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THE BLUE RESTORATION CONTRIBUTION TO FACE THE CHALLENGING SCALING-UP ISSUE OF MARINE CONSERVATION STRATEGIES IN THE NEXT DECADE

A contribuição da restauração azul para enfrentar o crescente desafio da questão das estratégias de conservação marinha na próxima década

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ABSTRACT

The continuing degradation of marine ecosystems is widely highlighted as having a significant impact on services they provide for human well-being. To this end, especially during the last decade, numerous national, regional and international aspirations, targets and commitments have been made in order to reverse the detrimental trend affecting the ocean health, which is expected to accelerate in the immediate future. Restoration actions are becoming a common strategy to speed-up the recovery pathway of degraded ecosystems. This recognition also depends on the fact that, in some cases, in addition to traditional conservation strategies (e.g. Marine Protected Areas and Maritime Spatial Planning), "active" restoration may be the only politically feasible approach able to increase the flow of marine ecosystem services to stakeholders, ensuring, at the same time, the mitigation of threats to coastal environments in a reasonable time lag. Given the time-bound target aimed to effectively protect/restore on third of global ecosystems in the upcoming decade, concrete considerations about the potential for scaling-up the restoration interventions across coastal ecosystems are required to prioritise and improve the strategies aimed to cope the urgent conservation issues faced by marine ecosystems at global scale. Here, capitalizing on the most upgraded information on restoration efforts worldwide carried out over nearly five decades, a synthetic (but not exhaustive) analysis of progresses is showed, which could helps to better address the upscaling issue of marine conservation strategies in the immediate future.

Keywords: marine ecosystem restoration, sustainable development, coastal habitats.

RESUMO

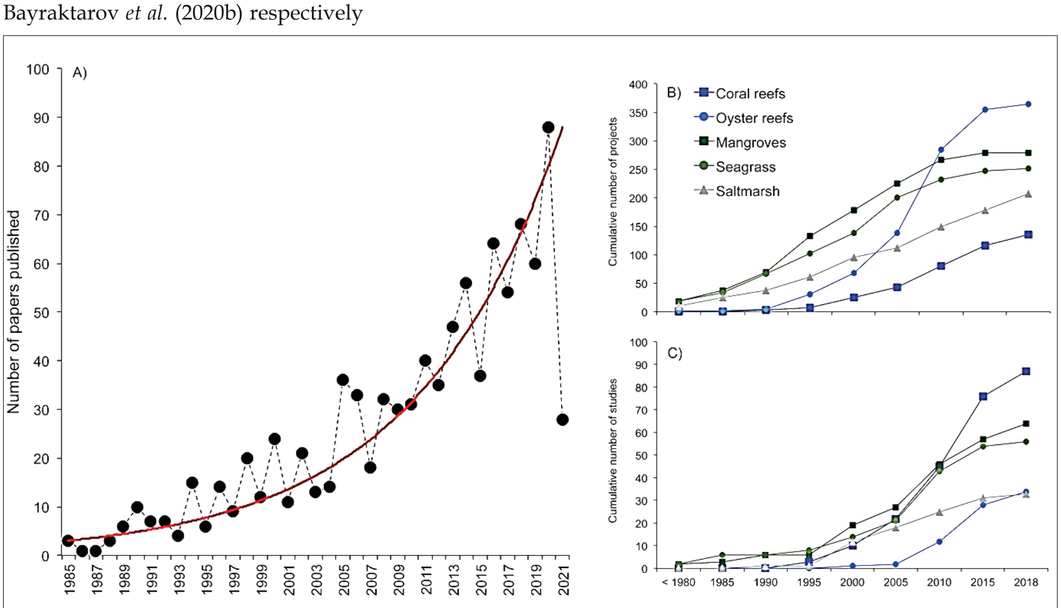
A degradação contínua dos ecossistemas marinhos é amplamente destacada como tendo um impacto significativo nos serviços que fornecem para o bem-estar humano. Para esse fim, especialmente durante a última década, numerosas aspirações, metas e compromissos nacionais, regionais e internacionais foram assumidos no sentido de reverter a tendência prejudicial que afeta a saúde dos oceanos, que se espera uma aceleração em um futuro imediato. Ações de restauração estão se tornando uma estratégia comum para acelerar a recuperação de ecossistemas degradados. Esse reconhecimento também depende do fato de que, em alguns casos, além das estratégias tradicionais de conservação (por exemplo: Áreas Marinhas Protegidas e Ordenamento do Territorial Marítimo), a restauração "ativa" pode ser a única abordagem politicamente viável capaz de aumentar o fluxo de serviços do ecossistema marinho aos envolvidos, garantindo, ao mesmo tempo, a mitigação das ameaças aos ambientes costeiros num lapso de tempo razoável. Dada a meta com limite de tempo destinada a proteger/restaurar efetivamente um terço dos ecossistemas globais na próxima década, considerações concretas sobre o potencial de ampliação das intervenções de restauração em ecossistemas costeiros são necessárias para priorizar e melhorar as estratégias destinadas a lidar com a urgência de questões de conservação enfrentadas pelos ecossistemas marinhos em escala global. Aqui, capitalizando as informações mais atualizadas sobre os esforços de restauração em todo o mundo realizados ao longo de quase cinco décadas, uma análise sintética (mas não exaustiva) dos progressos é mostrada, o que pode ajudar a resolver melhor a questão do aumento das estratégias de conservação marinha no futuro imediato.

Palavras-chave:* restauração do ecossistema marinho, desenvolvimento sustentável, habitats costeiros.*

A growing interest in marine ecosystem restoration, recently termed as "blue restoration" (Stewart-Sinclair *et al.*, 2020) has been emerging over the last decade. In particular, the "active restoration" approach (i.e. direct interventions that aim to speed up recovery, Hobbs & Cramer, 2008) is catching on due to the recognition that in many cases, current practices of conservation and environmental management (e.g. Marine protected areas [MPAs] and Maritime Spatial Planning [MSP]) are insufficient to halt or reverse the continuous and escalating degradation of ecosystems characterizing the Anthropocene (Jones *et al.*, 2018; He & Silliman, 2019). Intensive exploitation (e.g. fisheries, especially bottom trawling) coupled with other anthropogenic stressors acting locally (e.g. unsustainable land use, coastal development) and globally (climate change) represent the main causes driving, often irreversible, degradation trajectories (Butchart *et al.*, 2010; Burke *et al.*, 2011; IPCC, 2013). Worldwide, coastal ecosystems (such as coral and oyster reefs, seagrasses, macroalgal forests, mangroves, and saltmarsh) are clearly the most affected by these threats (Waycott *et al.*, 2009; Beck *et al.*, 2011; Burke *et al.*, 2011). The annual loss of coastal habitats over the past half-century has been estimated to reach 9% for coral reefs (Gardner *et al.*, 2003; Bellwood *et al.*, 2004; Wilkinson, 2008; Burke *et al.*, 2011), 2% for mangroves (Valiela *et al.*, 2001; Duke *et al.*, 2007; Giri *et al.*, 2011) and macroalgal forests (Krumhansl *et al.*, 2016), and seagrass beds have been disappearing at a rate of 7% in just two decades (Orth *et al.*, 2006; Waycott *et al.*, 2009). On average, ≈ 40% of coastal ecosystems global historical coverage have been lost around the world. In particular, ≈ 19% of coral reefs (Wilkinson, 2008), ≈ 35% of mangroves (Valiela *et al.*, 2001), 25-50% of saltmarsh (Crooks *et al.*, 2011; Duarte *et al.*, 2008), ≈ 29% of seagrass (Waycott *et al.*, 2009), ≈ 85% of oyster reefs (Beck *et al.*, 2011). Unfortunately, these trends are expected to further accelerate in the future (Jones & Cheung, 2015), with dramatic consequences for goods and services they provide for human well-being (Barbier, 2012; Halpern *et al.*, 2012; HLPE, 2014).

Based on these recognitions, the policy momentum for ecosystem restoration has been growing steadily in the last decade (e.g. CBD, 2010; Aronson & Alexander, 2013; Timpte *et al.*, 2018), including through the adoption of the United Nations Decade on Ecosystem Restoration 2021-2030 (Salvador, 2018; Duarte *et al.*, 2020; Waltham *et al.*, 2020). This decade declaration largely overlaps with the ambitious targets of the "Decade of Ocean Science for Sustainable Development 2021-2030" (UN, 2019), which generally aims to reverse deterioration of ocean health. Because of the wide range of ecological and socio-economic benefits provided by coastal ecosystems, such as coastal protection from flooding and erosion, fisheries habitat, water quality improvements, and carbon sequestration and storage (Barange *et al.*, 2014; Nagelkerken *et al.*, 2015), the literature on marine ecosystem restoration has expanded rapidly in the last three decades and an half, with a significant impetus, at 9.4% year^{-1}, since 2010 (Figure 1). This encouraging trend also depends from the recognition that, in some cases, in addition to traditional conservation strategies (i.e. generally referred as "passive" or "unassisted" recovery actions, such as MPAs and MSP) primarily focused on reducing human impacts and physical stressors on the marine environment (De'ath *et al.*, 2012; Knowlton, 2012), restoration may be the only politically feasible approach boosting the flow of marine ecosystem services to stakeholders (e.g. France, 2016; Christie *et al.*, 2018), ensuring, at the same time, the mitigation of threat related to climate change (IPCC, 2019; Hoegh-Guldberg *et al.*, 2019) and the biodiversity crisis (Galland *et al.*, 2012; Neumann *et al.*, 2017; Dundas *et al.*, 2020).

Figure 1 – A) Number of papers on estuarine and coastal restoration published annually. Data gathered from Web of Science (accessed April 1, 2021) using the search string (Ti = Estuar* OR Coast*) AND Ti = (Restor* OR Rehab*). The red line stresses the exponential trend in literature production. In B) and C) the temporal growth of restoration projects and studies across ecosystems is reported. Data gathered from Duarte *et al.* (2020b), and Bayraktarov *et al.* (2020b) respectively



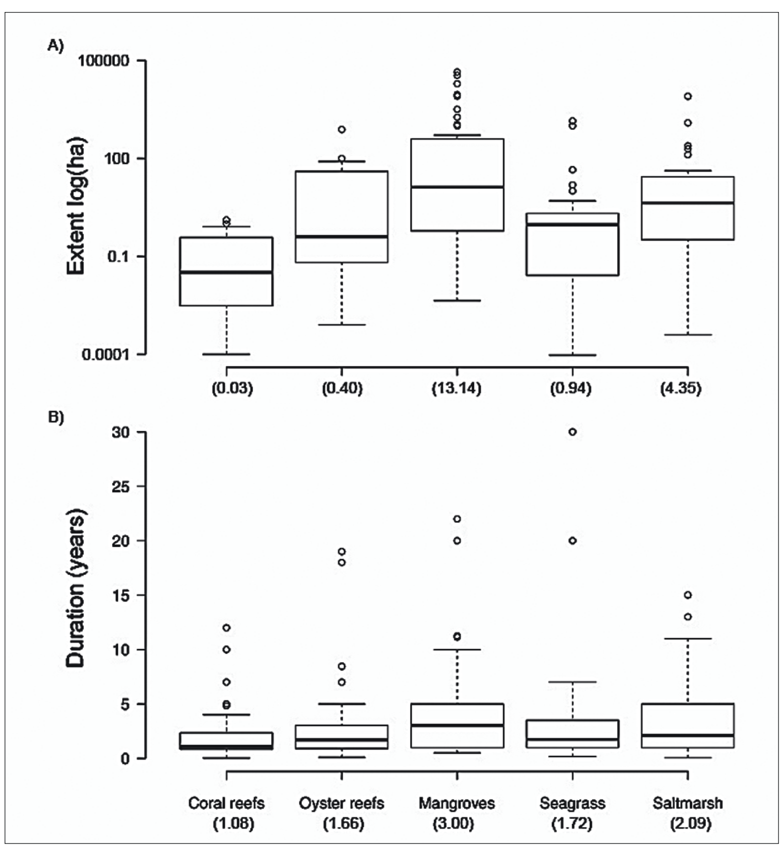
Obviously, the effectiveness (i.e. "the success") in achieving these objectives cannot disregard a careful analysis of the spatial and temporal dimension to which the restoration interventions must be carried out. In other words, the scale of restoration will be crucial in the immediate future, given that the ambitious goal of effectively protect/restore one third (i.e. 30%) of global ecosystems (considering both lands and oceans) should be reached in 2030 (O'Leary *et al.*, 2016; Dinerstein *et al.*, 2019; CBD, 2020). This time-bound objective, which imply a significant scaling-up of blue restoration practices, is extremely challenging, also taking into account that: i) the processes of degradation act on different spatial and temporal scales than those of recovery (Lotze *et al.*, 2006); and ii) blue restoration is generally associated with huge costs (i.e. sometimes as much as hundreds of thousands of dollars per hectare) if compared to terrestrial one (Van Dover *et al.*, 2014; Bayraktarov *et al.*, 2016). Moreover, it is also recognized that the feasibility (i.e. in terms of cost and benefits) of restoration projects strongly depends by differences occurring in the recovery rates across ecosystems (Jacob *et al.*, 2020 and references therein), as well as the level of uncertainty about the outcomes of the interventions, which could discourage investments in this direction (Walthman *et al.*, 2020).

Capitalizing on recent studies aimed to systematically review information on global blue restoration efforts (i.e. Duarte *et al.*, 2020a; Bayraktarov *et al.*, 2020a), the aim of this paper is to provide a synthetic analysis of progress over nearly five decades in relation to the ambitious requirements stated by policies mentioned above (e.g. CBD, 2020), which could helps to better address the upscaling issue of marine conservation strategies in the immediate future.

Based on the results derived by the most updated database concerning the restoration of key coastal marine ecosystems (e.g. Duarte *et al.*, 2020b; Bayraktarov *et al.*, 2020b), the number of projects/studies has generally increased consistently across ecosystems over the last 30 years (Figure 1b,c). A significant increase of restoration efforts (in terms of total amount of restoration sites) occurred for projects on oyster reefs and coral reefs, both ecosystems showing an increase at 10% year^{-1} since 2000 (Figure 1b). On average, the observed rate of increase is almost three times that found for the remaining ecosystems (i.e. mangroves, saltmarsh and seagrass) in the same time span that, however, are those in which the practice of restoration dates back to 60's (e.g. Thorhaug, 1986; Knight, 2018; Teas, 1977; Lewis, 1990; Katwijk *et al.*, 2016). The observed trend indicates that, if compared with the latter ones ecosystems, where the science and practice of restoration are well established, as far as that one focused on rebuilding biogenic reefs (i.e. oysters and corals) are still at a development stage. This pattern is also confirmed by the analysis on published studies (i.e. Figure 1c), based on Bayraktarov *et al.* (2020a), where a clear boost in the publication rate related to coral reefs and oyster reefs become evident starting from 2005. In fact, as also stressed by Bayraktarov *et al.* (2020a), to date the most common primary motivation to engage in coral and oyster reefs restoration was strictly experimental (i.e. 75% and 85% respectively). By contrast, for marshes and mangroves, the basic knowledge on restorative approaches are more advanced, and it is reasonable thinking that these ecosystems, and goods and services they provide, can bring back fairly regularly if supported by active restoration.

As a direct consequence of the level of confidence reached in restoration practices among the ecosystems considered in the analysis, a substantial difference can be observed in terms of both spatial and temporal scale of interventions (Figure 2). In fact, for mangroves and saltmarshes the greatest values in terms of spatial coverage of interventions can be observed (respectively showing a median value of 13.4 and 4.35 hectares), indicating that a transition towards landscape-scale restoration (i.e. tens of hectares) already begun for these ecosystems. By contrast, for the remaining ecosystems projects are still mostly conducted following a patch-specific approach (i.e. < 1 hectare), with median values ranging from 0.03 to 0.94 ha considering coral reefs and seagrass respectively. However, as far as oyster reefs, the analysis of the box and whisker plot (Figure 2a) suggests that, even in this case, a scaling-up of the approach is taking place. This is particularly impressive considering the relatively early development of restoration practices on these ecosystems. Beyond the practical and economic motivations making profitable oyster reef restoration practices, a possible explanation for this is the lower number of species interested by interventions (i.e. totally 4 species, but mostly *Crassostrea virginica* with an occurrence of 83% whit respect to the total number of records, Bayraktarov *et al.*, 2020b) if compared to other ecosystems, such as coral reefs (i.e. 229 different species from 72 genera, Boström-Einarsson *et al.*, 2020), which allows avoiding likely uncertainty related to paucity of basic ecological knowledge on species interested by restoration actions. Instead, logistical constraints are recognised as the main reasons making seagrass and coral reefs the most expensive to restore (i.e. median costs ranging from US$100,000 ha^{-1} to US$400,000 ha^{-1} respectively), which still impairs the shift to a seascape scale approach (Bayraktarov *et al.*, 2016, 2019).

Figure 2 – Box and whisker plots reporting the interval of A) project area, and B) duration for marine coastal restoration projects. For each ecosystem (i.e. coral and oyster reefs, mangroves, seagrass and saltmarshes) the minimum, quartiles, median, maximum, and outliers is reported. In brackets, median values are also reported. Data gathered from Bayraktarov *et al.* (2020) (https://doi.org/10.5061/dryad.zgmsbcc81)



In this regard, it should be stressed that actually the costs of restoration could be even higher, given that estimates are mostly based on short-term evaluation of interventions (i.e. less than 3 years, Figure 2b), which generally coincide with project funding opportunities (Bayraktarov *et al.*, 2016). Except for mangroves and saltmarshes, the general paucity of information on long-term maintenance and monitoring costs of restoration actions strongly impairs the possibility to provide actual cost-benefit analyses (Iftekhar *et al.*, 2017; Walthman *et al.*, 2020) that, in turn, could discourage an increase of investments on blue restoration necessary for an effective scaling-up.

According to the issues reported above, it is evident that the contribution of blue restoration to declared goals for the next decade is still severely limited, especially for some ecosystems. To date, lumping all together the wide spectrum of conservation strategies aimed at promoting the passive recovery of marine systems (e.g. MPAs), they cover about 7.65% of the area of the oceans (Figure 3a), whereas, just 0.001% is represented by active restoration considering the cumulative extent of projects carried out across ecosystems in recent decades (independently from the outcomes of interventions). This percentage further decreases if the contribution of interventions in mangrove and saltmarsh ecosystems is removed from calculations (Figure 3b). Although still far away from the achievement of stated goals of conservation policies, the analyses suggest a general and encouraging boost of actions aimed to recover the ocean's health. Obviously, this optimistic view cannot disregard careful consideration on the effectiveness of conservation strategies (Lubchenco & Grorud-Colvert, 2015; Hillebrand *et al.*, 2020). Percentage-based conservation targets are often criticised since, especially in the marine realm, success of conservation is more related to quality and participation than the quantity of conservation measures (Edgar *et al.*, 2014; Golden Kronen *et al.*, 2019; Grorud-Colvert *et al.*, 2021). Moreover, even if well-managed, protected areas are not immune to losses driven by external factors acting at wider scale (e.g. climate change, invasive alien species, seascape and/or landscape changes, Butchart *et al.*, 2010). Increasing human pressures and rapid global changes make ecological restoration within and around protected areas a valuable tool if carefully planned and managed (Possingham *et al.*, 2015). Given the considerable increase in protection efforts in the marine environment (i.e. MPA coverage increase ≈ 10% $year^{-1}$ since 60's, Figure 3a), the systematic inclusion of blue restoration within the management plans of MPAs could represent a significant step forward to make feasible the time-bound challenges of sustainable development policies (i.e. UN, 2019; CBD, 2020; Fraschetti *et al.*, 2021). Thoughtful and smart planning of restoration interventions can improve the performance of reserves even beyond their boundaries and, at the same time minimize the costs (both economic and social), often recognized as one of the main barrier limiting investments in this direction. Obviously, a transition in conservation thinking is crucial in the implementation of such strategies. Similarly, to what is happening to face COVID19 pandemic crisis, synergies among government, industry, scientists, local communities and stakeholders, coupled with strategic investment of resources (e.g. in monitoring activities which are crucial to identify likely tipping-points driving adaptive management) should occur in order to achieve the ambitious goals aimed to preserve life below water and related benefits we need.

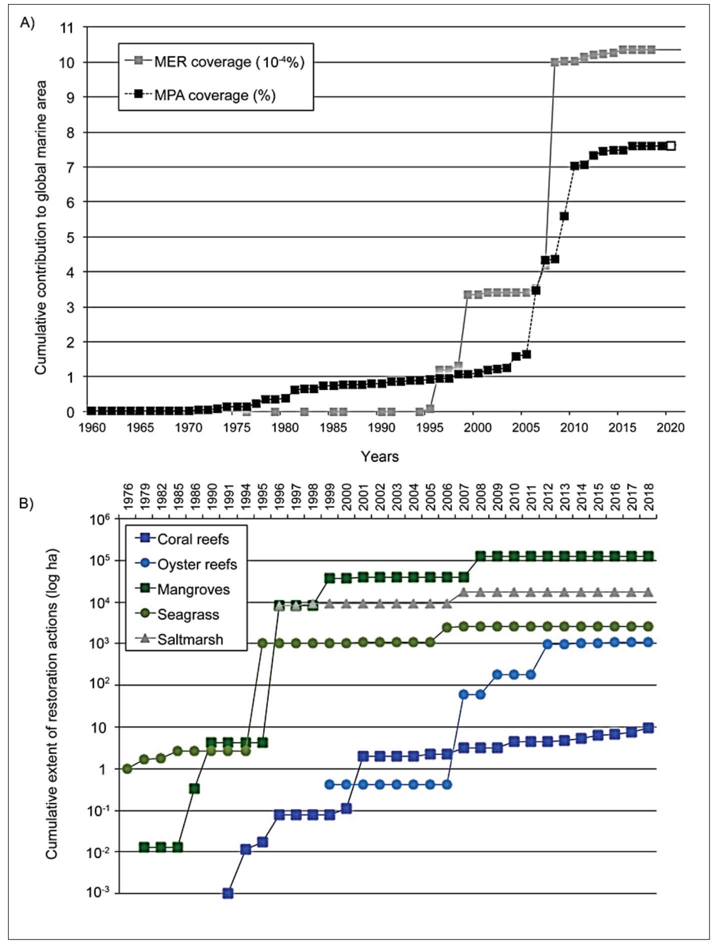


Figure 3 – A) Global increases of conservation efforts in terms of Marine Protected Areas (MPA*) and Marine Ecosystem Restoration (MER**) actions over time. In B) the temporal growth in the extent covered by restoration projects across ecosystems is also reported. * Data gathered from World Dataset on Protected Areas (WDPA, https://www.protectedplanet.net/en/thematic-areas/marine-protected-areas, accessed 30 April 2021). The empty square indicates the contribution of "designated/proposed" MPAs to overall % coverage with respect to total ocean area. ** Data gathered from Bayraktarov *et al.* (2020) (https://doi.org/10.5061/dryad.zgmsbcc81)

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