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1 **Link marine restoration to marine spatial planning through ecosystem based management to**
2 **maximize ocean regeneration**

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15

16 **Abstract**

17 1. The speed at which marine and coastal ecosystems are being degraded due to cumulative
18 impacts limits the effectiveness of conservation strategies. To abate ocean degradation and
19 allow ocean regeneration, conservation planning needs to be improved and ecological
20 restoration will be needed.

21 2. This study explores the potential of incorporating restoration into marine spatial planning
22 (MSP) anchored to ecosystem based management (EBM), termed EB-MSP, for maximizing
23 ocean regeneration. Our perspective explicitly brings both passive and active restoration into
24 EB-MSP in a broad and holistic framework for achieving the recovery of ocean ecosystems,
25 their functions, and their valuable services.

26 3. By proposing a restoration-focused EB-MSP framework we highlight the co-benefits of
27 interlinking MSP and marine restoration through the EBM core principles. Such benefits
28 include: a scaling up of restoration effectiveness, a greater guarantee that sustainability and
29 conservation goals will be met, and improvements in MSP as an integrated planning tool with

30 the potential to address climate change. Together this will promote ocean regeneration
31 alongside management for sustainable use, to prevent further degradation and to allow much-
32 needed ecological recovery.

33

34 **Keywords:** addressing climate change, blue economy, ecological principles, ecosystem services,
35 MSP, ocean sustainability, restoration planning, restoring marine ecosystems

36

37 **1. Introduction**

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

47 Restoration, rehabilitation and remediation (see Table 1 for terminology) are a set of interconnected
48 approaches for environmental recovery, the so-called “restorative continuum” (Gann et al., 2019;
49 Chazdon et al., 2021). Collectively these approaches can lead to ocean regeneration, a term we use to
50 depict the recovery of ocean ecosystems, their functions, and their valuable services. Restoration and
51 conservation strategies are synergic, and must draw on their complementary strengths to achieve their
52 goals (Wiens & Hobbs, 2015).

53 Marine restoration has been featured in numerous international environmental commitments
54 (Abelson et al., 2020). The need to restore degraded ecosystems has been recognized for years by the

55 Convention on Biological Diversity (CBD) initiatives and agreements (Miller, 1999; Maes et al.,
56 2008; De Groot et al., 2013) and by diverse European policy instruments (e.g., Habitats Directive,
57 EEC, 1992; Marine Strategy Framework Directive, EC, 2008); quantitative targets for restoration
58 now figure prominently in the CBD's Global Biodiversity Framework agreed in late 2022 (CBD
59 2022). Regeneration of aquatic ecosystems is now one of the main missions of the EU Biodiversity
60 Strategy 2030 which supports the Green Deal - the European agreement set to address the climate
61 crisis by protecting and restoring natural ecosystems and related capital (EU, 2019). Moreover,
62 marine ecosystem restoration is recognized as necessary to achieve many United Nations Sustainable
63 Development Goals (SDGs), especially SDG14 'Life Below Water' (Diz et al., 2018) and is
64 prominent in the UN Decade of Ecosystem Restoration (Aronson et al., 2020). Recently, the
65 European Commission has committed to proposing a legal framework for nature restoration
66 (https://environment.ec.europa.eu/publications/nature-restoration-law_en), a unique opportunity for
67 a significant improvement in the ecological quality of restoration outcomes, including its
68 implementation at large scale (Shumway et al., 2021; Cliquet et al., 2022). As such, ecological
69 restoration is broadly being recognized as a main pillar of ocean management in aiming to reverse
70 degradation trajectories of nature in peril (Coleman et al., 2020).

71 Marine spatial planning (MSP), a focus of numerous international marine policies and agreements
72 (e.g., UK Marine Policy Statement, 2011; European Directive of Maritime Spatial Planning, 2014;
73 Marine and Coastal Act of the Parliament of Victoria, Australia, 2018), is a public process aiming to
74 allocate maritime activities within the marine space by minimizing conflicts and maximizing
75 sustainability (Ehler & Douvère, 2009; Agardy, 2010; Frazão Santos et al., 2019). MSP is under
76 development or on track to be implemented in 75 countries around the world (half of the world
77 countries with territorial waters; Ehler, 2021) and has the potential to expand even further under the
78 EU and UNESCO IOC commitment (EC, 2014; [https://ioc.unesco.org/news/european-commission-
79 and-unesco-renew-their-joint-efforts-advance-marine-spatial-planning](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

80 Decade of Ocean Science for Sustainable Development (Heymans et al., 2020), supporting the
81 achievement of sustainability goals around the world.

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

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

104

105

106 **2. Envisioning a restoration-focused EB-MSP framework through EBM principles**

107 We present a rationale for the proposed perspective and define why and how a marine restoration-
108 focused EB-MSP framework can simultaneously catalyse restoration projects and achieve both
109 conservation and blue economy objectives (Gilliland & Laffoley, 2008). An ecosystem based
110 approach can have many dimensions, however we reduce these to the five core principles of EBM
111 pointed by UNEP in its EBM Manual (UNEP, 2011). In shorthand these are: 1) recognizing
112 connections; 2) taking an ecosystem services approach; 3) addressing cumulative impacts; 4)
113 managing for multiple uses; and 5) embracing change, learning, and adapting. Figure 1 summarizes
114 how these five EBM core principles can provide an overarching guide for inserting marine restoration
115 in MSP; in other words, we provide tips for an EB-MSP + restoration approach to operationalize the
116 restoration-focused EB-MSP framework. The principles and how they provide insertion points for
117 restoration in marine planning are described in detail in the following sections.

118

119 **2.1 Recognizing connections**

120 Much of restoration planning as currently practiced is small in scope, and because it is undertaken in
121 a geographically limited scale often fails to acknowledge connectivity, which takes place at broader
122 scales. We refer to ‘small scale’ restoration that focuses on a single habitat and localized human uses
123 in contrast to ‘large scale’ restoration that covers Large Marine Ecosystems (Sherman & Alexander,
124 1986) or national waters, inherently encompassing multiple ecosystems (Collie et al., 2013).
125 Connectivity, defined as “the degree to which landscapes and seascapes enable species to move freely
126 and ecological processes to function unimpeded” (UNEP, 2019; Balbar & Metaxas, 2019), is central
127 to many ecological processes, including migration of adults and dispersal of juveniles, nutrient fluxes,
128 gene flow, demographic recovery, and movement (Trembl & Halpin, 2012; Roberts et al., 2021). EBM
129 recognizes the need to consider ecological connectivity in order to effectively conserve and restore
130 marine ecosystems; when connectivity is not considered, ecological processes can be disrupted
131 leading to negative cascading effects on multiple ecosystem components (UNEP, 2011; Laffoley et

132 al., 2019). Some areas are more critical for maintaining ecological connectivity than others because
133 they differ in their functions as food subsidies, refuges from weather or predators, accessibility to
134 dispersal pathways, and in numerous other ecological properties that help to shape individual fitness,
135 population demography, and assemblage composition (Fobert et al., 2019).

136 Addressing ecological connectivity, by identifying and prioritizing connected sites when planning
137 restoration actions, has been identified as the most promising strategy when the aim is to restore
138 species populations (Gilby et al., 2018; Fraschetti et al., 2021; Fabbrizzi et al., 2023). For example,
139 artificial reefs or structures deployed underwater to enhance repopulation of both pelagic and benthic
140 species (e.g., fish, oysters, corals), have been shown to be more effective when networks of these
141 sites are designed to optimize the maintenance of connections between areas and species populations,
142 and by considering distance, dispersal mechanisms, currents, etc. (Blouet et al., 2022; Paxton et al.,
143 2022; Swam et al., 2022). Similarly, coral reef restoration is most successful when corals are
144 strategically outplanted in areas where their larvae dispersal targets a greater number of surrounding
145 reefs, which increases bet-hedging and contributes to the replenishment of the ecosystem beyond the
146 outplant site (Frys et al., 2020). Considering connectivity in reef restoration planning can also allow
147 inclusion of other ecosystems that support reef functioning, such as seagrass beds or estuarine
148 ecosystems. A focus on connections can also highlight potential synergies between land and reef
149 restoration projects, as is the case of reforestation actions that improve water quality benefiting coral
150 reefs (Suárez-Castro et al., 2021).

151 Maintaining the links between diverse habitats across wide seascapes is critical for the population
152 dynamic of many mobile species (McMahon et al., 2012). Biophysical models able to predict larval
153 dispersal, for instance, combine different environmental datasets in order to describe connectivity and
154 predict areas most likely connected (Jonsson et al., 2020; Sciascia et al., 2020; Swam et al., 2022).

155 EB-MSP relies heavily on such modelling approaches and can also guide allocation of restoration
156 initiatives. Moreover, planning that takes into account connectivity can allow restoration initiatives
157 to operate at large scales, which is essential to increase the chance of ocean regeneration success

158 (Duarte et al., 2015; Fabbri et al., 2023). An example is provided in the large restoration program
159 being undertaken in the Solent (UK), where active restoration of oyster reefs (Collins, 2022) is
160 coupled to passive restoration provided by restrictions on bottom trawling and dredging, along with
161 restoration of riparian habitats that result in improved water quality in estuarine / nearshore waters.
162 A melded EB-MSP and restoration framework thus makes it possible to optimize connectivity by
163 considering the big picture and the restoration opportunities at the landscape / seascape scale.

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

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

184 restoration-focused EB-MSP, passive and active restoration which restores connectivity can lead to
185 long-lasting outcomes even over large geographic scales (Diefenderfer et al., 2021).

186 Marine plans that incorporate restoration measures in particular zones at various scales (within, for
187 instance, protected areas, at the scale of subnational regions, or even at wider national scales) can
188 make them more effective. Additionally, implicitly linking local restoration interventions with
189 broader scale restoration policies through a spatially nested and coordinated restoration strategy is
190 recommended for improved delivery of both ecological and socio-economic benefits (Gilby et al.,
191 2021). Indeed, this would prioritize localized, small scale and interconnected restoration actions
192 within a wide area – e.g., by identifying interconnected sites to facilitate the simultaneous restoration
193 of oyster reefs, seagrasses and mangroves. This can optimize restoration investments to obtain the
194 greatest ecological and socio-economic benefits across a wide area – e.g., improved habitat that
195 supports fish populations and fisheries at the scale of multiple estuaries (Gilby et al., 2021).

196

197 **2.2 Taking an ecosystem services approach**

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

206 Although there may be considerable uncertainty about how quickly full recovery of ES can be
207 accomplished, ES studies can be used within a restoration-focused EB-MSP framework to guide the
208 achievement of conservation and related human wellbeing. When spatial multi-criteria decision
209 frameworks are applied to prioritize and select sites to be restored, planning interventions have the

210 potential to enhance ES delivery and catalyse positive biodiversity and socio-economic outcomes
211 (Pittman et al., 2022).

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

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

235 Restoration-focused EB-MSP can also guide investment in restoring blue carbon ecosystems. In some
236 cases such restoration combines recovery of mangrove, salt marsh, or seagrass with active restoration
237 involving human-engineered infrastructures, such as submerged breakwaters that mimic coral reef
238 structures to reduce shoreline erosion (Stender et al., 2021). Such restoration has been shown to
239 enhance opportunities for sustainable energy production (Vanderklift et al., 2019; Thiele et al., 2020),
240 and at the same time can increase coastal protection in the face of catastrophic climate change effects.
241 Moreover, considering the interconnected multi-habitat approach also gives more chance to increase
242 the connectivity between carbon source and sink habitats (e.g., between adjacent kelp forests and
243 seagrass, respectively), and through enhanced organic carbon transfer and burial, maximize the
244 carbon sequestration potential (Smale et al., 2018; McAfee et al., 2022a).
245 Balancing the trade-offs between ecological restoration benefits and economic interests is critical.
246 Efforts should be dedicated to analyse the complex interactions among multiple ES and human needs,
247 and set threshold values for ecosystem management (Wang et al., 2022). We suggest that a
248 restoration-focused EB-MSP could drive all these in a unique coordinated framework.

249

250 **2.3 Addressing cumulative impacts**

251 Restoration efforts which consider only single stressors and limit single sector / use-impact (e.g.,
252 limiting pollutant inputs or overfishing), may fail because degradation of an ecosystem is usually
253 caused by multiple activities and pressures (Brown et al., 2013; Gissi et al., 2021). Considering and
254 analysing all sources of pressures in a multi-use context, as EBM does, is essential in identifying
255 those that are the main cause of ecosystem degradation trajectory (Merovich & Petty, 2007; Teichert
256 et al., 2016). EB-MSP combines studies on cumulative impacts and ES provisioning hotspots and
257 such an approach can allow prioritization of restoration interventions and increase their efficiency
258 and success rates (Allan et al., 2013). Indeed, once cumulative impacts are addressed, the stage is set
259 for natural recovery or restoration actions through integrated and multi-use management (Paschke et
260 al., 2019). One example is provided by Farella and colleagues (2020) who supported the development

261 of MSP in Emilia-Romagna Region (Italy) through the application of an ad-hoc MSP modelling
262 framework. They simultaneously analysed cumulative pressures and their effects on the capability of
263 habitats and species populations inhabiting the territorial waters of the region to deliver ES. The study
264 provided practical guidelines and delineated some areas of conservation to support the restoration of
265 overexploited fish populations and of species of conservation priority.

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

278 By considering cumulative effects, EB-MSP can drive multi-sector cooperation and ultimately
279 effective management (Guerry et al., 2012; Halpern et al., 2019). That said, knowledge on
280 vulnerability and natural recovery of species and habitats is still limited, complicated by multiple
281 factors, including differences in the type and severity of the various impacts (Duarte et al., 2015 and
282 references therein), which increases uncertainty of model outputs. However, field studies and
283 manipulative experiments are filling knowledge gaps and are being incorporated in EB-MSP
284 decision-support tools to increase their reliability (see for instance Kotta et al., 2019). Furthermore,
285 advances in technology and transdisciplinary research such as use of large-scale satellite data
286 (Klemas, 2013; Ouellette & Getinet, 2016) and machine learning algorithms can increase the efficacy

287 and efficiency of restoration (Zellmer et al., 2019). Where knowledge gaps remain unfilled, an EB-
288 MSP + restoration approach should acknowledge uncertainty and apply the precautionary principle,
289 common practice for EB-MSP (Manea et al., 2020) and fundamental in restoration practices (Gann
290 et al., 2019).

291

292 **2.4. Managing for multiple uses**

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

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

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

321 McAfee and colleagues (2022b) provided an exemplary case of successful large-scale restoration
322 project of the disappeared oyster reefs in Australia. The initiative was triggered by awareness of the
323 numerous economic and ecological benefits that this habitat could have brought if restored. Through
324 the practical and financial support of a multitude of stakeholders (e.g., scientists, restoration
325 practitioners, policymakers, managers, local communities), multidisciplinary teams, and the
326 coordination of both public and private sectors (e.g., research, aquaculture, recreational fishing) over
327 a six year period (2015-2021), a substantial investment of funding has enabled 35 restoration projects.
328 This large-scale restoration initiative is ongoing and anticipates additional local projects supported
329 by the increased motivation of the multiple parties involved.

330 Restoration embedded into EB-MSP can thus benefit many stakeholders and can lead to long-lasting
331 positive outcomes that will expand stakeholder support, especially when done at large scales
332 (Bayraktarov et al., 2020). A participatory approach to restoration can emphasize the human-
333 ecosystem relationship, thereby increasing the willingness of stakeholders to support or even engage
334 in restoration. Volunteers can be fundamental for supporting restoration, especially when active
335 restoration is done across large geographies (Orth et al., 2020). Stakeholders can also be engaged in
336 evaluation of the success of restoration initiatives, by providing data on benefits flows and perceptions
337 about the level to which the ES delivery has been recovered. This is particularly useful for gauging
338 recovery of cultural ES, which are difficult to measure because they are intangible but directly linked

339 to human perception and health (Pouso et al., 2020). Furthermore, involving stakeholders can reduce
340 the risk that unrealistic expectations are set and then not met, generating mistrust in restoration
341 initiatives (Kodikara et al., 2017).

342

343 **2.5 Embracing change, learning, and adapting**

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

347 Detailed information on past and present distribution and condition of ecosystems, causes of
348 degradation and related footprints, conditions of the surrounding environments, and changes the area
349 is likely to face in the future is all needed in a restoration-focused EB-MSP framework. Planning is
350 built on baseline inventories of information from diverse knowledge sources, and involves a broad
351 range of experts including local knowledge (Lombard et al., 2019). Inclusion of local knowledge can
352 help reconstruct pre-disturbance conditions necessary for setting final goals (Gann et al., 2019). The
353 integration of indigenous and scientific knowledge is fundamental especially where published
354 information is scant. To deal with knowledge limitations planners and restoration experts can also
355 rely on accessible satellite data on distribution of habitats and environmental conditions (e.g.,
356 temperature conditions, chlorophyll concentration; Fingas, 2019). Another strategy can be integrating
357 the existing monitoring frameworks at both local and large scales - e.g., the European Marine Strategy
358 Framework Directive (Maccarrone et al., 2015; Abramic et al., 2020) within restoration-focused EB-
359 MSP, to optimize multi-scale monitoring efforts and obtain long-term data sets (Manea et al., 2022).
360 The integration of multiple knowledge sources is thus crucial for adapting management and
361 restoration as conditions change. A practical example on the potential of integrating local monitoring
362 with remote sensing data is provided by McClenachan et al. (2020) in which they combined these
363 diverse data sources to assess the restoration success of small-size shoreline and oyster reef
364 restoration projects at the scale of the ecosystem of Mosquito Lagoon, Florida, USA.

365 Adaptive management relies on the lessons learned from monitoring and evaluating the performance
366 of implemented management strategies and measures over time, while accounting for possible
367 environmental shifts due to climate change (Thom, 2000; Ellison et al., 2020). Adaptive restoration
368 similarly relies on systematic and long-lasting monitoring to track pace of recovery and regeneration.
369 Since the time needed for an ecosystem to recover after restoration interventions varies (Kodikara et
370 al., 2017; Boström-Einarsson et al., 2020), and because species and habitats present different recovery
371 capabilities (Bekkby et al., 2020), course corrections may be necessary. EB-MSP can and should
372 respond to the highly dynamic nature of marine systems, where environmental conditions are
373 constantly shifting. Climate change drives many of these shifts (Roberts et al., 2020), and discussions
374 on climate change mitigation and adaptation in coastal areas are accelerating (Flannery et al., 2020),
375 focused on how to make MSP an effective instrument to minimize climate impacts, support climate
376 adaptation, and allow mitigation actions (Frazão Santos et al., 2019; 2020). Restoration-focused EB-
377 MSP can build on conservation planning for climate change adaptation; key strategies under this
378 approach includes vulnerability assessments, supporting ecosystem resilience, protecting climate
379 refugia and predicting species and ecosystem shifts (Wilson et al., 2020). An EB-MSP + restoration
380 approach could strengthen nature based solutions (Gijssman et al., 2021) that enhance blue carbon, as
381 well as restoration of ecosystems that abate coastal vulnerability, eliminate cumulative pressures in
382 climate refugia (i.e., passive restoration), and foster active restoration projects in areas
383 accommodating shifts.

384

385 **3. Conclusions**

386 To date, MSP and restoration have been on separate tracks, ignoring both the potential synergies and
387 co-benefits provided by linking the two. MSP is a powerful tool to support marine conservation (Ehler
388 & Douvère, 2009; Reimer et al. 2023), but neither effective management of marine use nor
389 conservation can match the pace of marine environmental degradation (Coleman et al., 2020). Since

390 most marine ecosystems are no longer pristine, MSP that does not give space, quite literally, for
391 restoration is unlikely to result in desired outcomes of maintaining ES delivery under a blue economy.
392 The elements for a transformative shift in how to achieve ocean regeneration (summaried in Figure
393 2) are all here today, but disparate and unsystematic planning is unable to capitalize on the immense
394 opportunities that exist for this transformation to happen. Across the world today MSP is undertaken
395 at various scales to achieve diverse objectives (Ehler, 2021), mainly targeting blue growth as a goal,
396 with only marginal and insignificant attention paid to the environmental and social sustainability of
397 that economic growth (Frazão Santos et al., 2021). MSP processes that do base planning on EBM
398 principles are increasing but rarely strive to enhance ocean health. At the same time, the world is
399 witnessing a proliferation of active and passive restoration projects, primarily aimed at rebuilding one
400 habitat type across relatively small geographical scales (Fraschetti et al., 2021; Fabbrizzi et al., 2023).
401 At the moment, these restoration projects tend to be opportunistic rather than being a strategic part of
402 geographically large, integrated marine plans.

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

412 Restoration-focused EB-MSP can support the restorative continuum, i.e. both active and passive
413 restoration interventions, with the former designed to catalyze the latter. Passive restoration mediated
414 by EB-MSP with a wide scope is fundamental because local restoration projects, even if supported
415 by solid scientific understanding and post-care and monitoring actions, can fail in the face of multiple

416 anthropogenic pressures (Diefenderfer et al., 2021). Thus, the strategic easing of pressures on
417 ecosystems led by EB-MSP can predispose ecosystems for natural recovery, leading to restored
418 connectivity and functionalities, and simultaneously fostering the effectiveness of assisted or
419 reconstructive restoration projects.

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

427

428 As a summary, a list of priority main actions that can be taken in an EB-MSP restoration framework:

- 429 - put in place passive restoration as a first strategy to abate pressures wherever their provenance to
430 promote the natural recovery of ecosystems;
- 431 - establish active restoration measures as a second strategy following the logic of ecological
432 connectivity and linking local restoration interventions with broader scale restoration policies and
433 within spatial plans in concert with MPA designation;
- 434 - adopt the ES approach to guide the optimization of conservation and restoration measures and the
435 setting of thresholds, starting from previous ES assessment and through the identification of baseline
436 conditions and trade-offs;
- 437 - apply the modelling framework on which MSP relies with a view to identifying restoration measures
438 to be integrated into spatial plans and integrate empirical scientific knowledge from restoration
439 ecology into the models;
- 440 - coordinate restoration at multiple governmental, and thus geographical, scales;

- 441 - engage with stakeholders in defining objectives, fund raising strategies, monitoring and evaluating
- 442 of restoration performance;
- 443 - support and take advantage of existing monitoring frameworks integration also for tracking
- 444 restoration success;
- 445 - rely on the integration of multiple knowledge sources for building the initial assessment of
- 446 environmental conditions and for laying the foundations for marine restoration;
- 447 - address climate change by: investing in nature based solutions that favor blue carbon ecosystems
- 448 and restoration of ecosystems that abate coastal vulnerability, eliminating cumulative pressures in
- 449 climate refugia (i.e., passive restoration), and fostering active restoration projects in areas where
- 450 habitats is expected to shift.

451

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

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

467

468 **Declaration of interests**

469 The authors declare no competing interests.

470

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483

484 **Credit authorship contribution statement**

485 EM, TA and LB: Conceptualization, Methodology, Investigation, Writing - Original Draft, Writing -
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487

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853

854 **Tables**

855 **Table 1.** Restoration-related terminologies and their definitions.

Term	Definition
Ecological restoration	<p>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).</p> <p>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):</p> <p>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;</p> <p>Ecological perspective: it is an intentional activity that reinitiates ecological processes that were interrupted when an ecosystem was impaired;</p> <p>Conservation perspective: it recovers biodiversity in the face of an unprecedented, human-mediated extinction crisis;</p> <p>Socio-economic perspective: ecological restoration recovers ecosystem services (ES) from which people benefit.</p>

<p>“Passive” or “Natural” restoration</p>	<p>Allowing natural or unassisted ecosystem recovery after removing a source of disturbance (Atkinson & Bonser, 2020).</p>
<p>“Active” or “Assisted”, and “Reconstructive” restoration</p>	<p>Assisted restoration: Abiotic - e.g. 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 - e.g. Invasive species management, reintroduction of species, augmenting or reinforcing depleted populations of species (Atkinson & Bonser, 2020).</p> <p>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).</p>
<p>Rehabilitation</p>	<p>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 Floch, 1996; Simenstad et al., 2006).</p> <p>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).</p>
<p>Reallocation</p>	<p>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 favor the development of new trajectories that over the long-term produce new ecosystems and uses (Aronson and & Le Floch, 1996, Elliott et al., 2007).</p>
<p>Remediation</p>	<p>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).</p>

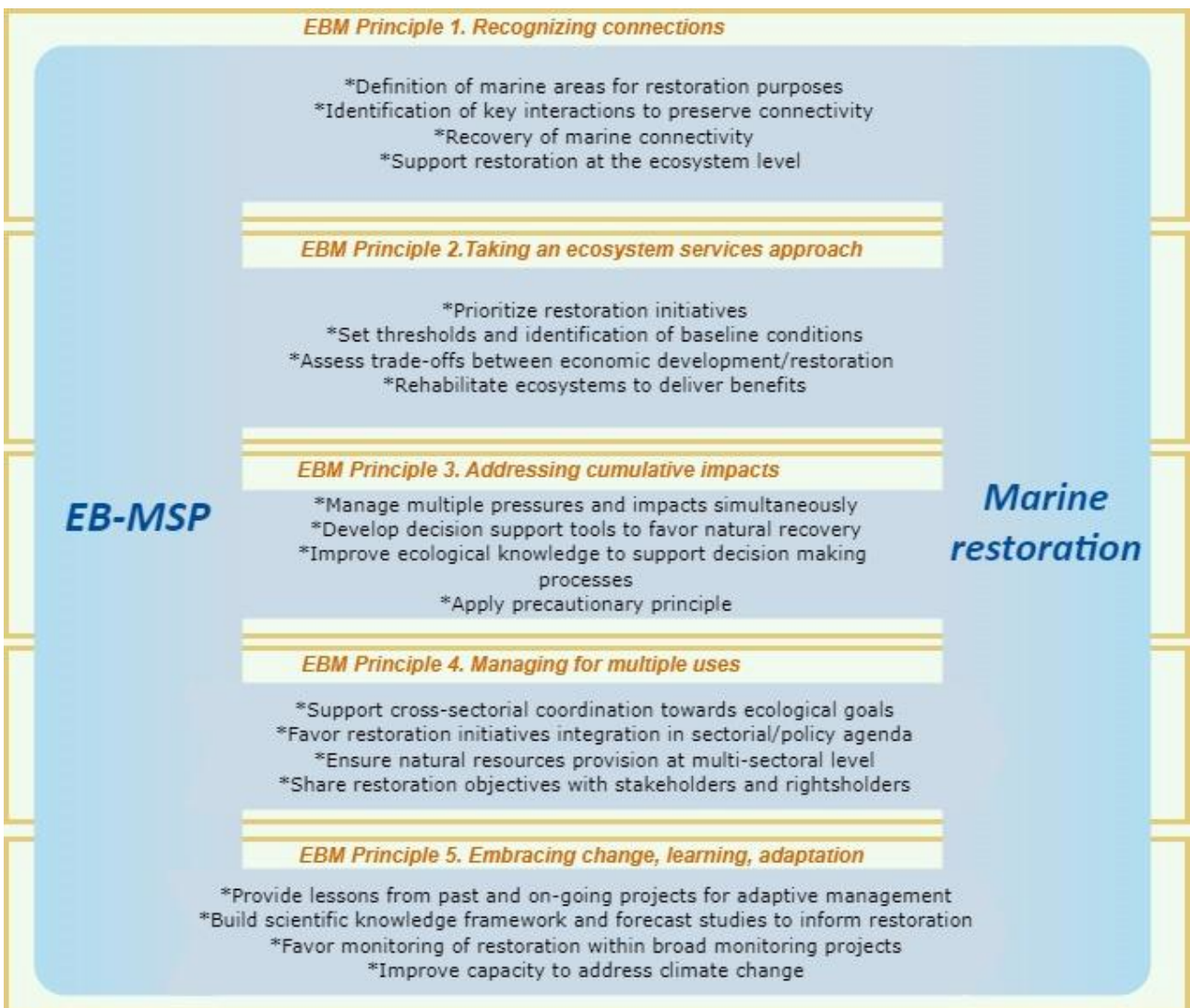
Recovery	The capacity or the process of a system to return to pre-disturbance condition, the original or reference state, after being in a degraded or disrupted one (Elliott et al., 2007). Recovery is the outcome sought or achieved of a restoration action. It can be active (human induced) or passive (natural).
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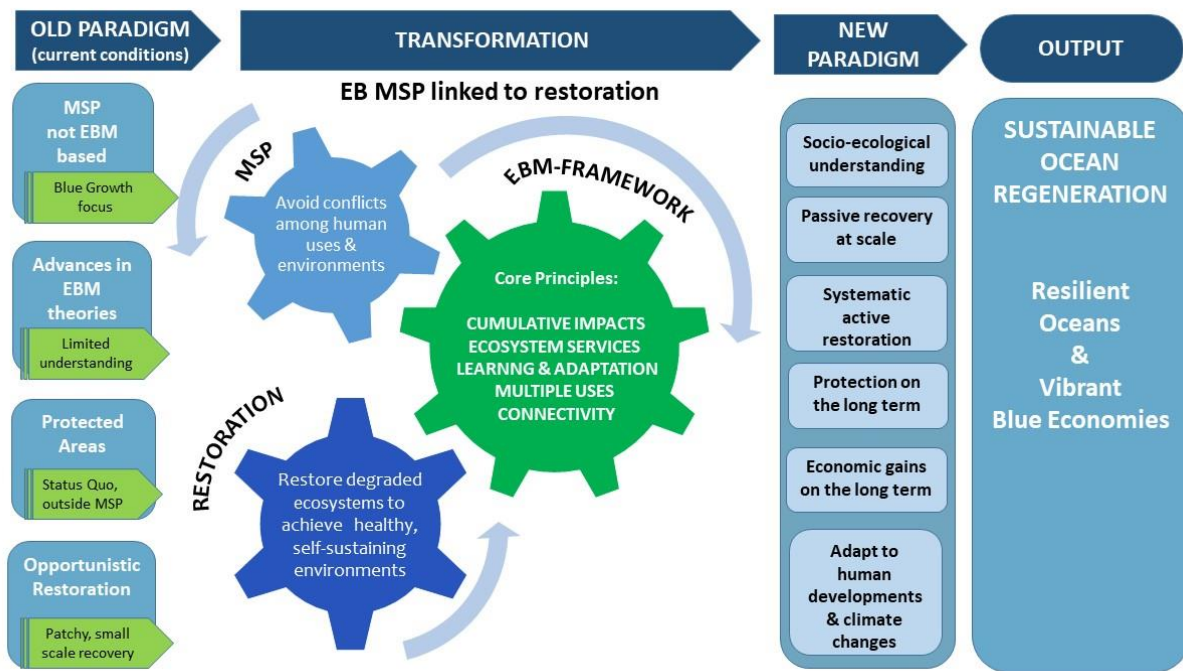
858 **Figure legends**

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860

861 **Figure 1.** EB-MSP and marine restoration benefits sharing. Schematic representation of how an EB-
 862 MSP implementing EBM core principles can operatively support marine restoration and the derived
 863 benefits. EBM principles are taken from UNEP (2011).



864

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