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Grant Proposal

Marine Protected Areas for Europe (MPA Europe)

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Abstract

The MPA Europe project will map the optimal locations for Marine Protected Areas (MPA) in European seas using measures covering the range of biodiversity from species to ecosystems, including habitats. The contribution of these measures to carbon storage will be quantified and mapped. The top 10% and 30% of the area that includes most species, habitats, and ecosystems, and maximises blue carbon benefits, will be prioritised as an MPA network. The geographic scope is the Atlantic Exclusive Economic Zones of the EU and its neighbours, and all of the Mediterranean, Baltic and Black Seas. Feedback from Marine Spatial Planning (MSP) stakeholders in the regional seas on the proposed MPA network and methodology will be reported. A first data-driven classification of ecosystems in European seas will use environmental data from Copernicus and EMODnet.Environmental niche models will map thousands of species, including habitat-forming species, ranges and contribute to existing seabed habitat maps in EMODnet.

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Analyses of spatial relationships between biodiversity measures and evidence of carbon storage will support the prioritisation analyses. Parallel modelling of current connectivity and the velocity of climate change will map connectivity within the proposed MPA network and how it will accommodate species distribution shifts due to anthropogenic climate change. All data and maps will be freely available through EMODnet, the Ocean Biodiversity Information System, ECKnowledge Centre for Biodiversity, and the project's online atlas. The atlas will provide transparency, traceability and enable reproducibility of the results. Its synthesis will show stakeholders (MSP, NGO, students, researchers) why areas have been prioritised. The use of decision support software will enable alternative network designs based on stakeholder preferences and could thus support wider MSP beyond the subject and study area.

Keywords

Marine biodiversity, biogeography, Systematic conservation planning, European and adjacent seas, organic carbon stores in seabed, climate resilience, species distribution modelling, marine protected area

1. Excellence

1.1 Objectives and ambition

MPA Europe will map the optimal locations for Marine Protected Areas (MPA) in European seas using a holistic range of measures that encompass the range of biodiversity from species to ecosystems, including habitats, covering the Exclusive Economic Zones of Member States and associated countries and Atlantic oceanic islands (Fig. 1, Fig. 2). Areas will be prioritised using systematic conservation planning software which enables alternative weighting of variables and multiple scenarios based on stakeholder preferences, and thus support wider marine spatial planning. For example, it may be preferred to locate MPA near and/or far from cities (so called "greening" of coastal cities could include blue areas), aquaculture sites, fish breeding areas, windfarms, protected areas on land and where species of high conservation or cultural importance are concentrated. The contribution of the biodiversity in such areas to the European MPA network can then be judged. State-of-the-art environmental niche models will map current biodiversity richspots and estimate how species and biogenic (biological) habitat distributions might change in and outside the MPA network due to warming caused by future anthropogenic climate change, as we and others have documented (Burrows et al. 2011, Burrows et al. 2014, Burrows et al. 2019, Pinsky et al. 2013, Pinsky et al. 2019, Pinsky et al. 2020, Assis et al. 2017a, McLean et al. 2018, Chaudhary et al. 2021). A novel carbon indicator mapping methodology will be developed and trialled to map where carbon capture and sinks are most likely to occur, and thus judge the risks of their release due to seabed disturbance (Sala et al. 2021).

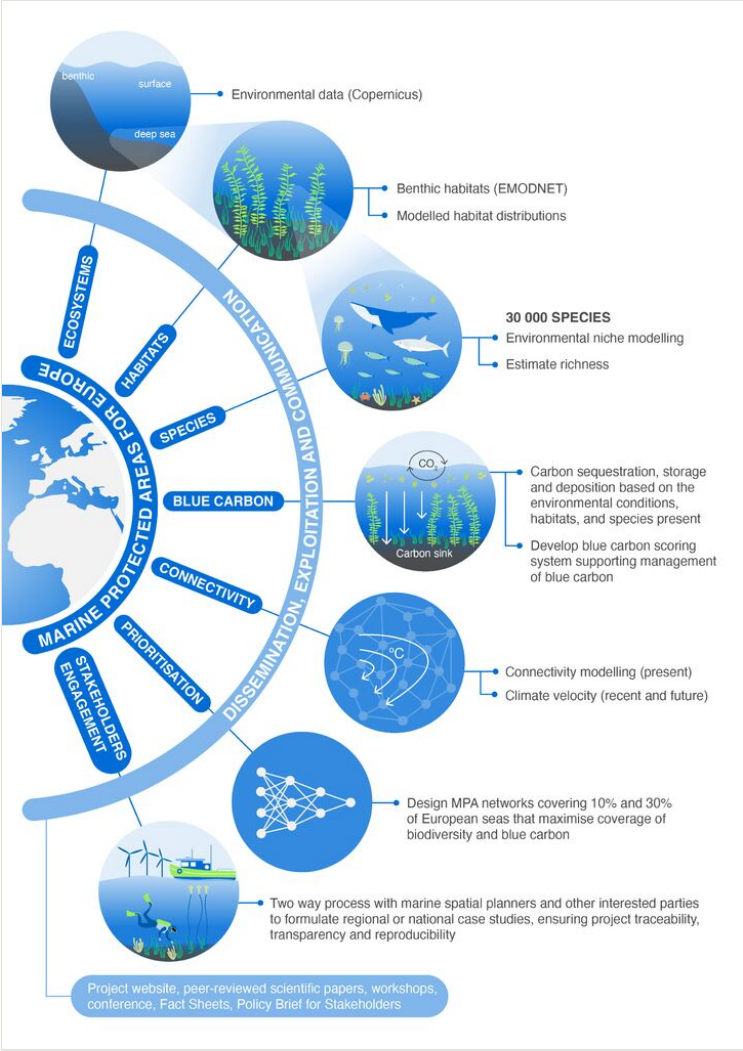


Figure 1.

Illustration of the six scientific components of this project and stakeholder engagement.

The project is ambitious in committing to achieve several firsts in terms of products based on new data and analyses.

- Maps of an optimal MPA network in European seas prioritised for biodiversity protection, blue carbon benefits and both together covering 10% and 30% of the seas area at a spatial resolution of 0.05 degrees (~5 km)
- Maps of species richness in European seas based on multiple indicators, including actual observed data, statistical estimators, and modelled geographic range maps of about 15,000 of the ~30,000 species in European seas

- Potential geographic distributions of important biogenic habitats in European seas, including seagrass meadows, kelp forests, fucoid seaweeds, maerl (rhodolith) beds and Lophelia reefs.
- The first data-driven classification of ecosystems in shallow and deep European seas based on a new comprehensive dataset of high-resolution environmental layers for bioclimatic modelling, including a wave exposure index and current and future climate velocity maps
- An online European marine biodiversity atlas for use by researchers, students, teachers, and in Marine Spatial Planning (MSP) by policy makers, industry and NGOs that ensures project traceability, transparency and reproducibility, including: key environmental variables for present-day and future climatologies (depth, rugosity, temperature, salinity, primary productivity, nutrient concentration, dissolved oxygen, wave exposure, etc.), ecosystems, biomes, habitats, species richness, species endemicity and rarity, threatened species and habitats locations, and “blue carbon” stores.

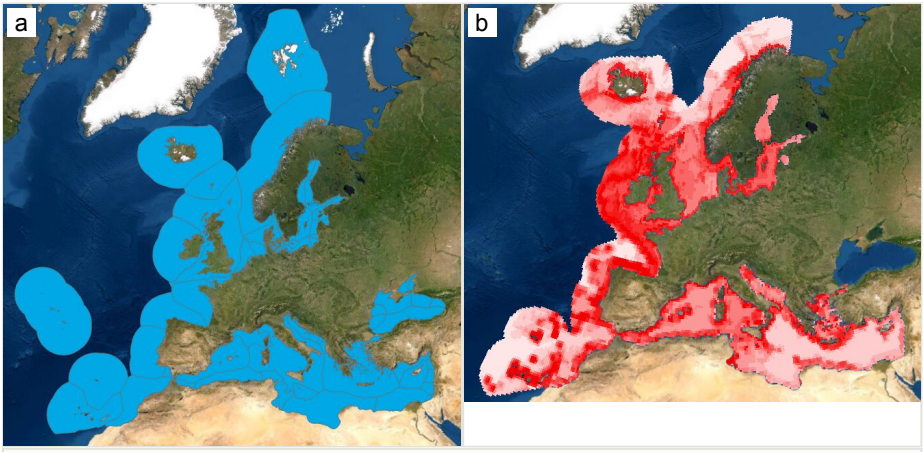


Figure 2.

The study area for this project is shown in light blue on the left map. The red shading on the map to the right illustrates how cells of biodiversity may appear when prioritised (darker red being higher priority).

Underpinning the science behind these products will be peer-reviewed papers justifying the statistical rigour of the methods and validating them through comparisons between variables and data layers so that the products make sense from both theoretical and practical viewpoints.

By taking this interdisciplinary approach, combining physical, chemical, and biological data, empirical field observations and state-of-the-art models, the project considers the breadth of biodiversity as defined by the Convention on Biological Diversity. In addition, it will include carbon sequestration benefits and consequences of future climate change on

species and biological habitat distributions as recently being proposed in conservation initiatives (e.g., Roberts et al. (2017), Duarte et al. (2020), Laffoley (2020), Hutto et al. (2021)). This will inform regional and national policy on how to best protect biodiversity, maximise climate change mitigation through blue carbon benefits, while adjusting the use of natural resources to be environmentally sustainable (Hoegh-Guldberg et al. 2019). This approach therefore supports incorporating adaptation and mitigation actions into Maritime Spatial Planning, allowing planning processes to respond to climate change. By taking a pan-European seas approach to mapping aspects of biodiversity and blue carbon (see below), this supports more coherent MPA designation and more integrated and coherent maritime spatial planning at the sea basin level. It will directly contribute to implementing the European Green Deal (European Commission 2019), Habitats Directive and Natura 2000, Water Framework Directive, Marine Strategy Framework Directive, Maritime Spatial Planning and the EU Biodiversity Strategy for 2030 (European Commission 2020). While this project is focused on environmental and biological data it includes a social (and associated economic) dimension by engaging with stakeholders to assess how they view the proposed MPA network and prioritisation algorithms. These stakeholder views will help define future research and planning priorities.

1.2 Methodology

This project takes an interdisciplinary approach by taking holistic measures of biodiversity, as defined in the Convention on Biological Diversity, to include variation within and between species and of ecosystems (including many environmental variables), and then including carbon cycle dynamics and climate change scenarios. The team thus includes experts in marine biology, taxonomy, ecology, oceanography, biogeochemistry, and biogeography, MPA network design, benthic habitat mapping, carbon dynamics, and species distribution and climate modelling. The project requires integration of physical, chemical and biological data, including water column characteristics (nutrients, light, temperature, salinity), wave height and current velocity, and seabed topography.

In addition to technical expertise, experts in Marine Spatial Planning and Blue Carbon accounting lead the Stakeholder Engagement WP6, and a professional science communication company leads Dissemination and Communication (WP7). Together with the technical WP they will translate the results to scientific, policy, and wider societal stakeholders and thus maximise its exploitation. This provides a social engagement component to the project.

Study area

The study area defined in the call is European regional seas, including EU and associated and neighbouring countries. This project will as a minimum cover the contiguous Exclusive Economic Zones (EEZ) of the Atlantic (including the Azores), Baltic, Black and Mediterranean Seas (Fig. 1). Water currents and species can potentially move freely across these seas so it makes sense to conduct a prioritisation based on the region

as a whole. Extending this further into the Atlantic High Seas, Arctic and Greenland is possible but would mean that a reduced range of biodiversity variables could be considered. The importance of extending the study area would be discussed with stakeholders during the project.

Ecosystems (WP2)

The project will provide the first classification of marine ecosystems in Europe from surface to seafloor, driven by a wide range of spatially complete and standardised environmental data that reflect both ecosystem conditions and functioning. For the purposes of this project, we define 'ecosystem' as "an enduring, spatially bounded environment where biological and energy interactions are greater within than with other ecosystems" (Zhao and Costello 2020). This will include data from Copernicus and EMODnet at as fine a spatial resolution as possible to capture local conditions. Based on present data, a spatial resolution of 0.05º (about 5 km at the equator) is planned for data layers in the maps.

We have previously quantitatively classified global marine ecosystems in surface waters using 20 variables, including seabed slope and depth, current and wind velocity, wave height, distance from land, sea surface temperature, light penetration, salinity, pH, oxygen, chlorophyll concentration and primary production, nutrients, and ice cover, and analysed how seasonal variation affects their distribution (Zhao and Costello 2020). In this project, we will develop high-resolution and ecologically meaningful marine data layers for the European region based on Copernicus data and the latest version of the Climate Model Intercomparison Project (CMIP6), both for sea surface and near seabed conditions, which will allow us to further classify deep-sea ecosystems. We will take advantage of the available state-of-the-art computational pipelines developed by our team (Assis et al. 2017b) to deliver a comprehensive dataset with numerous ecologically meaningful layers (e.g., temperature, O2, wave exposure index, salinity, pH, nutrients and productivity, etc.). Important additional layers based on the high-resolution harmonised EMODnet Digital Terrain Model (DTM) will also be developed (e.g., slope and rugosity). We are fortunate that within Europe several seabed layers exist that are not available globally, or only exist at a lower resolution, including broad-scale habitat maps and Photosynthetically Active Radiation (PAR) at the seabed (EMODnet Seabed Habitats). This seabed PAR predicts the depth limit of plant growth and is thus an important variable for mapping ecosystems. Because the analytical methods, previously validated through a peer-reviewed global analysis, account for correlations between variables, this means that the addition or omission of a variable is unlikely to alter the characterisation of the water body and associated seabed topography of an ecosystem. By using decadal-scale annual average data, the ecosystem classification will reflect the long-term enduring "climatology" that drives the distribution of species and habitats as distinct from seasonal and annual variation that affect population abundance. How this may change under future conditions will also be quantified.

Connectivity: present and future (climate change) (WP2)

The extent to which European marine areas are connected, including within the proposed MPA network, and able to accommodate range shifts of marine species under present and future climate change scenarios will be estimated by biophysical dispersal modelling using high-resolution Copernicus daily data of ocean currents (velocity and intensity). This is available as state-of-the-art computational pipelines developed by our team (Assis et al. 2021) and allows covering broad spatial and temporal scales, as well as multiple taxa, and have recurrently shown a good agreement with empirical connectivity estimates (Assis et al. 2015, Assis et al. 2018, Buonomo et al. 2017, Klein et al. 2016). These models simulate virtual oceanographic environments where propagules are advected by trajectories of ocean currents, while incorporating empirical biological components like species' propagule duration to increase the realism of connectivity processes. This will be complemented by graph theory to allow considering multigenerational stepping-stone processes and pinpoint area connectivity and isolation as well as connectivity corridors (Assis et al. 2021).

A related metric is the velocity of climate change (km/yr), which combines spatial gradients and temporal trends in temperature to map areas with fast and slow climate velocities (Burrows et al. 2011). Places with historically slow velocities may be environmentally stable on evolutionary timescales and harbour high numbers of endemic species (Sandel et al. 2011), and thus the species there may be sensitive to ocean warming. Climate velocity maps will indicate areas which will be climate traps, as suggested to occur in parts of the Mediterranean (Burrows et al. 2014). We will compare marine climate velocities against measures of biodiversity from species to habitats. This will be the first time such a comparison will be conducted at a regional scale and may provide insights into the factors influencing the distribution of biodiversity, as recently illustrated for the seas around Ireland (Queirós et al. 2021). Climate velocities will then be run on projected climate change scenarios spanning from high mitigation (e.g., Shared Socioeconomic Pathways; SSP119 matching the Paris Agreement) to business-as-usual scenarios (e.g., SSP585). In that way, we will be able to assess how well the proposed MPA network will facilitate species range shifts responding to climate change, through the inclusion of future as well as present biodiversity.

Seabed habitats (WP3)

The above-classified ecosystems would integrate the physicochemical conditions that reflect species' habitat requirements from the surface to the seabed. Morphological features of the seabed will be characterised by depth, slope, and associated modelling of seabed topographic variation (also called rugosity) derived from bathymetry. Because wave exposure is a key driver of the distribution of intertidal and subtidal marine species, the project will create a wave exposure index for all European coasts.

There have been many studies that have modelled the distribution of seabed habitats at varying spatial scales and extents. EMODnet Seabed Habitats provides a growing compilation of over 50 such models in Europe (Virtanen et al. 2019). The ICES/NAFO

Working Groups on Deep Water Ecology (WGDEC) and ICES WG on Marine Habitat Mapping (WGMHM) are investigating the use of predictive habitat models of Vulnerable Marine Ecosystems for identification of proposed fishery closures in data-poor areas of the deep sea. A Workshop on the Use of Predictive Habitat Models in ICES Advice (WKPHM) in 2021 developed a list of 48 criteria against which to assess and compare predictive habitat models, with each criterion accompanied by descriptions of "unacceptable", "required" and "desired" levels (ICES 2012, ICES 2014, ICES 2015, ICES 2016, ICES 2017, ICES 2019). The trade-off between spatial extent and model resolution meant that many basin-scale models could be used to flag broad areas of interest for spatial protection measures such as MPAs and indicate areas where finer-scale investigation is needed.

Biogenic habitats, formed by the growth of marine species, feature on multiple lists of habitats that could benefit from protection within MPAs, including Annex I of the Habitats Directive, MSFD special habitats, FAO Vulnerable Marine Ecosystems and GOOS Essential Ocean Variables. Therefore, the potential distribution of several biogenic habitats will be mapped through a combination of observed data and environmental niche models, as we have done for seagrass, kelp, and fucoid algae at global scales (Assis et al. 2017b, Assis et al. 2017a, Jayathilake and Costello 2018, Jayathilake and Costello 2020a, Jayathilake and Costello 2020b). This will be made possible using the compiled physio-chemical layers at a common resolution and grid (WP2 described above), and the compilation of >500,000 habitat point observations in Europe published by EMODnet Seabed Habitats*[1]. Many point observations of species and habitats will be at their source resolution and thus likely accurate to within 10-100 m. A 250 m resolution digital elevation model is available from EMODnet Bathymetry. The available kinetic energy model resolution at the seabed due to currents and waves are at various resolutions, often 3-5 km, in EMODnet Seabed Habitats. Where necessary, for example for narrow linear coastal species and habitat distributions, it is possible to re-interpolate the data to capture finer spatial resolution if necessary, as we have done for kelp biome mapping in the Arctic (Jayathilake and Costello 2020).

Thus, the potential distribution of seagrass, kelp and other seaweeds, maerl (rhodolith), Lophelia cold-water coral reefs, and mussel and oyster beds, will be mapped and compared with observed data, notably the habitat maps available in EMODnet. These include the composite data products that EMODnet Seabed Habitats have produced to date, which show the best available evidence of important habitats based on polygons and points from field surveys. These include seagrass beds, live hard coral cover and macroalgal canopy cover (O'Keeffe and Lillis 2019, Lillis 2021) and biogenic substrata (Lillis 2021).

Inaccurate predictions of where these biogenic habitats occur may be due to data limitations, modelling limitations, ecological factors, and/or human impacts (e.g., dredging, reduced light due to sediment plumes). The models will be designed and communicated in a way that will meet as many of the 48 ICES WKPHM assessment criteria as possible, and as such reducing these limitations where possible, and communicating the limitations where not possible.

In addition to the production of these models, we will work with the EMODnet Seabed Habitats consortium to add attribution of Red List conservation status (e.g., 'endangered', 'vulnerable', 'least concern') to the habitat maps already published via EMODnet (partner 10), including the broad-scale seabed habitat map for Europe, EUSeaMap*[2] (Vasquez et al. 2020) and the collection of over 800 habitat maps from surveys*[3]. Another complementary activity underway between two of the present partners, EMODnet Seabed Habitat and CCMAR (partner 3), is the compilation of Essential Fish Habitat data and maps to be completed in 2023. These results will provide an additional layer of information to compare with this project's Ecosystem, Habitat, Species richness and distribution, and prioritised areas for the MPA network in the third year of the project.

Species (WP3)

Because using only reported locations of species will bias the analysis towards better-sampled locations, species range maps will be prepared using well-established "environmental niche modelling" methods (e.g., state-of-the-art ensemble modelling of multiple algorithms; Assis et al. 2017a, Assis et al. 2017c). There are some 30,000 marine species in Europe and most are included amongst the 24 million species occurrence records for European seas in OBIS (Fig. 3). The availability of records in OBIS of 10,000 species for the Mediterranean, 8,000 in Atlantic European seas (including the Azores to Iceland), and 1,700 for the Baltic Sea, provides a good basis to create range maps of half of all marine species in Europe. This will include data on all kinds of animals and plants, including those that form (biogenic) habitats for other species. In addition, the data can be used to estimate richness per standardised geographic cells using repeat subsampling (rarefaction) statistical methods and to project potential range shifts from present-day conditions for future scenarios of climate change. Comparisons between species richness patterns derived from range maps and observed data may indicate locations with exceptional richness and numbers of rare and endemic species. The combination of past and projected climate velocities (WP2) and projected ranges of species in the future will map where climate change will be more or less (i.e., potential "refugia").

Our and others previous analyses show that the Black, Mediterranean, and Baltic Seas are biogeographically distinct in terms of species composition (endemicity) from the Atlantic (Costello et al. 2017). Further comparison with habitats, depth, and ecosystem distributions may explain why some areas have high numbers of species and/or rare species whether arising from their evolutionary history and/or local environmental conditions. Critical gaps in species and environmental data will be highlighted to encourage new field studies.

Some species are of special interest because they provide food, are threatened, create habitat for other species, and/or are indicators of environmental conditions. Those species listed as important for fisheries, in the Birds and Habitats Directives, Water Framework Directive, IUCN Red List, and by OSPAR, will be highlighted in the results to ensure they are adequately included in the MPA network.

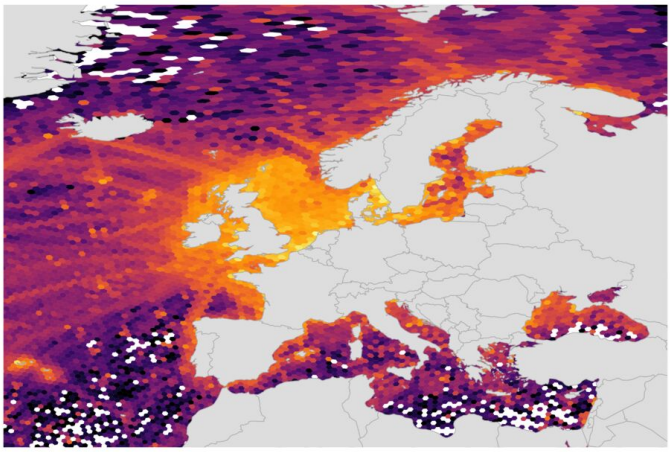


Figure 3.

The density of marine species distribution data already available in OBIS (yellow is more, purple is fewer records), including 24,238,051 records of 30,275 species, from the year 1526 to 2021.

Blue carbon (WP4)

Blue carbon, the role of the oceans to capture and retain carbon dioxide and help mitigate greenhouse gas emissions, has been highlighted as potentially significant but poorly quantified (Duarte et al. 2020, Douvere 2021). Vegetated sediment habitats such as salt marshes and seagrass meadows are well-documented as stores of blue carbon (Duarte et al. 2013). By contrast, macroalgal habitats, which dominate hard substrata, do not accumulate carbon but instead support significant carbon export to sinks in shelf sediments and in the deep sea where carbon from other sources also accumulate (Krause-Jensen and Duarte 2016). Hence, efficient protection of blue carbon must also include blue carbon sink areas (Luisetti et al. 2020). Open water systems also support blue carbon sources and marine mammals have been highlighted in this context.

In this project, a novel addition to past marine prioritisations will be scoring the relative benefits of areas for carbon sequestration, storage and deposition based on the environmental conditions, habitats, and species present. Management may then aim to sustainably maximise the ocean as a carbon sink in the context of the need to reduce greenhouse gas emissions. This project will combine empirical data on carbon fluxes and balances from the literature with ecosystem theory to support expert advice on how to define the contribution of areas to blue carbon benefits. These data will be examined together so we can score areas carbon benefits based on their combination of environmental conditions (e.g., sediment deposition), habitats (e.g., sheltered or wave exposed), and species (e.g., seagrass meadows, seaweed forests) present.

Prediction of areas where carbon may be deposited will be aided by a new European coastal wave exposure index developed in WP2 that will aid prediction of where

sediments, including carbon rich organic matter, may be eroded and deposited (Burrows et al. 2014, Burrows et al. 2017, Fitton et al. 2016).

Prioritisation (WP5)

Objective prioritisation requires standardised and complete data layers for the study area. Using systematic conservation planning software (e.g., *Zonation*), we will design (prioritise locations for) an MPA network covering 10% and 30% of European seas that maximise coverage of these data layers. For each one of these targets (10% and 30%) three different scenarios will be analysed. The first will consider only biodiversity conservation, the second only blue carbon benefits, and the third will consider biodiversity and blue carbon. These effectively score every geographic cell with a biodiversity value. The goal will be to include at least 80% of all species, habitats and ecosystems within 10% and 30% of the sea area, while maximising blue carbon benefits.

The proposed MPA network will be compared with current MPAs, and areas that are not MPA but are Other Effective area-based Conservation Measures (OECM). These will include Special Areas of Conservation in Natura 2000, marine World Heritage Sites, EBSA, and OSPAR prioritised locations. Similarly, any number of scenarios could be run to exclude and include particular areas in the MPA network during and after this project. This approach will allow us to compare our results with the current design and assess the adequacy of the current MPAs.

Once the optimal MPA network has been mapped based on the full range of biodiversity measures, maps of activities of social and economic importance can be overlaid to aid Marine Spatial Planning. It can also link to activities funded by the European Maritime Fisheries and Aquaculture Fund, in particular calls and projects on MSP, and also further support the work of the Technical Expert Group (TEG) on MSP data for making MSP plan data available across Europe. It will allow MSP to integrate biodiversity protection and carbon storage. For example, in a recent global study Sala et al. (2021) estimated carbon emissions by fishery trawling to be 15–20% of the amount absorbed by the ocean from the atmosphere (equivalent to global emissions by the global aviation industry). They calculated that protecting 45% of the ocean in marine reserves could protect over 71% of biodiversity, 92% of fisheries, and 29% of carbon stores.

The findings of this project will provide further information to be included to the currently elaborated National Plans of the Member States on MSP and lead national agencies to consider expanding, re-zoning, and/or changing management objectives in particular areas prioritised for protection that may already have some form of protection. However, considering that Natura 2000 only covers 9% of European seas, and only 1% is strictly protected (Agnesi et al. 2020), the results will most importantly inform how to optimally protect biodiversity, fill gaps in habitat and species protection, and maximise carbon stores, and balance other resource uses by creating new MPAs. In effect, the results will enable conservation to be SMART (specific, measurable, achievable, realistic and time-based) (European Commission 2021). A first step by national agencies may be to phase out negative human impacts in prioritised areas so they can recover naturally and self-

restore natural food webs and ecosystem structure. Such **restored ecosystems** can then become the benchmark or reference by which to judge the health and naturalness of adjacent areas.

Stakeholder engagement (WP6)

National and regional maritime spatial planning representatives of stakeholders for each sea basin will be invited to provide end-user feedback throughout the duration of the project on the mapping design, function and outputs to ensure the project meets user needs in incorporating biodiversity, blue carbon and ecosystem approaches into national and regional planning processes, and minimises conflicts. This will be via annual virtual and in-person workshops. Science-to-policy experts, including ICES, regional seas conventions and other MPA stakeholders, will also be invited to inform the project's outputs as part of the stakeholder engagement work package. Use cases will be articulated for each region, and a Policy Brief on Biodiversity, Blue Carbon and Marine Spatial Planning will be co-produced with stakeholders for dissemination internationally.

Open science (WP1)

All data, products, computer code and publications will be open access and follow the FAIR principles (i.e., Findable, Accessible, Interoperable and Reusable) (Wilkinson et al. 2016). All the data used in this project will already be open access prior to publication of papers. Primary species records will be available through the Ocean Biodiversity Information System (OBIS). We will develop semi-automated workflows to gather additional data from the Global Biodiversity Information Facility (GBIF) that are not already in OBIS, including research-grade citizen science data, and make these available through OBIS and EMODnet Biology with appropriate attribution and traceability. In addition, a new feature of OBIS will include thousands of species range maps produced by this project. The biogenic habitat range maps will be available to the EMODnet Seabed Habitats portal. The environmental data layers will be available through Bio-ORACLE. Thus, the environmental, ecosystem and habitat data (GIS) layers will be made freely available under the FAIR principle through the project's website, Bio-ORACLE, EMODnet and available to other platforms (e.g., JRC Environmental Marine Information Service, WCMC Ocean Data Viewer). All scientific publications will be available as green, gold or platinum open access.

International dimension outside Europe (WP1)

The applicants' international collaborators include two Associated Partners (AP) who are leading parallel efforts to map an MPA network in the Asian west Pacific. This research is underway with existing funding at the AP (OUC) in China, and the Japanese AP (Ryukyus) has secured 300 million yen (€2.3 million) over ten-years funding to gather the necessary data and conduct the analyses beginning in late 2021. A special task is included in the Project Management WP for comparison of methodologies and experiences between the European and Asia-Pacific MPA network research groups.

Gender dimension (WP1)

MPA Europe, by considering the Gender Equity Strategy 2020-2025 and the content of the Policy Brief Series Gender action, will plan the project so it can contribute to overcome existing gender biases in science. MPA Europe will bring the best science and knowledge to obtain the expected outcomes of the call; and we are convinced that these cannot be achieved without a real inclusion of scientists, independently of gender. To this end, MPA Europe will seek to eliminate any barriers that women may face in science. At present the European partners staff planned to be involved are 43% female. The project will seek opportunities to achieve gender balance in the team, including WP leaders, hiring of research staff, and promoting gender equity in meetings organised and supported.

2. Impact

2.1 Project's pathways towards impact

This project will contribute to the EU Biodiversity Strategy, a cornerstone of the European Green Deal, by using objective, standardised scientific data to identify where to optimally locate MPAs to protect and restore marine biodiversity within the context of Integrated Maritime Policy and overall Marine Spatial Planning (MSP). The holistic approach will enable present and future ocean management to optimise the availability of ecosystem health, social and economic benefits to coastal communities and society within a changing climate, and thus contribute towards a Sustainable Blue Economy.

Areas within the network would contribute information to the process to fill gaps in Natura 2000, and identify and/or update the Ecologically or Biologically Significant Areas (EBSA) which support policy-making within the Convention on Biological Diversity.

In addition to maritime spatial planners, academia and NGOs, commercial interests could utilise the results and supporting data to plan sustainable developments that minimise environmental impacts, are in line with the Green Deal's 'do no significant harm' vision and support the restoration of biodiversity and ecosystem services. For example, renewable energy installations, shellfish and seaweed culture may provide new and more sustainable economies for coastal communities while also enabling the restoration of biodiversity by reducing seabed trawling and overfishing, and thus being potential OECM.

2.2 Measures to maximise impact - Dissemination, exploitation and communication

The dissemination, exploitation, and communication (DEC) measures applied to the expected results have been designed to maximize the impact they can produce in the different target groups. A detailed DEC plan will be developed in WP7, in collaboration

with WP leaders by Month 4, led by Science Crunchers, and based on the elements described below.

Communication

The success and efficacy of the communication activities rely on their consistency and engagement with the different audiences that MPA Europe will target. A harmonious, modern and fresh visual identity of the project will be the starting point, to be developed by Science Crunchers (WP7, T7.2). This will include developing the project's website and setting up different social media accounts (YouTube Channel, Twitter, and LinkedIn). Ultimately, these online platforms will ensure fluent, consistent and constant external communication, thereby bringing the project (its topics of interest and the obtained results) closer to the different end-user targets, including scientists, policy makers, schools and the general audience. The website will also include an area to share documentation with external members, such as stakeholders and policy makers that will be engaged in the project (WP6). MPA Europe will liaise with the EU MSP Platform for the optimal way to present the outcomes and the tool in the European platform, that will make the easily accessible by MSP planners.

Digital communication will be developed during the project, including a minimum of 4 short videos, 4 posters, and 4 brochures, with key-facts about marine spatial planning, blue carbon and marine protected areas, and with the main take-home messages and results from the project. These will be published digitally. In addition, the partners of the consortium also have social media accounts that will be used, in coordination with the Science Crunchers , to bring together messages and maximize their impact in the society, scientific community, and media.

To further contribute to bridging the gap between science and local kids and schools, and led by Science Crunchers (WP7, T7.5), scientists from the partner organizations will write at least 6 dissemination articles targeting children older than 8 years old. The articles will focus on key topics covered by MPA Europe, such as: why MPA are needed; MPA benefits; measuring biodiversity at ecosystem, habitat and species levels; maximising Blue Carbon; and how to optimise protection of biodiversity and carbon stores using MSP decision making software. Each article will be written in the native language of each partner (Danish, English, French, Greek, Norwegian, and Portuguese), and peer-reviewed by local children (and supervised by their teachers) from selected schools participating in the European Blue Schools network. The articles will be illustrated by Science Crunchers and translated to the different languages represented in this consortium upon approval by the young reviewers. The articles will be disseminated in open access via the project's website, and also with other platforms with whom the consortium will engage (e.g., EUROGOOS). Partners from other projects funded in this call will also be invited to participate in this initiative to maximize the countries and topics covered in this initiative, thereby contributing to the international dimension and collaborative and integrative approach of MPA Europe.

Associated partners of this proposal besides those located in Europe, such as those in China and Japan, will also actively collaborate in the translation of the digital communication materials to maximise the international impact of the project's results. Press releases will be prepared and disseminated through the media of each partner country upon the project's kick-off and finish.

Internal communication will be secured through an Office Teams group (WP1) to ensure communication, daily work organization, exchange of information and data sharing. This tool will also be used for project planning, tracking the completion of tasks, achievement of milestones, and progress of deliverables. Regular meetings among the project partners will also be organized via the Teams group.

To improve the internal and external communication, in the month before the annual meetings, an anonymous survey will be submitted to all team members to check the satisfaction with the communication, identify deficiencies, and request actions to improve. The results will be presented at each annual meetings and improvements will be proposed in the minutes, together with a calendar of implementation.

Dissemination

Numerous dissemination actions are planned to maximise the impact of the research results and their engagement with and application by potential users. For MPA Europe, the project's results will target mainly the scientific community, stakeholders, and policymakers who are committed to achieving shared biodiversity and conservation goals, as well as engaged in MSP.

Dissemination of the project's results to the scientific community will be promoted through the publication of scientific publications. Some of the publications will have a more fundamental science orientation, whereas others will have a management and policy focus, thereby disseminating the tools, applications, methods, and approaches developed in MPA Europe. Target scientific audiences range from those interested in biodiversity assessments to biogeographical modelling, climate change, and MSP and policy. All papers will be open access. MPA Europe will organise a special issue (WP7, T7.4) in an open-access, reasonably priced, peer-reviewed journal, where review papers and some of the project's results are expected to be published, as well as other significant advances in the field of MSP for MPA by other projects. Partners from other projects funded in this same topic (HORIZON-CL6-2021-BIODIVE-01-12) will also be invited to participate in this special issue to maximise the collaboration between funded projects as part of WP1 (T7.6).

The scientific community will also be engaged in the project's results through the participation of an international conference on MSP for MPA that will be organised at the end of the project and hosted by Nord. As far as possible, this activity will be organised together with other projects funded under this same call. In addition, the topics covered in this conference will also be of interest to stakeholders and policy makers, such as those

who will be directly involved in MPA Europe (see WP6), and DG Environment and DG MARE.

To promote the dissemination of the project and the expected results to policy makers, a policy brief will be produced on Biodiversity, Blue Carbon and Marine Spatial Planning, targeting policy makers in Europe and internationally (WP6, T6.3).

Exploitation

For the purpose of allowing others to exploit the developed tools and the resulting outputs of MPA Europe, build on them, reproduce the research, and conduct new analyses, all data, maps, and code will be freely available online. In particular, all relevant data and models will be available to the EMODnet Ingestion portal (https://www.emodnet-ingestion.eu), which will ensure that the information is deposited in the appropriate EMODnet repository. The publication of map layers in an online Atlas will allow for the switching on and off map layers, displaying the aspects of biodiversity that are important at particular locations, and how these relate to areas of social and economic interest. The results of MPA Europe will be submitted to the atlases of the European Atlas of the Seas (https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/), as well as of the Joint Research Centre EC Knowledge Centre for Biodiversity, which will further contribute to conveying the findings to policymakers, including the Convention on Biological Diversity, which they attend. The results will be an important contribution to the EU MSP Platform as previously mentioned.

Regarding “Technology Readiness Level” (TRL), this proposal shows that the partners and available resources are at TRL 1 and 2 now. The experimental proof of concept (TRL3) will be apparent in the preliminary results at the end of year two, and validated and demonstrated (TRL 4, 5, 6) in year three. The MPA network design, process and online atlas will be available for Marine Spatial Planning at the end of the project (TRL7, 8). The final stage would be for national agencies to use the results to expand their MPA network (TRL9).

2.3 Key Elements of the Impact Section

Specific Needs

1. International targets to protect biodiversity in 30% of ocean area and the EU commitment to 10% no-take (fully protected) have not yet been achieved and existing MPA designation fails to consider all aspects of biodiversity holistically.

2. The need to link ecological, social and economic elements spatially to meet long standing commitments from EU and associated countries to protect marine biodiversity through Natura 2000 and other measures, including (Marine) Spatial Planning towards a Sustainable Blue Economy.

3. The EU Biodiversity Strategy recognising the need to both protect biodiversity, sustainable use of natural resources, and mitigate the effects of climate change.

D & E & C Measures

1. An online atlas of all the key biodiversity and blue carbon data layers to show **traceability** of the methodology and to illustrate and explain the approach as an educational resource for students, researchers, industry and policy makers.

2. All data and results available open access to enable **reproducibility** of the recommend MPA network, and alternative prioritisations based on stakeholder feedback.

3. Policy Brief co-developed with Marine Spatial Planning stakeholders, Fact Sheets associated with infographics and animations, communicating the underlying science and issues.

4. Communication of key messages and results to the general audience through videos, factsheets, digital brochures and articles for children.

Expected Results

1. The primary results is a map of the optimal locations for a Marine Protected Area network for Europe that include as high a proportion of species, habitats and ecosystem level measures of biodiversity as possible. The maps will highlight the top 10% and 30% area, while showing the relative ranking of other areas.

2. Added value will be a ranking of all areas in European seas by their blue carbon value, and supplementary prioritisations of how best to protect these ecosystem functions, and synergies with biodiversity protection.

3. Underpinning these maps will be new datasets, models, and several peer-reviewed papers in international scientific journals validating the results and methods.

Target Groups

The results will be of wide interest to the public because of their significance for protecting biodiversity and mitigating climate change through wise ocean management. Policy makers at EU and national level, regional and national environmental NGOs, and all marine industries will take interest. The latter include all blue economy sections, including tourism, energy, fisheries, aquaculture, transport, and oil, gas and aggregate extraction industries.

Using the projects online atlas, stakeholders and Marine Spatial Planners will be able to overlay maps of features of their special interest (e.g., potential windfarm locations,

aquaculture zones, cable zones, shipping routes) to see how they may interact with the top areas for biodiversity protection.

Regional workshops for the Atlantic, Baltic, Mediterranean and Black Sea basins will include outlines of future case studies of how to implement MPA to both protect biodiversity in context of climate change mitigation and adaptation, and sustainable use of resources.

Outcomes

National authorities designating MPAs within the proposed network areas, including expanding Special Areas of Conservation, and increasing levels of protection in existing areas.

Inclusion of marine areas in national climate change mitigation plans to safeguard blue carbon deposits and aid increased carbon capture.

Improved science-based Marine Spatial Planning for EU sea basins which ensures full aspects of biodiversity, blue carbon and ecosystem services under a changing climate are incorporated in decision-making.

Impacts

Wider and deeper societal awareness of the importance of and benefits from protecting marine biodiversity and blue carbon mechanisms in terms of a healthy planet, sustainable development and reducing climate change. This will enhance public and political support for an Integrated Maritime Policy.

3. Implementation

3.1 Work plan and resources

The project will go through phases of data compilation, analysis and MPA network design with regard to environmental data and ecosystem classification (WP2), habitat, species composition and richness maps (WP3), and blue carbon (WP4) mapping (Fig. 4). WP5 will integrate these data and design the MPA network. In parallel, WP6 will engage with stakeholders with increased sharing of project results in the later part of the project, while WP7 will provide professional services in dissemination and communication. Details of the timetable of WP Tasks, Deliverables are shown in Fig. 5.

3.2 Capacity of participants and consortium as a whole

The applicants are well-placed to lead this research in that they have previously conducted similar prioritisation for the world ocean and the Coral Triangle (which is the richest region in marine biodiversity globally) (Asaad et al. 2018a, Asaad et al. 2019).

The global study won an Elsevier Atlas award for its potential contribution to the United Nations Sustainable Development Goals. It was the first global prioritisation to include data-driven maps of marine ecosystems, habitats, biomes, species richness and endemicity. Current work, testing how well it encompasses the distribution of threatened species, indicates it captures parts of all threatened marine species' ranges and expanding the proposed global MPA network from 30% to 40% of the ocean could include each threatened species' range and be representative of all wider biodiversity (Jefferson et al. 2021).

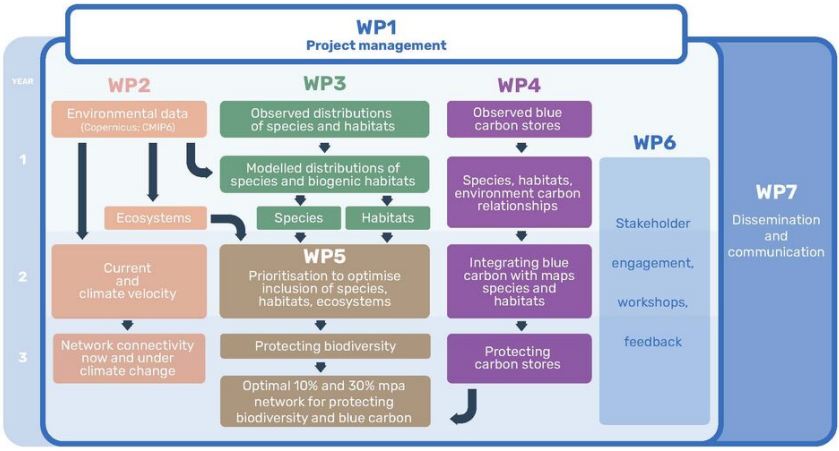


Figure 4.

Diagram of the relationships of the Work Packages (WP) and indicative timeline.

The project coordinator, Costello (NORD), has experience leading the coordination of EU projects in the 1990s while he was based in Ireland, including the EU BioMar-LIFE project mapping and classifying marine habitats in Britain and Ireland, the European Register of Marine Species, and two Coordination Actions on sea lice biology and control. He has been a leader in the new field of Ocean Biodiversity Informatics, including being first Chair of the World Register of Marine Species and Ocean Biodiversity Information System, vice-chair of the Global Biodiversity Information Facility Science Committee, and publishing a series of papers to advance thinking and practice in the field (Costello 2000, Costello 2009a, Costello 2009b, Costello and Vanden Berghe 2006, Costello et al. 2013d, Costello et al. 2013c, Costello et al. 2014, Costello et al. 2015a, Costello et al. 2015b, Costello et al. 2018a, Costello et al. 2021, Costello and C. 2005, Costello and Wieczorek 2014, Costello et al. 2013a, Costello 2019, Costello 2015, Costello et al. 2001, Costello et al. 2013b, Costello et al. 2006, Appeltans 2012). Thus, he has a good understanding of the potential and limitations of the data. Through co-chairing the first decade of the Marine Biodiversity Observation Network (MBON), which is part of the Group on Earth Observations (GEO), he has a large network of collaborators

to draw on for expertise and additional data should this need materialise during the project.

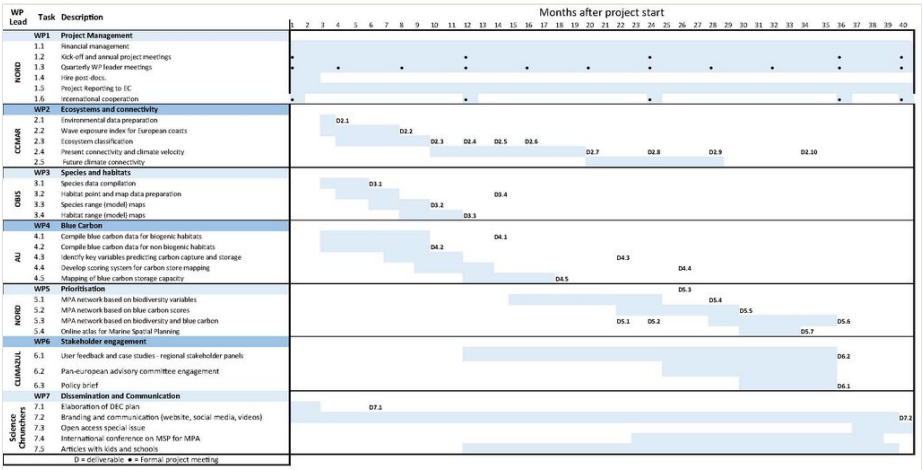


Figure 5.

A Gannt chart indicating project Work Packages (WP), Tasks (T), Deliverables (D) and Milestones (M).

The project coordinator, Costello (NORD), has experience leading the coordination of EU projects in the 1990s while he was based in Ireland, including the EU BioMar-LIFE project mapping and classifying marine habitats in Britain and Ireland, the European Register of Marine Species, and two Coordination Actions on sea lice biology and control. He has been a leader in the new field of Ocean Biodiversity Informatics, including being first Chair of the World Register of Marine Species and Ocean Biodiversity Information System, vice-chair of the Global Biodiversity Information Facility Science Committee, and publishing a series of papers to advance thinking and practice in the field (Costello 2000, Costello 2009a, Costello 2009b, Costello and Vanden Berghe 2006, Costello et al. 2013d, Costello et al. 2013c, Costello et al. 2014, Costello et al. 2015a, Costello et al. 2015b, Costello et al. 2018a, Costello et al. 2021, Costello and C. 2005, Costello and Wieczorek 2014, Costello et al. 2013a, Costello 2019, Costello 2015, Costello et al. 2001, Costello et al. 2013b, Costello et al. 2006, Appeltans 2012). Thus, he has a good understanding of the potential and limitations of the data. Through co-chairing the first decade of the Marine Biodiversity Observation Network (MBON), which is part of the Group on Earth Observations (GEO), he has a large network of collaborators to draw on for expertise and additional data should this need materialise during the project.

Costello conducted his PhD in Ireland's only Marine Reserve, and while in New Zealand led benthic habitat mapping of its first Marine Reserve and a proposed new Marine Reserve (Leleu et al. 2012, Remy-Zephir et al. 2012, Lee et al. 2015). He led the largest ecological mapping of Ireland's coast as part of the BioMar-LIFE project, which provided the Marine Habitat Classification that now underpins EMODnet and EUNIS (Costello and

C. 2005 Costello and Emblow 1997, Costello et al. 1997, Picton et al. 1999). Beyond these local-scale mapping projects, he has collaborated with global-scale analyses of the ocean water masses and topography in three dimensions (Costello and Chaudhary 2017 , Costello et al. 2010, Costello et al. 2018, Costello and Breyer 2017, Sayre et al. 2017, Basher and Costello 2020).

Using distribution data on 60,000 species from OBIS, Costello published the first data-driven classification of ocean biogeography at a global scale (Costello et al. 2017, Costello et al. 2018bCostello et al. 2018), and combined with citizen science data on coral and rocky reefs, showed contrasting latitudinal gradients in fish and benthic invertebrates (Edgar et al. 2017). He has supervised PhD projects that mapped

- the global distribution of the seagrass and laminarian kelp biomes (Jayathilake and Costello 2018, Jayathilake and Costello 2020a, Jayathilake and Costello 2020b, Jayathilake and Costello 2020, Jayathilake and Costello 2021),
- past (last glacial maximum), present and future distribution of Antarctic shrimp and global razor clams (Basher and Costello 2016, Saeedi et al. 2016), and
- the most holistic (and award-winning) MPA network prioritisation for the world (Zhao and Costello 2020) and the first for the Coral Triangle (Asaad et al. 2017, Asaad et al. 2018a, Asaad et al. 2019, Asaad et al. 2018b).

From 2004-2020 Costello coordinated perhaps the only MSc course on Marine Protected Areas while based at the University of Auckland in New Zealand. The course included visits to urban and rural Marine Reserves (fully protected MPA), MPA science, policy and local and national management issues, history of the Ross Sea Antarctica MPA, and perspectives of the Indigenous Maori. The collaboration with speakers on the course led to several papers (Abecasis et al. 2015, Costello and Ballantine 2015, Costello et al. 2016). Other studies reviewed and clarified issues regarding biodiversity, conservation and MPA science (Costello 2000, Costello 2001, Costello 2014, Bates et al. 2019, Costello and Chaudhary 2017, Costello and Connor 2019), and provided a gap analysis of MPA coverage of global coral reefs (Mora et al. 2006). He participated in the 2016 IUCN workshop on OECM and one focused on marine OECM in 2021 (hosted by ICES). To increase outreach regarding MPA science and practice, he started the Facebook page on Marine Reserves in 2018, which has 574 followers, where a news item is posted about every day.

Costello is a Lead Author in the current International Panel on Climate Change (IPCC) Working Group 2, including co-leading the Cross Cutting Chapter on Biodiversity Hotspots. His group has shown how natural and anthropogenic climate change has been altering the latitudinal gradient in marine species since the last glacial maximum (Yasuhara et al. 2020) and 1950s (Chaudhary et al. 2021), and that there is a dip in species diversity at the equator due to it already exceeding the maximum tolerated by some species (Chaudhary et al. 2016, Chaudhary et al. 2017, Saeedi et al. 2017). His research unit specialises on the effects of climate change on marine biodiversity (Lavin et al. 2021, Gordó-Vilaseca et al. 2021). He has supervised over 100 early career researchers, including over 60 graduate students. Current PhD students are studying the

effect of climate change on oxygenated habitat in the world ocean (Zhiyuan Shi), marine food web ecology (Cesc Gordo-Vilaseca), ecology of fishery species (Charles Lavin), and designing a global MPA network to optimise protection of threatened species (Tamlin Jefferson).

Also at Nord University, Dr Alexander Jueterbock brings cross-disciplinary research expertise in (epi)genomics, bioinformatics, ecological modelling, and coastal ecology, with a focus on the base of the food web, including macroalgae and seagrass. He has hind- and forecasted the distributional range of marine macrophytes along the North-Atlantic (Jueterbock et al. 2013, Jueterbock et al. 2016) and West-Pacific coast (Zhang et al. 2019, Zhang et al. 2020, Hu et al. 2021), also in relation to Marine Spatial Planning (Queirós et al. 2021), and developed an R package 'MaxentVariableSelection' (Jueterbock 2015) as a tool to identify the most important environmental variables in setting species' distribution limits.

At CCMAR, Assis is a macroecologist and data scientist leading the Biodiversity Data Science research group (CCMAR; University of Algarve). He teaches Marine Ecological Modelling and Climate Change in MSc and PhD programmes at the University of Algarve. He has developed high-resolution environmental layers for the global ocean (Bio-ORACLE v2.0) for present-day conditions and multiple scenarios of future climate change (Assis et al. 2017b), modelled and validated the role of oceanographic connectivity to marine biodiversity by bio-physical modelling, including the connectivity of the European MPAs (Assis et al. 2020, Assis et al. 2021, Buonomo et al. 2017), developed platforms for free access to biodiversity distribution data (Assis et al. 2020), and has estimated the potential impact of past and future climate changes across multiple biodiversity groups in both hemispheres (marine forests of kelp, corals, seagrasses, fish, and maerl beds, etc.) using state-of-the-art ensemble distribution modelling (e.g., Boavida et al. 2016, Assis et al. 2015, Assis et al. 2017a, Assis et al. 2017c, Fragkopoulou et al. 2021, Ramos Martins et al. 2021). He also works with high-performance computational facilities (e.g., at CCMAR; ceta.ualg.pt; 336 cores, 2.4TB RAM) which allow performing the demanding models and simulations of the current proposal.

Abecasis (CCMAR) is a marine biologist who has published on connectivity across Mediterranean MPA (Assis et al. 2021), used species distribution modelling (Ramos Martins et al. 2021), and researched the suitability and recovery of species in MPA (Abecasis et al. 2014a, Abecasis et al. 2014b, Abecasis et al. 2015, Abecasis et al. 2017, Abecasis et al. 2013, Afonso et al. 2016, Gandra et al. 2018, Stratoudakis et al. 2019, Timonet and Abecasis 2020, Martínez-Ramírez et al. 2021, Priester et al. 2021). He was part of the working group, established by the Portuguese Sea Minister, on Marine Protected Areas and has been collaborating with the Azores regional government towards the implementation of a regional MPA network. As required in this project, he has used decision support software (Marxan) to design optimal MPA networks in Portugal. He is thus well placed to advise on MPA network design methods and connectivity.

Appeltans is UNESCO's marine biodiversity focal point, coordinator of the Ocean Biodiversity Information System (OBIS) and a member of the CBD's EBSA advisory committee. He is also UNESCO's focal point in the current negotiations of a new UN legally binding instrument to conserve and sustainably use marine biodiversity in areas beyond national jurisdiction, which includes discussions on establishing a network of MPAs in the High Seas. He is also a member of the Global Ocean Observing System Biology and Ecosystems (GOOS BioEco) panel, which is developing the framework for a globally coordinated ocean biodiversity observing system. Appeltans runs a project on monitoring marine invasive species in the Pacific Islands using molecular methods and in 2022 will coordinate, together with the secretariat of the World Heritage Convention, a new citizen-science project on censusing biodiversity in the light of climate change, by collecting environmental DNA across the 50 UNESCO marine World Heritage Sites. OBIS is one of the flagship persistent projects under the UNESCO-IOC's International Oceanographic Data and Information Exchange programme. In this proposal, we refer to OBIS as UNESCO's entity that will perform the assigned tasks.

Also at OBIS, Provoost (UNESCO) is a data scientist and software engineer with a background in marine ecology and biogeochemical modelling. As the data manager at the Ocean Biodiversity Information System (OBIS) he is responsible for the development of data pipelines that integrate observations of marine species as well as environmental data from a global network of OBIS nodes and data providers. He is also involved in the development of biodiversity data standards in close collaboration with the Global Biodiversity Information Facility (GBIF) and Biodiversity Information Standards (TDWG), and supports the Global Ocean Observing System Biology and Ecosystems panel with advice on data management (Satterthwaite et al. 2021).

Burrows (SAMS) has modelled North Atlantic and Pacific species to show how their thermal niches can be used to track their already shifting distributions due to climate change (Burrows et al. 2019). With the project's associated partner in Japan, García Molinos, he has used climate velocity (the direction and speed of warming) to show globally how species tracking climatic conditions can shift their future climatic changes, with important consequences for patterns of biodiversity (García Molinos 2019). These approaches to climatic drivers of change in species distributions are beginning to be applied to designing future climate-smart MPA networks (Brito-Morales et al. 2018), including the deep ocean (Morales et al. 2021) and the complexities of vertical gradients in temperature with depth.

Krause-Jensen (AU) is a specialist in Blue Carbon of coastal vegetated ecosystems and how the protection and restoration of marine vegetated habitats may serve as win-win nature-based solutions to climate change mitigation while also supporting biodiversity and other co-benefits. She is involved in International and European-level, Arctic, and national Danish projects on this theme. Major contributions to the field are a seminal paper highlighting the substantial role of macroalgae in marine carbon sequestration via export from coastal habitats to off-shore carbon sinks (Krause-Jensen and Duarte 2016), associated studies documenting and quantifying such contributions (Queirós et al. 2021), and synthesizing blue carbon findings for the high level panel's report on ocean solutions

to climate change (Hoegh-Guldberg et al. 2019) and UNESCOs quantification of blue carbon stocks in the marine world heritage sites (Duarte et al. 2020) as part of the lead author teams.

Leal is Science Crunchers (legal name Scitation Lda) founder and manager. Leal is an expert in marine biology and biotechnology, with wide academic expertise in functional biodiversity and trophic interactions. Leal founded Science Crunchers in 2017, and in four years has assembled a team of 12, with a mix of scientists (most are PhD holders and include marine biologists) and designers with various backgrounds. Over 200 projects have been accomplished thus far associated with Life, Environmental, and Animal sciences. Scientists, writers, and designers work together to ask the right questions and think critically about the Clients' challenges and needs, delivering comprehensive, innovative, and custom-made solutions. Science Crunchers has extensive expertise in science-based communication to a wide range of audiences, from children to adults, and from laypeople to scientists. Most work is done with private companies, non-governmental organisations, as well as research institutes and universities. At the international level, clients include the Prince Albert II of Monaco Foundation (Monaco), AIR Centre (International), BioBased Industries joint undertaking of the European Union (EU), CERN (International), Merck (USA), University of Wageningen (Netherlands), University of Miami (USA), OBIS and OceanTeacher Global Academy (IOC-UNESCO), Skretting (Norway), World Aquaculture Society (International), Chr. Hansen (Denmark), International Coral Reef Initiative (International), Partnership for Observation of the Global Ocean (International), and Royal Canin (Canada), among others.

The JNCC team specialises in adding value to seafloor habitat data and data products. This includes gathering disparate sources of data and making it freely available in standard, easy-to-discover and easy-to-understand formats (e.g., Duncan et al. 2021; Virtanen et al. 2019) and combining these standardised datasets into new data products to show the best available evidence on the extent and distribution of key marine habitats (Castle et al. 2021, JNCC 2021, O'Keeffe and Lillis 2019, Lillis 2021, Lillis et al. 2020).

These are key activities of the EMFAF-funded EMODnet Seabed Habitats project, of which Lillis is currently the coordinator (2021-2023 phase, but also co-lead in 2019-2021 (alternating with Manca during maternity leave) and coordinator in 2017-2019). Manca, Castle and Lillis have played leading roles in another key activity of EMODnet Seabed Habitats, the production of the EMODnet broad-scale seabed habitat map for Europe, EUSeaMap (Vasquez et al. 2021a, Vasquez et al. 2020, Vasquez et al. 2021b,Populus et al. 2017). Manca and Castle are leading on the development of a broad-scale habitat map for the Beibu Gulf in China and the pilot application of a habitat classification in the area based on the European Nature Information System (EUNIS) habitat classification system, as part of the EMODnet Partnership for China and Europe (EMOD-PACE). The partnership focuses on marine data and knowledge exchange working closely with the Chinese National Marine Data Centre (NMDIS). Manca and Lillis are active contributors to the ICES Working Group on Marine Habitat Mapping (ICES 2012, ICES 2014, ICES 2015, ICES 2016, ICES 2017, ICES 2019). Lillis and Castle lead a task on behalf of the

OSPAR Commission to maintain the database of threatened and/or declining habitats in the Northeast Atlantic. Castle has recently led on the creation of a composite data product showing the best available evidence on the extent of seabed habitat types in the Northeast Atlantic for OSPAR (Castle et al. 2021) and contributed towards the evaluation on the extent of blue carbon habitat in the UK by producing habitat suitability models for maerl beds and *Zostera marina* beds (JNCC 2021). Lillis has contributed to the recent update to the EUNIS habitat classification system and understands the impact of different classification systems on habitat mapping (Galparsoro et al. 2012, Strong et al. 2019). Manca and Lillis has worked with European partners to develop correlations between EUNIS habitat classification and Marine Strategy Framework Directive Benthic Broad Habitats. These which contribute to making broad-scale habitat maps useful for MSFD assessments (Manca et al. 2017) and the development of the deep-sea section of the UK habitat classification (Parry et al. 2015). As a result of working for a statutory nature conservation body, the team has a good understanding of policy requirements for seafloor habitat data, maps and models in Europe (Andersen et al. 2018, Lillis et al. 2020).

The **Climazul** team includes **Bramley**, a blue economy consultant with stakeholder engagement experience supporting co-produced marine research for marine spatial planning in Seychelles and led a 2021 white paper on the Blue Economy in Practice featuring international case studies including on marine spatial planning and ocean policy (Bramley et al. 2021). **Smanis** is a blue economy expert with integrated maritime policy experience supporting different EU Sea Basins through DG MARE Assistance Mechanisms (WestMed, Black Sea) and in close collaboration with respective regional actors. Additionally he is the Expert Coordinator of the EU MSP Platform. **Urgeghe** is a conservation ecology expert with stakeholder engagement and participatory approach experience promoting the implementation of knowledge-transfer strategies, oriented to translate ecological information into advice on sustainable natural resource management. She supports the European Investment Bank in the alignment of their operations with the EU Taxonomy on Sustainable Finance, developing an Environmental Sustainability (ES) and Climate Action (CA) Tracking and Monitoring System. Additionally, she collaborated in the identification of sustainability criteria and indicators for the Blue Economy for the EU.

The project's **Associated Partners** bring unique knowledge and skills in big data analysis especially regarding biodiversity data and climate change, and funding of similar magnitude to the present proposal to map an MPA network in the Asia-Pacific region.

Zhao won an Elsevier Atlas award for his PhD paper that produced the most comprehensive and entirely data-driven prioritisation of MPA for the world (Zhao et al. 2020b). His prior work produced the first data-driven classifications of marine ecosystems at a global scale, including the effects of seasonality (Zhao and Costello 2019, Zhao and Costello 2020, Zhao et al. 2020a). Currently, he is working on a similar approach to prioritise MPAs for biodiversity conservation at regional scales with Yan **Sun** (Ocean

University of China). Dr Sun is an experienced modeller of carbon cycles and will advise this project's work regarding modelling Blue Carbon.

Kubota has won ten-year funding related to the UN Decade of Ocean Science for Sustainable Development. from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan for "*Technologies for mainstreaming the marine biodiversity big-data to conserve ocean wealth*". In addition to his own experience in macroecology and biodiversity conservation (Kubota and Kusumoto 2020), the project focuses on anthropogenic impacts (e.g. fishery, marine transportation, and climate change) on marine biodiversity (García Molinos 2019) and quantitative assessments of MPA benefits and costs based on systematic conservation planning (Takashina 2016, Takashina et al. 2017Shiono et al. 2021). This project includes experts in species distribution modelling to uncover macroecological marine biodiversity patterns and spatial conservation prioritization analysis to account for socioeconomic factors and climate change effects, notably Jorge **Garcia Molinos** (Hokkaido University), Nao **Takashina** (The University of Tokyo), and Takayuki **Shiono** (University of the Ryukyus).

4. Management structure and procedures

The project had six Work Packages (WP), described below. Details of WP, Deliverables (where M = month delivered), Milestones, Risk mitigation, and staff effort, are provided in Tables 1, 2, 3, 4, 5 respectively.

Table 1.

List of work packages (WP).

WP no.	WP Title	Lead Participant No.	Lead Participant Short Name	Person-Months	Start Month	End month
1	Project management	1	NORD	39.0	0	40
2	Ecosystems and connectivity	3	CCMAR	41.5	3	36
3	Species and habitats	2	UNESCO	42.0	3	36
4	Blue carbon	4	AU	47.5	3	36
5	Prioritisation	1	NORD	22.0	13	36
6	Stakeholder engagement	7	CLIMAZUL	34.0	3	36
7	Dissemination and communication	5	Science Crunchers	36.0	0	40
			Total person- months	**262**		

Table 2.
List of Deliverables.

Deliverable no.	Deliverable name	WP no.	Short name of lead part.	Type	Dissemin-ation level	Delivery date (in months)
1.1	Data Management Plan	1	NORD	R	PU	2
1.2	Report from the kick-off meeting	1	NORD	R	PU	2
1.3	Report from international cooperation	1	NORD	R	PU	36
2.1	Compilation of marine environmental data ready for ecosystem classification analysis and distribution modelling	2	CCMAR	R	PU	6
2.2	Paper on wave exposure index for all European coasts	2	CCMAR	DATA, R	PU	8
2.3	Marine ecosystem classification for surface waters of Europe	2	CCMAR	R	PU	10
2.4	Marine ecosystem classification for near seabed waters of Europe	2	CCMAR	R	PU	12
2.5	Depth integrated marine ecosystem classification for Europe.	2	CCMAR	R	PU	14
2.6	Paper on the marine ecosystem classifications for surface and near seabed waters of Europe	2	CCMAR	R	PU	16
2.7	Current connectivity map of European seas	2	CCMAR	DATA	PU	20
2.8	Climate velocity map for European seas under recent conditions	2	CCMAR	DATA	PU	24
2.9	Climate velocity map for European seas under future climate change scenarios	2	CCMAR	DATA	PU	28
2.10	Paper on how the proposed MPA network accommodates connectivity through current and climate velocities, now and under climate change scenarios.	2	CCMAR	R	PU	34
3.1	Compile additional data and publish it into OBIS.	3	UNESCO	DATA	PU	6
3.2	Publish maps and models of species environmental niches and geographic distributions in Europe on OBIS	3	UNESCO	DATA	PU	10
3.3	Publish maps and models of biogenic habitat distributions in Europe on EMODnet	3	UNESCO	DATA	PU	12
3.4	Database of species and habitats conservation status.	3	UNESCO	DATA	PU	16
3.5	Paper on marine species and habitat distribution models.	3	UNESCO	DATA	PU	30

Deliverable no.	Deliverable name	WP no.	Short name of lead part.	Type	Dissemin-ation level	Delivery date (in months)
4.1	Database of estimated carbon storage in European marine biogenic habitats	4	AU	DATA	PU	12
4.2	Database of carbon storage in European marine non-biogenic sediment habitats	4	AU	DATA	PU	12
4.3	Report on carbon storage within and beyond biogenic habitats	4	AU	R	PU	14
4.4	Scoring system for carbon storage capacity in European marine biogenic habitats and beyond.	4	AU	R	PU	16
4.5	Map of carbon storage capacity for European marine habitats	4	NORD	DATA	PU	18
5.1	Compilation of the layers of marine environment and ecosystem (created in WP2), species distribution and habitat (created WP3), and blue carbon (created in WP4) ready for prioritisation analysis.	5	NORD	DATA	PU	20
5.2	Paper on the spatial relationships between the measures of biodiversity and environmental conditions..	5	NORD	R	PU	24
5.3	Prioritisation analysis based on biodiversity variables	5	NORD	DATA	PU	26
5.4	Prioritisation analysis based on blue carbon scores.	5	NORD	DATA	PU	28
5.5	Prioritisation analysis based on biodiversity variables and blue carbon.	5	NORD	DATA	PU	30
5.6	Paper on the MPA networks in European Seas based on the prioritisation analysis for biodiversity conservation and blue carbon.	5	NORD	R	PU	36
5.7	Online atlas for Marine Spatial Planning	5	NORD	DATA	PU	34
6.1	Policy Brief on how proposed MPA network supports of Marine Spatial Planning in Europe with regard to Biodiversity and Blue Carbon.	6	Climazul	R	PU	36
6.2	Four regional case studies synthesising stakeholder views identified and outlined, meeting end user needs.	6	Climazul	R	PU	28
7.1	Communication, dissemination and exploitation plans	7	Science Crunchers	R	PU	4
7.2	Project website and social media accounts	7	Science Crunchers	DEC	PU	2
7.3	Development of four dissemination videos	7	Science Crunchers	DEC	PU	30

Deliverable no.	Deliverable name	WP no.	Short name of lead part.	Type	Dissemin-ation level	Delivery date (in months)
7.4.	Dissemination articles for children	7	Science Crunchers	DEC	PU	24
7.5	Impacts from the Communication, dissemination and exploitation activities	7	Science Crunchers	R	PU	38

Table 3.

List of milestones.

Milestone number	Milestone name	Related work package	Due date (month)	Means of verification
1	Environmental data ready for analysis	WP2	6	Data public in BioOracle and/or EMODnet
2	Ecosystem classification complete and submitted for publication	WP2	18	Paper submitted for publication
3	Current and climate velocity within proposed MPA network	WP2	34	Paper submitted for publication
4	Species data ready for analysis	WP3	6	New data public through OBIS
5	Species and biogenic habitat ranges maps complete	WP3	14	Maps visible online in OBIS and EMODnet
6	Paper submitted on Blue carbon scoring and mapping	WP4	32	Map published through EMODnet
7	Prioritisation analysis integrating biodiversity and blue carbon	WP5	30	Paper submitted for publication
8	Online atlas of prioritisation layers and environmental context for stakeholders	WP5	34	Atlas publicly available online
9	Network of stakeholders established	WP6	9	List of stakeholders on project website
10	European stakeholder workshop held	WP6	29	Report on outcome of discussion
11	Website online	WP7	2	Publicly visible online
12	International conference	WP7	35	Accomplishment of the event and book of abstracts

WP 1 Project management

Objectives

Lead and coordinate activities within the available budget to achieve the contractual obligations.

Table 4.

Critical risks for implementation.

Description of risk (indicate level of (i) likelihood, and (ii) severity: Low/Medium/ High)	Work package(s) involved	Proposed risk-mitigation measures
Early career team members lacking expertise or skills in parts of analysis (low likelihood, medium severity)	WP2, 3, 4, 5	Multiple advisors available amongst the partners to help the postdocs. For example, Assis, Burrows, Jueterbock, Costello and Kubota have experience in species and habitat modelling. Zhao, Costello and Abecasis have experience in spatial prioritisation software methods.
Illness or other unavailability of key staff (e.g., parental leave) (medium likelihood, medium severity)	WP2, 3, 4, 5	The partnership includes a range of expertise that is both complementary and synergistic. A reorganisation of responsibilities would be negotiated amongst the partners and the EC should a personnel issue compromise the project.
Lack of engagement from national maritime spatial planners	WP6	Climazul team includes the EU MSP Platform expert coordinator, and hence professionally connected with many existing MSP representatives. Partners have already contacted key stakeholders in preparing this proposal and received positive responses towards engaging if the project is funded. The project has also included a travel budget should stakeholders not have their own funding to attend meetings, or require honoraria.
Cancelling of the final conference due to public health situation (e.g., pandemic) (medium likelihood, low severity)	WP7	Virtual meeting as an option

Description of work

Objectives

Lead and coordinate activities within the available budget to achieve the contractual obligations.

Management (all tasks in WP1 lead by NORD)

Task 1.1. Financial management. Collate financial data and report to European Commission (EC) according to the Grant Agreement.

Task 1.2 Detailed Data Management Plan documented. The project participants have a long track record in advocating for open access to biodiversity and environmental data, as outlined in the Section 1.2 Methodology “Open science”. Here, this plan will detail the technical formats and metadata needed for the publication of project results into OBIS, EMODnet, JRc and other platforms which may find the data useful. For example, we note the recommendation of the Technical Expert Group (TEG) on MSP data to use the

EMODNET MSP model that combines “Basemaps” and MSP INSPIRE data models (Anonymous 2021).

Table 5.
Summary of staff effort in person months (PM). Highlighted yellow/bold for WP-leaders.

Participant Number/Short Name	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total PMs per Participant
1 NORD	**12.5**	0.5	4.0	18.0	**14.0**	2.5	4.0	**55.5**
2 SAMS	1.0	5.0	1.0	0	0	0	0.5	7.5
3 CCMAR	4.5	**31**	1.0	0	0.5	0.5	0.5	**38.0**
4 Science Crunchers	4.5	0	0	0	0	2.0	**25.0**	**31.5**
5 AU	3.0	0	0	**25.5**	4.0	2.0	1.5	**36.0**
6 UNESCO	4.5	0	**34**	0	0.5	0.5	0.5	**40.0**
7 CLIMAZUL	5.0	0.5	0	2.0	2.0	**26.0**	2.5	**38.0**
8 OUC	1.5	3.0	0	0	0	0	0.5	5.0
9 RYUKYUS	1.5	0	0	0	0	0	0.5	2.0
10 JNCC	1.0	1.5	2.0	2.0	1.0	1.0	0.5	9.0
Total Person Months	**39**	**41.5**	**42**	**47.5**	**22.0**	**34.0**	**36**	**262.0**

Task 1.3. Project reporting. Progress technical reports will be provided to the EC as required according to the Grant Agreement. Nord will synthesise the WP reports into a coherent overall report.

Meetings

Task 1.4. One kick-off and three annual meetings of all project participants, in-person. The kick-off meeting will review the proposal and latest science to finalise the methodologies and timetable. Meetings will circulate between the WP leaders Bodo, Algarve and Aarhus. (Months 0, 12, 24, 36).

Task 1.5. Quarterly online meetings with WP leaders to approve reports to EC, assess progress, budget and other contractual obligations.

In addition, other WP leaders will call specific meetings and workshops on technical aspects to discuss and agree details of methods and interpret results.

International Cooperation

Task 1.6. Within Europe, we note that related research projects will be funded by Horizon Europe, e.g., Biodiversity Partnership (HORIZON-CL6-2021-BIODIV-02-01). The coordinator will engage with these projects and other relevant Horizon Europe Missions and partnerships to seek a synergy of effort and collaboration. In addition, the coordinator has been involved in the Group on Earth Observations for over a decade and will actively forge links with its GEOSS and GEO BON (including Europa BON).

Task 1.7. Beyond Europe, the project will exchange knowledge, skills and experiences with its Associated Partners in Japan and China who have won independent funding to conduct similar MPA network mapping in the Asia Pacific seas. They will be involved within individual WP tasks where of common interest, and their travel costs covered to visit Europe for the annual meetings.

Deliverables (brief description and month of delivery)

Technical and financial reports will be provided to the EC as required in the contract.

D1.1 Data Management Plan (M2)

D1.2 Report from the kick-off meeting (M2)

D1.3 Report from international cooperation (M36)

Deliverables (brief description and month of delivery)

Technical and financial reports will be provided to the EC as required in the contract.

D1.1 Data Management Plan (M2)

D1.2 Report from the kick-off meeting (M2)

D1.3 Report from international cooperation (M36)

WP 2 Ecosystem and connectivity modelling

Objectives

Prepare high resolution marine environmental layers for bio-climatic modelling tailored for Europe.

Classify surface and near seabed marine ecosystems in European seas using environmental data.

Map MPA oceanographic connectivity.

Map climate velocities.

Compare connectivity to the proposed MPA network.

Compare climate velocity to the proposed MPA network.

Assess how the proposed MPA network accommodates future species distributions under climate change.

Description of work This work will be conducted by a postdoc at CCMAR under the direct supervision of Assis, with advice from Burrows (SAMS), and OUC (Zhao).

Task 2.1 Prepare high resolution environmental layers

Marine data layers for surface and near seabed present-day conditions (years 2010-2019) will be produced with data from Copernicus and European Centre for Medium-Range Weather Forecasts global ocean (re)analysis. Future layers (years 2030-2100) will be produced for different "Shared Socioeconomic Pathway" (SSP) climate change scenarios, by averaging data from (at least 5) distinct Atmospheric Ocean General Circulation Models (AOGCM) and ensembles provided by the Coupled Model Intercomparison Projects (CMIP6). Scenarios will span from the high mitigation SSP119, matching the Paris Agreement, to the lower mitigation SSP460 and SSP585 (business-as-usual). This will be performed for temperature, salinity and sea ice thickness, light at sea bed (exponential function integrating depth, photosynthetically active radiation and turbidity; Assis et al. 2017b), dissolved oxygen, nitrate, phosphate, iron, productivity, pH, current velocity, silicate, chlorophyll, air temperature and precipitation. Six predictors per variable will be produced for ecological modelling: the long-term average; the minimum and maximum records; the long-term average of the minimum and maximum records per year (e.g., temperature of the warmest month, on average); and range. These predictors will be statistically downscaled to a common spatial resolution of 0.05º by fitting a kriging model based on the 12 nearest values of each focal cell (methods detailed in Assis et al., 2017a). The reliability of downscaled layers will be inferred with in situ quality-controlled data provided by the Global Ocean Data Analysis Project (GLODAP V2) for temperature, salinity, phosphate, nitrate, silicate, dissolved oxygen and chlorophyll, by cross-validating the outputs of downscaling the raw data used to produce data layers at the locations (geographical position and depth) of GLODAP, with the actual data provided by this dataset (e.g., Assis et al., 2017a). *Lead: CCMAR*

Task 2.2. Calculate wave exposure index for all European coasts

Wave exposure indices will be calculated for Europe at a fine scale (50-100m,1-2 arcseconds) by modelling wave fetch (the distance to the nearest land in all directions) around focal grid cells using a multiscale search algorithm (Burrows 2012, Burrows et al. 2008). These indices will be complemented with the direction of the average wave fetch vector, allowing estimation of alignment with wind directions and the angular standard deviation of fetch directions. Wave exposure indices will be calibrated against wave data and data products in areas where fine scale, fully parameterised wave climate models exist. *Lead: SAMS*.

Task 2.3 Identify surface and deep-sea marine ecosystems in European seas using environmental data

The marine ecosystems in European seas will be identified by an unsupervised cluster analysis (Zhao et al. 2020a) following a principal components analysis (PCA) of the physical, biochemical, and nutrient variables produced in Tasks 2.1 and 2.2. Because many variables are correlated, the PCA extracts the key relationships that distinguish the character of the ecosystems. The clustering analysis for identifying surface and deep-sea ecosystems will be respectively based on surface and deep-sea variables. The clustering

analysis for the future distribution of marine ecosystems will be based on available predicted future variables. The method of unsupervised cluster analysis can analyse millions of observations with many variables. We have previously applied it in a global-scale marine ecosystem identification (Zhao et al. 2020b), which showed good correspondence with previous global classifications that were respectively based on clustering analysis (Sayre et al. 2018), biological species (Costello et al. 2017), and an expert's opinion. The global marine ecosystems identified by this method have been used as the layers of marine ecosystems in the prioritisation for global marine biodiversity conservation (the paper won an Elsevier Atlas Award) (Zhao et al. 2020a, Zhao et al. 2020b). A similar method was further applied to explore seasonal variations of the marine ecosystems globally (Zhao and Costello 2019). *Lead: CCMAR, Participants Nord, OUC*.

Task 2.4 MPA oceanographic connectivity and climate velocity

MPA connectivity estimates will be inferred with a biophysical model based on previous developments of our team for present-day conditions with current data from *Copernicus* (e.g., Assis et al. 2021, Assis et al. 2018, Buonomo et al. 2017, Klein et al. 2016). Individual particles simulating planktonic propagules will be released on a daily basis throughout a complete year from source sites located at regular distances (e.g., 1 km) along European coastlines. The model will incorporate key biological parameters such as spawning, settlement and mortality, and will determine the position of each particle at every hour of simulation using trilinear interpolation over the ocean velocity fields (method details in Assis et al. (2021)). Individual trajectories will be aggregated to develop pairwise connectivity matrices of probability between sites by dividing the number of particles released from site *i* that reached site *j*, by the total number of particles released from site *i*. To account for interannual variability, the model will perform individual runs per year (e.g., 2010-2019, 2090-2099). The database of marine species planktonic duration (Assis et al. 2021) will facilitate the overall interpretation of connectivity patterns by grouping biodiversity into higher taxa and ecological groups with similar average planktonic duration. Network analyses will use the connectivity estimates per group to structure graphs (nodes: sites; edges: probability of connectivity) that will allow determining centrality and betweenness, i.e., hubs for connectivity and stepping-stone links (Assis et al. 2021). *Lead: CCMAR, Participants SAMS*

Task 2.5. Future climate velocity and connectivity

Thousands of marine species have been moving their geographic distribution in response to ocean warming since the 1950s (Chaudhary et al. 2021). These movements happen regardless of the locations of MPA because even species within MPA occur outside (Costello and Connor 2019). Except for equatorial low latitudes where species richness is decreasing (Chaudhary et al. 2016, Chaudhary et al. 2017, Chaudhary et al. 2021), species richness is increasing in high latitudes as species shift their distributions so they remain in their optimal thermal niche; a pattern also seen in climate velocity-based predictions (García Molinos et al. 2016). Within Europe we thus expect to observe species arriving from lower latitudes while polar species may contract their ranges. It would be reassuring to know whether the MPA network proposed in this project would

still accommodate species under future climatic conditions, and if so what species. Thus, following the MPA prioritisations and completion of Task 2.4, species distributions would be remodelled using future climate change scenarios based on an average annual global warming of 1.5, 2 and 3 ^{o}C, and the future ranges compared with the proposed MPA network. *Lead: CCMAR, Participants SAMS*

Deliverables

D2.1. Compilation of marine environmental data ready for ecosystem classification analysis, and for species and biogenic habitat distribution modelling (WP3). (M6).

D2.2. Paper on wave exposure index for all European coasts. (M8).

D2.3. Marine ecosystem classification for surface waters of Europe. (M10).

D2.4. Marine ecosystem classification for near seabed waters of Europe. (M12).

D2.5. Depth integrated marine ecosystem classification for Europe. (M14).

D2.6 Paper on the marine ecosystem classifications for surface and near seabed waters of Europe. (M16).

D2.7. Current connectivity map of European seas. (M20).

D2.8. Climate velocity map for European seas under recent conditions. (M24).

D2.9. Climate velocity map for European seas under future climate change scenarios. (M28).

D2.10. Paper on how the proposed MPA network accommodates connectivity through current and climate velocities, now and under climate change scenarios. (M34).

WP 3 Species and biogenic habitat distributions

Objectives

Gather additional observed (recorded) marine species distribution data not already in OBIS (e.g., from GBIF), so species are mapped by latitude, longitude, depth and year.

Run Species Distribution (Environmental Niche) Models on as many species as have adequate data (estimated 15,000) and publish these as a new service on OBIS.

Model biogenic habitat distributions, and validate and refine from comparison with observed EMODnet habitat maps, and publish these on EMODnet.

Map observed and modelled species richness, and compute richness indices to support understanding of marine biodiversity distribution in Europe.

Description of work

Task 3.1. Compile data and prepare workflows for future efficiencies to access marine data from GBIF and other sources.

A growing gap in the data available in OBIS is the increased marine data that is published in the Global Biodiversity Information Facility (GBIF) through quality assured citizen science initiatives and large datasets which may contain only a small proportion of marine species (e.g., herbarium collections). At present researchers would need to go to both OBIS and GBIF to access the full range of data available, resulting in time-consuming filtering of duplicate data in both data systems. To maximise available data, this project will build streamlined workflows to search for additional data in GBIF not already in OBIS, following quality checks, and make it available to OBIS users. If additional significant sources of data are also identified not online and accessible through the GBIF and OBIS Darwin Core standard for Europe these will also be digitally published through OBIS. A post-doc will conduct this task under the supervision of Ward Appeltans and Pieter Provoost of OBIS. After an initial focused addition of data to support Tasks 3.2 and 3.3, a reassessment of potential additional data availability will be conducted every six months (Fig. 5). *Lead: UNESCO*

Task 3.2. Model marine species and biogenic habitat geographic ranges and environmental niche for Europe.

Several statistical algorithms are in use for modelling species environmental niche and geographic range, including methods like Boosted Regression Trees and the MaxEnt, as well as methods used in AquaMaps (e.g., Ramos Martins et al. 2021, Fragkopoulou et al. 2021, Assis et al. 2018, Assis et al. 2017a, Assis et al. 2017c, Boavida et al. 2016, Assis et al. 2015). AquaMaps has published digital range maps for some 25,000 species which have been used at a global scale by this project's participants (Zhao et al. 2020b, Lin et al. 2020). However, these are at too coarse a spatial resolution for use in Europe and their use of FAO areas to delimit geographic ranges results in artificial straight-line range boundaries.

Thus, this project will utilise observed species distribution records in OBIS and collated environmental layers (WP2) to statistically (mean, median, standard deviation etc.) define the environmental niche (e.g., temperature, ice cover, nutrient concentration, dissolved oxygen, salinity, depth) of as many species with sufficient data points, and thereby predict its potential distribution under those environmental conditions. We estimate half of the species in OBIS and Europe may have sufficient data for modelling, that is, about 15,000 species. Such a large dataset will provide a good basis to estimate regional variation in species richness. Because it also includes species composition, areas with few but unique species will also be identified.

The same data can be used to model the distribution of biogenic habitats and biomes (i.e., large areas of similarly structured vegetated habitat) that comprise different species, as we have demonstrated for seagrass and kelp, and other have for corals and

mangroves, at global scales (Jayathilake and Costello 2018, Jayathilake and Costello 2020a, Jayathilake and Costello 2020b, Jayathilake and Costello 2020, Jayathilake and Costello 2021). This approach has the advantage in that it can include all species comprising the biome, including rare species which could not be modelled alone. Alternatively, observations that have been pre-classified to a particular habitat may be used as the predictor variables for habitats. Thus, the project will predict distributions of biogenic habitats that have been recognised as benefiting from spatial protection measures such as MPAs and/or make a sustainable contribution to carbon sequestration. These maps will be published on the EMODnet Habitats portal.

Individual niche models will also be projected to layers representing environmental conditions of contrasting SSP scenarios of future climate change (e.g., years 2030-2100 under SSP19, SSP460 and SSP585; WP2) to map distributional range shifts per species, as well as key conservation areas of climatic refugia, where species might persist in the long-term.

This species and biogenic habitat modelling work will be conducted by the postdoc based at OBIS UNESCO who will be advised by experts at Nord (Costello, Jueterbock), SAMS (Burrows), CCMAR (Assis, Abecasis) and international collaborators in China and Japan. *Lead: UNESCO. Participants SAMS, CCMAR, NORD, JNCC*.

Task 3.3. Maps of species richness using observed and modelled data.

Estimating species richness is always compromised by data insufficiency. However, estimates of species richness with confidence limits can be calculated based on the observed data produced in Task 3.1, and compared with modelled species ranges from Task 3.2. This project will develop workflows to estimate species richness using a range of measures ranging from actual counts, to rarefaction and subsampling estimators (e.g., Hurlberts Index, ES50), and overlaid maps of species ranges.

The Prioritisation WP5 will compare these estimates to the distribution of ecosystems and habitats (from EMODnet). Previous studies find that areas with high environmental heterogeneity tend to have high species diversity (e.g., Asaad et al. (2019)), although exceptions may occur. This improved understanding of the relationships between measures of biodiversity and environmental conditions will support policy decisions that need to be made where data is incomplete. *Lead: UNESCO*

Task 3.4. Apply conservation status to species and habitats in Europe.

This task will review the growing number of designations of species and habitats that note their importance for nature conservation and assign these attributes to enable them to be prioritised in WP5. Sources to be reviewed will include the Bird and Habitats Directives (European Council 1992, European Council 2009), Marine Mammal Habitat areas, OSPAR, HELCOM, ICES Vulnerable Marine Ecosystems (VME), Special Protected Areas under the Barcelona Convention, Ecologically or Biologically Significant marine Areas (EBSA) under the Convention on Biological Diversity, EU Red Lists of Threatened (marine) Species and Habitats (Gubbay et al. 2016), the Ramsar sites under the

Convention on Wetlands of International Importance, and IUCN Red List status. We note the resources identified by the Marine Expert Group under the Birds and Habitat Directives in its meeting of February 2021.

For seabed habitats we will work with the EMODnet Seabed Habitats consortium to add attribution of Red List conservation status (e.g., 'endangered', 'vulnerable', 'least concern') to the habitat maps already published via EMODnet, including the broad-scale seabed habitat map for Europe, EUSeaMap *[2] (Vasquez et al. 2021b, Vasquez et al. 2021a, Vasquez et al. 2020) and the collection of over 800 habitat maps from surveys *[3] .

For fishery species, this project would note that under the EU Common Fisheries Policy that there are fish species prohibited to fish for under the Technical Measures regulation, and Fish Stock Recovery areas established under its Article 8. The World Register of Introduced Species (WRiMS), initiated by the proposal coordinator, provides information on Introduced and Invasive species in European seas (Costello et al. 2021).

Lead: UNESCO. Participants JNCC, NORD.

Deliverables

Following delivery of data for WP5 by the Months indicated, these deliverables will be published in scientific journals to increase their visibility and may need to be revisited if required during prioritisation data analyses (e.g., alternative spatial resolutions).

D3.1. Compile additional data and publish it into OBIS. (M6).

D3.2. Publish maps and models of species environmental niches and geographic distributions in Europe on OBIS. (M10).

D3.3. Publish maps and models of biogenic habitat distributions in Europe on EMODnet. (M12).

D3.4. Database of species and habitats conservation status, linked to EMODnet Habitat maps. (M16).

D3.5. Paper on marine species and habitat distribution models. (M30)

WP 4 Blue Carbon

Objectives

Generate overview on blue carbon storage of marine habitats as background for mapping and modelling of current and future blue carbon (hereafter carbon) storage capacity at the European scale. Specific objectives are:

(1) A review informing an open-source database of existing carbon data in biogenic habitats and beyond,

(2) Identification of key variables regulating carbon storage,

(3) Development of a scoring system for carbon storage capacity, and

(4) European map reflecting carbon storage capacity.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

A post-doc at Nord will devote most of their first year to this WP under AU supervision while the biodiversity data layers are being prepared for the prioritisation analysis (WP5).

Task 4.1. Review of the literature and existing databases (e.g., PANGAEA) for data on carbon storage (including stocks, burial rates) in *marine biogenic (flora and fauna dominated) habitats* that occur in Europe. Data will be grouped by habitat and key species and assigned preliminary carbon scores for each group. Data to be available in open-source database. *Lead: AU. Participants Nord, JNCC, SAMS*.

Task 4.2. Review of the literature and existing databases (e.g., PANGAEA; MOSAIC described by van der Voort et al. (2021)) for data on carbon storage (including stocks, burial rates) in marine *non-biogenic sediment habitats* that occur in Europe, noting key site information (e.g., wave and current exposure, depth, sediment grain) and sampling information (e.g., depth of sediment stock, method). Data to be available in open-source database. *Lead: AU, Participants: Nord, SAMS, JNCC*.

Task 4.3. Identify key variables regulating carbon storage within and beyond biogenic habitats. Based on the geographic position of carbon data (compiled in Task 4.1 and 4.2), we extract matching environmental data (e.g., current velocity and exposure, temperature, nutrients, chl. a, oxygen, light, depth, distance from shore, seafloor topography (e.g., sedimentation basin or not) from the layers in WP2 to be used as predictors in empirical analyses of factors influencing carbon storage capacity. Analyses will be conducted separately for biogenic habitats and non-biogenic habitats, to the extent data allow; and are likely to include non-parametric clustering techniques and generalised additive models (GAM). Part of the data should be used for validation. Even within biogenic habitats dominated by (for example) a given seagrass species, carbon storage capacity may vary considerably, e.g., due to temperature, wave and current exposure conditions. Wave sheltered habitats typically store more carbon than exposed ones, which would suggest variable carbon storage scores within given habitats depending on environmental conditions. The variability of carbon storage in non-biogenic sediment habitats is much less well understood than that of biogenic habitats and there are also major knowledge gaps on the net effect of e.g., increasing temperature, acidity, and decreasing oxygen concentrations on the carbon storage (e.g., Diesing et al. 2017). *Lead: AU, Participants: Nord, SAMS*.

Task 4.4. Development of a scoring system (rubric) for carbon storage capacity based on information gained in Tasks 4.1-4.3. For biogenic habitats, we expect it will be reasonable to assign a specific score by habitat and/or dominant species, probably with subdivision depending on environmental conditions (e.g., wave or current sheltered vs exposed settings). For the sediment habitats that are not biogenic habitats, we expect assigning

variable carbon storage scores based on combinations of environmental settings as identified in task 4.3. *Lead: AU, Participants: Nord*.

Task 4.5. Mapping of carbon storage capacity. The scoring system developed in Task 4.4 will enable mapping of carbon storage capacity in European seas. It will then be used to optimise MPA locations for carbon storage benefits in WP5 and published as another data layer on EMODnet. The scoring system will also guide future predictions of carbon storage capacity; for the biogenic habitats, the approach will also apply carbon scores to the projected future environmental conditions and species and habitat distributions. *Lead: Nord, participants: AU, Participants: OUC, JNCC*.

The combined effort in task 4.1 to 4.5 will thus result in easily accessible information on carbon storage and form the basis for predictions of carbon storage capacity under different management schemes. The developed scoring system will also support decision makers in quantifying ecosystem services related to climate change mitigation, and link management of climate change and biodiversity. After the datasets are ready for WP5 to begin prioritisation mapping, this WP will write up the data, scoring system and map outputs as a paper (Milestone 6).

Deliverables

D 4.1 Database of estimated carbon storage in European marine biogenic habitats based on review. (M12).

D 4.2 Database of carbon storage in European marine non-biogenic softbottom habitats based on review. (M12)

D 4.3 Report (draft paper) on carbon storage within and beyond biogenic habitats (Report, M14)

D 4.4 Scoring system for carbon storage capacity in European marine biogenic habitats and beyond. (M16)

D 4.5 Map of carbon storage capacity for European marine habitats. (M18).

WP 5 Prioritisation

Objectives

This WP will utilize the results of WP 2, 3, and 4 to conduct prioritization analysis for designing MPA network for biodiversity conservation and blue carbon. Through the prioritization, 10% and 30% of European seas will be identified as an optimal MPA networks for biodiversity, blue carbon and both together. Online atlas of the proposed MPA networks and associated environmental, habitat and species layers will be published to aid practical Marine Spatial Planning.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

A postdoc at Nord will conduct this under the supervision of Costello (Nord) and advice from CCMAR (David Abecasis) and international Associated Partners OUC (Zhao) and Ryukyus.

Task 5.1. MPA network based on biodiversity variables.

The environment, ecosystem, species distribution and habitat layers created in WP2 and WP3 will be introduced into the prioritization analysis to identify where MPA networks should be optimally established for marine biodiversity conservation. A specific prioritization algorithm in the software *Zonation* will be applied to design MPAs networks covering 10% and 30% of European seas meanwhile maximizing biodiversity conservation efficiency. This software selects the most parsimonious area to maximize inclusion of all biodiversity measures (species, habitats and ecosystems) within the 10% and 30% limits.

Previously we reviewed the range of overlapping criteria that have been developed for such prioritisations across all international protected area designations (Asaad et al. 2017). Our analysis found the above suite of species and habitat variables provided the necessary measures of biodiversity required. Furthermore, there were significant positive correlations in the spatial relationships of these variables at regional and global scales (Asaad et al. 2018a, Asaad et al. 2018b, Asaad et al. 2019). Our subsequent global analysis shows that while most threatened species will occur within a global MPA network, some may not (Jefferson et al. 2021). Thus, highly threatened species will still need species specific protection measures which may be additional to the proposed MPA network. To aid understanding of why particular areas may be more and less important for biodiversity we will analyse the spatial relationships between the biodiversity variables and threatened species and habitats status.

Task 5.2 MPA network based on blue carbon scores

As conducted in Task 5.1, the blue carbon layer created in WP4 will be used to prioritize areas for maximizing carbon storage. The same prioritization algorithm will be applied to identify the 10% and 30% areas of European seas which would best support the blue carbon targets in Europe to help reduce greenhouse gas concentrations.

Task 5.3 MPA network based on biodiversity and blue carbon

Synthesizing the research conducted in Task 5.1 and 5.2, a prioritization analysis will aim to maximise protection of both biodiversity and blue carbon within 10% and 30% of European seas as an integrated MPA network for biodiversity conservation and blue carbon simultaneously. The proposed MPA network will aim to (target) (1) include at least 80% of all species; (2) be representative of all habitats and ecosystems; and (3) maximize blue carbon benefits, within 10% and 30% of the sea area.

The proposed MPA networks will be compared with current MPAs, OECM and the sites in the Common database of Designated Areas hosted by the European Environment Agency. These will include Special Areas of Conservation in Natura 2000, and areas

prioritised as UNESCO World Heritage Sites, Important Bird Areas, Key Biodiversity Areas, CBD EBSA, Ramsar, Barcelona Convention, HELCOM and OSPAR prioritized locations. The network can be re-designed assuming all or some of these areas are protected.

Task 5.4 Online atlas for Marine Spatial Planning

The optimal MPA networks created in Task 5.1, 5.2, 5.3 will be made available through (1) EMODnet, (2) the **EC Knowledge Centre for Biodiversity** and Global Conservation and Development (European Commission Joint Research Centre Directorate D – Sustainable Resources) and (3) as an online atlas mapped via ArcGIS. Users will be able to switch on and off maps (data layers) showing the physical and chemical environmental variables, species richness estimators, habitat distributions, and thus understand the data behind the MPA network proposed.

Additional maps of activities of social and economic importance could be added in the online atlas and overlaid with the MPA network to aid Marine Spatial Planning. It can also link to activities funded by the European Maritime and Fisheries Fund, in particular calls and projects on Maritime Spatial Planning.

Deliverables

D5.1. Compilation of the layers of marine environment and ecosystem (created in WP2), species distribution and habitat (created WP3), and blue carbon (created in WP4) ready for prioritisation analysis. (M20).

D5.2. Paper on the spatial relationships between the measures of biodiversity and environmental conditions. (M24).

D5.3. Prioritisation analysis based on biodiversity variables. (M26).

D5.4. Prioritisation analysis based on blue carbon scores. (M28).

D5.5. Prioritisation analysis based on biodiversity variables and blue carbon. (M30).

D5.6. Paper on the MPA networks in European Seas based on the prioritisation analysis for biodiversity conservation and blue carbon. (M36).

D5.7. Online atlas for Marine Spatial Planning. (M34).

WP 6 Stakeholder engagement

Objectives

Engage maritime spatial planning, science to policy and MPA stakeholders within each EU sea basin to solicit feedback on the project's atlas design and to support uptake of the prioritisation algorithms of the atlas by planners and other maritime stakeholders.

Description of work

We are aware of current activities within DG Environment Nature Protection to provide advice to member states regarding achieving MPA goals and engaging with stakeholders (e.g., European Commission 2021). Thus, the work programme here will support these efforts and the project partners will adapt the work plan to synergise efforts. For example, to combine meetings to reduce stakeholders travel time and costs.

The WP6 leader will participate in project team meetings and work packages on ecosystems and connectivity (Task 2.3), blue carbon (Task 4.4) and prioritisation (Tasks 5.3 and 5.4) to understand elements of the research methodology, results, and aid design of the online atlas, incorporating end user feedback as identified below.

Task 6.1. We will engage with relevant science, policy and conservation stakeholders for each sea basin, as proposed in the table below, and invite their participation in regional project advisory panels. We have contacted some of the institutional stakeholders below and they have confirmed their interest in engaging with the project.

We will form four Stakeholder Advisory Panels, one for each sea basin, including science to policy experts; regional seas conventions contacts; national and regional maritime spatial planning authority representatives; academic advisors; and NGOs supporting marine protected area implementation.

We will engage with (1) the Regional Seas Conventions OSPAR, HELCOM, Barcelona Convention (UNEP/MAP), WestMed Initiative, and Common Martime Agenda for the Black Sea, (2) MSP coordinators through the EU MSP Platform, National representatives, Technical Expert Group (TEG) on Data for MSP; and (3) Relevant ongoing or recently completed projects/activities and MPA NGOs, including TBDSIM ATLANTIC, MOSES, INTEMARES, MSP-OR, eMSP NBSR, Birdlife, WWF, HELCOM VASAB MSP WG, MARMONI, MedPAN, MSP-MED, MPA NETWORKS, MUSES, PHAROS4MPAS, MARSPLAN II.

We will host online meetings as the project is developed to share knowledge and insights on incorporating biodiversity and ecosystem services in maritime spatial planning and decision-making, highlighting compatible sectors where synergies exist and information needs of stakeholders. Preliminary project results will be shared with stakeholders to capture their feedback, thereby ensuring scientific terms, assumptions and methods are clearly explained as relevant to the needs of end users.

Our project will hold regional workshops each year (virtual and in-person) to identify with stakeholders potential use cases for the atlas to support an ecosystem approach to maritime spatial planning, incorporating targets to protect biodiversity in 30% of the sea basin area, and a commitment to 10% no-take (fully protected). We will capture details of proposed future case studies. Where possible, in-person workshops will be convened to coincide with EU Maritime Spatial Planning Expert Group meetings, to reduce costs and maximise attendance. *Lead: CLIMAZUL*

Task 6.2 Form a project Stakeholder Advisory Board which includes at least two representatives from each regional advisory committee. Host virtual meetings annually to share outcomes of discussions and insights from regional committees and distil recommendations for the project and for policy guidance. *Lead: CLIMAZUL*

Task 6.3 Co-create a policy brief on Biodiversity, Blue Carbon and Marine Spatial Planning with stakeholders for dissemination internationally. *Lead: CLIMAZUL, Partners: Science Crunchers*.

Deliverables

D6.1. Policy Brief on how proposed MPA network supports Marine Spatial Planning in Europe with regards to Biodiversity and Blue Carbon. (M36).

D6.2: Four regional case studies synthesising stakeholder views identified and outlined, meeting end user needs. (M28).

WP 7 Dissemination and Communication

Objectives

Ensure effective external communication of the project to promote that (i) the lessons learnt are adequately disseminated to target stakeholder audiences, including society to raise ocean literacy, and (ii) the results are exploited by key end-users, through WP6, scientific papers from WP2, 3, 4, and 5, and in cooperation with other projects of this Horizon Europe call.

Description of work

The tasks here described operationalize the Dissemination, Exploitation, and Communication plan (as detailed in section 2.2 of this proposal and highlighting how the different tasks will contribute to achieving the outcomes of the project and maximize their impact).

Task 7.1 Elaboration of the communication, dissemination and exploitation plans. *Lead: Science Crunchers. Partners: NORD*

Task 7.2 Branding and communication. Develop the visual identity of the project, publish and manage the project website, and set up a YouTube Channel and Social media accounts (Twitter and LinkedIn) for fluent external communication and bring the project close to different audiences. Graphic guidelines will be developed for digital and print communication (e.g., videos, posters, brochures, slide decks) for consistent and coherent communication by all partners. At least 4 short videos, 4 brochures and 4 posters about the project and key messages and results will be produced and published on these digital platforms. Videos will target key concepts in the project, such as (i) Why an MPA network is needed in Europe, (ii) How such a network is being designed to prioritise biodiversity and maximise blue carbon, (iii) results of the prioritisation and why they matter, and (iv) how to use the online atlas. *Lead: Science Crunchers*.

Task 7.3 International conference on Marine Protected Areas and Marine Spatial Planning. An international conference will be organized at the end of the project (and hosted by Nord), in close collaboration with the European MSP Platform, where the project's results will be presented and open to the scientific community. Keynote speakers will be invited, as well as partners from other approved projects under the same call as MPA Europe and beyond Europe. *Lead: NORD, Partners: Science Crunchers*.

Task 7.4. Special Issue of a Journal. As an outcome from the conference the project will sponsor an Open Access Special Issue of an international, reasonably priced open access, peer-reviewed journal (e.g., PeerJ, Frontiers in Biogeography, Scientia Marina). *Lead: NORD*.

Task 7.5 Bridging the gap between science and children. Scientists from different partners will write articles appropriately written for children (over 8 years old) and connect with local schools from each partner country to have the articles peer-reviewed by local children (and supervised by their teachers). At least 6 articles will be produced covering different topics of the project. The articles will be produced in different languages (to involve different countries represented in this consortium and in the other projects funded within this same call), translated into various languages (DK, EN, FR, GR, NO, PT), illustrated, and disseminated via the website and the other digital channels. *Lead: Science Crunchers. Partners: all partners*.

Deliverables

D7.1 Communication, dissemination and exploitation plans (M4).

D7.2 Website and social media accounts' implementation (M2).

D7.3 Development of four dissemination videos (M30).

D7.4. Dissemination articles for children (M24).

D7.5. Impacts from the Communication, dissemination and exploitation activities (M38).

EUSeaMap broad-scale predictive habitat map for Europe: http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/10d3d35c-8f8e-40ff-898f-32e0b037356c

EMODnet Seabed Habitats collated habitat maps: http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/061c9d9c-8dc4-449f-8ac6-758840253fc3

5. Outcomes

MPA Europe has delivered a broad range of Dissemination, Exploitation and Communication (DEC) actions across the main planned channels, including the project website, social media, videos, infographics, scientific publications, conferences, stakeholder engagement, and policy-relevant communication. By the end of June 2026, these actions had generated 58,798 website visits, 2,923 LinkedIn connections and

234,873 LinkedIn impressions, plus 277 followers and 129 mentions across Twitter/X and Bluesky. They also supported more than 16,000 interactions with infographics and videos across several platforms. These and other achievements have been summarised in the MPA Europe In Numbers page.

The project's DEC activities also contributed to substantial scientific, policy, and stakeholder engagement. By June 2026, MPA Europe had participated in or organised more than 135 events, engaged 12,476 people (https://mpa-europe.eu/mpa-numbers/) and produced 59 publications, including 21 peer-reviewed papers. Compared with D7.1, the strategy was refined through stronger KPI monitoring, greater emphasis on intermediate as well as final results, and a more integrated use of web, social media and partner-led dissemination activities. Beyond the end of the project, and for at least four years, MPA Europe will maintain the accessibility and usability of its core public-facing assets, including the website, public deliverables, open-access publications, repository-based outputs, and the stakeholder and communication networks established during implementation.

Target audiences

The initial DEC plan identified a broad set of target audiences for MPA Europe, reflecting the scientific, policy, technical, and societal relevance of the project. These included scientists, policymakers, non-governmental organisations, European regional sea organisations, stakeholders involved in Marine Protected Areas (MPA) and Maritime Spatial Planning (MSP), and the general public. This overall audience structure remained valid throughout the project duration. However, as the project progressed, the types of outputs produced, and the channels used to reach these audiences, became more clearly differentiated.

Scientific audiences were primarily addressed through peer-reviewed papers, published datasets and data papers, conference presentations and technical outputs. Policy and governance audiences, as well as marine managers and planners, were addressed through stakeholder workshops, and their respective reports and FAQs, the project's LinkedIn page, the International Conference on Marine Protected Areas in Marine Spatial Planning (MPAinMSP) organised by the consortium, policy-facing communication, the MPA Europe Atlas for MSP, and the gradual release of project tools and results, available in MPA Europe's website and Zenodo community. Broader communication towards the general public and education-oriented audiences was supported through videos, infographics, articles for children, lectures, interviews, media activities, and other outreach activities, all published in the website.

Dissemination

In the original DEC Plan (D7.1), dissemination was defined as the sharing of project results with audiences most likely to use them, particularly scientists, policymakers, practitioners, and other relevant stakeholders. The original plan foresaw dissemination

through the project website, scientific publications, newsletters, a policy brief, the MPAinMSP International Conference, and other joint meetings and activities. The updated DEC framework confirms that these objectives were addressed through a broad set of scientific, policy-facing and stakeholder-oriented dissemination activities.

The project website functioned as the main access point for public outputs, including peer-reviewed publications, participation in webinars, seminars and other scientific meetings, supporting the visibility and uptake of project results among research and expert audiences. Many of these participations were reported in the News section of the website.

Newsletter-based dissemination also contributed to the transfer of project updates, results, and opportunities to interested audiences beyond direct website traffic and LinkedIn reach. Over the course of the project, MPA Europe circulated eight project newsletters (from September 2023 to June 2026), helping consolidate a growing mailing list of subscribers interested in project developments, outputs, and events. The number of subscribers increased from 31 in the first newsletter to 190 by December 2024 and reached 250 by December 2025. In addition, MPA Europe contributed to the Blue Horizons newsletter from Issue #1 onward. This joint newsletter of the 12 sister projects included in the *MPA Community Network* allowed for expanding the visibility of MPA Europe activities and results within a broader community working on Marine Protected Areas, Maritime Spatial Planning, and related marine policy themes.

A major dissemination milestone was the first International Conference on Marine Protected Areas in Marine Spatial Planning (MPAinMSP), held in Bodø in July 2025. The conference brought together science, policy, and practice, with 180 participants from 23 countries, 50 oral presentations, eight keynote talks, and 39 poster presentations. The programme, book of abstracts and conference statement are publicly available in the conference page, hosted in MPA Europe's website, while keynote presentations are made available through the project's YouTube channel. A special issue of Frontiers of Biogeography, an open-access international peer-reviewed journal, will be publishing papers related to the scientific work presented at the MPAinMSP International Conference.

Dissemination towards stakeholder and practitioner audiences was strengthened through the development of a stakeholder network, which has a dedicated page on the project's website, and a series of regional workshops covering the Baltic Sea, Black Sea, Mediterranean Sea, and North-East Atlantic, many of them co-hosted with other EU-funded projects focusing on MPAs or MSP. Workshop presentations and reports are available through the project website, together with FAQs raised by stakeholders and the project's responses to them. Additional policy-relevant resources, including marine policy links and the extended and short versions of the project Policy Brief, further supported the transfer of MPA Europe results to audiences involved in marine protection, spatial planning, and biodiversity governance.

Overall, by June 2026, the project had produced 59 publications, including 21 peer-reviewed papers; consortium members had participated in 54 scientific events, including the MPAinMSP International Conference organised by the consortium, and 70 stakeholder-dedicated events, including the four stakeholder workshops organised by the consortium, as summarised in the MPA Europe in Numbers page.

These outputs and activities helped ensure that MPA Europe results reached both the scientific community and the policy, planning and practitioner audiences most likely to use or build on the project results, during MPA Europe's lifetime and in the four years after its funding period. The MPA Europe Zenodo community publishes all the project reports and deliverables.

Communication

In D7.1, communication was defined as the set of activities aimed at informing wider audiences about the project, its goals, relevance and progress, from the start of the action until its end. The original plan identified visual identity, website and social media, videos, digital and print materials, articles for children, and stakeholder-facing communication as the main communication tools and outputs of MPA Europe. Within this framework, branding was not treated as a standalone design task, but as the basis for ensuring that project communication remained recognisable, accessible, and coherent across channels and outputs.

This objective was implemented through the development and consistent application of a dedicated visual identity system, formalised in the MPA Europe Brand Book. The brand system was built around the logo in which the letter P from “Protected” (in Marine *Protected* Areas)

functions as the project’s central graphic device, representing MPAs as defined spaces bounded by imagined lines. This logic was extended across the colour palette, typography, iconography, illustration style, photography guidance and project templates, ensuring a coherent visual language across outputs.

Building on this identity, the project developed a series of communication materials that evolved in parallel with the maturity of the results. Early outputs focused on foundational and explanatory materials, including the project 2-pager, flyer, poster and timeline (all available here: https://mpa-europe.eu/project/). As results became more substantial, communication outputs expanded into more content-rich formats, including infographics on blue carbon, species maps and models, and the economic benefits of Marine Protected Areas for fisheries and tourism (all available here: https://mpa-europe.eu/infographics/).

Over time, audiovisual communication also became increasingly important, with videos emerging as an effective format for explaining the project’s complexity (all available here: https://mpa-europe.eu/videos-resources/), milestones, and relevance in an accessible way.

Social media accounts, namely LinkedIn, Twitter/X and YouTube, were established in January 2023 as part of the communication framework set out in D7.1. As the project progressed, political and policy changes in the social media landscape made X less favourable as a primary channel for scientific and institutional communication, while Bluesky emerged later as a complementary but still small platform. In this context, MPA Europe increasingly concentrated its efforts on LinkedIn, which became the project's primary social media channel for reaching scientific, policy, and stakeholder audiences. This is reflected in the evolution of LinkedIn connections (increased from 168 in 2023 to 2,923 in June 2026) and impressions (from 5,990 to 234,873). YouTube also gained importance over time, with video views increasing from 110 in 2023 to 1,834 in June 2026.

Communication towards broader and younger audiences was strengthened through Deliverable 7.4, Dissemination articles for children, an activity already identified in D7.1 as part of the project's wider communication and ocean literacy approach. Through this deliverable, scientists from different MPA Europe partner countries and work packages developed five articles for children over eight years old, covering key themes such as marine animals and habitats, habitat-forming species, seagrasses, species distribution modelling, and the meaning of protection in MPAs. The articles were reviewed by children from five schools in Belgium, Denmark, England, Norway, and Portugal, involving 173 students aged 9 to 17, under the supervision of their teachers. Their feedback was used to improve the clarity and accessibility of the articles before they were illustrated, translated, and compiled into the booklet Our Big Blue Home: Learn and Protect!, available in eight languages: Danish, Dutch, French, Greek, English, Norwegian, Portuguese, and Spanish. Printed copies of the booklets in all eight languages have been offered to those who expressed their will to receive one through a dedicated form in the MPA Europe's website.

As the project progressed, MPA Europe also moved beyond its own communication ecosystem and gained visibility through external media and public-facing science communication activities. These included coverage on the Norwegian Broadcasting Corporation's regional live news programme Good Morning Nordland, participation in the Science4Parliament podcast, wide media coverage of research on the economic benefits of MPAs, and two participations on the RTÉ Radio 1's CountryWide podcast – one in November 2025 and another in June 2026. Together, these activities strengthened MPA Europe's public profile and supported one of the project's key messages: that effective marine protection can deliver benefits for biodiversity, climate resilience, fisheries, and coastal communities.

Exploitation

In D7.1, exploitation was defined in line with the Grant Agreement as the use of project results by the beneficiaries or by other entities, including through further research, practical application, service development, and support to policy and management. The original plan identified several result areas with clear exploitation potential, including

blue carbon databases, maps and models of species, habitats and ecosystems, stakeholder workshops and associated outputs, and the online atlas for MSP. These were conceived not only as scientific deliverables, but as resources intended to support future use by researchers, policymakers, planners, non-governmental organisations, and other relevant end users during and beyond the project duration.

As implementation advanced, the exploitation strategy became more clearly structured around specific output families and user communities. Blue carbon outputs, including dedicated databases and carbon storage scoring approaches, provide a basis for further research and for policy and planning discussions on the role of marine habitats in climate-relevant ecosystem functions. Species and habitat maps, ecosystem classifications, connectivity outputs, climate velocity maps, and prioritisation analyses support future reuse by scientific piers, data infrastructures, and planning-oriented audiences. Other blue carbon-related outputs, maps and models of species and habitats, and climate velocity and ocean connectivity scenarios for MPAs prioritisation are publicly available on MPA Europe's Zenodo community and easily accessed by subject using the Deliverables table in MPA Europe's resources page. These outputs contribute to the scientific evidence needed to identify areas of ecological importance and to support discussions on MPA networks design, biodiversity conservation, blue carbon, and climate-resilient MSP beyond the project's lifetime.

Stakeholder-facing outputs also played an important exploitation role. The regional workshops, public reports, presentations, FAQs and policy-related resources (all accessible at MPA Europe's page dedicated to these resources) helped connect project results with the needs and questions of practitioners, planners, policymakers, and regional sea actors. These activities supported the interpretation of project results in applied contexts and create a basis for continued dialogue and uptake after the end of the project.

A central exploitation asset is the MPA Europe platform for publishing modelled geographic ranges and environmental niche information on marine species distributions (https://shiny.obis.org/distmaps/) and the MPA Europe Atlas for MSP (https://iobis.github.io/mpaeu_atlas/; https://atlas.mpa-europe.eu/). By bringing together biodiversity data, climate scenarios, prioritisation layers, and other project outputs in a web-based format, the Atlas was designed to support consultation, analysis, and potential use by MSP professionals, researchers, marine managers, policymakers, and other stakeholders. Its post-project value lies in keeping key spatial outputs accessible in a format that can inform future research, planning processes and discussions on the expansion, redesign or implementation of MPA networks.

Regarding Technology Readiness Level (TRL), the exploitation pathway foreseen in D7.1 progressed from concept and proof-of-concept stages towards demonstrated, publicly accessible outputs. The original plan anticipated progression from TRL1–2 at project start, through experimental proof of concept and validation during the project, towards the availability of the MPA network design process and online atlas for MSP by the end of the project. The delivered outputs (all publicly available on MPA Europe's

Zenodo community and easily accessed by subject using the Deliverables table in the MPA Europe's resources page), including blue carbon datasets, species and habitat maps and models, climate velocity and connectivity products, prioritisation analyses and the Online Atlas, are consistent with the TRL7–8 ambition described in D7.1, as they provide demonstrated resources for use in relevant planning and knowledge contexts. Full TRL9 would depend on verified uptake by competent national or regional authorities, for example where MPA Europe results are used to support the expansion, redesign, or implementation of MPA networks after the end of the project.

After project completion, exploitation will depend on maintaining the accessibility, visibility, and usability of these outputs. The website and Zenodo will be maintained and updated with relevant outputs for at least four years after project completion, the open-access publications derived from project results, the Online Atlas for MSP and relevant external platforms such as OBIS and EMODnet, which will also be maintained and updated with relevant assets, will therefore remain important routes for supporting post-project uptake. Where appropriate, partners may also continue to use MPA Europe results and outputs in further research, publications, policy discussions, stakeholder engagement, education and related initiatives, in line with the Horizon Europe requirement to make best efforts to exploit project results beyond the lifetime of the grant, at least for four years (Articles 16 and 17 and Annex 5 of the Grant Agreement). Such materials will keep referring to the EU funding and the disclaimer excluding the funding agency of responsibility for any use of the results (in line with Article 17 of the Grant Agreement) and all publications will be submitted to the EC via MPA Europe's "continuous reporting module".

DEC Implementation and Impact Assessment

The original DEC Plan included a schedule of planned DEC activities, together with the partner(s) responsible for their implementation and the indicators foreseen to assess progress. In this updated version, that forward-looking schedule has been revised into an implementation and impact assessment section, documenting the activities carried out during the project, the outputs delivered, the partners involved, the timing of implementation, and the performance achieved against the relevant KPIs.

Overview of implemented DEC activities

The initial DEC Plan presented the planned schedule of DEC activities and defined the KPIs used to monitor progress. In this updated deliverable, these elements are consolidated into a single implementation and impact assessment table. This table should be read as a consolidated implementation record rather than as a simple update of the original schedule. It shows how the activities foreseen in D7.1 were delivered, where implementation evolved in response to project progress, and how the resulting outputs contributed to DEC objectives. It also provides the basis for the KPI assessment presented in Section 4.2.

Performance against KPIs

The performance of MPA Europe's DEC activities was assessed against the KPIs defined in the original DEC Plan and the evidence collected during implementation. Overall, the project delivered the main DEC activities foreseen in D7.1, with all channels exceeding the initial expectations in terms of reach, audience growth, output production, stakeholder engagement, and accessibility of results.

Digital communication showed particularly strong performance. The project website became the main public entry point for information, resources, publications, deliverables, stakeholder materials, infographics, videos and access to the Online Atlas. By June 2026, the website had received 18,553 unique visitors and 58,798 page views, exceeding the original target of 3,000 unique visitors and 10,000 page views. This confirms the role of the website as both a communication platform and a long-term access point for project results.

Social media also exceeded the original targets, especially LinkedIn, which became the project's primary platform for professional communication with scientific, policy, and stakeholder audiences. By June 2026, LinkedIn had reached 2,923 followers and 234,873 impressions, compared with the initial target of 50 connections and 2,000 impressions. Twitter/X and Bluesky provided complementary visibility, reaching 277 followers and 129 mentions plus 751 Bluesky impressions. YouTube also gained relevance over time, with video views increasing up to 1,834 as audiovisual outputs became more central to the communication of complex project themes and results.

The production of communication materials also contributed to KPI achievement. The project produced a range of supporting materials, including the 2-pager, leaflet, roll-up, timeline, posters, infographics, and videos. These outputs helped maintain consistency across partner communication and supported a gradual shift from introductory project visibility towards more result-oriented communication. Although infographics' views and shares underperformed against the target KPIs, together with videos they generated over 16,000 interactions (views, shares, likes, and impressions) across YouTube and LinkedIn by June 2026, confirming the value of visual and audiovisual formats for communicating scientific results to wider audiences.

Dissemination KPIs were addressed through scientific publications, datasets, reports, public deliverables, conference participation, and stakeholder-oriented activities. Newsletter-based dissemination also performed well, with eight Project Newsletters circulated during the project and the subscriber list growing from 31 recipients in the first issue to 250 by June 2026. In parallel, MPA Europe contributed from Issue #1 onward to *Blue Horizons*, the joint newsletter of the MPA Community Network sister-project cluster, extending the visibility of project results within a broader community working on MPAs, MSP and related marine policy themes. By June 2026, the project had produced 59 publications, including 21 peer-reviewed papers, and had participated in or organised more than 124 events. Moreover, MPA Europe's Zenodo downloads reached a total of 9,127, including 4,047 dataset/database-related downloads, 528 map downloads, 2,627

downloads of deliverable reports and papers, and 600 downloads of stakeholder-related materials. The MPAinMSP conference alone was an important dissemination hub, bringing together 180 participants from 23 countries, with 50 oral presentations, eight keynote talks, and 39 poster presentations, supporting exchange between science, policy, and practice.

Stakeholder engagement was another strong area of performance. The project engaged over 12,000 people through its dissemination and communication activities and partners attended 70 stakeholder-dedicated events, including the four regional stakeholder workshops organised by the consortium. These activities helped connect project outputs with the needs of policymakers, marine planners, conservation practitioners, regional sea actors, and other end users, supporting the interpretation and potential uptake of results in applied contexts.

Public engagement and ocean literacy KPIs were supported through dedicated outputs for non-specialist audiences. Deliverable 7.4 resulted in the production of five articles for children, reviewed by 173 students aged 9 to 17 from five schools in Belgium, Denmark, England, Norway, and Portugal. These articles were illustrated, translated, and compiled into the booklet Our Big Blue Home: Learn and Protect!, available in eight languages. These booklets were downloaded 1,325 times from MPA Europe's Zenodo and 954 printed copies were requested via MPA Europe's website. Another article for children, centred in the benefits of Marine Protected areas, was published in the Environmental Science Journal for Kids in October 2024 and is available in the MPA Europe's resources page dedicated to articles for children. These outputs extended the reach of MPA Europe beyond technical audiences and contributed to the project's broader ocean literacy objectives.

Exploitation-oriented KPIs were supported by the delivery of concrete outputs with post-project value, including blue carbon datasets, species and habitat maps and models, climate velocity and connectivity products, prioritisation analyses, stakeholder workshop materials, and the MPA Europe Online Atlas for MSP. These outputs were not only produced as project deliverables, but made available through the website, Zenodo, and relevant repositories (including open access scientific journals where appropriate). This strengthens their continued accessibility and provides a basis for future use by researchers, policymakers, marine planners, and other stakeholders beyond the project's duration.

Taken together, the KPI performance data show that the DEC strategy was implemented successfully and refined where needed. The strongest areas of performance were the consolidation of the website as a resource hub, the growth of LinkedIn, the production of scientific and stakeholder-oriented outputs, the increasing use of visual and audiovisual formats, and the development of exploitation-ready resources designed to remain accessible and useful for at least four years after the end of the grant.

Implementation refinements supporting future use of results

The refinements introduced during the implementation of the DEC strategy were not limited to improving visibility during the project. They also strengthened the conditions for the continued accessibility, reuse, and uptake of MPA Europe outputs after project completion. This is particularly relevant in the context of Horizon Europe, where DEC activities are expected to support the long-term value of project results beyond the lifetime of the grant.

First, the project moved progressively from general awareness-raising towards result-oriented communication/dissemination. Early communication focused on explaining the project's objectives, scientific areas and expected outputs. As results became available, the strategy shifted towards communicating the outputs, including publications, datasets, stakeholder workshop reports, maps and models, the MPAinMSP conference, the Policy Brief, and the Online Atlas. This refinement makes the project's outputs visible as usable resources, rather than only as evidence of completed activities.

Second, the project strengthened the accessibility and traceability of its outputs. Public deliverables, publications, workshop materials, infographics, videos, children's articles, datasets and atlas-related outputs were made available through the project website, Zenodo, and other relevant platforms. This increases the likelihood of post-project uptake by ensuring that different audiences can continue to find, access, and refer to the project's results after the formal end of MPA Europe in July 2026.

Third, communication formats evolved in response to the maturity and complexity of the results. The project moved from foundational materials, such as the 2-pager, leaflet, poster, and timeline, towards more detailed infographics, videos, and web-based resources. This refinement supports future use by making complex outputs easier to understand and apply, particularly for policy actors, practitioners, stakeholders, and non-specialist audiences who may not engage directly with scientific publications.

Fourth, the social media strategy was adjusted to prioritise the channels with the strongest relevance for professional and stakeholder audiences. LinkedIn became the project's main platform for sustained external visibility, while YouTube supported the dissemination of audiovisual outputs and Bluesky was added as a complementary channel. This focus helped build an audience that can remain relevant for the continued circulation of project outputs, including policy-facing materials, scientific results, and resources linked to the Online Atlas for MSP.

Finally, the exploitation dimension became more explicit as the project matured. The updated DEC strategy links future uptake to specific result families, including blue carbon databases, species and habitat maps and models, climate velocity and connectivity outputs, prioritisation analyses, stakeholder workshop outputs, the Policy Brief and the Online Atlas for MSP. By connecting these outputs to relevant user communities, such as researchers, policymakers, marine planners, regional sea actors and MPA managers, the project strengthens the pathway from dissemination to exploitation.

Together, these refinements support the continued visibility, accessibility and usability of MPA Europe results beyond the end of the grant. They help ensure that project outputs do not remain isolated deliverables, but can continue to inform research, policy discussions, MSP, conservation practice and future initiatives related to MPAs, biodiversity, blue carbon, and climate-resilient ocean governance. If specific results require additional support to identify interested users or exploitation opportunities after the end of the project, the Horizon Results Platform may be used in line with Horizon Europe obligations and the provisions already reflected in the original DEC Plan. In this way, MPA Europe's DEC legacy is designed to extend beyond the production of deliverables, supporting the continued transformation of project results into knowledge, tools and evidence that can be used by others.

Conflicts of interest

The authors have declared that no competing interests exist.

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Endnotes

*1 EMODnet Seabed Habitats collated point data:http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/ef3966c9-187b-416a-8a74-e0a853f6fcfa

*2 EUSeaMap broad-scale predictive habitat map for Europe: http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/10d3d35c-8f8e-40ff-898f-32e0b037356c.

*3 EMODnet Seabed Habitats collated habitat maps: http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/061c9d9c-8dc4-449f-8ac6-758840253fc3.