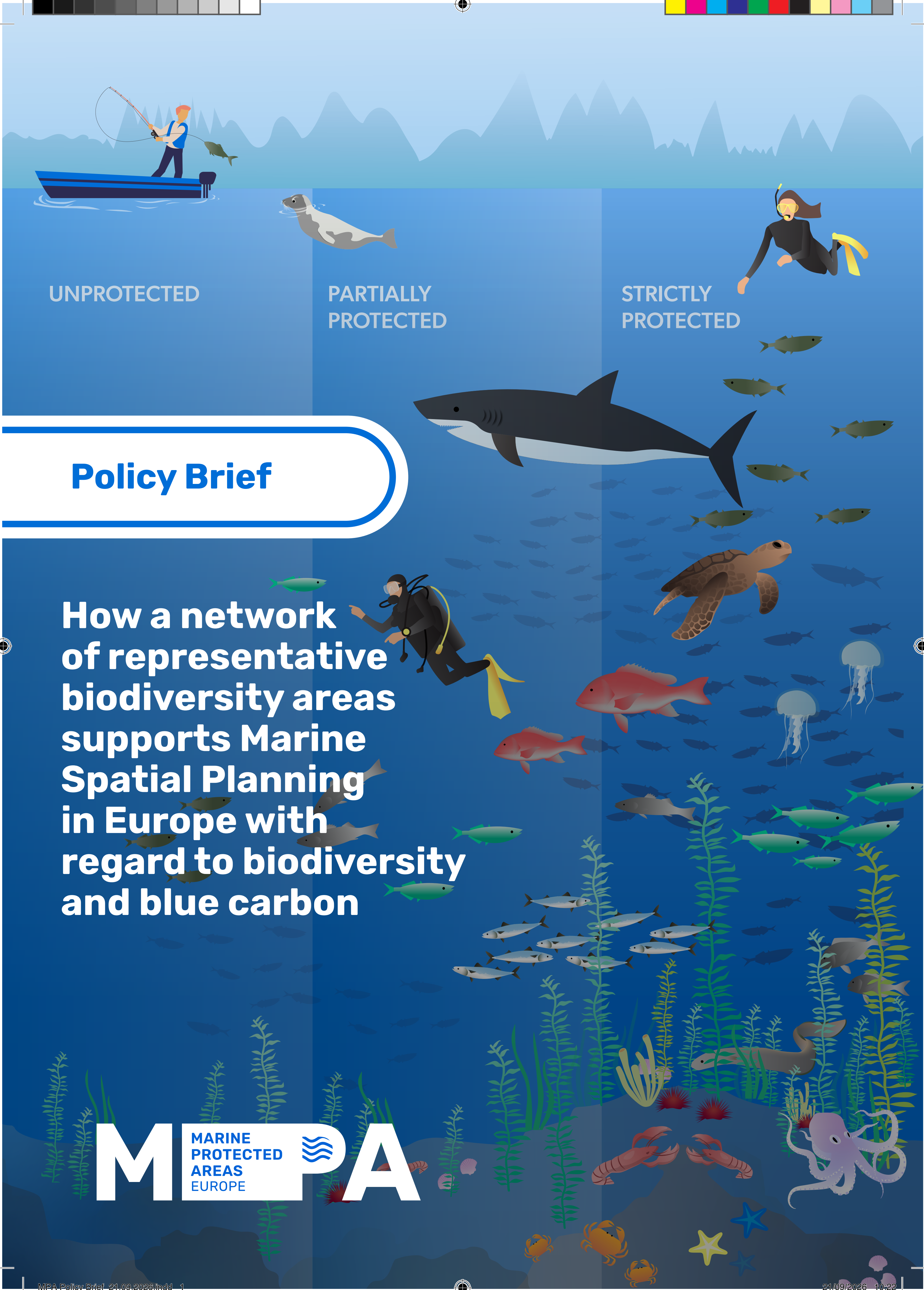

Policy Brief

How a network of representative biodiversity areas supports Marine Spatial Planning in Europe with regard to biodiversity and blue carbon

MPA
MARINE PROTECTED AREAS EUROPE

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Coordinator

Overview

This document presents policy recommendations for stakeholders of *MPA Europe* on how to use our analysis and results of standardised environmental and species distribution data, mapped distribution of organic carbon content in the seabed, and representative biodiversity areas, which show an optimal network for Marine Protected Areas (MPA) in science-based marine and maritime spatial planning (MSP) in Europe.

Recommendations are particularly relevant for our principal stakeholders, the European Commission (EC), the Regional Seas Conventions OSPAR, HELCOM, UNEP and Black Sea Commission, and Member States, in addition to national research institutes, and the European Environment Agency.

Scientific results

The *MPA Europe* **project mapped a geographically optimal, ecologically coherent, network of Representative Biodiversity Areas (RBAs) across Europe's seas** at a spatial resolution of ~5 km (Figure 1), at European, marine region and country level[1, 2, 3]. This is based on the geographic ranges of over 10,000 species which represented the range of habitats, ecosystems and biogeographic provinces in the region, including marine species listed in the Birds and Habitats Directives, endangered species and species endemic to Europe. Where isolation occurs as in the Mediterranean and Macaronesian islands, endemic species may evolve; thus, these areas were highly prioritised by the *MPA Europe* RBA[2]. The top 10%, 30% and 50% of this network could include 55%, 79% and 91% of all species in the region respectively, with similar percentages for threatened species. Over 80% of the species that form habitats for others, including seagrasses, kelps and corals, were well-represented in 10% of the RBA[1, 2]. When ecosystems were mapped based on surface to seabed environmental data[4], and biogeographic provinces based on the species observations[5], we found that the RBA included all of them. Hence, the RBA is representative of the species, habitats, ecosystems and biogeography of European seas. The 10% most prioritised areas covered most coasts, offshore islands and edges of the continental shelf throughout the study area. This was expected as these areas collectively contain most species. The methodology follows best practice in systematic conservation planning, recently reviewed by the Horizon Europe MarinePlan project[6].

International cooperation outside Europe, including researchers in India and China, supported the prioritisation. We prioritised where to optimally protect finfish and shellfish species of fishery importance in European seas[7]. We found similar areas to the all-species prioritisation using two different source datasets (i.e., Food and Agriculture Organization (FAO) and the Sea Around Us Project (SAUP)), with negligible difference if using either species presence or species weighted by their biomass. A prioritisation of the West Pacific region found ~30% and ~60% of species could be protected in 10% and 30% of that area respectively[8], and that simple metrics for species richness did not correlate with ecosystems and should thus not be used for prioritising areas for conservation[9]. We showed that there were coastal and High Seas areas in common across all six past global marine prioritisation studies even though these studies used different data and methods, yet they have not been recognised or utilised at global or regional scales[10]. Also, at a global scale and using expert derived (instead of modelled) species range maps, we showed that 51%, 75%, and 100% of marine species could be protected in 10%, 30%, and 50% of the global ocean respectively[11]. The consistencies in all these studies, and our use of different sub-samples of the species for prioritisation[2,3], indicates the results are robust, such that additional data and models will not alter

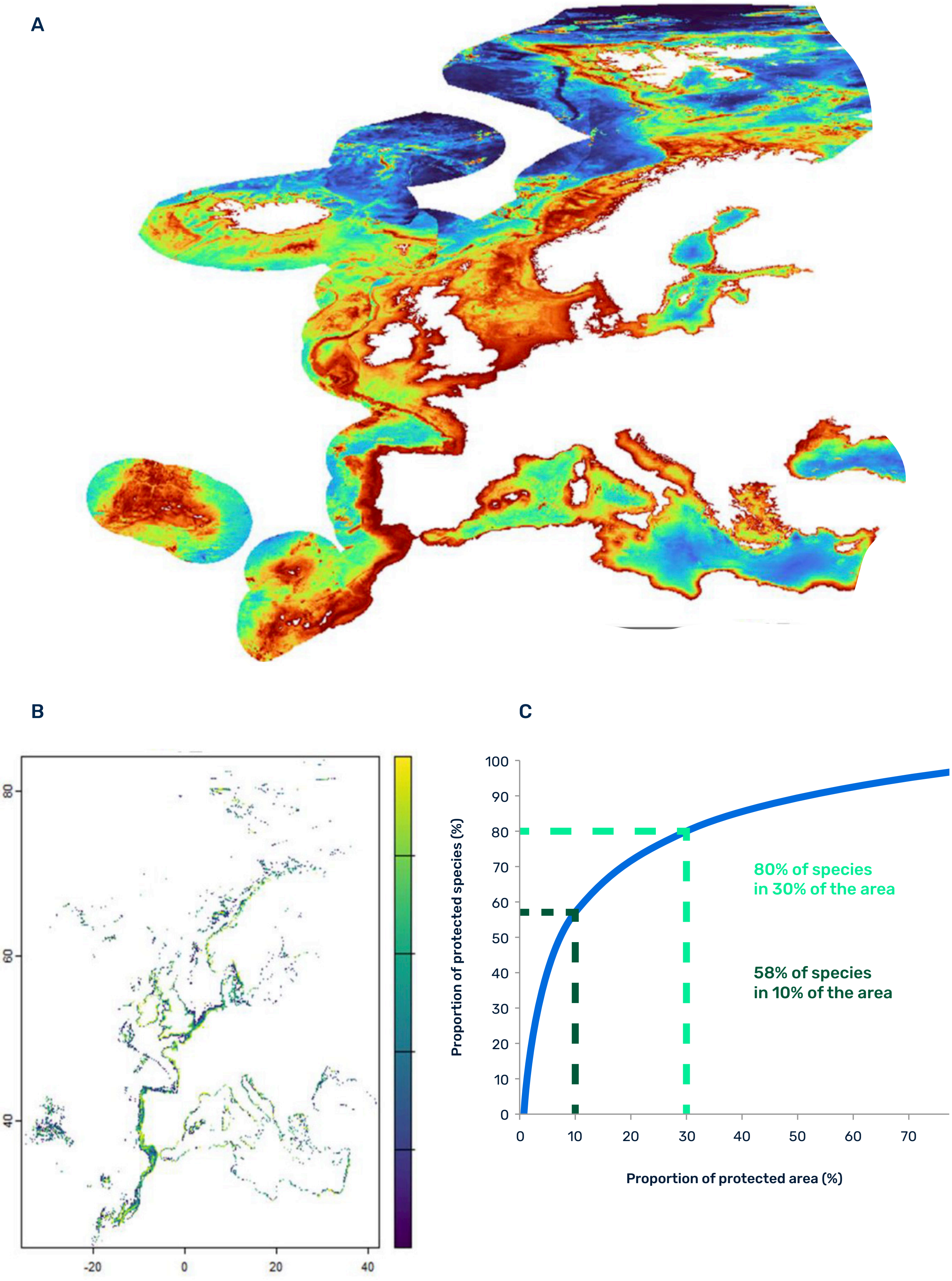

Figure 1. The prioritisation of Representative Biodiversity Areas (RBA) in all European seas (red is more, dark blue is less) (A) and the top 10% of the areas (B). The graph (C) shows the proportion of species that can be included in the proportion of the area if the optimal places are protected. Data from[2].

the overall geographic prioritisation. However, species highly threatened with extinction would still require species-specific conservation measures, such as interventions to protect feeding, spawning and nesting sites[10, 12, 13].

We significantly **expanded available data** to support marine conservation and resource planning in Europe in three ways. First, the Ocean Biodiversity Information System (OBIS) was expanded to now include 67 million distribution records for ~30,000 species in European seas[14]. Second, the Bio-ORACLE platform was further developed to provide ~6,500 global spatial layers across 18 environmental variables, spanning the sea surface to the seabed, including climate change (CMIP6-based) projections for five climate change scenarios from 2050 to 2100[15]. These global environmental data layers are at 0.5 degrees spatial resolution, include long-term averages, maxima, minima, and range, for surface and near seabed depths, air and sea temperature, salinity, oxygen, pH, nitrate, phosphate, silicate, iron, chlorophyll, productivity, sea ice cover and thickness, current speed and direction, mixed layer depth, diffuse attenuation coefficient, photosynthetically active radiation, bathymetry, slope, topographic aspect and variation. Third, and for the first time, a wave exposure layer at European scale was published[16, 17], because it is known to be a key variable in influencing coastal species distribution[18]. We also found it was the strongest predictor of seabed carbon content when prioritising at a pan-European scale (at sea basin scale, other drivers including riverine input can be more significant)[19].

Together, the species occurrence and environmental data were used to map the geographic ranges of over 10,000 species, including human-introduced species (Figure 2)[20, 21, 22]. These provided standardised data for the prioritisation analysis. All the data and distribution models are open access on *MPA Europe* Map Platform (https://shiny.obis.org/distmaps)[23].

Our **online atlas** for MSP on the *MPA Europe* Map Platform[24] incorporates open-source species distribution models (SDM), the species distribution data used in the SDM, selected environmental variables, the RBA and the seabed carbon map based upon our new EURO-CARBON database[25, 26, 27] (Figure 3). These new data and maps provide multiple opportunities to support Regional Seas Conventions and Member States with delivery of plans and measures required under the Nature Restoration Regulation (NRR)[28], the EU Biodiversity Strategy for 2030 (BDS)[30], the Marine Strategy Framework Directive (MSFD)[31], the Maritime Spatial Planning Directive (MSPD)

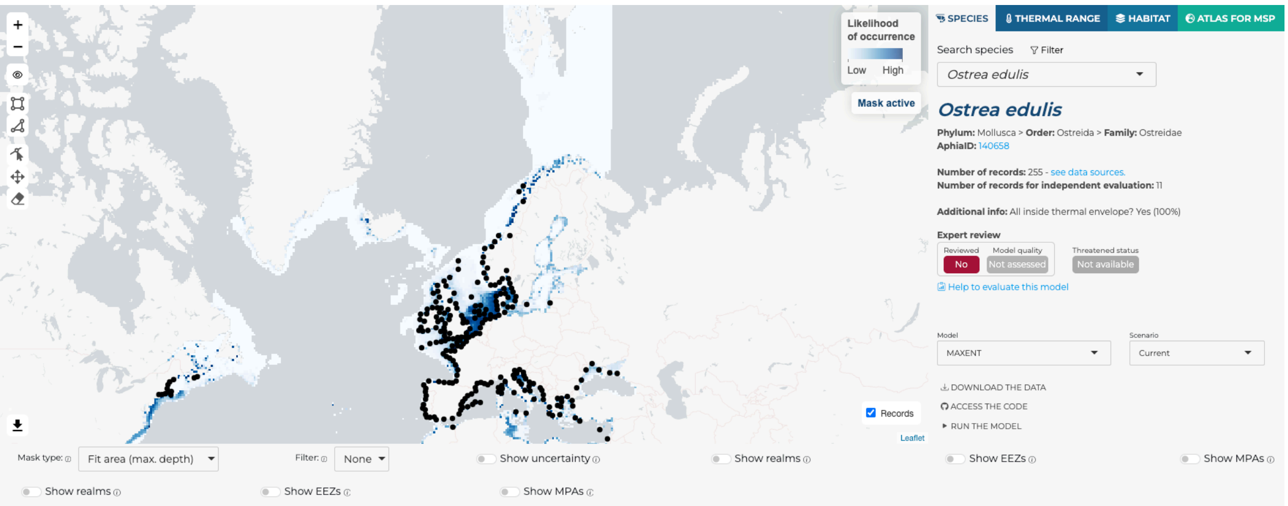

Figure 2. Screenshot of the new atlas on the MPA Europe Map Platform of ~10,000 marine species (e.g., European oyster), including groups representing species that are habitat forming and of conservation interest. Multiple species distribution models are shown for present and future climate scenarios, and the observed data records. All source data and codes are open access https://shiny.obis.org/distmaps/.

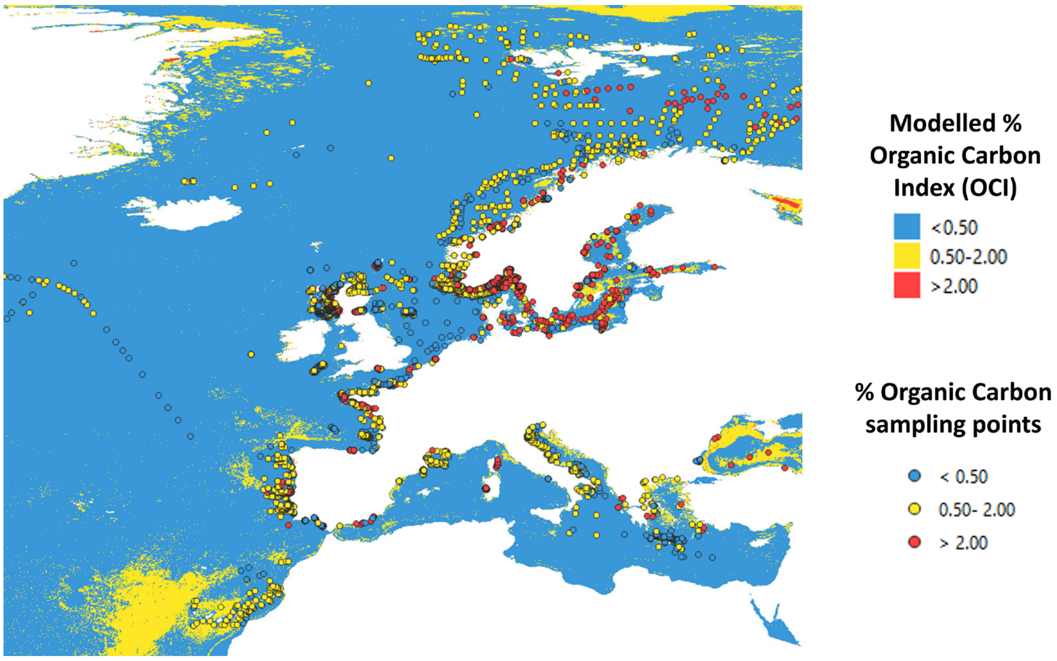

Figure 3. Map of the modelled (background) and source data records of organic carbon in the seabed. Highest concentrations are coastal, especially fjords and estuaries, and in Posidonia seagrass beds in the Mediterranean Sea. Data from[41].

and the Birds and Habitats Directives (BHD)[32, 33]. For example, the species range maps predict where a species may occur due to environmental suitability. Thus, if a species is not present is that due to lack of observations, human impacts, or loss of habitat. In this case, if the cause of its absence is addressed then the species should return if the habitat is restored. The RBA can be used to guide prioritisation of areas for nature conservation efforts because if the highest priority cells are chosen, then most species will recover in the RBA as the background environmental conditions are likely to be suitable for them. In addition, monitoring the most highly prioritised areas in the RBA would most cost-efficiently detect trends in marine biodiversity at a European and national scales. Thus, the RBA provides marine and maritime spatial planning (MSP) with data-driven knowledge for managing human activities to minimise loss of biodiversity. With increased focus on biodiversity-inclusive and climate-smart MSP, the systematic conservation planning analyses can be repeated using additional data that may become available and to take account of areas protected or restored. Such measures may be strict MPA, Other Effective area-based Conservation Measures (OECM), similarly long-term (decadal) regulations protecting fisheries, and/or designation of areas for activities with limited impact on biodiversity if suitably located and managed appropriately (e.g., ecotourism, cable zones). The seabed carbon map identifies areas of higher organic carbon content in seabed sediments, and the atlas shows the potential range of habitat forming species. Together these layers can be used in MSP to preferably locate human activities which may disturb the seabed (e.g., anchoring, dredging, mobile bottom-contact fishing) outside of such areas.

In spite of the fact that most of the public are in favour of MPA[34], problems persistent in implementing MPA for several reasons, including the existence of conflicting views of the socioeconomic and ecological costs and benefits of MPA, and MPA not being seen as political priorities[35]. To address such questions from stakeholders, we reviewed the scientific literature and polled thousands of MPA experts for evidence of fishery losses due to MPA. We found 48 examples of fishery benefits and no examples of any fishery losing catch due to no-fishing MPA or displacement effects of MPA on fisheries[36, 37] (Figure 4). Rather, benefits to fisheries were reported from 25 countries in relation to finfish and shellfish species. These findings were also presented to the Portuguese parliament to support their designation of MPA, including strict (no-fishing) MPA, in the Azores. In addition, we found benefits of MPA in terms of tourism revenue and job creation (Figure 4).

We assessed **how well marine species ranges overlapped the present MPA sites in Europe** using the world standard "MPA Guide"[38]. This guide indicates how effectively MPA may be expected to protect biodiversity based on which human activities are allowed in the sites. We found most areas which may be consider as MPA (largely Natura 2000 sites) would not deliver effective conservation outcomes because they permit human activities that are incompatible with conservation. Thus, increased protection from human pressures in line with international standards should be a priority throughout the region[39, 40].

Climate resilience and adaptation options were considered with regard to projected species distributions under climate change scenarios[20, 21], and the distribution of carbon stores in seabed sediments based on sampled organic carbon content[25, 41]. We found that the marine species projected distributions under the most extreme climate change scenarios by 2100 were encompassed in the RBA[2, 3]. Thus, the RBA were predicted to be a climate change resilient network. Using the newly established EuroCarbon database, we mapped organic carbon content and identified the main predictors and patterns of sediment organic carbon across regional seas at a European scale[20, 21, 41]. Human activities that release organic carbon from the seabed and potentially enhance degradation of these pools, such as trawling and dredging, could be prohibited in the areas with highest carbon stores[42, 43]. Prohibiting these habitat destructive practices would also benefit biodiversity in those areas. However, generally, we found that the most highly prioritised areas in the RBA were not in the same places as the highest carbon content[1, 2, 3]. Thus, MSP needs to consider restoring and protecting biodiversity, and safeguarding carbon stores in the seabed, separately.

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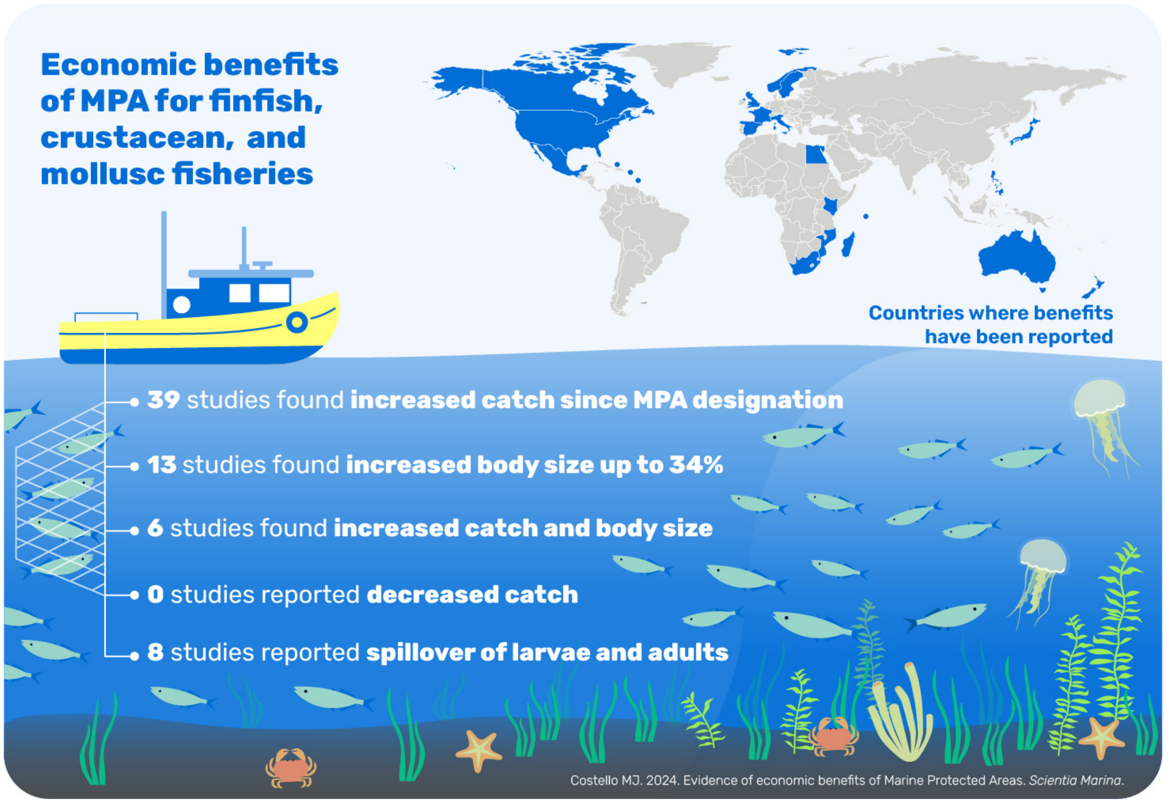

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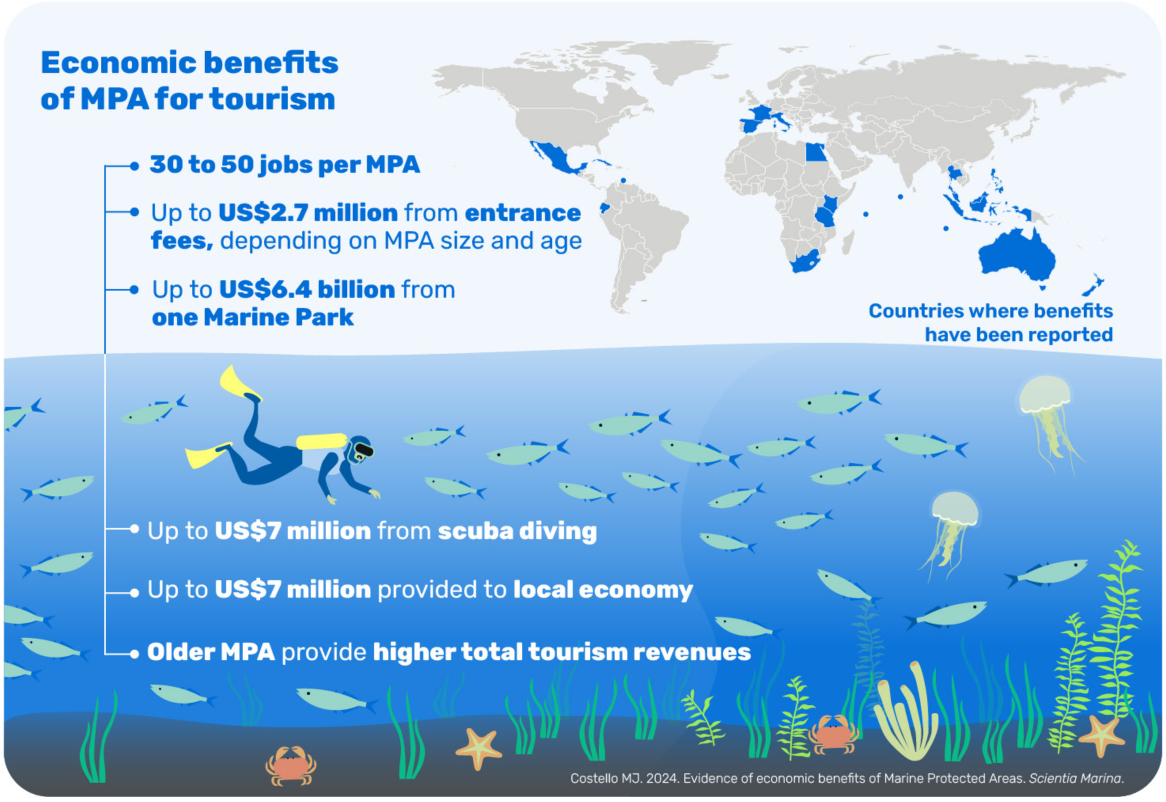

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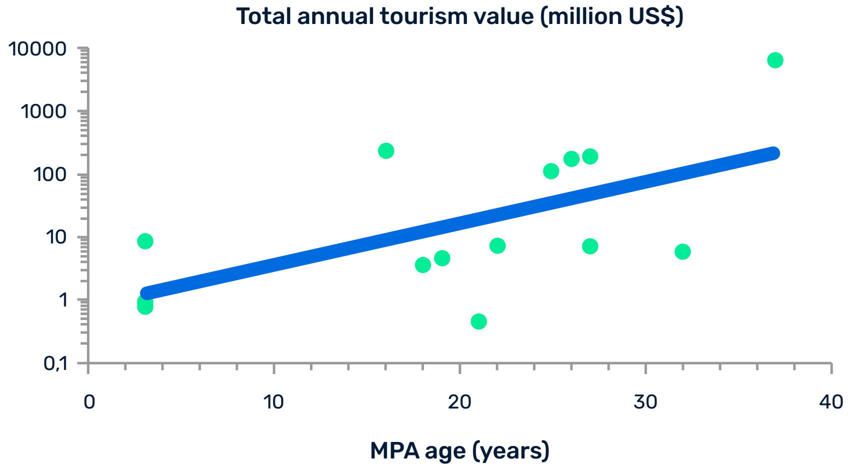

Figure 4. The economic benefits of MPA apply to (A) fisheries around the world; 91% of MPA benefiting fisheries were fully protected with no-fishing. (B) Tourism can also benefit with (C) increasing revenue with MPA age. No examples of a decline in fishery due to MPA were found. This is not surprising and can be considered a general rule. Data from[36].

Stakeholder engagement and feedback

We have engaged extensively from the outset of our project with almost 180 organisations[44] representing regional and national stakeholders in the Baltic, Black and Mediterranean Seas and North-East Atlantic Ocean, to share the knowledge of the project and seek stakeholder feedback. These included Regional Seas Conventions, Member States, national institutes, cross-sector organisations, regional fisheries advisory groups, blue economy actors and NGOs. Through over 30 workshops and events, we have sought to inform stakeholders about *MPA Europe*'s approaches, tools and results; we invited stakeholders to provide feedback on these and experts to validate the SDM[14, 45]; and to propose case studies which use *MPA Europe*'s methods, tools or results. Discussions with stakeholders are captured in our four Regional Seas workshop reports[46, 47, 48, 49]. Stakeholder "frequently asked questions" are on the *MPA Europe* website (https://mpa-europe.eu/faqs/) and have informed our recommendations here.

We worked closely with the Horizon Europe and EMFAF projects MSP4BIO, Marine Plan, PROTECT BALTIC, MSP Green and MEDIGREEN, including through joint stakeholder workshops, and contributed to a joint Think Tank coordinated by the MSP4BIO project which led to a joint Policy Brief[50]. We contributed to recent MSP Global international guidelines on MSP for the Biodiversity Inclusive Principle[51] and Climate-smart Principle[52] , and to IUCN guidance for establishing MPA in a changing climate[53]. Therefore, **our policy recommendations build on the scientific results and reflect questions from stakeholders.**

Lack of MPA network coherence

Our work confirmed previous findings that the current network of MPA in Europe lacks coherence; it is not representative of all biodiversity. This has arisen because the Birds and Habitats Directives, which underpin most of the current MPA designations via the Natura 2000 network, do not adequately represent marine ecosystems and species[54]. Because the Nature Restoration Regulation defines a fuller range of marine habitats and has a strict timetable, it should advance more coherent protection as well as restoration. In most marine habitats, passive restoration, that is, removing deleterious impacts, is the only practical approach to restoration. At the same time the MSFD explicitly requires the creation of coherent and representative networks of MPA. According to Article 13(4) of the Directive, the Member States must use spatial protection measures to contribute to the directive's primary goal to achieve or maintain Good Environmental Status (GES) for all EU marine waters by applying an ecosystem-based approach to management.

New MPA may be sited sub-optimally within national MSP processes. For example, stakeholders reported that Denmark's MSP process set aside 30% of its sea for renewable energy before finding 30% of the sea for marine protection, so new MPAs were designated in residual sites[48]. These places have the lowest political cost and are not necessarily the areas that have the highest potential to recover or support the highest biodiversity[48]. Continuing this trend of protecting biodiversity piecemeal from a national perspective and without prioritising important biodiversity areas nationally within MSP may result in European MPA networks which continue to lack coherence, and which are inefficient in the use of marine space within MSP processes[55]. MSP needs to apply the precautionary principle while considering where existing and new human activities can minimise further loss of biodiversity. The RBA indicates where protection of biodiversity should be strengthened to provide an optimal return on MSP investment.

Unprotected MPA

The contemporary Horizon Europe MARHAB project found that protection in Europe's MPA is a magnitude lower than protected area coverage, with only 0.2% of EU MPA effectively protected and over 80% not qualifying as MPA because they permit human activities that are incompatible with effective marine conservation[56]. We extended these data to include the UK[39] and are preparing a European scale assessment of how well the present "MPA" could protect species based on the *MPA Europe* data[40].

Stakeholders recommended that *MPA Europe*'s results should be used to improve and update protected area management plans[46]. They noted that some interests such as fisheries organisations have different ambitions or expectations for MPA, and MPA range from fully to partially protected, so stakeholders need to agree conservation objectives (including for fisheries as relevant), appropriate management measures and the outcomes they expect from an MPA, taking these discussions forward within MSP processes[48].

Most MPA in Europe permit mobile bottom contact fishing gear. EU citizens and NGOs see a contradiction between protection in theory and protection in practice (the "paper parks" phenomenon) and are concerned about the lack of implementation plans to exclude certain fishing practices (such as bottom trawling) in MPA. Management of the seabed could ban disturbance of sediments with high organic carbon to prevent degradation of these stores and potential release of greenhouse gases such as carbon dioxide[42].

Climate change and connectivity

Our stakeholder engagement work identified a misconception among stakeholders that MPA may need to move in response to species range shifts influenced by climate change (https://mpa-europe.eu/faqs). Marine planners are unclear about the impacts of climate change on species and lack relevant knowledge[57]. Considering the years it takes to establish MPA, and the nature of spatial planning and subsequent regulatory relationships with human activities, it is impractical to move MPA. It can take decades for biodiversity to recover in an MPA[58], so to move it could mean a reversal of restoration achieved. However, in the context of climate change, species are only likely to change their geographic distribution when temperatures exceed their tolerances in their present range (such as in lower latitudes or due to local heatwaves), and/or previously unsuitable areas become more suitable (such as warming in higher latitudes). Comparisons of species' geographic ranges now and under projected climate change conditions in the *MPA Europe* atlas (Figure 2) show that many species ranges will change negligibly, while some will extend their distribution into Arctic waters[59] and others contract their range in southern European seas. Thus, most species will still occupy most of their present range under climate change this century. At local scales, species abundance is not only a reflection of oceanic climate, but ecological interactions and physical habitat conditions; including salinity, productivity, seabed substrata, wave and current exposure, and topographic heterogeneity. Because the distribution of these physical variables will not change significantly under climate change, areas that are suitable for species now, and/or may contain more species, will still be important for biodiversity under climate change.

It is fortunate that the RBA is climate resilient for marine species[2]. MPA build climate resilience through restoring habitats and populations to abundance and acting as refugia for genetic diversity[60, 61, 62] and they support ecological and social adaptation to climate change via multiple pathways[63]. Moreover, emerging evidence indicates shading by macroalgae reduces the impacts of heatwaves on seabed life[64], and inclusion of deep waters may provide thermal refugia for fish and reduced exposure to heatwaves[66].

Marine species generally fill their environmental niche within their native range, indicating that their distribution is more limited by their physiology and environmental suitability rather than their dispersal ability[67, 68, 69, 70]. The only hard barriers to their movement are land, as evident from the ranges of species filling their environmental niche (geographic) space as shown on the *MPA Europe* atlas. Thus, connectivity is most important where a species needs to extend its range to adapt to climate change. The present distribution of species in the near absence of MPA shows that MPA are not necessary for species' connectivity. Observations of marine species moving their distribution at global scales in concert with ocean warming[71] including a doubling of fish species in the Barents Sea since the 1980s[59], show that connectivity is not limiting fish species' expansion under climate change. Exceptions to these general trends may be species endemic to the Mediterranean and Macaronesian islands, particularly if they are exposed to extreme heat waves[72, 73]. Because most species already have wide ranges extending beyond existing MPA and RBA, connectivity is not a general problem for marine nature conservation[74], assuming seabed trawling and pollution are not so severe as to have formed barriers to species dispersal. However, some large mammals, birds, turtles and fish species with low abundance, may need protection from accidental mortality (e.g., in fishing gear, ship-strikes) during their seasonal migrations which is another form of connectivity[75]. The application of MSP, using the RBA, is complementary to measures needed to protect species which may need protection throughout their range. Furthermore, local scale data on particular areas important for spawning, breeding, nesting, feeding, and as nurseries, would add value to the wider geographic context provided by the RBA.

Terminology and awareness

Stakeholders also sought clarity on terminology related to ecosystems and habitats classifications, including biogenic habitats[46]. Arising from such questions, EMODnet Habitats (a partner in *MPA Europe*) has now labelled such habitats, formed by particular habitat forming species, as such in its platform. There remains varying use and misuse of terminology regarding the concepts of habitats, ecosystems and biomes, especially in marine sciences, which should be streamlined with the definitions in terrestrial ecology[76].

Our stakeholders identified a need to raise awareness and educate the business sector and civil society on MPA networks, since the need for urgent biodiversity protection is not as widely understood as the need to address climate change. Indeed, protection of biodiversity is a prerequisite for climate change adaptation, particularly to reverse the losses to biodiversity from past and continuing existing human activities[60, 77, 78, 79]. Some stakeholders also noted environmental protection is lacking in national MSP processes[47].

Ocean P(A)ct and MSP

Our work showed MPA should be framed as an engine for a sustainable blue economy, not an obstacle to it, while acknowledging there is a time lag for the recovery of biodiversity before ecological and economic benefits are realised[80]. The European Ocean Pact[81] adopted in June 2025, is a **comprehensive strategy** to better protect the ocean, promote a thriving blue economy and support the well-being of people living in coastal areas. Its first priority refers to "protecting and restoring ocean health", with main areas of action to support Member States to restore degraded coastal and marine habitats. The European Ocean Pact proposes to evaluate and revise the **Maritime Spatial Planning Directive**; encourage Member States to establish and manage **marine protected areas**; and create European **blue carbon reserves**.

The upcoming European Ocean Act will build on a revision of the MSP Directive and aim at strengthening and modernising MSP as a strategic tool that will serve the priorities of the Ocean Pact and their implementation. It seeks to improve the coherence of maritime policies, streamline reporting, and create a single point of reference for economic, environmental, and social targets, revising Directive 2014/89 on MSP to better manage marine waters, and to strengthen and modernise MSP as a strategic tool that serves and implements the European Ocean Pact's priorities. It seeks to do this through increased cross-sectoral coordination at national level and a better organised sea-basin approach. It also aims to improve ocean observation governance. Therefore, MSP is becoming a more important tool and MSP processes are a route to sharing accurate, best available evidence on MPA experiences, to dispel myths and address stakeholder concerns about the impacts of MPA. We heard from stakeholders that the Common Fisheries Policy creates a challenge to Member States establishing MPA outside their territorial waters, because they find the process is too complicated[48]. It may also result in weaker final restrictions than proposed by the Member State[82].

At the same time, fisheries are facing "spatial squeeze" resulting in reduced or more distant fishing opportunities, as offshore energy and other maritime sectors expand, alongside new MPA designations[48]. More inclusive and participatory MSP processes targeting fisheries groups and economic support for a just transition for fishing communities can be used in tandem to facilitate more constructive engagement on MPA, as demonstrated recently in the Azores[83].

The EC and Member States can use *MPA Europe*'s educational an d scientific resources for MSP processes and stakeholder communication campaigns on the benefits of MPA networks (e.g., for ocean literacy). These include our videos, presentations, and infographics accessible on the *MPA Europe* website[84]. Regional Seas Conventions and Member States can use *MPA Europe*'s Map Platform in conjunction with national data for developing evaluations of ecosystem services, and contributing to the adoption of a natural capital approach to MSP decision-making.

Policy recommendations

Recalling that "the BDS, BHDs, NRR, and the renewed view of MSFD spatial protection call for a coherent and representative network of protected areas to halt biodiversity loss and to increase the resilience of the marine environment, particularly vis-à-vis climate change"[85], we recommend that Regional Seas Conventions and Member States use and build on *MPA Europe*'s atlas and data layers for planning future MPA networks in Europe's seas. Furthermore, Regional Seas Conventions and Member States should enhance the *MPA Europe*'s Map Platform by including regional and national data into OBIS, including for example species abundance data. Additional information for areas of conservation importance, such as Key Biodiversity Areas, which include Important Marine Mammal Areas, Important Bird Areas, Important Shark and Ray Areas, and fish nursery areas can also be added to OBIS, or maps of these areas can be overlaid with the atlas, to further inform optimal areas for protection. The results can also be placed into a wider spatial context, including the High Seas and global ocean by examination of our published papers[7, 8, 9, 10, 12, 13].

1. The 10% and 30% Representative Biodiversity Areas should be prioritised

for increasing protection and restoring habitats, through expanding existing MPA, establishing new MPA, recognising OECM and other regulatory measures, to achieve the 2030 targets as part of climate smart Marine and Maritime Spatial Planning (MSP) to implement the Nature Restoration Regulation, Bird and Habitat Directives, Marine Strategy Framework Directive, Maritime Spatial Planning Directive, and EU Biodiversity Strategy.

2. Prioritise action on strictly protected MPA

as strict protection is most effective for ecological restoration and fishery benefits and applies both the precautionary principle and whole ecosystem-based approach to environmental management.

3. Determine new MPA designations with local communities and stakeholders

including MPA boundaries and management informed by local knowledge of species and habitat distributions, and human values; coordinated by local and national government, to ensure social equity and compliance with regulations.

4. Member States and regional seas convention organisations should apply SMARTIE goals

(specific, measurable, attainable, relevant, time-bound, inclusive and equitable) for marine biodiversity protection and MSP.

5. Enable Regional Seas Conventions to lead MPA planning to optimise effective conservation

through transboundary MSP to harmonise sensitivity mapping, ecological objectives and sectoral constraints across borders, so that national plans collectively deliver a coherent basin-scale conservation network.

6. MPA planning, aims, management and reporting, would be clarified and simplified by international standards

such as the IUCN Categories for protected areas and the "MPA Guide".

7. Prohibit human activities that damage habitats in MPA

to preserve site integrity.

8. Prohibit human activities that disturb seabed areas with high carbon stores

as a precautionary approach to minimise carbon emissions is warranted pending greater scientific understanding.

9. Provide regular training and communications materials to Member states on effective MPA management

practices and climate change effects on marine species and ecosystems, to inform marine protection and restoration, and adaptive climate-smart MSP.

10. The European Commission and Member States should mandate that national species distribution, abundance and associated environmental and sampling data are published

into the international standardised data systems that integrate data to enable ease of data access, reproducibility and reusability; such as EMODnet, OBIS, and GBIF.

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