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Mapping and Evaluating Marine Protected Areas and Ecosystem Services: A Transdisciplinary Delphi Forecasting Process Framework

Andrea Belgrano[1,2], Camilla Novaglio[3,4], Henrik Svedäng[2,5], Sebastián Villasante[6], Carlos J. Melián[7], Thorsten Blenckner[8], Ulf Bergström[9], Andreas Bryhn[9], Lena Bergström[9], Valerio Bartolino[1], Mattias Sköld[1], Maciej Tomczak[5], Sofia A. Wikström[5], Andreas Skriver Hansen[10], Sebastian Linke[11], Richard Emmerson[2], Andrea Morf[2] and Kajsa Tönnesson[2]*

[1] Department of Aquatic Resources, Institute of Marine Research, Swedish University of Agricultural Sciences, Lysekil, Sweden, [2] Swedish Institute for the Marine Environment (SIME), University of Gothenburg, Gothenburg, Sweden, [3] Institute for Marine and Antarctic Studies (IMAS), University of Tasmania, Hobart, TAS, Australia, [4] Centre for Marine Socio-Ecology, University of Tasmania, Hobart, TAS, Australia, [5] Baltic Sea Centre, Stockholm University, Stockholm, Sweden, [6] Department of Applied Economics, University of Santiago de Compostela, Santiago de Compostela, Spain, [7] EAWAG, Center for Ecology, Evolution and Biogeochemistry, Dubendorf, Switzerland, [8] Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, [9] Department of Aquatic Resources, Institute of Coastal Research, Swedish University of Agricultural Sciences, Öregrund, Sweden, [10] Unit for Human Geography, Department of Economy and Society, School of Business, Economics and Law, University of Gothenburg, Gothenburg, Sweden, [11] School of Global Studies, University of Gothenburg, Gothenburg, Sweden

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***Correspondence:**
Andrea Belgrano
andrea.belgrano@havsmiljoinstitutet.se; andrea.belgrano@slu.se

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Marine Protected Areas (MPAs) are an important tool for management and conservation and play an increasingly recognised role in societal and human well-being. However, the assessment of MPAs often lacks a simultaneous consideration of ecological and socio-economic outcomes, and this can lead to misconceptions on the effectiveness of MPAs. In this perspective, we present a transdisciplinary approach based on the Delphi method for mapping and evaluating Marine Protected Areas for their ability to protect biodiversity while providing Ecosystem Services (ES) and related human well-being benefits – i.e., the ecosystem outputs from which people benefit. We highlight the need to include the human dimensions of marine protection in such assessments, given that the effectiveness of MPAs over time is conditional on the social, cultural and institutional contexts in which MPAs evolve. Our approach supports Ecosystem-Based Management and highlights the importance of MPAs in achieving restoration, conservation, and sustainable development objectives in relation to EU Directives such as the Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD), and the Common Fisheries Policy (CFP).

Keywords: biodiversity, fisheries, blue economy, ecosystem-based management, human well-being, socio-ecological systems, surveys

INTRODUCTION

Marine Protected Areas (MPAs) play an increasingly important role in biodiversity conservation and restoration (Selig and Bruno, 2010; Edgar et al., 2014: Grorud-Colvert et al., 2014; Rasheed, 2020) and are an integral operational tool toward Ecosystem-Based Management (EBM) (UNEP-CBD, 1998; Morf et al., 2017; Bryhn et al., 2020). In 2019, there were nearly 17,000 MPAs worldwide, covering 8% of the world's ocean and amounting to more than 28 million km^2 (UNEP-WCMC and IUCN, 2019). The International Union for Conservation of Nature (IUCN) defines an MPA as a "geographical space recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services (ES) and cultural values" (IUCN - WCPA, 2008). In practice, the term MPA encompasses a wide range of areas, from areas that are closed to all activities and where resource extraction is forbidden (no-take MPAs) to areas that are partially protected and where restrictions apply only to selected activities and uses (Partially Protected Marine Areas) (Morf et al., 2017). The level of marine biodiversity protection that an MPA offers mostly depends on the type of MPA and on its enforcement, with well-enforced no-take MPAs being the most effective as they significantly enhance species abundance and diversity (Ban et al., 2014; Edgar et al., 2014). MPAs also contribute to human well-being: a recent review of 118 scientific papers found that half of the documented MPAs' outcomes in regard to human well-being were positive, while only a third of the outcomes were negative (Ban et al., 2019). For example, it has been recently demonstrated that having a higher level of relative wealth or more diversified livelihoods is associated with higher scores for distributional equity in 11 MPAs of the Mediterranean Sea (Bennett et al., 2020).

The need for increased marine protection to maximize ecological and socio-economic benefits from the ocean has been highlighted globally. The UN Sustainable Development Goal 14 (Life Below Water; United Nations, 2020), and the Convention of Biological Diversity Aichi Target 11 (CBD, 2020), which are globally established guidelines aimed at promoting ocean sustainable development and conservation, identify the extension of MPAs to cover about 30% of territorial seas by 2030 as a key priority (European Commission, 2020a). As a first step toward meeting this target, different countries are committed to a gradual increase of their MPAs coverage. For example, in 2016, the Swedish government doubled the Swedish MPAs from covering 6.7% of the Swedish seas to covering 13.6% (SwAM, 2016). However, further actions will be required to fully meet SDG 14 and Aichi Target 11 by 2030 for Sweden and, more broadly, the EU. To maximize outcomes, the extension of MPAs must also be followed by a comprehensive evaluation of their effectiveness. This evaluation requires new methodologies that incorporate considerations on the MPA's ability to protect and restore biodiversity and to support the provision of Ecosystem Services (hereafter, ES), i.e., the ecosystem outputs from which people benefit, including fish production and carbon sequestration (Palumbi et al., 2009; Belgrano et al., 2018; Lindegren et al., 2018), and related benefits to human well-being. The evaluation of MPAs must also include a broader human dimension (Jentoft et al., 2007; Fredriksen et al., 2020; Hynes et al., 2020) given that an MPA's effectiveness over time usually depends on the social, cultural, and institutional contexts in which the MPAs has been established and also support important socio-cultural aspects such as community identity and heritage (Charles and Wilson, 2009; Christie et al., 2017).

Ecological and socioeconomic evaluations of MPAs are of particular interest in light of increased economic activity and investment in the oceans and ongoing consideration of the policies and regulatory frameworks that should underpin Blue Economy developments (Novaglio et al., 2021). Effective MPAs are key to achieve Blue Economy goals because maintaining marine natural capital will contribute to providing key ES that can help to mitigate climate change impacts while also promoting economic and societal development (Dasgupta, 2021). For example, a global study recently found that natural protected areas received eight billion visitors a year, generating up to an estimated USD$600 billion, making it approximately 8% of the travel and tourism market in 2015 (Balmford et al., 2015). MPAs also need to incorporate Blue Justice in accordance with various UN principles (e.g., FAO, 2015) and Agenda, 2030 (Colglazier, 2015; United Nations, 2020) and thus to ensure equitable distribution of multiple monetary and non-monetary benefits and values they provide (Belgrano and Villasante, 2020; Jentoft, 2020), in particular in relation to vulnerable coastal based communities and other social groups (Lopes and Villasante, 2018).

In this Perspective paper, we propose a novel approach to assess the effectiveness of MPAs based on the ES they provide and their links with human well-being. While our approach can be applied to MPAs globally, we consider the MPAs of Sweden as a means of demonstration (SwAM, 2016). The Swedish coast stretches for about 48,000 km (**Figure 1**), includes numerous rocky archipelagos and a wide range of habitats, and is exposed to different environmental conditions and gradients of human pressures (e.g., shipping, aquaculture production, fishing, and tourism; Andersen et al., 2013). Several types of MPAs have been established in Sweden, mostly aimed at protecting marine species, seabed habitats and seascapes, as well as enhancing sustainable resource use and cultural outcomes, such as recreation, knowledge development, and enjoyment. These MPAs include marine national parks, marine nature reserves, core breeding, and resting sites for rare and threatened species, prioritized habitats (European Commission, 2020b), wildlife protection areas, as well as sector-based use regulation areas (SwAM, 2016). In addition to MPAs, fisheries closures have been established as management measures for protecting declining fish stocks and sensitive habitats. These closures include no-trawl areas, which cover about 50–80% of shallow habitats along the Swedish coast. The status of Swedish coastal marine systems and the ES that these systems provide has recently been evaluated on a general level (Bryhn et al., 2015) and in relation to pressures from a broad range of human activities (Bryhn et al., 2020) and cumulative impacts (Bergström et al., 2019).

The present study represents a first step in the roadmap toward assessing the ecological and socio-economic benefits of MPAs, with a particular focus on the MPA network in Swedish waters. It highlights the importance of such assessment if MPAs are to support the restoration, conservation, and sustainable development of marine systems in relation to EU Directives such as the Common Fisheries Policy (CFP), the

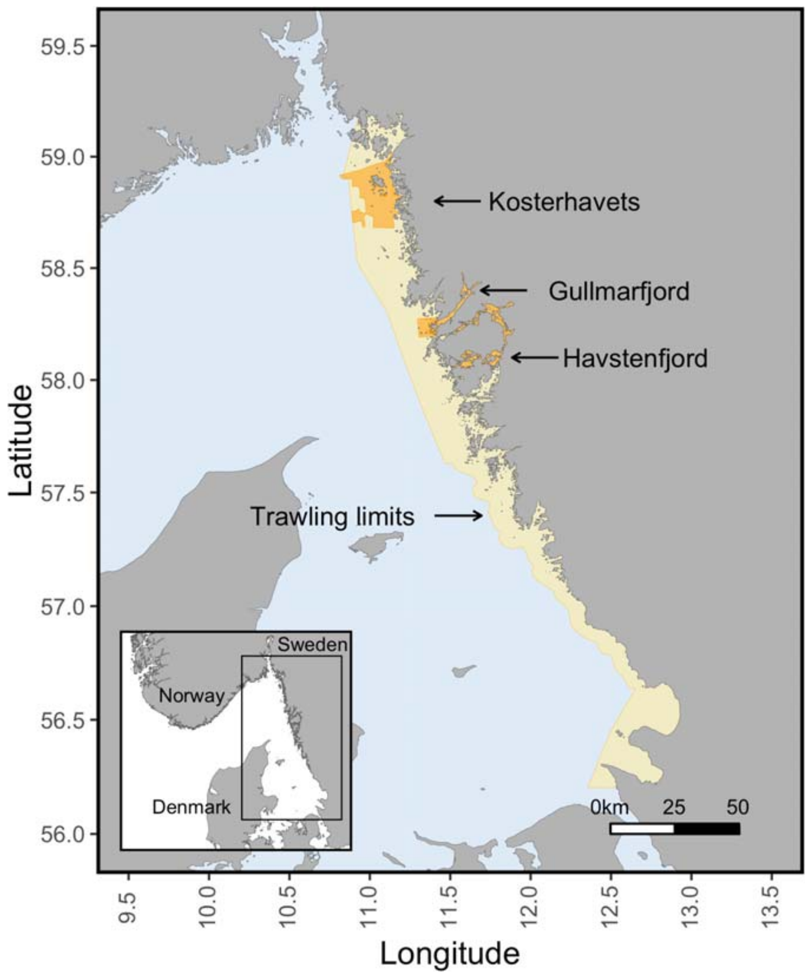

FIGURE 1 | Map of the Swedish west coast (bordering both the Baltic and the North Sea) showing the trawling limit, which define coastal and offshore waters, and the boundaries for the three MPAs: Kosterhavets, Gullmarsfjord, and Havsstenfjord.

Marine Strategy Framework Directive (MSFD), and the Maritime Spatial Planning Directive (MSPD).

THE SWEDISH WEST COAST AS A POTENTIAL CASE STUDY

Our example is taken from the Swedish west coast, which is characterized by fjords and extensive archipelagos of particular importance to biodiversity and conservation. Up until the second half of the 20th century, the Swedish west coast harbored a diverse and productive fish fauna but has now lost much of its former species diversity, predominantly due to prolonged overfishing (Svedäng, 2003; Svedäng and Bardon, 2003; Bartolino et al., 2012; Cardinale et al., 2012, 2014). To counteract depletion and promote recoveries of local fish stocks, several fishing regulations have been imposed over the last 20 years (Sköld, 2011; Cardinale et al., 2017). However, the effectiveness and validity of these regulations warrant re-evaluation, in light of evidence of regulations being too weak, being applied too late to be effective, or not fully addressing overfishing from the commercial sector (Cardinale et al., 2017).

Many MPAs with a varying degree of protection have been established in the area. However, the main changes in management schemes that have taken place since the early 2000s are related to: (1) the extension of the trawling limit within which no trawling can occur from two to four nautical miles off the Swedish west coast in 2004 (**Figure 1**; Sköld, 2011); (2) the establishment of MPAs within this limit to buffer the ecological impact of other activities (specifically in the Gullmarsfjord, Havsstenfjord, and Kosterhavet national parks; **Figure 1**); (3) a greater sampling coverage as the Swedish coastal trawl survey was established in 2001 (Svedäng, 2003; Cardinale et al., 2009; Sköld, 2011) and the International Bottom Trawl Survey was extended to sample more offshore locations (IBTS; ICES, 2016); and (4) the introduction of a ban on all commercial and recreational fishing on cod, haddock (*Melanogrammus aeglefinus*), and pollack (*Pollachius pollachius*) in the first quarter of the year within this trawling limit to protect spawning fish. These regulations predominantly affect the coastal area. Additionally, commercial and recreational fishing efforts have been reduced since 2001 in offshore, internationally managed waters of the North Sea region, including the eastern Skagerrak (Sköld, 2011). Despite more than a decade since implementation of most measures, with presumably significant reductions in fishing pressure on coastal fish stocks, there are still no lasting signs of recovery to be found in the historically productive gadoid and flatfish stocks (Cardinale et al., 2017). The time is ripe for a re-assessment of the management regulations adopted in this region, including MPAs. The approach that we develop and describe in the following section can be applied to the Swedish coast as a first step toward such assessment. It can be generalized to other MPAs globally.

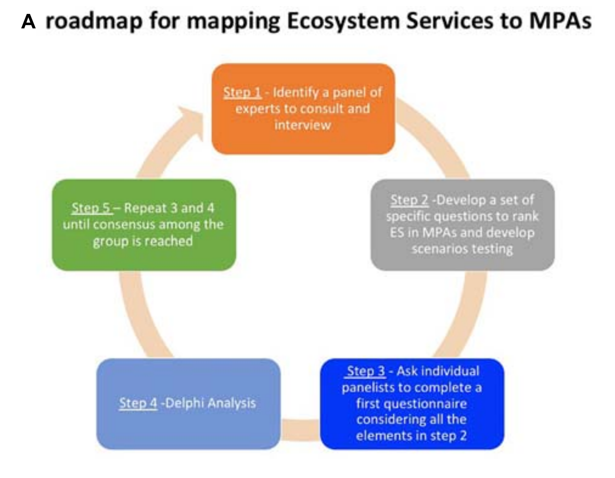

FIGURE 2 | A conceptual roadmap for mapping ecosystem services to MPAs describing the five sequential steps.

A PROPOSAL FOR A NEW MAPPING AND EVALUATION APPROACH FOR MPAs

Assessing the role of MPAs as an integral part of EBM requires an understanding of the link between the implementation of MPAs and the provision of ES. The knowledge to be used for such analyses includes scientific expertise but can also be based in practical managerial and local users' knowledge (Villareal-Rosas et al., 2020). This kind of evaluation entails the need to combine complex data, often beyond the level of what can be captured by unified metrics, and across different spatial and temporal scales. We propose a modified version of the Delphi approach as a way to resolve this challenge. The Delphi approach is typically defined as a forecasting process framework that aims to elicit experts' knowledge and reach consensus among them through a series of carefully designed questionnaires (Dalkey and Helmer, 1963; Okoli and Pawlowski, 2004). This approach is well suited to advance our knowledge of the role of MPAs in enhancing and maintaining ESs (Villareal-Rosas et al., 2020). It is characterized by a set of reiterative steps (**Figure 2**), which in our case include:

1. Identify a panel of experts to consult and interview. Experts may include scientists with a track-record of publications on MPAs and ES, stakeholders and managers that are currently working on MPAs and have a track-record of their engagement, and users such as recreational fishers.
2. Develop a set of specific questions that help to isolate and rank ES in MPAs, to frame potential scenarios of what might happen if spatial management were to change, and to explore links between changes in MPAs, biodiversity and ESs (Cairns and Wright, 2018). The development of these questions is based on the information and methodology established in ICES (2014) and Tam et al. (2017) and on a number of assessment criteria rooted in six key elements, which are detailed below (see also **Supplementary Table 1** for a list of ES, key element and criteria).
3. Ask individual panelists to complete a first questionnaire and thus to consider all elements identified in step 2.
4. Analyze results from step 3 and present them to the panel of experts to foster discussions. Questionnaire data can be analyzed using a semi-quantitative approach where each ES deemed relevant for the MPA in question is ranked against each assessment criterion. In such case, a score of zero means that the ES does not meet the criterion, a score of one means that the ES partly meets the criterion, and a score of two means that the ES fully meets the criterion. The ranking score for each ES can then be expressed as percentage of the maximum possible score, as suggested from other studies (ICES, 2014; Tam et al., 2017). The list of ESs has been compiled according to CICES (TEEB, 2010; Belgrano et al., 2018; Haines-Young and Potschin, 2018). See **Supplementary Table 1** for an example of the ranking system and how to plan a survey based on the Delphi approach to be conducted on the Swedish MPAs described here.
5. Repeat steps 3 and 4 until consensus among the group is reached.

The use of a combination of individual valuations (step 3) with interactive discussions (intercalibration workshop, step 4) is of particular importance to resolve issues of calibration and varying knowledge levels among experts between different sets of criteria, which can be highly disciplinary (Armoškaite et al., 2020).

The six key elements and related criteria (mentioned in step 2) on which the set of specific questions is to be based are:

Key Element 1: Availability of Underlying Data to Identify Measurable ES in Each MPA

Ecosystem services for each MPAs can be listed as Provisioning, Regulating and Supporting, and Cultural ES (MEA, 2005; Belgrano et al., 2018; Díaz et al., 2019; IPBES, 2019). For the Swedish Exclusive Economic Zone, Bryhn et al. (2020) provide a list of ES that can be linked to MPAs. The Regulating and Supporting ES include: Biodiversity, Food Web Dynamics, Habitat, and Biological Regulation. The Provisioning ES include: Food and Genetic Resources. The Cultural ES include: Recreation, Cultural and Natural Heritage, Esthetic Values, Inspiration, Identity, Recreational Values, Science, and

Education. Information on the relevant ES is dependent on the availability of data and monitoring practices. It is also essential to evaluate the spatial and temporal coverage of the data used to measure ES relevant to the MPA considered and their change.

Criteria Linked to Key Element 1

- Existing data
- Relevant spatial coverage
- Relevant temporal coverage

Potential Question

What are the ES that are most relevant to this MPA? What are the ecological and socio-economic indicators that can be used to quantify ES and their changes? For which of these ES do we have spatially and/or temporally resolved data to calculate such indicators?

Key Element 2: Links Between ES and Ecosystem Components

Ecosystem services are linked to ecosystem components, such as fish stocks, seagrass meadows, coral reefs, and changes in any ES may reflect changes in the underlying ecosystem components and overall biodiversity within the MPA considered. Understanding such dependencies is essential for the assessment of MPAs.

Criteria Linked to Key Element 2

- Relevance to biodiversity conservation/loss
- Relevance to the sustainability of ocean activities including commercial and recreational fishing, and tourism
- Relevance to ecosystem functioning

Potential Question

For each ES deemed most relevant to this MPA, does a change in the ES reflect a change in one or more ecosystem components? If so, in which component(s)? For example, a change in "Food webs dynamics" may reflect a change in predators, prey, and their interactions; a change in the provisioning of "Food" for human consumption may reflect a change in fish biomass.

Key Element 3: Conceptual Links Between ES and the Effectiveness of MPAs

The relationship between ES and the effectiveness of MPAs has been widely studied and the literature around this topic is expanding. A thoughtful MPA assessment takes into consideration the existing scientific literature to build new understanding and consolidate knowledge.

Criteria Linked to Key Element 3

- Scientific credibility
- Association with key MPAs features (e.g., partially protected areas/no take zones).
- Degree of uncertainty linking MPAs to ES

Potential Question

Has each of the ES considered been linked to this or other MPAs in the literature? Has the ES been associated with a specific MPA type?

Key Element 4: Management Relevance

Marine ecosystem management, including the implementation of MPAs, aims at maintaining and restoring ecosystems to promote the long-term sustainable use of marine resources and to ensure the persistence of ES. The effectiveness of each MPA is assessed against the management objectives that underpin its implementation and depends on whether these objectives are met. The proposed assessment asks which ESs is particularly relevant for each management objective that the MPA aims to achieve (e.g., the ES "fisheries production" is particularly relevant if the management objective is to increase the provision of food). It considers if and how these ES can be maintained and whether the acquisition of information for each of these ES is cost-effective and relevant for management.

Criteria Linked to Key Element 4

- Relevance to management
- Management targets estimable
- Cost-effectiveness
- Technological innovation
- Regulatory/economic measure connected to ES
- Regulatory/economic measures allowed within or outside MPAs

Potential Question

Which ES is particularly relevant for management? Can a management target for these ES be identified and maintained? Would collecting more information on these ES help management?

Key Element 5: Communication and Public Awareness

Effective communication of the benefits promoted by marine conservation ensures a successful engagement of key players (policymakers, stakeholders, managers, and the general public) with MPAs. Key element 5 of our MPA assessment questionnaire aims at evaluating whether the link between ES and the MPA under assessment is comprehensible by policymakers, stakeholders, users, and the general public and hence whether these key players accept and are satisfied with the MPA.

Criteria Linked to Key Element 5 Categories

- Relevance to policymakers, stakeholders and managers
- Relevance to the general public

Potential Question

Are key players aware and well informed about which ES and overall benefits the MPA promotes?

Key Element 6: Societal Benefits and Distribution Thereof

Key element 6 evolves around human well-being and equity. It considers whether ES contributes to human wellbeing and if the benefits and costs associated with ES and the implementation of MPAs, management and maintenance are fairly distributed across society.

Criteria Linked to Key Element 6

- Socially constructed by local communities and relevance to Blue Justice
- Relevance to human well-being
- Fair distribution of the benefits and costs associated with ES and MPAs across society (age, gender, class, etc.).
- Sense of place/linkages to place

Potential Question

Do the ES under consideration contribute to human wellbeing? Who benefits from and who pays the costs associated with this ES?

The semi-quantitative approach, as supported by the Delhi method, offers a survey-based methodology where scientific experts, stakeholders, and the general public can be engaged to gain information on the current status of MPAs and their effectiveness and thus to include both an ecological and socio-economic perspective to the evaluation of ES. The outcome of this approach can provide valuable information on knowledge gaps and suggest novel ideas for improving the design and governance of MPAs as tools for implementing conservation measures in line with the EBM framework. This approach can be complemented with other data-driven methods. For example, analysis of spatial data can provide insight on the relationship between the provision of each ES and the degree of spatial protection (e.g., inside and outside MPAs or along a gradient of human disturbance). These analyses can further contribute to linking MPAs to EBM, in particular to explore whether MPAs are socially and ecologically coherent.

The proposed approach has, however, limitations which mostly relate to three main aspects. The first is the inability to identify all the ES (and indicators) pertinent to the MPA under assessment at the first round of the Delphi analysis since this exercise requires consideration of "all voices" and values and hence time, experience, and knowledge on the data flow. The second aspect relates to challenges in the selection of experts and the organization of meetings to ensure an inclusive approach that helps to consider "all voices" and ES and that contributes to a better understanding of the trade-offs between conservation, re-building, collective action, and management (Basurto et al., 2016). The third aspect relates to the increased challenge in quantifying ES for MPAs network (as opposed to single MPAs) given their interconnections and area covered.

MEASURING THE EFFECTIVENESS OF MPAs

Understanding biodiversity changes transgressing the levels of ecosystem organization at multiple trophic levels (Soliveres et al., 2016) is a scientific challenge, which needs to be faced when managing natural resources. The implementation of MPAs can help to meet species and habitat-specific conservation targets as well as societal goals (Claudet, 2011; Guilhaumon et al., 2015; Horta e Costa et al., 2016; Basurto, 2017). However, there is an urgency to provide adequate tools and synthetic indices that can be used to quantify the links between changes in human pressures and the rate of change in biodiversity within these areas, and to measure related changes to ES flow and human-well-being. This particularly relates to key element 1 (availability of underlying data to identify measurable ES in each MPA) considered in the above section.

A wide range of ecological indicators have been used to assess the effectiveness of MPAs in achieving EBM objectives (e.g., Pomeroy et al., 2004; McClanahan et al., 2006; Gill et al., 2017; Hornborg et al., 2019; Meehan et al., 2020). Examples of common ecological indicators are the biomass and size of target or sensitive fish species, which are often summarized into concise indices such as the Large Fish Index (Modica et al., 2014), and more complex measures that relate to fish recruitment success, food web integrity, recovery, and water quality. Higher-level (macroecological) indicators include those that measure species density and richness, which can be captured, for example, by biomass accumulation curves and species area relationships (SARs).

The SAR can prove valuable in the evaluation of MPAs. It is regarded as one of the ecological generalizations that applies across ecosystems (Arrhenius, 1921; Holt, 1992; Brown et al., 1995; Rosenzweig, 1995) to quantify broad patterns of species abundance and diversity in time and space (Guilhaumon et al., 2008). More specifically, SAR has been used to predict human impacts on fish assemblages, providing a sensitive community-level indicator (Tittensor et al., 2007; Novaglio et al., 2016) that can be operationally applied for conservation and management in MPAs, and, more broadly, for marine conservation and Marine Spatial Planning (MSP). In most cases, SAR is described by a power or an exponential function. These functions are linear in logarithmic space, and their slope informs on the rate of species accumulation as the area sampled increases. The slope depends on multiple community properties (Hillebrand and Blenckner, 2002), such as richness, single species abundance, community evenness, and degree of intra-specific aggregation (i.e., species spatial distribution), with decreases in one or more of these properties lowering the slope of SAR (Novaglio et al., 2016). Since fishing modifies the structure of fish communities through species extirpation, depletion, range contraction, and habitat degradation (He and Legendre, 2002; Hilborn et al., 2003), the slope is expected to decrease as fishing intensifies (Tittensor et al., 2007; Novaglio et al., 2021). For instance, the slope characterizing demersal fish communities of South East Australia was shown to decrease as bottom trawling exploitation increased (Novaglio et al., 2016), and the slope characterizing coral reef fish communities worldwide was lower outside MPAs than inside MPAs (Tittensor et al., 2007).

Ecological indicators alone cannot provide a clear picture of the effectiveness of MPAs and must be used in conjunction with socio-economic indicators. Among the socio-economic indicators that have been used to measure the benefits of MPAs to communities are indicators linked to market (e.g., value of catches) and non-market values (e.g., cultural sense of place), livelihoods, food security and human health, and effective and equitable management process. These can be measured as number of direct and indirect employees involved in fishing and/or tourism and other ocean activities, number of enterprises depending on the activities within and around the MPAs as well as local values and beliefs, perceptions of seafood availability, material lifestyle, quality of human health, and enforcement capacity and compliance of MPAs (e.g., Pomeroy et al., 2004; McClanahan et al., 2006; Gill et al., 2017).

MPAs AND ESs: COMPLEMENTARY QUANTITATIVE ANALYSES

Marine Protected Areas can be seen as key model systems to evaluate ES connections accounting for biodiversity, social, economic, and biogeochemical metrics. There are open issues to quantify the dimensionality of MPAs to ES/biodiversity connection. Levin's triangle (Levins, 1966) can be useful in this regard (**Figure 3**). From one side, we would need general models to obtain generalities connecting, for example, MPAs to biodiversity metrics. On the other side, we would need high resolution and (transdisciplinary) data to support the assessment of linkages between ES and socio-economic aspects, to bring accuracy and realism into the analysis to contrast the dimensions needed to take into account many other disciplines into the MPAs to ES connection (Cavaletti et al., 2020). Improving our understanding of connections between MPAs and ES also requires further understanding and consideration of the linkages between species traits, population, and ecosystem dynamics, and of spatial connectivity to assess MPAs networks (Jonsson et al., 2019). This may also further connect to models at the regional and global scale that encompass the social and economic relevance of biodiversity (such as the Ocean Health Index; Halpern et al., 2012, 2014; Blenckner et al., 2021), of place-based and practice-oriented methods [such as the Open Standards for the Practice of conservation approach used in quite a few coastal MPA processes across Sweden; Morf et al., forthcoming and e.g., Gee, 2019), and of the UN SDGs (Claudet et al., 2020).

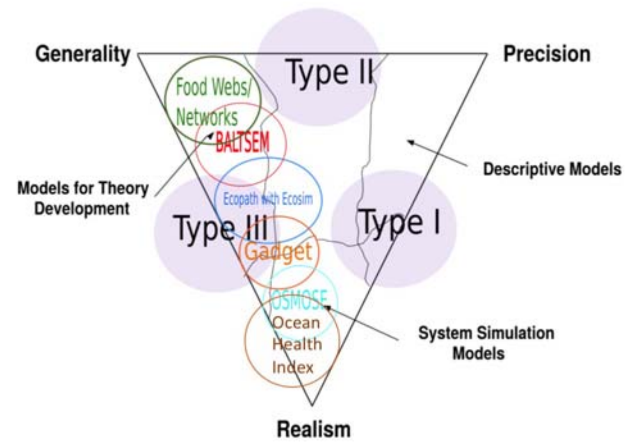

FIGURE 3 | Levins' modeling trade-offs explore models along the Generality (i.e., Food webs and Networks and BALTSEM as models for theory development) and Realism gradient (i.e., Ecopath with Ecosim, OSMOSE, Gadget, Ocean Health Index as System Simulation Models). These are all Type III modeling frameworks, which sacrifice precision for the sake of generality and realism. Along the generality-realism axis, Type I models sacrifice generality for the sake of realism and precision and Type II models sacrifice realism for the sake of precision and generality.

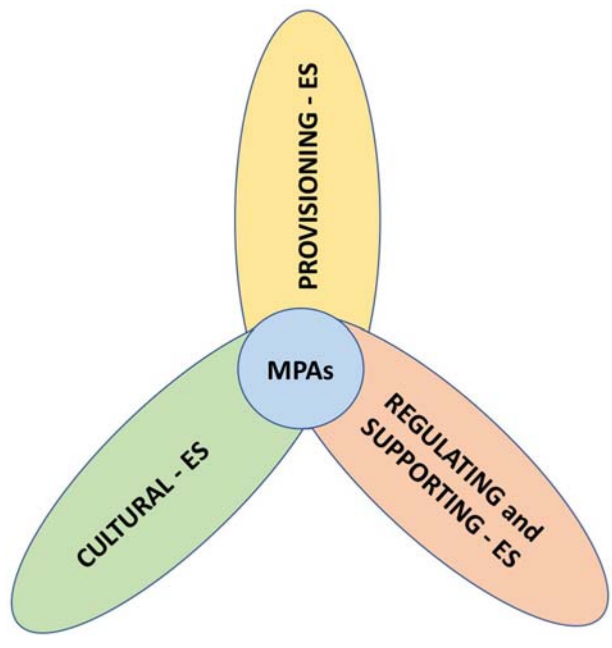

FIGURE 4 | MPAs as a tool for mapping the diverse range of ES including: Provisioning ES—Regulating and Supporting ES—Cultural ES.

OUTLOOK: LINKING MPAs WITH THE BLUE ECONOMY

Marine Protected Areas need to be seen within, as well as logically and managerially linked to, a wider context of integrative coastal and ocean governance. The economic benefits of MPAs and other Spatial Protection Measures (SPMs) have been recently evaluated by the European Commission (2018) which documented the economic benefits to different sectors including commercial fishing, tourism, and other sectors of the Blue Economy, emphasizing the importance to consider the links between MPAs, SPMs, biodiversity, and ESs.

Equity issues related to the spatial distribution of MPAs in relation to, for example, the traceability of fishery catches is another aspect to consider when assessing the effectiveness of MPAs (European Commission, 2018). Olsen et al. (2013) provide a description of the potential role of MPAs in the context of coupling EBM and MSP and the importance of relating this to ES. Another aspect worth consideration is the evaluation of the ecological changes due to the implementation of MPAs and how these changes, in turn, effect the dynamic of ES. Spatial end-to-end modeling techniques such as Ecopath with Ecosim and Ecospace (Steenbeek et al., 2013) or Atlantis (Audzijonyte et al., 2019) are valuable tools to explore such dynamics. They have been used to explore, for example, the consequences of the implementation of MPAs on the broad ecosystem context at different spatiotemporal scales (Corrales et al., 2020; Steenbeek et al., 2020) and the effects of cross-sectoral interplays in socio-ecological systems (Bauer et al., 2019; Hyytiäinen et al., 2019). MPAs can be used as an analytical and geographical focal point to assess the intersection of a diverse range of ES and related chains of human well-being, and their distribution in coastal communities (**Figure 4**). Different management settings can provide varying contexts to develop and test scenarios for adaptive management, also considering for example climate change scenarios as a threat to the functionality and effectiveness of MPAs at protecting and conserving biodiversity and ES (Bruno et al., 2018). This also includes considerations on cultural aspects of ecosystems services and human well-being in coastal communities in relation to MPAs (Rodrigues et al., 2017).

As part of the roadmap to consider the ecological and socio-economic benefits of MPAs, our study highlights the need for mapping ES in MPAs as to evaluate the effectiveness of MPAs in relation to EBM. This approach complements and contributes to the ongoing efforts for the conservation of biodiversity and ES that various international directives and platforms undertake and promote. These directives and platforms include, but are not limited to, the UN Sustainable Development Goals (Claudet et al., 2020), the CFP, the MSFD, the MSPD, OSPAR, HELCOM, IPBES, and CBD.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

ABe designed the study. All authors equally contributed to wrote and finalized the perspective.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2021.652492/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.