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Assessment tool addresses implementation challenges of ecosystem-based management principles in marine spatial planning processes

Check for updates

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Ecosystem-based marine spatial planning is an approach to managing maritime activities while ensuring human well-being and biodiversity conservation as key pillars for sustainable development. Here, we use a comprehensive literature review and a co-development process with experts to build an assessment framework and tool that integrates the fundamental principles of an ecosystem approach to management and translates them into specific actions to be undertaken during planning processes. We illustrate the potential of this tool through the evaluation of two national marine spatial plans (Spain and France), in consultation with the representatives involved in their development and implementation. To ensure more coherent future planning, socio-ecological system evolution in a climate change scenario and the future marine space needs of maritime sectors should be considered, as well as improving the governance structure and knowledge of ecosystem processes. This framework provides a consistent and transparent assessment method for practitioners and competent authorities.

The growing demand for marine resources and space necessitates an integrated approach to the management of human activities, to ensure present and future human well-being and healthy ecosystems¹. Rapidly expanding marine sectors, such as offshore renewable energy, aquaculture, and tourism^{2–6}, together with newly-proposed activities, such as deep-sea mining^{7,8}, need to coexist with long-term established activities, such as fishing and maritime traffic^{9,10}. Such diversification and intensification of human activities translate into growing demand for sea space, creating new challenges for balancing biodiversity conservation and economic growth

targets^{11,12}, thereby exacerbating tensions in marine governance¹³. In addition, the Kunming-Montreal Global Biodiversity Framework (GBF) of the UN Convention on Biological Diversity (CBD) sets the agenda for global aspirations and actions to reverse biodiversity loss and calls for the conservation of at least 30% of marine and coastal areas by 2030, with 10% earmarked for strict protection of areas of particular importance for biodiversity, ecosystem functions, goods and services¹⁴. Achieving these conservation targets requires establishing ecologically relevant, well-connected networks of Marine Protected Areas (MPAs) and other effective area-based

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conservation measures^{15–19}. In addition, the need to promote ecosystem restoration activities to prevent, halt and reverse the degradation of ecosystems is recognized²⁰. As a result, 2021–2030 was proclaimed, by the United Nations, as the Decade on Ecosystem Restoration²¹, with many countries adopting nature restoration into their legal framework²².

Area-Based Management Tools, including Marine (or Maritime) Spatial Planning (MSP), have been globally adopted to allocate human activities in space and time to achieve ecological, economic, and social objectives²³. Nevertheless, MSP processes must be strengthened in their integrative capacity²⁴ and explicitly embrace an ecosystem-based approach (EBA)²⁵. EBA is a strategy for integrated management that promotes equitable holistic protection and sustainable use, aligning with CBD principles²⁶. EBA and ecosystem-based management (EBM) are terms often used interchangeably, embodying similar concepts^{27–30}. EBM is recognized as the best practice for managing multiple ocean-use sectors, explicitly assessing trade-offs among them³¹. However, its implementation is perceived as challenging and often slow^{32,33}, which could be exacerbated in regions with limited economic resources^{25,34}. The lack of operational governance structures, narrow stakeholder engagement processes, limited financial, political and staff/technical support, uncertainty, technology, communication and data availability are identified as the major impediments to the further implementation of EBM^{32,35,36}.

Although MSP has emerged as an overarching governance process for implementing EBM (i.e., ecosystem-based marine spatial planning; EB-MSP)^{23,37–41}, a gap still exists between conceptualization and practice^{42,43}. Current practices in MSP vary greatly^{29,44–46} and a standardized framework for aligning EBA principles into MSP is absent³⁰. According to IOC-UNESCO⁴⁷, over 300 MSP initiatives are currently underway across 102 countries and territories, at different stages of implementation. Thus, for effective and holistic marine management, there is an urgent need for methodologies and tools that facilitate the implementation of EB-MSP, assess existing plans, and foster their improvement through targeted actions^{31,40}.

In this context, we present a framework and tool that support the assessment and alignment of EBA principles within wider MSP processes. The assessment tool considers specific actions that should be addressed at each stage of the MSP process and highlights key issues that potentially are barriers to the implementation of EBA-related actions in MSP processes. The applicability of this EB-MSP assessment tool is exemplified and illustrated by its use in the transboundary context of the Bay of Biscay (France and Spain), but it is designed to be applicable in any geographic context.

Results

Ecosystem-based marine spatial planning assessment tool

The proposed EB-MSP assessment tool is the result of a collaborative, iterative and transparent process. The tool concept was developed based on the most up-to-date scientific literature and discussion, with the ambition of providing a fit-for-purpose tool to overcome the EB-MSP implementation barriers reported by experts and managers (Fig. 1). The EB-MSP assessment tool is publicly available as a web app (see Data Availability section) and a dedicated video tutorial on the use of the tool can be accessed at Supplementary Movie 1.

The EB-MSP assessment framework consists of 130 statements (Supplementary Table 1). The statements encompass the cross-cutting nature of EBA and represent specific tasks and actions that should be adopted throughout each of the five stages of an MSP process or when dealing with the different topics that should be addressed during the planning process. In brief, 44 statements correspond to Stage 1 (defining), 37 to Stage 2 (developing), 29 to Stage 3 (assessing), 4 to Stage 4 (implementing) and 16 to Stage 5 (following-up) (Fig. 2).

The EB-MSP assessment tool has been designed to apply to any marine spatial plan, regardless of its stage of development:

- *Assessment of an existing plan*: evaluates the conformity of the plan with EBA principles.

- *Assessment of a plan in progress*: evaluates the context of the planning site such as economic, social and environmental objectives, legal and governance structures, practitioner insights and available scientific knowledge needed to inform the development of the spatial plan.
- *Assessment of a plan in an ecologically relevant transboundary region*: evaluates national spatial plans within transboundary regions to identify commonalities or differences and determine coherence and/or equivalence between individual national plans (where coherence refers to using the same methods and equivalence to using different methods but with the same outcome⁴⁸).

For each of the 130 statements, with regard to tasks/actions to be addressed during the planning process, six complementary fields of information are collated (Supplementary Table 2): (i) the degree to which each task/action has been addressed during the planning process; (ii) the relevance of each action or task for the assessed planning site; (iii) the main source of knowledge base supporting the task/action; (iv) the respondent(s) confidence; (v) approaches, tools and methods implemented, and (vi) justification of the responses. A semi-quantitative scoring is given to the first four information fields to provide a benchmark for examining the progress of each action/task (see Fig. 3) and for the potential comparison across different plans (see Supplementary Table 2). This score is supplemented with two descriptive information fields (i.e., fields v and vi), to enable planners and stakeholders, with first-hand experience with the planning process, to justify their responses in a narrative format.

The EB-MSP assessment tool is a Decision Support System that leads users through a step-by-step procedure for evaluating a specific plan. Upon first access to the EB-MSP assessment tool, the user must register in the web app. The evaluation can be conducted by documenting the actions and tasks implemented during the assessed planning process or by examining how EB-MSP cross-cutting topics have been incorporated into the plan. Users can conduct multiple assessments in a single session or in different sessions and can retrieve the information from previous sessions. Once the assessment is performed, the results are displayed in stacked bars or disaggregated through radar plots. All the responses are also stored in a table, which can be downloaded as an Excel spreadsheet.

Assessment of two spatial plans in a transboundary region

The practical implementation of the EB-MSP assessment tool was performed in a transboundary setting of the Bay of Biscay (in the NE Atlantic, under the jurisdiction of two European Union countries - Spain and France). Each plan was independently evaluated by completing the EB-MSP assessment framework in three on-line workshops with five representatives of the MSP competent authorities.

The assessment results, according to the marine spatial plan implementation stages, are shown in Fig. 3 and Supplementary Fig. 1. Both countries presented a high degree of implementation of the statements related to the identification of the management problems for which the plans were developed (substage 1.1) and the legal framework and governance structure settings (substage 1.4). Nevertheless, practitioners signaled that, although highly relevant, the need to implement an ecosystem approach to management, and the consideration of climate change and its effects, were not sufficiently addressed and that further progress should be pursued in subsequent revisions of the plans. Specific environmental, economic and social objectives and targets of the plans (substage 1.2) were not adequately defined, especially in the Spanish plan. This is mainly explained by the lack of SMART (specific, measurable, achievable, relevant, and time-bounded) social and economic objectives, and associated indicators and targets/thresholds, due to the substantial lack of data, and because the long-term strategic goals (>6 years) were only defined for specific sectors (e.g., aquaculture, renewable energies). The assessment results also showed that current plans do not account for the targets included in the new Nature Restoration Law, which entered into force after both spatial plans were approved. Additionally, the geographical extent and temporal boundaries of

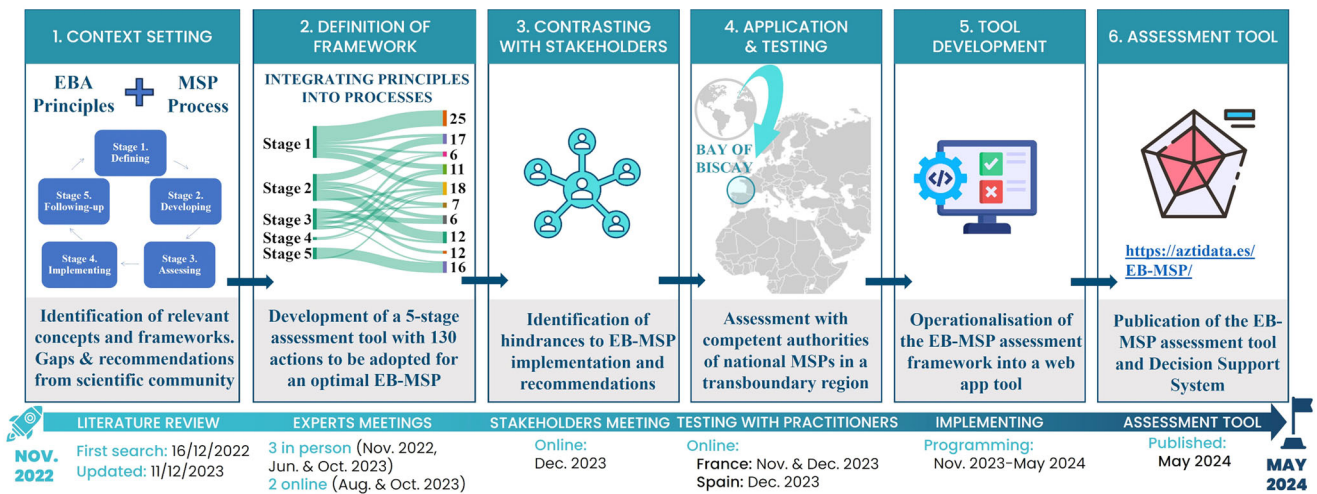


Fig. 1 | Timeline of the ecosystem-based marine spatial planning assessment tool development process. The figure shows the stages followed from conceptualisation to publication of the assessment tool.

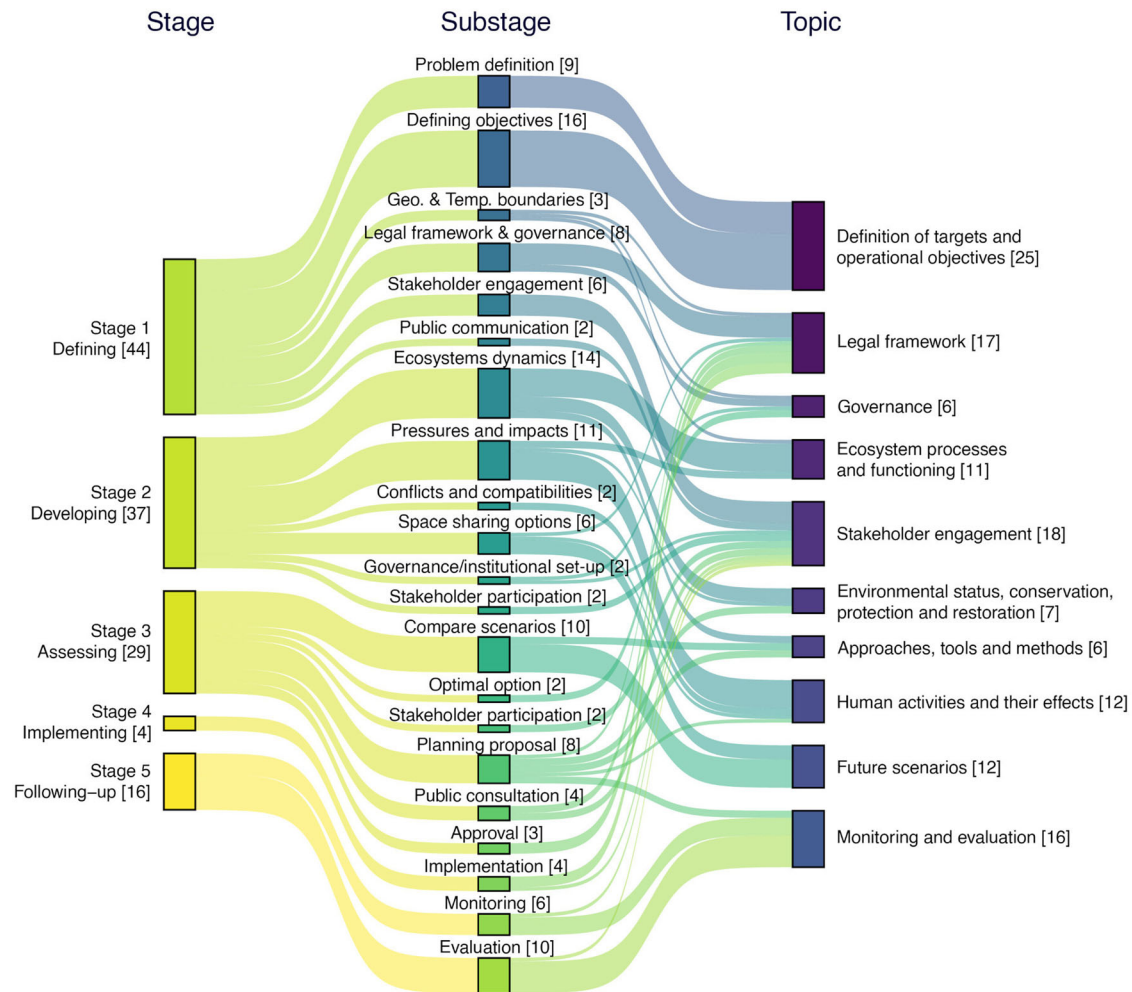


Fig. 2 | Ecosystem-based marine spatial planning framework. The framework consists of five stages, and sub-stages, representing the marine spatial planning implementation process. The numbers in brackets represent the specific actions and

tasks (130 in total) to be adopted during the marine spatial planning process to ensure alignment with ecosystem-based approach principles. Each action/task is linked to the major ecosystem-based marine spatial planning topics.

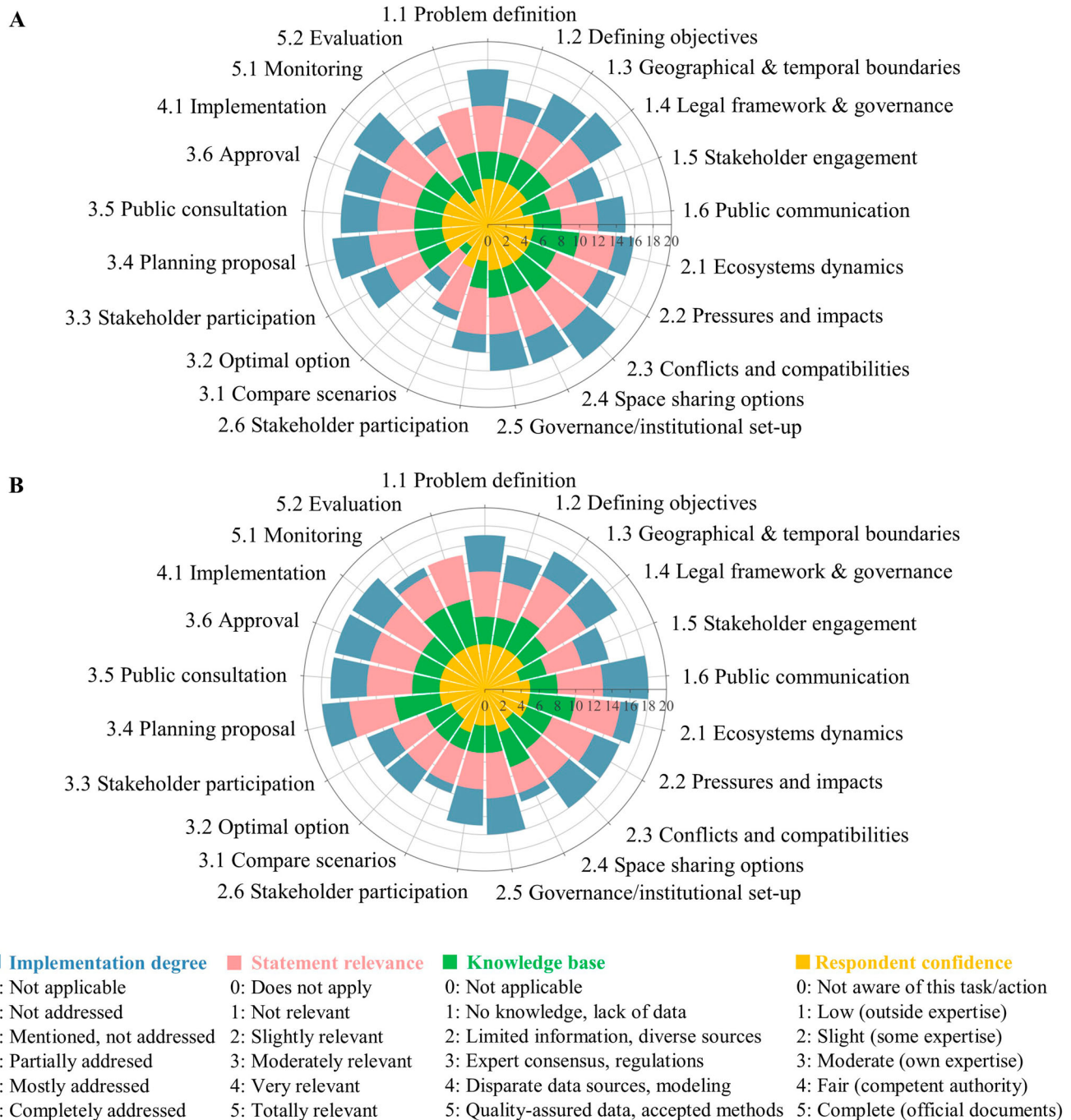


Fig. 3 | Ecosystem-based marine spatial planning assessment results. Results for Spain (A) and France (B) according to planning stages and substages (Stage 1 Defining (1.1-1.6); Stage 2 Developing (2.1-2.6); Stage 3 Assessing (3.1-3.6); Stage 4 Implementing (4.1); Stage 5 Following-up (5.1-5.2)). The stacked bars represent the medians of the task/actions present at each substage: the blue bars represent the

implementation degree, the pink bars the relevance, the green bars the knowledge base and the yellow bars the confidence of the respondent. Extended descriptions of each information field can be found in Supplementary Table 2, and the interactive online graphs can be found at <https://aztidata.es/EB-MSP> ("Result examples" section).

the plans (substage 1.3) were based on jurisdictional boundaries, rather than the broader biogeographical setting of the planning site.

Stakeholder engagement and participatory processes (substage 1.5) were partially addressed by both plans. However, although French stakeholders were allowed to participate in the definition of objectives, and to provide insights into societal choices, this was not the case for Spain, which followed a top-down approach. Furthermore, there was no established cross-border stakeholder process for the definition of objectives relevant to the whole Bay of Biscay region. Regarding public communication (substage 1.6), while in both countries the goals and the stakeholder participation

procedure were announced and published at the beginning of the planning processes, Spain did not publish the list and roles of the stakeholders involved in the process.

During the plan development phase (Stage 2), a low degree of implementation of procedures was detected concerning the capturing of the integrity, functioning and dynamics of marine ecosystems (substage 2.1). Current plans lack proper consideration of ecosystem processes and functioning (e.g., ecological connectivity, ecological carrying capacity, social-ecological systems and valuation of ecosystem services) and the need to adopt nature restoration measures.

Similarly, the assessment of human pressures and impacts (inventory and mapping, substage 2.2) was not sufficiently addressed during the planning process, mainly because of the difficulties faced in dealing with existing complex and resource-intensive methods for monitoring and assessing cumulative pressures and their effects. These sub-stages were recognized by practitioners as highly relevant, requiring further elaboration in the subsequent revision of the plans.

Spatial use conflicts and compatibilities and the subsequent environmental, social and economic implications (substage 2.3) were mostly addressed in both plans, but high discrepancies were found in identifying different options for sharing the marine space (substage 2.4). While the Spanish MSP developers forecasted future scenarios, in terms of the spatial and temporal needs of human uses and considered other area-based management regulations and priority areas for conservation when identifying the sharing options, that was not the case for France. In addition, none of the plans envisaged co-use and co-location options for activities, nor did they define possible alternative scenarios in the context of climate change.

Representatives of both countries referred to governance instruments and institutional arrangements (substage 2.5) as being very relevant during the planning process and indicated that they were adequately addressed. Spanish practitioners reported that, for some topics, expert groups had been designated for integrating the most recent knowledge, while French practitioners indicated that the initial assessment was based on scientific reports from expert groups, notably linked to the Marine Strategy Framework Directive (MSFD) and its Good Environmental Status (GES) Descriptors. Regarding the presence of a governance structure that allows the capture of local knowledge, in Spain the level of resolution was at the level of the autonomous communities, while in France a bottom-up approach was established, where local knowledge was incorporated during the development of the plan. France included more considerations regarding stakeholder participation (substage 2.6), compared to Spain, where only a few sectoral stakeholders (e.g., fisheries, energy) that could be affected by the plan were consulted during the process. In France, a public debate with stakeholders was organized and a report on the participation process was published. This was not the case in Spain during the first plan elaboration, but an assessment of the success of the stakeholder participation process is planned in the forthcoming revision process.

With regard to assessing different alternatives for sharing the marine space and the choice of the best alternatives (Stage 3), both countries reported that none of the actions were addressed (e.g., accounting for the environmental and socio-economic effects of the plan, assessing potential trade-offs, considering the uncertainty of background information or that of future scenarios) related to the assessment of the planning options and the comparison of future scenarios (substage 3.1). In this respect, Spain did not consider alternative planning options and France pointed at the lack of data as the main impediment to addressing such issues. Consequently, selecting the optimal planning option (substage 3.2) was not properly addressed. Stakeholder participation (substage 3.3) was only partially addressed in both plans, as only the feedback of some sectoral stakeholders was considered when selecting the optimal planning option. As such, practitioners reported that in the coming revision of the plans, specific workshops with a wide range of sectors, to discuss trade-offs of the different planning options, are planned. Conversely, other aspects were thoroughly considered during the development of both plans, including the preparation of the planning proposal (substage 3.4), public consultation (substage 3.5), and actions towards its approval (substage 3.6). Public participation is a mandatory process in both countries, consisting of an institutional and authority consultation round, followed by a public consultation period. Some areas for improvement were identified by the practitioners, such as the use of additional dissemination mechanisms to ensure that the information reaches the whole population, together with reducing the complexity of the results to ease their understanding. It was also noted that the number of consultee-

responses received were published, but that sometimes the specifics of how the issues raised by the public had been addressed were not indicated.

The plan implementation processes (Stage 4) were conducted properly by both countries, being compliant with legal regulations and obligations, developing synergies with other processes (e.g., Water Framework Directive (WFD), MSFD) and informing stakeholders of the implementation of the plan.

Finally, the lowest degree of implementation was observed for the plan following-up phase (Stage 5). Both plans were recently adopted (2022 in France and 2023 in Spain) and neither is yet in the assessment and performance evaluation phase. However, a major difference was identified between the two plans, in that the Spanish monitoring plan is adapted to integrate new data and knowledge, with an annual update intended, whereas the French plan is linked to the six-year cycle of other legal instruments (e.g., MSFD, Habitats and Species Directive (HD)), without intermediate updates.

In summary, based on the assessment results, both plans show a similar degree of implementation of EBA principles, only exhibiting slight differences in some specific actions. Both Spanish and French MSP practitioners considered all actions and tasks included in the assessment framework to be 'very' or 'totally' relevant for their respective management areas. Practitioners acknowledged that national and international agreements and legal obligations were the main drivers guiding the actions adopted during the planning process. When there was a lack of empirical data and scientific knowledge, a consensus of expert groups was used to implement specific tasks/actions during the planning process. In Stages 2 (Developing), 3 (Assessing) and 5 (Following-up), disparate information sources—including modeling approaches, algorithms, tools, and quality-assured monitoring data and/or data derived from accepted methods - were used. The confidence level of the information reported by the respondents was high, as they were involved in the development of the marine spatial plans of each country. Thus, the responses reflect the planning process and the information present in MSP-related official documents. The practitioners involved in the assessment indicated that the EB-MSP framework and tool provided an excellent opportunity to reflect on the process followed in the development of the plans and that it was valuable to inform future revisions of the plans.

Discussion

Current practice and tool for ecosystem-based marine spatial planning assessment

Numerous MSP initiatives are currently in place or in progress worldwide^{47,49}. Ensuring the development of effective marine plans that align with global goals, for a healthy, diverse, clean and productive ocean, requires the development of operational guidelines and dedicated tools that facilitate the incorporation of EBA principles into management and MSP processes^{30,50}. The EB-MSP assessment tool responds to such a need, allowing MSP practitioners, scientists, stakeholders, and policymakers to assess the degree of implementation of EBA in their plans or guide them during the development and implementation of new ones³³.

The EB-MSP assessment tool was shaped through a co-development process. Needs and recommendations from MSP practitioners and managers of 10 European countries, representing diverse socioeconomic and ecological contexts and at various MSP development stages, were considered during the development of the tool. Participating stakeholders emphasized the need for clearly defined and easily understandable criteria and user-friendly tools that provide support and guidance during the planning process and/or enable the assessment of existing plans. Unfortunately, current approaches and tools do not appear to fully meet their requirements because they are either too conceptual or too complex, thereby demanding a high level of background technical knowledge and requirements^{32,51}. The assessment approach developed here is intended to overcome such issues.

The EB-MSP tool, designed in conjunction with marine environmental managers and subjected to multiple iterations by interdisciplinary experts

and MSP practitioners, is expected to be instrumental for marine planners and the scientific community in supporting spatial planning efforts. The EB-MSP assessment tool provides six fields of information; these consist of the implementation degree of each task/action in the assessed planning process and the knowledge base used to support them, the relevance of each task, the confidence of the respondent and the justifications provided, including the description of the approaches, methods and tools implemented. Such a structured assessment provides a benchmarking for examining the progress of each action/task and reveals hidden aspects of the planning process. The success or failure of a plan depends, to a large extent, on the plan development process⁵², and this tool would facilitate the communication of results, guiding the development of novel MSP processes. It will also ensure additional transparency during the evaluation phase of already implemented spatial plans, in support of adaptive management.

The assessment results provide insights into the impact of a plan on conservation and sustainability, as well as into the adaptive management actions. In summary, the tool helps to assess whether environmental, social, economic, governance aspects and stakeholder and public participatory processes are adequately considered during the plan development³¹. Moreover, the use of common criteria and benchmarking facilitates the comparison between different plans; this is especially valuable in transboundary contexts^{53,54}, as it could inform the adaptation of national MSP processes based on successful approaches applied in other countries sharing the same sea basin. In addition, the tool has been designed in such a way that it can be used globally in any MSP context.

Conducting the assessment with first-hand experience MSP practitioners is preferable to using information extracted from approved spatial plans or grey literature and reports. The interviews with Spanish and French MSP practitioners each lasted 5 h but synthesised almost 10 years of the planning process (i.e., from the start of the plan development until final legal approval). This also removed the need for consulting a large number of official documents, meeting minutes and reports, which could have made the assessment vulnerable to the misinterpretation by readers. The EB-MSP assessment tool relies on the self-assessment undertaken by MSP practitioners and managers to identify potential gaps in the plan; it is of benefit that this can subsequently inform the adoption and adjustment of measures to enhance the alignment of the plan with EBA principles⁴⁰. Such an evaluation can take the form of a formal third-party audit or a less formal review by the planning competent authority, in consultation with stakeholders⁵⁵.

If applied during the dissemination and participatory evaluation of the plan, the framework can provide a valuable structure and potential themes to guide discussions with stakeholders and among planners⁵⁶, contributing to the ocean literacy strategy, knowledge exchange^{31,57}, and capacity building. The assessment can be repeated any time a significant milestone is reached (e.g., the completion of a certain stage of the planning process, when the plan enters into the evaluation phase, or when adaptations to the existing plans are needed). As the assessments are stored in the app, the user only needs to sign in and modify the actions/tasks that have changed.

Ecosystem-based marine spatial planning assessment outputs

The evaluation of national plans in Spain and France has provided first-hand information on the planning processes in these countries. Practitioners have indicated that many of the objectives and targets set in the plans derive from the requirements set out in European legislation. MSP is a crucial instrument for sustainable ocean management and the achievement of environmental and socio-economic targets (i.e., the EU Biodiversity Strategy for 2030⁵⁸; the Green Deal⁵⁹; the new approach for a sustainable blue economy⁶⁰; the REPowerEU Plan⁶¹; the Renewable Energy Directive⁶²; and the newly adopted EU Restoration Law²³). Furthermore, MSP is being regarded as a necessary part of the Programme of Measures required to achieve a GES under the EU MSFD⁶³. Existing marine spatial plans are already progressing towards meeting the EU targets, and will surely have a more relevant influence in the forthcoming years, especially in securing

efficient governance structures, effective stakeholder engagement, consideration of social aspects, economic development, conservation and restoration, and adaptation to climate change⁶⁴. However, marine spatial planning has to be seen as a continuous adaptive process and approved marine spatial plans may require modifications to meet new targets established by the EU (e.g., ensuring the success of the Nature Restoration Law⁶⁵).

Failing to estimate the ocean space requirements of present and future activities can result in conflicts between different sectors. The MSP process of Spain and France did not consider the trade-offs of the different space designations for activities. In turn, this point is also related to the forecast of future needs and requirements of maritime sectors, an action that was not properly addressed in the current plans. This is in particular with regard to trade-offs such as the balance between energy extraction and preservation of fishing grounds or the assessment of the socio-economic impacts of the designation of new MPAs. Failure to consider trade-offs could lead to significant negative consequences, including ecological degradation, economic losses, and social conflicts^{66,67}. Accordingly, practitioners acknowledged that this topic was highly relevant, and it was expected to be addressed in a subsequent revision when the demand for marine space would be less uncertain and more data for trade-off analysis of management options would be available.

Inadequate governance systems and stakeholder participatory mechanisms can hamper the effectiveness of plans. France's national programme was implemented through subdivisions (i.e., *façades*) that followed a systematic, prescriptive participation method, where the planning and participation process of each *façade* was tailored to its geographical context and the dynamics of regional stakeholder networks⁶⁸. Similarly, Spain defined five subdivisions (i.e., *demarcaciones*) to create plans that best fit the ecological and socio-economic context of each subdivision. French national authorities paid particular attention to the involvement of maritime stakeholders and the wider public at each subdivision, compared to their Spanish counterparts, by adopting various strategies and a transparent process. However, according to Tissi re and Trouillet⁶⁸ and Guyot-T ephany et al.⁶⁹, the process was inconsistent, did not equally represent the interests of the general public and those of 'maritime stakeholders' and, overall, did not meet participant expectations, thus requiring further attention in future revisions of the plan.

As in other geographical locations, insufficient attention has been given to transboundary aspects in the Bay of Biscay during the plan elaboration process⁷⁰, reflecting similar impediments to those encountered during the implementation of other legal obligations (e.g., the MSFD⁷¹). Assessment results in Spain and France indicate that although both countries produced outputs of similar scope and fulfilled their legal obligations (i.e., approval and implementation of the spatial plan), differences in the outcomes of each plan (i.e., efficient marine management) could be expected due to specificities of each planning process. In the best case, there needs to be coherence between areas across boundaries, in which the same methods leading to the same outcomes are required; failing that, at least equivalence of outcomes is needed even if the methods used on either side of the boundary are different⁴⁸. Thus, there is a need to promote transboundary coordination and cooperation in the region, including the establishment of better dialogue channels between stakeholders from the same sectors^{72,73}. As such, the EB-MSP assessment results might facilitate the path for the future development of collaborative planning and governance approaches to address common challenges⁷⁴, learning from each other's strengths and jointly creating more appropriate solutions for this ecologically relevant transboundary area.

Another relevant aspect is the consideration of climate change, such as its effects on ecosystem processes and the consequences for maritime sectors. Marine spatial plans need to integrate climate-related knowledge, be flexible to changing conditions and promote sustainable practices towards climate change adaptation and mitigation⁷⁵. Although considered highly relevant aspects by the national focal points of both countries, climate change, and its effects, have not been currently addressed in the spatial plans due to the lack of data. Further scientific information and guidance for

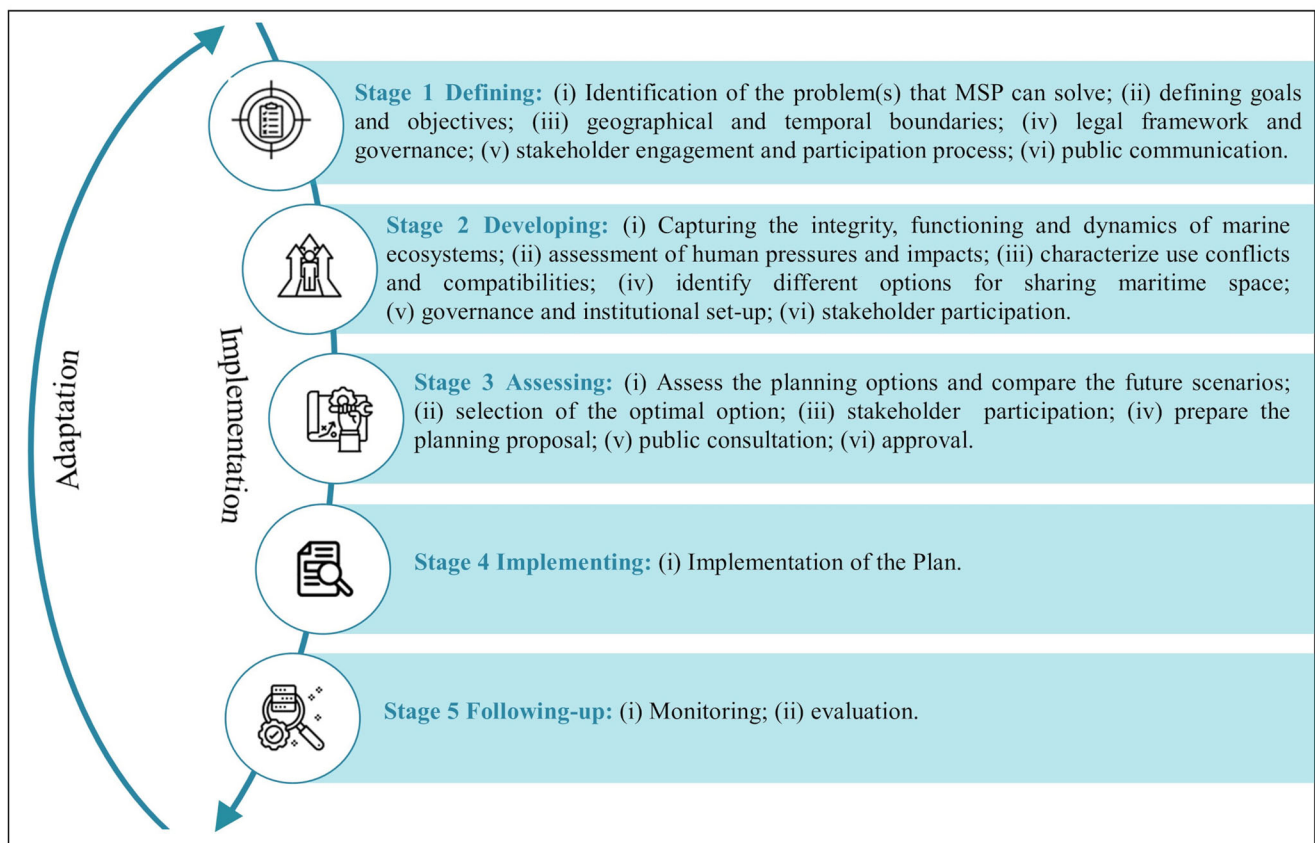


Fig. 4 | A 5-stage framework representing a theoretical marine spatial planning process. Each stage is divided into specific and “operationalizable” sub-stages, providing the framework to allocate the statements representing specific actions and

tasks to be adopted during the planning process to ensure alignment with identified ecosystem-based approach (EBA) principles. Adapted from Altwater et al.⁷⁹, Piet et al.²⁹ and Strosser et al.⁸⁰.

proper consideration of climate change is needed to inform future revisions of the plans.

Finally, a limited understanding of ecosystem processes and the impact of human activities on the goods and services they provide can hinder effective planning. Amongst the most critical actions not addressed during the French and Spanish planning processes, was the assessment of the effects of cumulative pressures (or cumulative impact assessment). This is a particularly relevant topic for improving the integration of environmental considerations into strategic decision-making, which could be strengthened by improving data collection methods and rendering these rather complex data into a readily understandable format that informs the likelihood of the environmental consequences of different management options⁷⁶. Similarly, ecosystem processes and functioning (e.g., difficulties in establishing the boundaries of ecosystems, varying temporal scales and the delay (lag) in the onset of effects), were not adequately addressed in current plans, mainly due to the lack of data and scientific knowledge, but these should be pursued in future revisions of the plans. Also, the adoption of the precautionary approach and the assessment of uncertainty, at all stages of the planning processes, were not adequately addressed. On the one hand, the precautionary principle in MSP can help prevent the overlapping or the over-concentration of marine activities and spatial conflicts in sensitive areas. On the other, embracing the uncertainty of background information, climate effects and socio-economic contexts can facilitate the adoption of appropriate management strategies.

Future developments of the ecosystem-based marine spatial planning tool

The bottom-up co-development process outlined here has resulted in a robust and adaptable tool, which is intended to be further developed, modified, and improved based on user experiences and feedback. Future

steps will require further testing of the EB-MSP assessment tool in other MSP contexts, reflecting a wide diversity of settings and ecoregions, to ensure the flexibility of the tool to accommodate different realities and promote its widespread application. The tool facilitates the evaluation of MSP processes and outcomes but ultimately is intended to promote learning and knowledge sharing between MSP practitioners and the scientific community. Most importantly, it aims to create coherent, equivalent, successful and sustainable management regimes within and between marine areas.

Conclusions

While the scientific community and managers recognize the importance of EBA and MSP, there is still limited guidance for the operationalisation of EBA principles within the broader MSP discipline. This can be pursued by specifying the EBA-related tasks and actions to be addressed at different stages of the MSP process, thus ensuring that the resulting plan(s) will fulfil EBA criteria. The developed EB-MSP assessment tool has embraced this approach by considering the principles adopted by international conventions and the needs reported by MSP practitioners and managers. We have demonstrated the applicability of the proposed tool by assessing two EU national spatial plans in a transboundary context. This comprehensive structured assessment has allowed us to determine the degree of implementation of EBA in the MSP processes of both countries, by identifying both the actions/tasks that have been adequately addressed, and those that need to be strengthened in the future revisions of the plans. In addition, comparing both plans has identified the key topics that would benefit from further development and collaboration between the countries to ensure more coherent future planning within the Bay of Biscay transboundary setting. This emphasises the need to consider the socio-ecological system evolution in a

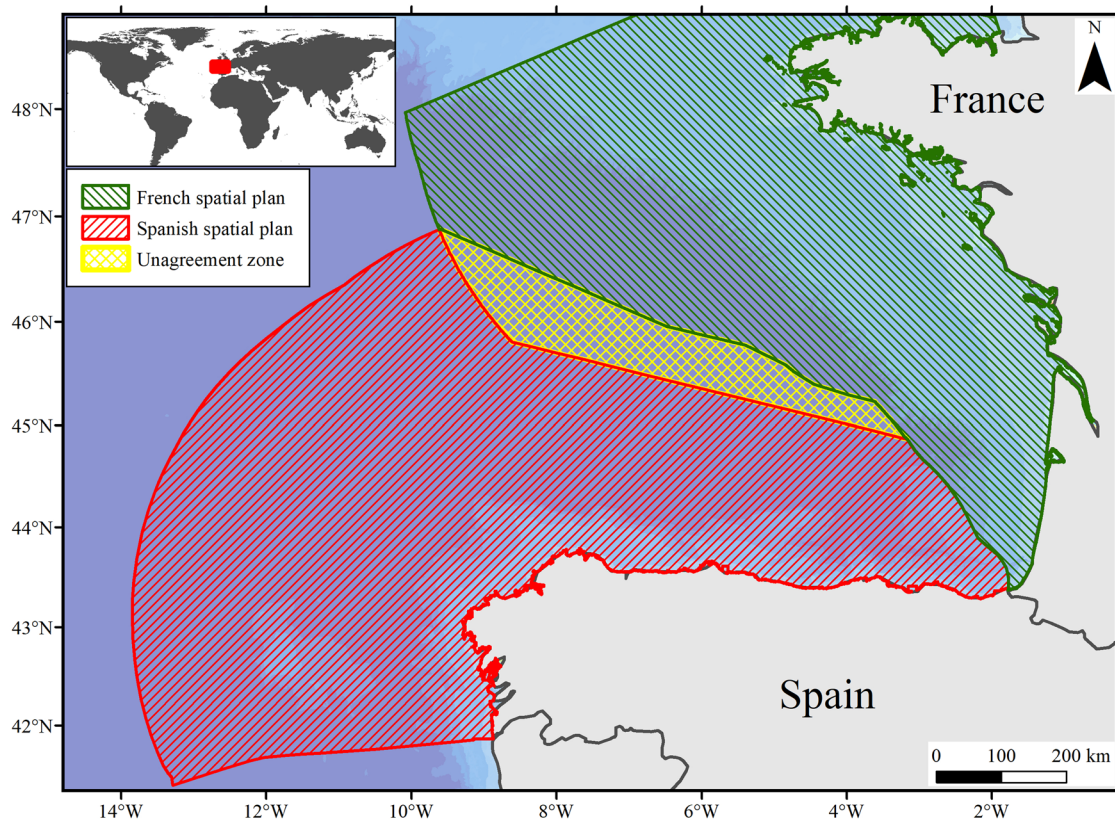


Fig. 5 | Bay of Biscay and the geographical limits of Spanish and French maritime spatial plans. The top left box represents the geographical location of the Bay of Biscay. The green dashed polygon represents the administrative limits of the French spatial plans (i.e., covering the South Atlantic, Communiqué de presse 2022/05/04⁸⁸;

and North Atlantic-West Channel Sea basins, Interprofessional Decree No. 2022/073⁸⁹). The red dashed polygon represents the administrative limits of the Spanish spatial plan (Royal Decree 150/2023⁹⁰). The yellow dashed polygon represents the overlapping area of both marine spatial plans.

climate change scenario and the future needs for marine space by maritime sectors, as well as improving the governance structure and the knowledge of ecosystem processes. The EB-MSP assessment tool has been made publicly available, aiming at the consistent and transparent implementation of EB-MSP by statutory and competent authorities and consultants.

Methods

Development and structure of the ecosystem-based marine spatial planning assessment tool

The literature review^{77,78} aimed at producing the background knowledge for the development of the structure of the EB-MSP assessment tool. This required identifying the state-of-the-art definitions of EBA principles, proposed approaches for their integration into MSP, and the main impediments to operationalising EB-MSP.

Five members of the authorship team were involved at this stage of the process. The Web of Science, ScienceDirect and Scopus search engines were used to retrieve scientific publications. The search was conducted on the 16th of December 2022 and updated on the 11th of December 2023, by using the following keyword strings: “ecosystem-based” AND (“marine spatial planning” OR “maritime spatial planning” OR “MSP”). From the systematic search, 3126 documents were retrieved. In addition, a search for grey literature was performed through Google Scholar and Google search engines, using a snowballing approach, resulting in additional 15 documents. After their screening, 30 relevant documents remained for information extraction (see Supplementary Fig. 2 and Supplementary Table 3, for the detailed description of the workflow and document selection/exclusion criteria). The selected documents were analysed to identify and extract EBA principles, MSP processes, and EB-MSP frameworks proposed by international organizations and the scientific community.

Eight different EB-MSP frameworks were identified (see Supplementary Table 4). Within them, similarities and differences were explored to determine the most appropriate structure for the assessment tool, which would ensure its applicability to most MSP processes. Finally, the 5-stage framework (i.e., defining, developing, assessing, implementing and following up), proposed by Altwater et al.⁷⁹ and subsequently endorsed by Piet et al.²⁹ and Strosser et al.⁸⁰, was adopted. The 5-stage framework was further elaborated by dividing each stage into more specific and “operationalizable” sub-stages (see Fig. 4).

Taking the CBD 12 Malawi principles⁸¹ as a starting point, additional principles were considered, resulting in the identification of 45 cornerstone principles (see Supplementary Table 5). All the principles mentioned in the literature were given equal weight and selected for further incorporation into the EB-MSP assessment tool. Then, each EBA principle was associated with the corresponding marine spatial plan stage(s) (i.e., some principles are transversal and therefore needed to be reflected in more than one stage) to ensure they were embedded throughout the MSP process. Subsequently, each EBA principle was rephrased into stage-specific tasks/actions (e.g., stakeholder participation is represented in all the stages, but the associated tasks/actions differ based on the stage) that should be addressed during the planning process. The statements of the tasks/actions were captured from the most relevant scientific documents identified through the literature review. In addition, recognizing the high diversity of worldwide MSP processes and their different level of development, to accommodate different realities each of the tasks/actions was also classified in terms of EBA and MSP cross-cutting topics (i.e., Definition of targets and operational objectives; Legal framework; Governance; Stakeholder engagement; Environmental status, conservation, protection and restoration; Ecosystem processes

and functioning; Human activities and their effects; Future scenarios; Monitoring and evaluation, and Approaches, tools and methods)^{25,29}.

The EB-MSP assessment structure was agreed upon by the whole authorship team, composed of renowned interdisciplinary MSP experts from ten European countries (Belgium, Denmark, Germany, Greece, Ireland, Italy, Portugal, Spain, the Netherlands and the United Kingdom). Several meetings were organized for the rewording of the tasks/actions and the definition of the information fields and benchmarking criteria for the assessment of spatial plans⁵⁴. The following six information fields were agreed to be useful for a detailed assessment of spatial plans: (1) degree to which each task/action has been addressed during the planning process; (2) relevance of each task/action for the EB-MSP process in the assessed planning site; (3) main source of knowledge base that was used to support the action/task; (4) self-assessment of the respondent confidence in the response given for each statement; (5) description of implemented approaches, methods and tools, and (6) justification and additional comments.

A semi-quantitative scoring was given to the first four information fields to provide a standardized approach for examining the progress of each action/task, for their graphical representation and for the potential comparison across different plans (see Supplementary Table 2). To supplement this score, two descriptive information fields (i.e., 5 and 6) were allocated to allow users to justify their responses in a narrative format⁵². The information to complete such fields can be provided preferably by planners and/or managers with first-hand experience of the planning process, or it can be extracted from published or grey literature and reports. The assessment tool structure was further refined through three additional face-to-face and two online meetings of the authorship team and additional individual feedback (June–December 2023). Once the EB-MSP assessment framework and tool were conceived, an on-line workshop with practitioners, managers and EU Commission officers was held on 11th of December 2023, with the aim of introducing the tool, gathering feedback on the challenges they faced when integrating EBA into marine spatial plans and obtaining recommendations for improving the developed EB-MSP assessment tool to accommodate their requirements. The workshop was organized ensuring geographic and disciplinary diversity. Individual invitations were sent through the EU Member States Expert Group on Maritime Spatial Planning. The workshop was attended by 36 experts, from 10 European countries, comprising high-level policymakers, managers, and practitioners involved in conservation and MSP in Europe. The issues raised by the stakeholders were considered for refining the assessment tool (i.e., the need for guidance in the implementation of EBA into MSP, good practice guidelines and automated tools that provide a single assessment “image” or “score” to assess the success of the selected management option, that can be easily updated, and provide links to other supporting data and literature).

Finally, the EB-MSP assessment template was integrated into an online web app. The tool was developed in R 4.1.0⁸² using Shiny⁸³.

Ecosystem-based marine spatial planning assessment tool testing and validation

The performance of the EB-MSP assessment tool was tested in two EU countries (Spain and France), which share the Bay of Biscay transboundary area (Fig. 5). The transnational Bay of Biscay, encompassing 175,000 km², is recognized for its distinct biogeographic characteristics and significant ecological value^{84,85}. Historically, the human activities of both countries span the entire region⁸⁶. Both countries have transposed the European Maritime Spatial Planning Directive⁸⁷ into their national legislation. The Directive states that MSP should promote sustainability by applying an ecosystem-based approach and calls for effective cross-border cooperation among Member States. France adopted four marine spatial plans, the “Documents Stratégiques de Façade” (DSF), in April/May 2022, two corresponding to the Bay of Biscay (i.e., covering the South Atlantic, *Communiqué de presse* 2022/05/04⁸⁸; and North Atlantic-West Channel Sea basins, *Interprofessional Decree No. 2022/073*⁸⁹). In parallel, Spain adopted its marine spatial plan (i.e., “Planes de Ordenación del Espacio Marítimo” (POEM)) by the

Council of Ministers in February 2023, through a Royal Decree⁹⁰. Plans have been established for each of the five Spanish marine subdivisions (“*demarcaciones*”), with the North Atlantic subdivision bordering the French Atlantic region. In Spain and France, the review of marine plans is connected to other European legislation (e.g., MSFD, HD), and as a result, it is anticipated to occur every six years. Both countries are now considering how the evaluation of plans to support adaptive management will be carried out.

Two on-line workshops were held with the French MSP focal points, on the 28th of November and the 1st of December 2023, with the participation of three representatives of CEREMA (Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning). Similarly, an online workshop with the Spanish counterparts was held on the 12th of December 2023, with two representatives of the IEO (Spanish Institute of Oceanography). Both French and Spanish representatives were involved in the development and implementation of their respective maritime spatial plans. In both cases, the completion of the EB-MSP assessment template required ~5 h.

The workshops were moderated by three members of the authorship team, who addressed inquiries and provided clarifications to the questions raised by the national representatives during the completion of the template. This approach led to a common understanding of the process, enabling the subsequent comparison of the obtained results. The responses obtained were filtered, analysed, and communicated back to the respondents, providing them with the opportunity to refine their answers. The final version of the EB-MSP assessment tool incorporated the considerations raised by the French and Spanish focal points regarding the rewording of some tasks/actions of the EB-MSP framework to enhance the user understanding of the tool.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

The EB-MSP assessment tool is available as a web app at <https://aztidata.es/EB-MSP>. A dedicated video tutorial on the use of the tool can be found at: <https://doi.org/10.5281/zenodo.14209518>. The data underlying this article are available at <https://doi.org/10.5281/zenodo.14169488>.

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Competing interests

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Additional information

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