating digital tools. (4)

c. Data Handling Skills - Familiarity with data management, including organizing and preparing datasets, is required. (3)

d. Data Analysis Proficiency - Prior experience with data analysis methods or software is essential for effective use. (2)

e. Advanced Programming Skills - Requires significant experience with programming languages and code-based operations. (1)

1.c. Tool Language Complexity – Assesses how difficult it is to understand the language technicality in the tool.

a. Easy to Understand - The language used is accessible and straightforward, suitable for non-scientists. (3)

b. Requires Above Medium Technical Language Knowledge - The language used includes technical terms and concepts, requiring some prior technical knowledge to understand. (2)

c. Almost Not Understandable for Non-Scientists - Language is highly technical or complex, making it challenging for non-scientists to comprehend. (1)

1.d. Time to Learn and Use – Time needed to invest to use and learn how to use the tool

a. Few Hours - The tool can be learned and used within a few hours. (5)

b. Few Days - The tool requires a few days to learn and effectively use. (4)

c. Few Weeks - The tool requires a few weeks to become proficient in its use. (3)

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d. Few Months - Several months are needed to learn and fully utilize the tool. (2)

e. More Than a Few Months - A significant time investment, over a few months, is needed to master the tool. (1)

1.e. General Info availability – Assesses the availability of information for easy usage.

1.e.1.User Manual – Checks the presence and practicality of the tool's guide.

a. Yes, Detailed - A comprehensive manual or help guide is available, providing in-depth instructions and support. (2)

b. Yes, Basic - A basic guide is available, offering fundamental instructions but limited detail. (1)

c. No - No training manual or help guide is provided with the tool. (0)

1.e.2. Tool's purpose description – Clarity of the tools aims and options for the user.

a. Comprehensive Overview Available - A clear, detailed description of the tool's purpose and features is readily accessible, providing users with a thorough understanding. (5)

b. Concise Overview Available - A brief but informative summary of the tool's purpose and main options is available, giving users a basic orientation. (4)

c. Self-Explanatory Interface - The tool's purpose and features are intuitively understood through its design and layout, with minimal need for additional explanation. (3)

d. Unclear or Confusing Documentation - The tool's purpose is mentioned in the documentation, but the information is vague or hard to interpret. (2)

e. No Information Available - There is no accessible information about the tool's purpose or features. (1)

1.e.3. FAQ – Is there a frequently asked questions section available for the tool?

a. Yes - A Frequently Asked Questions (FAQ) section is available for the tool. (1)

b. No - The tool does not include a FAQ section. (0)

1.f. Cocreation and Communication: Assesses stakeholder involvement in tool development and updates.

1.f.1. User Co-Creation - Has the tool been or is being co-created with stakeholders or end users.

a. Co-Creation with Stakeholders - The tool/framework was or is developed in collaboration with stakeholders or end users. (1)

b. No Co-Creation - The tool/framework was developed without any direct collaboration with stakeholders or end users. (0)

1.f.2. User feedback – Do the users have the option to give feedback or co-create the tool.

a. Feedback Possible - Users can provide feedback on the tool. (1)

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b. No Feedback Option - The tool does not allow users to provide feedback. (0)

2. **Data and outputs**

2.a. Data in Tool

a. Yes, the tool includes data from multiple areas. (2)

b. Yes, the tool includes data from different areas. (1)

c. No, the tool does not include any ecological or environmental data. (0)

2.b. Data Uploading – Assesses if the tool allows user data uploading/input (Evaluates the tool's flexibility to meet diverse user needs).

a. Yes - The tool allows users to upload or input their own data, enabling customization and personalized analysis. (1)

b. No - The tool does not support any form of data upload. (0)

2.c. Realms Coverage

a. Cross realm – The tool can perform analyses across multiple realms (coastal, open sea, deep sea). (2)

b. Single realm – The tool covers only a single realm (coastal, open sea, deep sea). (1)

2.d. Outputs – Assesses outputs/results provided by the tool.

2.d.1. Complexity – Assesses the complexity of the outputs can we score this?

a. Advanced Technical Outputs - Requires specialized knowledge or expertise (e.g., in a scientific or technical field) to interpret accurately.

b. Intermediate Technical Outputs - Requires general technical knowledge or familiarity with core scientific concepts.

c. Basic Technical Outputs - Accessible to a general audience with little to no specific technical knowledge required.

2.d.2. Uncertainty Estimates **–** Assessing confidence estimates of the output

a. Statistical/Quantitative Confidence Estimates - The tool provides quantitative confidence metrics, such as confidence intervals, standard errors, ranges etc. (3)

b. Qualitative Confidence Indicators - The tool includes qualitative confidence indicators without detailed statistical backing, such as qualitative levels (e.g., "high confidence," "moderate confidence"). (2)

c. No Confidence Estimates Provided - The tool does not offer any form of confidence estimates or indicators for its outputs. Example: Results are presented without any indication of reliability or uncertainty, leaving confidence in results open to user interpretation. (1)

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2.d.3. Downloading – Examines if tool outputs can be downloaded.

a. Downloadable/Exportable - The tool provides options to download or export outputs. (3)

b. Partially Downloadable/Exportable - The tool provides options to download or export only part of the outputs produced. (2)

c. Not Downloadable/Exportable - The tool does not offer any functionality for downloading or exporting outputs. (1)

2.d.4. Transparency – Examines the tools and outputs' transparency, reliability, and presence of metadata.

a. Detailed Explanation of Process - The process to obtain outputs is thoroughly explained, providing users with a clear, step-by-step understanding. (3)

b. Process Cryptically Explained - The process to obtain the outputs is briefly explained and lacks detail, leaving critical parts of the process unclear or ambiguous. (2)

c. Process Not Explained (Black Box) - The process to obtain outputs is not explained, functioning as a black box with no transparency. (1)

2.e. Applicability – refers to previous usage of the tool.

a. Yes - applied in multiple sites (2)

b. Yes - one case study (1)

c. Not applied with real data/info not available (0)

3. **Accessibility**

3.a. Accessibility

3.a.1. Open access

a. Open Source - The tool is freely available (excluding cost for training or user assistance). (2)

b. License Required - Access to the tool requires purchasing or obtaining a license. (1)

3.a.2. Downloading/accessing effort

a. Easy to access/download at a specific website (3)

b. Difficult to download/access (2)

c. Access/download via personal communication (1)

3.b. Multilanguage Support

a. The tool can be used in multiple languages. (2)

b. The tool is only available in English. (1)

3.c. User Support

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a. Yes, Contacts Provided - User support is available, with contact information provided for online or email assistance. (1)

b. No - The tool does not offer any user support. (0)

3.d. Aimed Users

a. Mainly directed to scientist (1)

b. For scientist and decision-makers (2)

c. For scientist, decision-makers, (MPA) managers (3)

d. For scientist, decision-makers, (MPA) managers, and other stakeholders (4)

4. **Technical Aspects**

4.a. Technical Requirements

4.a.1. System Demands – Refers to the system needs for tool operation.

a. Basic Computer and/or Medium Internet Speed Needed - The tool can be used on a standard computer with a medium-speed internet connection. (2)

b. High-Performance Computer and/or High Internet Speed Needed - The tool requires both a high-performance computer and a high-speed internet connection. (2)

4.a.2. Platform type

a. Web-based digital tool (2)

b. Desktop-based digital tool (1)

4.b. Integrability – Refers to the ability to integrate with other platforms or databases.

a. High Expansion and Integration Potential - The tool has strong potential for adding new features, enhancing functionality, and integrating with other tools or data infrastructure platforms, allowing for significant scalability and interoperability. (3)

b. ‘Moderate Expansion and Integration Potential - The tool could support additional features and integrations with other tools or data platforms, though some development effort or structural adjustments would be required. (2)

c. Limited Expansion and Integration Potential - Opportunities for adding new features or integrating with other tools or data infrastructure are minimal, due to the tool’s current design or technical limitations. (1)

4.c. Tool Longevity – refers to the updates and maintenance of the tool

c. High - updated versions from 2000-2025, recent tool with ongoing development (3)

a. Medium - tool from 2016-2020 and updated to a newer version (2)

b. Low - only first version available since development before 2020 (1)

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