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VIEWPOINT

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Link marine restoration to marine spatial planning through ecosystem-based management to maximize ocean regeneration

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Abstract

1. The speed at which marine and coastal ecosystems are being degraded due to cumulative impacts limits the effectiveness of conservation strategies. To abate ocean degradation and allow ocean regeneration, conservation planning needs to be improved and ecological restoration will be needed.
2. This study explores the potential of incorporating restoration into marine spatial planning (MSP) anchored to ecosystem-based management (EBM), termed EB-MSP, for maximizing ocean regeneration. This perspective explicitly brings both passive and active restorations into EB-MSP in a broad and holistic framework for achieving the recovery of ocean ecosystems, their functions and their valuable services.
3. By proposing a restoration-focused EB-MSP framework, we highlight the co-benefits of interlinking MSP and marine restoration through the EBM core principles. Such benefits include a scaling-up of restoration effectiveness, a greater guarantee that sustainability and conservation goals will be met and improvements in MSP as an integrated planning tool with the potential to address climate change. Together, this will promote ocean regeneration alongside management for sustainable use to prevent further degradation and to allow much-needed ecological recovery.

KEYWORDS
addressing climate change, blue economy, ecological principles, ecosystem services, MSP, ocean sustainability, restoration planning, restoring marine ecosystems

1 | INTRODUCTION

Achieving sustainability in the use of ocean space and resources requires improving the ecological status of ecosystems and securing the interconnections between them. Many marine and coastal ecosystems have been degraded by cumulative impacts that strain their resilience and exert pressure on the ability of the ocean to provide ecosystem services (ES) (Halpern et al., 2019). Systematic conservation planning can identify marine areas to conserve, but as local anthropogenic and climate change pressures intensify, degraded environmental conditions are inevitable (Saeedi et al., 2019). Restoration science has matured to be able to offer practical guidance on how to assist the recovery and the re-establishment of many degraded marine habitats such as seagrass beds, mangroves, oyster beds and coral reefs.

Restoration, rehabilitation and remediation (see Table 1 for terminology) are a set of interconnected approaches for environmental recovery, the so-called 'restorative continuum'

TABLE 1 Restoration-related terminologies and their definitions.

Term	Definition
Ecological restoration	The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2004). Returning an ecosystem to a close approximation of its condition prior to disturbance by re-establishing pre-disturbance aquatic functions and ecosystem processes, and related physical, chemical and biological characteristics, and allowing reintroduction of indigenous species (NRC, 1992; Aronson & Le Floc'h, 1996; Simenstad et al., 2006) Such restoration aspires to substantial recovery of the native biota and ecosystem functions (contrast with rehabilitation). When full recovery is the goal, an important benchmark is when the ecosystem demonstrates self-organization (Gann et al., 2019). It includes the following components and perspectives (Clewell & Aronson, 2013; Gann et al., 2019): Adaptive component – it aims to move a degraded ecosystem to a trajectory of recovery that allows adaptation to local and global changes, as well as persistence and evolution of its component species Ecological perspective – it is an intentional activity that reinitiates ecological processes that were interrupted when an ecosystem was impaired Conservation perspective – it recovers biodiversity in the face of an unprecedented, human-mediated extinction crisis Socio-economic perspective – ecological restoration recovers ecosystem services (ES) from which people benefit
'Passive' or 'natural' restoration	Allowing natural or unassisted ecosystem recovery after removing a source of disturbance (Atkinson & Bonser, 2020)
'Active' or 'assisted' and 'reconstructive' restoration	Assisted restoration: abiotic – for example, active remediation of substrate conditions (physical or chemical), habitat creation, reshaping watercourses, reintroduction of environmental water flows, applying artificial disturbance to promote seed germination; biotic – for example, invasive species management, reintroduction of species, augmenting or reinforcing depleted populations of species (Atkinson & Bonser, 2020) Reconstructive restoration: a combination of the above strategies with the reintroduction of a major proportion of the desired biota. Possibly mimicking natural successional dynamics (Atkinson & Bonser, 2020)
Rehabilitation	The act of partially or, more rarely, fully replacing structural or functional characteristics of an ecosystem that have been reduced or lost (Elliott et al., 2007). In the short term, management measures favour one group of species or ES (Aronson & Le Floc'h, 1996; Simenstad et al., 2006) The goal of rehabilitation projects is not native ecosystem recovery, but rather reinstating a level of ecosystem functioning for renewed and ongoing provision of ES potentially derived from non-native ecosystems as well (Gann et al., 2019)
Reallocation	Literally, this entails changing the way something is allocated for conversion of an ecosystem to a different kind of ecosystem or land use primarily for purposes other than the conservation management of local native ecosystems (Aronson et al., 1993). Reallocation can favour the development of new trajectories that over the long-term produce new ecosystems and uses (Aronson & Le Floc'h, 1996; Elliott et al., 2007)
Remediation	Action taken, following anthropogenic disturbance, to restore or enhance the ecological value of a site (Emu Ltd., 2004), hence giving emphasis to the action or process rather than the end-point reached (Bradshaw, 2002; Elliott et al., 2007)
Recovery	The capacity or the process of a system to return to pre-disturbance condition, the original or reference state, after being in a degraded or disrupted one (Elliott et al., 2007). Recovery is the outcome sought or achieved of a restoration action. It can be active (human induced) or passive (natural)

(Gann et al., 2019; Chazdon et al., 2021). Collectively, these approaches can lead to ocean regeneration, a term used to depict the recovery of ocean ecosystems, their functions and their valuable services. Restoration and conservation strategies are synergic and must draw on their complementary strengths to achieve their goals (Wiens & Hobbs, 2015).

Marine restoration has been featured in numerous international environmental commitments (Abelson et al., 2020). The need to restore degraded ecosystems has been recognized for years by the Convention on Biological Diversity (CBD) initiatives and agreements (Miller, 1999; Maes, 2008; De Groot et al., 2013) and by diverse European policy instruments (e.g. Habitats Directive, EEC, 1992; Marine Strategy Framework Directive, EC, 2008); quantitative targets for restoration now figure prominently in the CBD's Global Biodiversity Framework agreed in late 2022 (CBD, 2022). Regeneration of aquatic ecosystems is now one of the main missions of the EU Biodiversity Strategy 2030, which supports the Green Deal – the European agreement set to address the climate crisis by protecting and restoring natural ecosystems and related capital (EU, 2019). Moreover, marine ecosystem restoration is recognized as necessary to achieve many United Nations Sustainable Development Goals (SDGs), especially SDG14 'Life Below Water' (Diz et al., 2018) and is prominent in the UN Decade of Ecosystem Restoration (Aronson et al., 2020). Recently, the European Commission has committed to proposing a legal framework for nature restoration (https://environment.ec.europa.eu/publications/nature-restoration-law_en), a unique opportunity for a significant improvement in the ecological quality of restoration outcomes, including its implementation at large scale (Shumway et al., 2021; Cliquet et al., 2022). As such, ecological restoration is broadly being recognized as a main pillar of ocean management in aiming to reverse degradation trajectories of nature in peril (Coleman et al., 2020).

Marine spatial planning (MSP), a focus of numerous international marine policies and agreements (e.g. UK Marine Policy Statement, 2011; European Directive of Maritime Spatial Planning, EC, 2014; Marine and Coastal Act of the Parliament of Victoria, Australia, 2018), is a public process aiming to allocate maritime activities within the marine space by minimizing conflicts and maximizing sustainability (Ehler & Douvere, 2009; Agardy, 2010; Frazão Santos et al., 2019). MSP is under development or on track to be implemented in 75 countries around the world (half of the world countries with territorial waters; Ehler, 2021) and has the potential to expand even further under the EU and UNESCO IOC commitment (EC, 2014; https://ioc.unesco.org/news/european-commission-and-unesco-renew-their-joint-efforts-advance-marine-spatial-planning). It is a key tool in the UN Decade of Ocean Science for Sustainable Development (Heymans et al., 2020), supporting the achievement of sustainability goals around the world.

MSP has roots in marine conservation, with early spatial planning focused on marine protected area site selection and zoning (Agardy, 2010; Vaughan & Agardy, 2020). However, in the last 15 years, MSP has gone beyond conservation, aspiring to become a multi-objective approach that balances ecological and socio-economic goals while delivering conservation outcomes (Shabtay et al., 2019; Gissi et al., 2022). When MSP recognizes ecological systems as multiple interacting elements, it rests on the principles of ecosystem based management (EBM). Such MSP, called 'ecosystem-based marine spatial planning' or EB-MSP, focuses management strategies on 'how the ecosystem works and functions' (Curtin & Prellezo, 2010; UNEP, 2011) by reducing threats and by explicitly supporting the recovery of marine ecosystem functioning (Arkema et al., 2006; Foley et al., 2010). In practice, however, most MSP processes fail to implement EBM and often marginalize conservation objectives (Frazão Santos et al., 2021; Fabbrizzi et al., 2023; Reimer et al., 2023), and the explicit strategic inclusion of restoration processes as an objective of MSP is even more rare, accentuating the risk that conserving and restoring marine ecosystems remains an aspiration rather than an outcome.

The intersection of MSP, in general terms, with marine restoration strategies has been recommended previously (Lester et al., 2020; Fraschetti et al., 2021; Fabbrizzi et al., 2023), but no systematic framework exists for achieving this. We contend that MSP that steadfastly stays true to the EBM approach and principles can boost marine restoration. Conversely, explicitly bridging the worlds of MSP and marine restoration, whereby planners guide investment in marine restoration, represents a significant opportunity for MSP to augment its potential for promoting ocean regeneration and the continuous delivery of ES to obtain both conservation and long-lasting socio-economic outcomes.

2 | ENVISIONING A RESTORATION-FOCUSED EB-MSP FRAMEWORK THROUGH EBM PRINCIPLES

This paper presents a rationale for the proposed perspective and defines why and how a marine restoration-focused EB-MSP framework can simultaneously catalyse restoration projects and achieve both conservation and blue economy objectives (Gilliland & Laffoley, 2008). An ecosystem-based approach can have many dimensions; however, we reduce these to the five core principles of EBM pointed by UNEP in its EBM Manual (UNEP, 2011). In brief, these are: (i) recognizing connections; (ii) taking an ES approach; (iii) addressing cumulative impacts; (iv) managing for multiple uses; and (v) embracing change, learning and adapting. Figure 1 summarizes how these five EBM core principles can provide an overarching guide for inserting marine restoration in MSP; in other words, we provide tips for an EB-MSP + restoration approach to operationalize the restoration-focused EB-MSP framework. The principles and how they provide insertion points for restoration in marine planning are described in detail in the following sections.

2.1 | Recognizing connections

Much of restoration planning as currently practised is small in scope, and because it is undertaken at a geographically limited scale, it often fails to acknowledge connectivity, which takes place at broader scales. We refer to 'small scale' restoration that focuses on a single habitat and localized human uses in contrast to 'large scale' restoration that covers large marine ecosystems (Sherman & Alexander, 1986) or national waters, inherently encompassing multiple ecosystems (Collie et al., 2013). Connectivity, defined as 'the degree to which landscapes and seascapes enable species to move freely and ecological processes to function unimpeded' (Balbar & Metaxas, 2019; UNEP, 2019), is central to many ecological processes, including migration of adults and dispersal of juveniles, nutrient fluxes, gene flow, demographic recovery and movement (Treml & Halpin, 2012; Roberts et al., 2021). EBM recognizes the need to consider ecological connectivity in order to effectively conserve and restore marine ecosystems; when connectivity is not considered, ecological processes can be disrupted, leading to negative cascading effects on multiple ecosystem components (UNEP, 2011; Laffoley et al., 2019). Some areas are more critical for maintaining ecological connectivity than others because they differ in their functions as food subsidies, refuges from weather or predators, accessibility to dispersal pathways, and in numerous other ecological properties that help to shape individual fitness, population demography and assemblage composition (Fobert et al., 2019).

Addressing ecological connectivity, by identifying and prioritizing connected sites when planning restoration actions, has been identified as the most promising strategy when the aim is to restore species populations (Gilby et al., 2018; Fraschetti et al., 2021; Fabbrizzi et al., 2023). For example, artificial reefs or structures

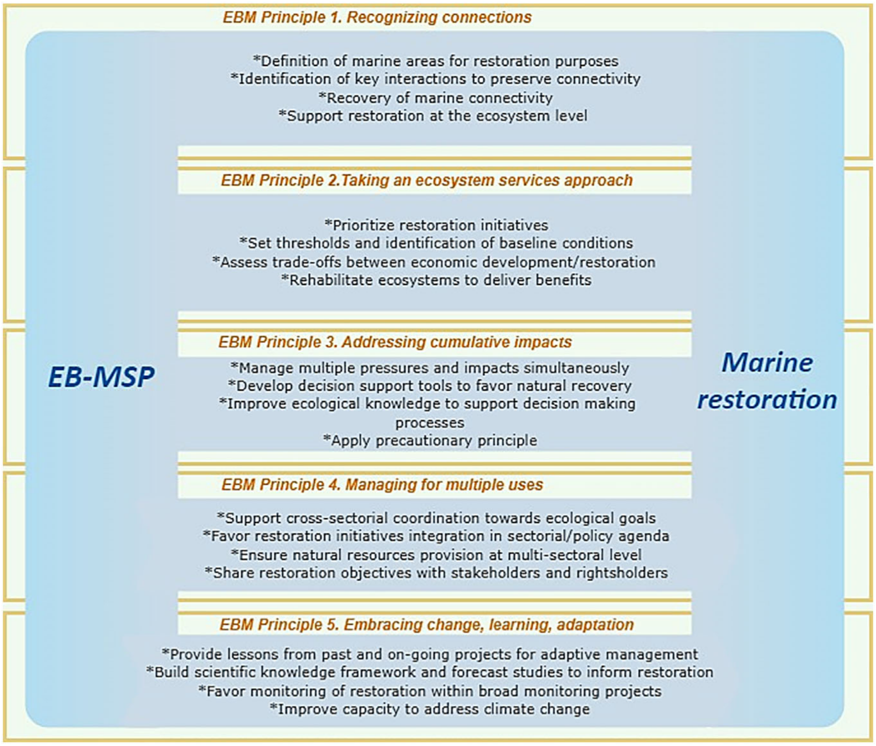

FIGURE 1 Ecosystem-based marine spatial planning (EB-MSP) and marine restoration benefits sharing. Schematic representation of how an EB-MSP implementing ecosystem-based management (EBM) core principles can operatively support marine restoration and the derived benefits. EBM principles are taken from UNEP (2011).

deployed underwater to enhance repopulation of both pelagic and benthic species (e.g. fish, oysters, corals) have been shown to be more effective when networks of these sites are designed to optimize the maintenance of connections between areas and species populations and by considering distance, dispersal mechanisms, currents etc. (Blouet et al., 2022; Paxton et al., 2022; Swam et al., 2022). Similarly, coral reef restoration is most successful when corals are strategically outplanted in areas where their larvae dispersal targets a greater number of surrounding reefs, which increases bet-hedging and contributes to the replenishment of the ecosystem beyond the outplant site (Frys et al., 2020). Considering connectivity in reef restoration planning can also allow inclusion of other ecosystems that support reef functioning, such as seagrass beds or estuarine ecosystems. A focus on connections can also highlight potential synergies between land and reef restoration projects, as is the case of reforestation actions that improve water quality benefiting coral reefs (Suárez-Castro et al., 2021).

Maintaining the links between diverse habitats across wide seascapes is critical for the population dynamic of many mobile species (McMahon et al., 2012). Biophysical models able to predict larval dispersal, for instance, combine different environmental datasets in order to describe connectivity and predict areas most likely connected (Jonsson et al., 2020; Sciascia et al., 2020; Swam et al., 2022). EB-MSP relies heavily on such modelling approaches and can also guide allocation of restoration initiatives. Moreover, planning that takes into account connectivity can allow restoration initiatives to operate at large scales, which is essential to increase the chance of ocean regeneration success (Duarte et al., 2015; Fabbrizzi et al., 2023). An example is provided in the large restoration programme being undertaken in the Solent (UK), where active restoration of oyster reefs (Collins et al., 2022) is coupled to passive restoration provided by restrictions on bottom trawling and dredging, along with restoration of riparian habitats that result in improved water quality in estuarine/nearshore waters. A melded EB-MSP and restoration framework thus makes it possible to optimize connectivity by considering the big picture and the restoration opportunities at the landscape/seascape scale.

It has been showed that where multiple interconnected habitats are co-restored, their positive interactions mutually benefit each other to stabilize and even accelerate ecosystem recovery (McAfee et al., 2022a). This has been well documented in case studies from South Australia, which showed how constructed boulder reefs provide opportunities to co-restore shellfish and kelp forests, while stabilizing sediment for seagrass recovery. Another case describes re-introducing tidal flows into tidally restricted areas (e.g. via tidal gates, sea walls), providing the opportunity to restore mosaics of connected intertidal seagrass, mangrove and saltmarsh habitats (McAfee et al., 2021).

Resting on the connectivity principle, a restoration focused-EB-MSP framework approach could guide a multi-habitat approach and also the prioritization of restoration interventions to be explicitly included in zoning of marine areas, that is, the allocation of ocean space for various uses, protection modes and managing objects (Agardy, 2010). EB-MSP can direct active, assisted or reconstructive restoration (Atkinson & Bonser, 2020) (see Table 1 for terminology) that enhances connectivity among populations and habitats. Active restoration includes engineered replanting, shoreline or reef stabilization, pollution controls, species reintroductions, removal of non-native invasive species and other deliberate actions by managers meant to either restore habitats that were previously present or enhance degraded habitats to make them more resilient to human and climate change pressures. Many options are available to planners; however, choosing particular passive or active restoration measures requires a case-by-case cost–benefit analysis, considering the trade-offs of the two approaches and their direct and indirect costs (e.g. longer recovery time and vigilance costs in natural restoration strategies and material and labour costs in active restoration strategies; Zahawi et al., 2014). With restoration-focused EB-MSP, passive and active restoration that restores connectivity can lead to long-lasting outcomes even over large geographic scales (Diefenderfer et al., 2021).

Marine plans that incorporate restoration measures in particular zones at various scales (within, for instance, protected areas, at the scale of subnational regions or even at wider national scales) can make them more effective. Additionally, implicitly linking local restoration interventions with broader scale restoration policies through a spatially nested and coordinated restoration strategy is recommended for improved delivery of both ecological and socio-economic benefits (Gilby et al., 2021). Indeed, this would prioritize localized, small-scale and interconnected restoration actions within a wide area – for example, by identifying interconnected sites to facilitate the simultaneous restoration of oyster reefs, seagrasses and mangroves. This can optimize restoration investments to obtain the greatest ecological and socio-economic benefits across a wide area – for example, improved habitat that supports fish populations and fisheries at the scale of multiple estuaries (Gilby et al., 2021).

2.2 | Taking an ES approach

EBM that aims to maintain the delivery of ES, or the goods and services provided by the diversity of species and their functions (for instance food provision, shoreline stabilization and buffering of land from storms, hydrological balances, pest control and carbon storage; Normile, 2010), can create public support for management actions. A prerequisite for ensuring the capacity of ecosystems to deliver ES is the maintenance of their ecological processes and properties. Under this perspective, an ecosystem can be considered recovered when the biodiversity is accomodated before degradation is restored and it reacquires its capability of delivering ES (Orth et al., 2020).

Although there may be considerable uncertainty about how quickly full recovery of ES can be accomplished, ES studies can be used within a restoration-focused EB-MSP framework to guide the achievement of conservation and related human well-being. When spatial multi-criteria decision frameworks are applied to prioritize and select sites to be restored, planning interventions have the potential to enhance ES delivery and catalyse positive biodiversity and socio-economic outcomes (Pittman et al., 2022).

Operationalizing the ES approach to serve restoration-focused EB-MSP may require targeted ES assessments to ascertain conditions prior to ecosystem degradation in order to provide baseline information. ES assessment helps set thresholds, identify baseline conditions and guide restoration to meet established targets. Such assessments can feed decisions based on explicitly identified trade-offs to pinpoint the most beneficial planning solution (White et al., 2012). Information coming from such assessments should be considered during the initial phase of MSP, which is focused on creating the knowledge framework that will guide the building of the spatial plan. Subsequently, once restoration has been initiated, the rates at which ES are delivered should be monitored for long enough to provide meaningful information regarding restoration success (Gómez-Baggethun et al., 2019). Knowing which areas previously delivered important ES, or would in the future if restored, can help prioritize site selection for spatial zoning and make explicit the benefits of restoration. Thus, taking an ES approach not only promotes more ecologically sustainable planning, but it also can create impetus for restoration and the enhanced ES flows that such restoration would bring.

In restoration-focused EB-MSP, economies of scale can be achieved if single restoration projects are strategically integrated within larger MSP programmes and are planned and designed in a way to be physically and functionally linked to underpin ecological connectivity and thus ES delivery. Thus, although restoration can be costly, especially when performed at large scales, when appropriately planned, benefits can outweigh costs (De Groot et al., 2013; Strassburg et al., 2019). Evaluations that confirm this include a successful large-scale seagrass restoration project along the mid-Atlantic coast of the USA in which the numerous ES recovered, delivering benefits beyond the scale of the restored area (Orth et al., 2020). These benefits include improved water quality and ample habitat recovery with consequent increasing fish populations to support the fishery and an augmented capacity of nitrogen and carbon sequestration to help abate climate change effects.

Restoration-focused EB-MSP can also guide investment in restoring blue carbon ecosystems. In some cases, such restoration combines recovery of mangrove, saltmarsh or seagrass with active restoration involving human-engineered infrastructures, such as submerged breakwaters that mimic coral reef structures to reduce shoreline erosion (Stender et al., 2021). Such restoration has been shown to enhance opportunities for sustainable energy production (Vanderklift et al., 2019; Thiele et al., 2020) and at the same time can increase coastal protection in the face of catastrophic climate change effects. Moreover, considering the interconnected multi-habitat approach also gives more chance to increase the connectivity between carbon source and sink habitats (e.g. between adjacent kelp forests and seagrass, respectively) and, through enhanced organic carbon transfer and burial, maximize the carbon sequestration potential (Smale et al., 2018; McAfee et al., 2022a).

Balancing the trade-offs between ecological restoration benefits and economic interests is critical. Efforts should be dedicated to analysing the complex interactions among multiple ES and human needs and set threshold values for ecosystem management (Wang et al., 2022). We suggest that a restoration-focused EB-MSP could drive all these in a specific coordinated framework.

2.3 | Addressing cumulative impacts

Restoration efforts which consider only single stressors and limit single sector/use-impact (e.g. limiting pollutant inputs or overfishing) may fail because degradation of an ecosystem is usually caused by multiple activities and pressures (Brown et al., 2013; Gissi et al., 2021). Considering and analysing all sources of pressures in a multi-use context, as EBM does, is essential in identifying those that are the main cause of ecosystem degradation trajectory (Merovich & Petty, 2007; Teichert et al., 2016). EB-MSP combines studies on cumulative impacts and ES provisioning hotspots, and such an approach can allow prioritization of restoration interventions and increase their efficiency and success rates (Allan et al., 2013). Indeed, once cumulative impacts are addressed, the stage is set for natural recovery or restoration actions through integrated and multi-use management (Paschke et al., 2019). One example is provided by Farella et al. (2020) who supported the development of MSP in the Emilia-Romagna Region (Italy) through the application of an ad hoc MSP modelling framework. They simultaneously analysed cumulative pressures and their effects on the capability of habitats and species populations inhabiting the territorial waters of the region to deliver ES. The study provided practical guidelines and delineated some areas of conservation to support the restoration of overexploited fish populations and of species of conservation priority.

Map-based threats assessments coupled to restoration science can help identify areas of greatest restoration need, guide the prioritization of threats to be addressed and steer implementation of a portfolio of restoration actions (Allan et al., 2013; Neeson et al., 2016). Sophisticated tools to inform EB-MSP and support decision makers in managing multiple anthropogenic uses and impacts exist (e.g. predictive models as habitat suitability models – Marxan and Bayesian belief networks for scenario analyses, InVEST for ES assessment and trade-off) and can also incorporate knowledge on vulnerability and natural recovery capability of marine ecosystems in multi-use contexts (e.g. cumulative effects assessment models; Andersen et al., 2013; Menegon et al., 2018; see the above cited example by Farella et al., 2020). Another example that combines different modelling approaches is provided by Uusitalo et al. (2016), who explored the effect of diverse scenarios of fishing pressure and nutrients inputs reduction in the Baltic Sea to inform the management of cumulative pressures to allow the recovery of Baltic ecosystems and fish populations.

By considering cumulative effects, EB-MSP can drive multi-sector cooperation and ultimately effective management (Guerry et al., 2012; Halpern et al., 2019). That said, knowledge on vulnerability and natural recovery of species and habitats is still limited, complicated by multiple factors, including differences in the type and severity of the various impacts (Duarte et al., 2015 and references therein), which increases uncertainty of model outputs. However, field studies and manipulative experiments are filling knowledge gaps and are being incorporated in EB-MSP decision-support tools to increase their reliability (see, for instance, Kotta et al., 2019). Furthermore, advances in technology and transdisciplinary research such as use of large-scale satellite data (Klemas, 2013; Ouellette & Getinet, 2016) and machine learning algorithms can increase the efficacy and efficiency of restoration (Zellmer et al., 2019). Where knowledge gaps remain unfilled, an EB-MSP + restoration approach should acknowledge uncertainty and apply the precautionary principle, common practice for EB-MSP (Manea et al., 2020) and fundamental in restoration practices (Gann et al., 2019).

2.4 | Managing for multiple uses

Managing for multiple uses under EBM implies cross-sectoral coordination. To do this effectively, cumulative impacts should be systematically assessed, along with analysis of capacity for addressing these impacts with existing institutions, policies, regulations and norms (Agardy, 2010). EB-MSP integrates this holistic management to respond to multiple stressors and maximize efficiencies through coordinated and cooperative actions. Such an approach not only prevents further environmental degradation but also sets the stage for natural recovery and restoration. Management that is supported by EB-MSP can (and should, wherever possible) include a blueprint for both passive and active restorations (see Table S1 for possible restoration measures). Marine restoration projects should likewise include multi-use management as a goal (Paschke et al., 2019), focusing on managing the pressures that have caused degradation or impede recovery.

With all this in mind, the first strategy of an EB-MSP + restoration approach will probably be passive restoration (here used as synonym of natural restoration), in which pressures, wherever their provenance, are reduced to promote the natural recovery of ecosystems and of ecological processes (Chazdon et al., 2021). Through management measures, EB-MSP can mitigate anthropogenic pressures in areas where passive recovery will require time, for instance, by imposing fishery bans or preventing coastal infrastructure development that hinders species recolonization. Furthermore, EB-MSP can guide siting and establishment of MPAs by highlighting which areas/habitats are ecologically most critical to protect. With protected areas utilized in concert with effective management of multiple uses, socio-economic development and ecosystem recovery can be in balance (Trouillet & Jay, 2021).

Since EB-MSP should be coordinated at diverse governmental and/or institutional levels, restoration within an EB-MSP framework might need to extend beyond jurisdictional boundaries, requiring coordination between different political institutions (van Tatenhove et al., 2021). At the same time, EB-MSP is multi-sectoral and aims to build sectoral integration and coordination among multiple governance and management levels (Grip & Blomqvist, 2021); thus, it can only be effective by actively involving a variety of stakeholders. Planners should involve stakeholders to understand their priorities, allow co-creation of plans and secure their support for management and restoration policies, regulations and interventions.

McAfee et al. (2022b) provided an exemplary case of a successful large-scale restoration project of the disappeared oyster reefs in

Australia. The iniatative was triggered by awareness of the numerous economic and ecological benefits that this habitat could have brought if restored. Through the practical and financial support of a multitude of stakeholders (e.g. scientists, restoration practitioners, policymakers, managers, local communities), multidisciplinary teams and the coordination of both public and private sectors (e.g. research, aquaculture, recreational fishing) over a 6-year period (2015–2021), a substantial investment of funding has enabled 35 restoration projects. This large-scale restoration initiative is ongoing and anticipates additional local projects supported by the increased motivation of the multiple parties involved.

Restoration embedded into EB-MSP can thus benefit many stakeholders and can lead to long-lasting positive outcomes that will expand stakeholder support, especially when done at large scales (Bayraktarov et al., 2020). A participatory approach to restoration can emphasize the human–ecosystem relationship, thereby increasing the willingness of stakeholders to support or even engage in restoration. Volunteers can be fundamental for supporting restoration, especially when active restoration is done across large geographies (Orth et al., 2020). Stakeholders can also be engaged in evaluation of the success of restoration initiatives by providing data on benefits flows and perceptions about the level to which the ES delivery has been recovered. This is particularly useful for gauging recovery of cultural ES, which are difficult to measure because they are intangible but directly linked to human perception and health (Pouso et al., 2020). Furthermore, involving stakeholders can reduce the risk that unrealistic expectations are set and then not met, generating mistrust in restoration initiatives (Kodikara et al., 2017).

2.5 | Embracing change, learning and adapting

Embracing change is imperative for achieving positive outcomes and improve prospects for success of future initiatives (Ellison et al., 2020). Part of embracing change is recognizing where change is happening and why and learning from the application of management over time.

Detailed information on past and present distribution and condition of ecosystems, causes of degradation and related footprints, conditions of the surrounding environments and changes the area is

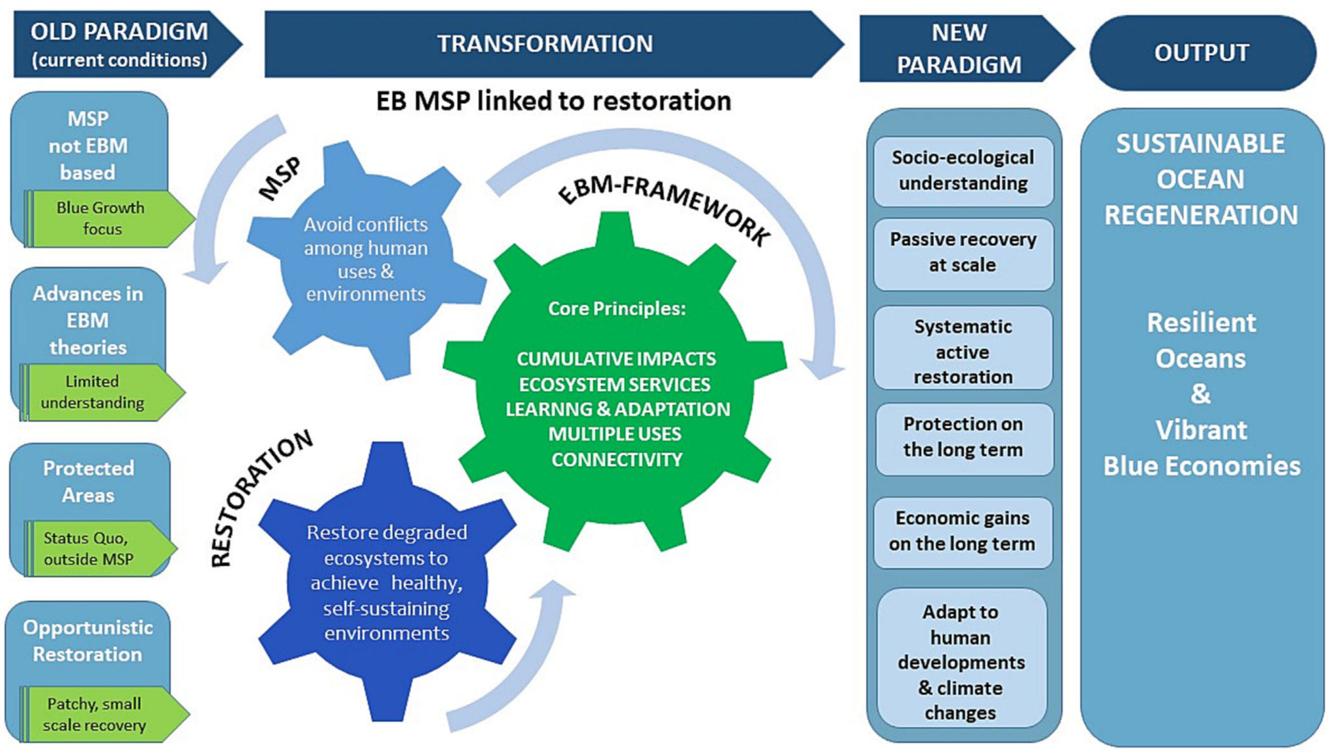

FIGURE 2 How restoration-focused ecosystem-based marine spatial planning (EB-MSP) drives more efficient ocean regeneration. The elements for a transformative shift from an old to a new ocean regeneration paradigm are all here today, but disparate and unsystematic planning is unable to capitalize on the immense opportunities that exist for this transformation to happen. This transformation can be reached by staying focused on the five ecosystem-based management (EBM) core principles – recognizing connections (to build a solid understanding of the ecology of marine and coastal systems and identify critical ecological elements to protect or restore as well as the links that connect those), taking an ecosystem services approach (as a way to communicate the values of healthy oceans), addressing cumulative impacts and managing for multiple uses (to allow institutional integration and effective management of uses, resources and ocean space), embracing change, learning and adaptation (to trial solutions and practise adaptive management, allowing also the incorporation of human development and climate changes). This is what the restoration-focused EB-MSP frameworks make possible.

likely to face in the future is all needed in a restoration-focused EB-MSP framework. Planning is built on baseline inventories of information from diverse knowledge sources and involves a broad range of experts including local knowledge (Lombard et al., 2019). Inclusion of local knowledge can help reconstruct pre-disturbance conditions necessary for setting final goals (Gann et al., 2019). The integration of indigenous and scientific knowledge is fundamental, especially where published information is scant. To deal with knowledge limitations planners and restoration experts can also rely on accessible satellite data on distribution of habitats and environmental conditions (e.g. temperature conditions, chlorophyll concentration; Fingas, 2019). Another strategy can be integrating the existing monitoring frameworks at both local and large scales – for example, the European Marine Strategy Framework Directive (Maccarrone et al., 2015; Abramic et al., 2020) within restoration-focused EB-MSP – to optimize multi-scale monitoring efforts and obtain long-term datasets (Manea et al., 2022).

The integration of multiple knowledge sources is thus crucial for adapting management and restoration as conditions change. A practical example on the potential of integrating local monitoring with remote sensing data is provided by McClenachan et al. (2020) in which they combined these diverse data sources to assess the restoration success of small-size shoreline and oyster reef restoration projects at the scale of the ecosystem of Mosquito Lagoon, Florida, USA.

Adaptive management relies on the lessons learned from monitoring and evaluating the performance of implemented management strategies and measures over time while accounting for possible environmental shifts due to climate change (Thom, 2000; Ellison et al., 2020). Adaptive restoration similarly relies on systematic and long-lasting monitoring to track the pace of recovery and regeneration.

Since the time needed for an ecosystem to recover after restoration interventions varies (Kodikara et al., 2017; Boström-Einarsson et al., 2020), and because species and habitats present different recovery capabilities (Bekkby et al., 2020), course corrections may be necessary. EB-MSP can and should respond to the highly dynamic nature of marine systems, where environmental conditions are constantly shifting. Climate change drives many of these shifts (Roberts et al., 2020), and discussions on climate change mitigation and adaptation in coastal areas are accelerating (Flannery et al., 2020), focused on how to make MSP an effective instrument to minimize climate impacts, support climate adaptation and allow mitigation actions (Frazão Santos et al., 2019; Frazão Santos et al., 2020). Restoration-focused EB-MSP can build on conservation planning for climate change adaptation; key strategies under this approach include vulnerability assessments, supporting ecosystem resilience, protecting climate refugia and predicting species and ecosystem shifts (Wilson et al., 2020). An EB-MSP + restoration approach could strengthen nature-based solutions (Gijsman et al., 2021) that enhance blue carbon, as well as restoration of ecosystems that abate coastal vulnerability, eliminate cumulative pressures in climate refugia (i.e. passive restoration) and foster active restoration projects in areas accommodating shifts.

3 | CONCLUSIONS

To date, MSP and restoration have been on separate tracks, ignoring both the potential synergies and co-benefits provided by linking the two. MSP is a powerful tool to support marine conservation (Ehler & Douvere, 2009; Reimer et al., 2023), but neither effective management of marine use nor conservation can match the pace of marine environmental degradation (Coleman et al., 2020). Since most marine ecosystems are no longer pristine, MSP that does not give space, quite literally, for restoration is unlikely to result in desired outcomes of maintaining ES delivery under a blue economy.

The elements for a transformative shift in how to achieve ocean regeneration (summarized in Figure 2) are all here today, but disparate and unsystematic planning is unable to capitalize on the immense opportunities that exist for this transformation to happen. Across the world today, MSP is undertaken at various scales to achieve diverse objectives (Ehler, 2021), mainly targetting blue growth as a goal, with only marginal and insignificant attention paid to the environmental and social sustainability of that economic growth (Frazão Santos et al., 2021). MSP processes that do base planning on EBM principles are increasing but rarely strive to enhance ocean health. At the same time, the world is witnessing a proliferation of active and passive restoration projects, primarily aimed at rebuilding one habitat type across relatively small geographical scales (Fraschetti et al., 2021; Fabbrizzi et al., 2023). At the moment, these restoration projects tend to be opportunistic rather than being a strategic part of geographically large, integrated marine plans.

The enabling conditions that could allow the needed transformation to occur include a solid understanding of the ecology of marine and coastal systems, accounting for the identification of ecologically critical areas to protect or restore, and a solid understanding of the connectivity between different elements of the ecosystem. Alongside this approach, communications about the values of a healthy ocean (taking an ES perspective) and institutional integration that allows effective management of all uses of ocean space and resources (considering cumulative impacts and managing for multiple use) are needed. The transformation is further made possible by learning from trialling management, requiring a continuous linking of restoration with initial planning and with the 'replanning' that is needed for adaptive management.

Restoration-focused EB-MSP can support the restorative continuum, that is, both active and passive restoration interventions, with the former designed to catalyse the latter. Passive restoration mediated by EB-MSP with a wide scope is fundamental because local restoration projects, even if supported by solid scientific understanding and post-care and monitoring actions, can fail in the face of multiple anthropogenic pressures (Diefenderfer et al., 2021). Thus, the strategic easing of pressures on ecosystems led by EB-MSP can predispose ecosystems for natural recovery, leading to restored connectivity and functionalities and simultaneously fostering the effectiveness of assisted or reconstructive restoration projects.

Utilizing a restoration-focused EB-MSP framework, a potential paradigm shift in marine planning outlined in Figure 2, will ensure that interventions end up creating truly resilient 'systems', instead of the façade of reconstructed habitats. Such successful interventions will build on ecological science, oceanography and hydrology, as well as user knowledge, to create understanding of ecosystem connectivity, vulnerability and recovery rates (Danovaro et al., 2021; Fabbrizzi et al., 2023). Planners who consider all the important elements of marine ecosystems, at various ecological levels and spatial scales, through restoration-focused EB-MSP will see their plan lead to durable outcomes.

The priority main actions that can be taken in an EB-MSP restoration framework are:

- put in place passive restoration as a first strategy to abate pressures wherever their provenance to promote the natural recovery of ecosystems;
- establish active restoration measures as a second strategy following the logic of ecological connectivity and linking local restoration interventions with broader-scale restoration policies and within spatial plans in concert with MPA designation;
- adopt the ES approach to guide the optimization of conservation and restoration measures and the setting of thresholds, starting from previous ES assessment and trough the identification of baseline conditions and trade-offs;
- apply the modelling framework on which MSP relies with a view to identifying restoration measures to be integrated into spatial plans and integrate empirical scientific knowledge from restoration ecology into the models;
- coordinate restoration at multiple governmental, and thus geographical, scales;
- engage with stakeholders in defining objectives, fundraising strategies, monitoring and evaluating of restoration performance;
- support and take advantage of existing monitoring frameworks integration also for tracking restoration success;
- rely on the integration of multiple knowledge sources for building the initial assessment of environmental conditions and for laying the foundations for marine restoration; and
- address climate change by investing in nature-based solutions that favour blue carbon ecosystems and restoration of ecosystems that abate coastal vulnerability, eliminating cumulative pressures in climate refugia (i.e. passive restoration) and fostering active restoration projects in areas where habitats is expected to shift.

We suggest that adopting an EB-MSP + restoration approach and demonstrating restoration-focused EB-MSP will spur replication and a wide upscaling of effective marine management for ocean regeneration. MSP that fully incorporates marine restoration through EBM within its goals has the potential to support and boost the recovery of ecological structure, function and resilience while enabling enhanced ES delivery that maximizes socio-ecological and economic benefits-sharing. Multiple restorative actions can thus be implemented within EB-MSP to contemporarily boost sustainable economy and ocean regeneration.

In conclusion, restoration-focused EB-MSP is desirable for numerous reasons: (i) it allows scaling-up of marine restoration advancements within large-scale planning mechanisms; (ii) it delivers important means for sustainable blue economy and helps meet conservation objectives; and (iii) it can lead to integrated MSP, able to better manage ecosystems across biomes and the pressures derived from climate change. Recovery of marine life, and broader ocean regeneration, can only be achieved if immediate strategic action is taken (Duarte et al., 2020). Restoration-focused EB-MSP can be the vehicle to accomplish this, allowing marine life to recover from centuries of impact and promoting a more sustainable way for humankind to benefit from the global ocean.

AUTHOR CONTRIBUTIONS

Elisabetta Manea, Tundi Agardy and Lucia Bongiorni: Conceptualization; methodology; investigation; writing—original draft; writing—review and editing; visualization; supervision.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The manuscript doesn't publish data, no data availability statement is needed.

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