Future MARES

Policy Brief 4

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EUROPEAN DIGITAL MARINE LABS: TESTING THE ROLE OF NBS IN CLIMATE CHANGE MITIGATION AND SUSTAINABLE FISHERIES

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HIGHLIGHTS

Digital marine laboratories are advanced research platforms that leverage digital technologies to study multiple aspects of marine ecosystems and cumulative impacts of human activities to assess "what-if" scenarios and inform management. These labs integrate computational tools, modelling frameworks, and data visualization techniques to develop digital experiments that simulate oceanographic and environmental processes, and the interactions between physical, chemical, biological, ecological and socioeconomic drivers.

FutureMARES used state-of-the-art digital laboratories for virtual experiments to investigate the effects of climate change and management interventions on human activities for three socio-political scenarios (Global Sustainability GS, National Enterprise NE and World Markets WM) for European regional seas. These experiments used an ecosystem-based perspective and combined Nature-based Solutions (NBS) with Nature-inclusive Harvesting (NIH).

In a context of future climate change, with expected further increases in temperature and changes in primary production, **these digital laboratories provide new tools to help management interventions to maintain and restore biodiversity and support productive, sustainable fisheries**.

This Policy Brief outlines the results of seven digital representations of European seas that take either a regional perspective (North Sea, Baltic Sea, Bay of Biscay and Western Mediterranean Sea), or a sub-regional perspective (Finnish Archipelago Sea, NW Mediterranean Sea, and the Portuguese Shelf).

Specifically, spatial-temporal marine ecosystem models, using the Ecopath with Ecosim and Ecospace framework, were refined and developed to explore impacts of contrasting climate projections with and without additional management interventions.

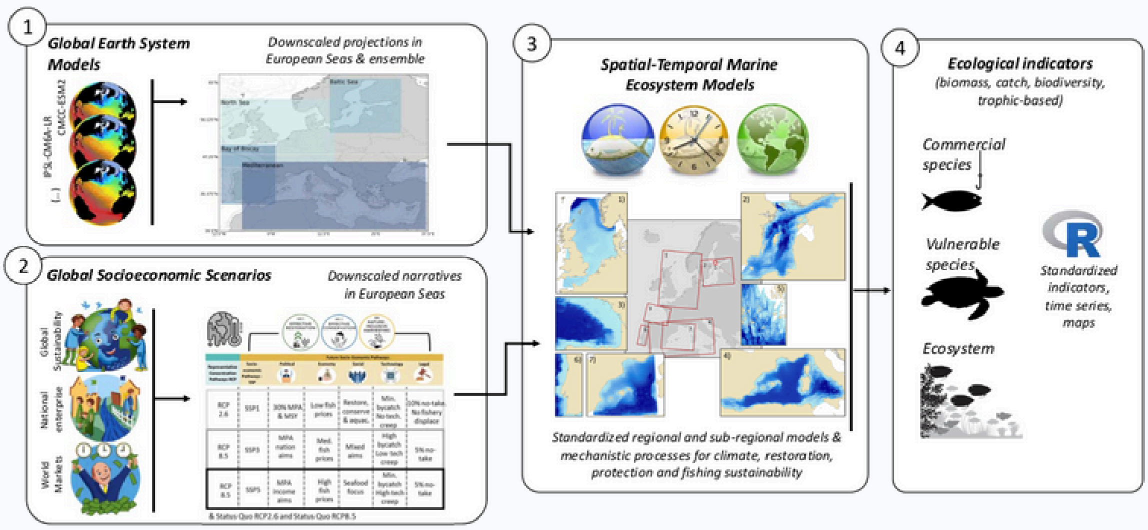

Figure 1. Workflow developed under FutureMARES to link global Earth System models, socioeconomic scenarios and marine ecosystem models to develop scenarios of NBS and NIH for each of 4 regional European Seas and 3 sub-regional areas.

Multiple management interventions were included simultaneously to capture their cumulative effects on the ecosystem, and management goals for actions were specific to each region or subregion according to ecological and policy contexts and stakeholders' preferences. For example, the restoration of habitat-forming species was a priority in the Mediterranean Sea (*Posidonia* meadows and in the North Sea (native flat oyster reefs), while reductions in nutrient loading were considered a priority for the Baltic Sea.

Furthermore, in each area, the protection of areas was chosen specifically to achieve international targets (such as 10% full protection and 20% high protection by 2030) alongside the achievement of sustainable fishing practices (such as reducing discard and bycatch rates and the attainment of maximum sustainable yields).

The digital marine laboratories highlight that taking management actions now can make a difference to the status of ecosystems in a future climate.

NBS 1	Representative Concentration Pathways - RCP	Future Socio-Economic Pathways						
		Socio-economic Pathways - SSP	Political	Economic	Social	Technological	Legal	Enviromental
Global Sustainability	Minimal warming [RCP2.6]	SSP1	Collaboration, Cross–border restoration activiites	Nature as non–profitable asset, Free access to natural environment	Social awareness, Restoration success is a priority	Innovations, Integrated restoration efforts	EU Restoration Law followed, Focus on Natura2000 sites	Mitigation to and adaptation of climate change
National Enterprise	Strong warming [RCP8.5]	SSP3	Poor linkages and limited efforts for joint restoration activities	Restoration of high–value species (food/job security, coastal protection)	Restoration in national waters is the priority	Little or no technological advancement	National targets will prevail for the restoration within MPAs	No mitigation or adaptation to climate change, MPA surface increase only 5%
Word Markets	Strong warming [RCP8.5]	SSP5	EU Green Deal, Transnational restoration efforts	Restoration of species with high economic value	Awareness for market valuable resources	Technological advances, better restoration methods	No restoration of habitat-forming species because the effort will be in fish habitats	Adaptation to climate change, No mitigation

Figure 2. PESTLE (political, economic, social, technological, legal and environmental) scenarios developed for NBS1 (habitat restoration).

NBS 2	Representative Concentration Pathways - RCP	Future Socio-Economic Pathways						
		Socio-economic Pathways - SSP	Political	Economic	Social	Technological	Legal	Enviromental
Global Sustainability	Minimal warming [RCP2.6]	SSP1	Collaboration, MPA > 30%	Nature as non profitable asset, MPA free access	Social awareness, MPA effectiveness priority	Innovations, Integrated MPA management systems	International commitments	Mitigation of climate change
National Enterprise	Strong warming [RCP8.5]	SSP3	Independence, MPA according to national policy	Less financial supports to MPAs	Engagement, MPA effectiveness, Diversity	Little or no technological advancement	International commitments not universally upheld by all countries	Serious effects of climate change, MPAs local to mitigate the impact
Word Markets	Strong warming [RCP8.5]	SSP5	Focus on Economy, MPAs for Economic Growth	Nature as profitable asset, Entrance fees to MPAs	Awareness for market valuable resources	Technological advances, Better MPA management	No international commitments, Conflicts about MPAs	Serious effects of climate change, Mitigate impact on developed countries

Figure 3. PESTLE (political, economic, social, technological, legal and environmental) scenarios developed for NBS2 (habitat conservation).

NIH	Representative Concentration Pathways - RCP	Future Socio-Economic Pathways						
		Socio-economic Pathways - SSP	Political	Economic	Social	Technological	Legal	Enviromental
Global Sustainability	Minimal warming [RCP2.6]	SSP1	MPA 30% by 2030 with Max. Sustainable Yield	Low fish prices, No increase in fishing effort	Focus on restoration, conservation & aquaculture	Minimal bycatch, No creep	10% sea no–take, Avoid fisheries displacement	Mitigation to and adaptation of climate change
National Enterprise	Strong warming [RCP8.5]	SSP3	MPAs for national aims	Medium fish prices, Fishing effort increases with time	Mixed aims	High bycatch, Low tech creep (0.4% p.a.)	5% of sea no–take	No mitigation or adaptation to climate change
Word Markets	Strong warming [RCP8.5]	SSP5	New MPAs – commercial fish habitat	High fish prices, Fishing effort increases with time	Focus on seafood	Minimum by–catch, High tech creep (0.9% p.a.)	5% of sea no–take	Adaptation to climate change, No mitigation

Figure 4. PESTLE (political, economic, social, technological, legal and environmental) scenarios developed for NIH (Nature-inclusive Harvesting).

KEY STATEMENTS

- NBS – the restoration of habitat-forming species and protection of key marine areas, alongside reductions in excessive nutrient loadings and the attainment of conservation targets for MPAs - together with NIH actions - the reduction of fishing effort and associated rates of discards and bycatch- are predicted to play a vital role in mitigating the impacts of climate change in the future. Using digital laboratories, we showed divergent trajectories between the **FutureMARES** scenarios and their climate change analogues for the biomass of many species and ecological indicators demonstrating likely impacts of management interventions.

- Significant spatial variability in the biomass of species and fishery catch projections has been projected, driven by diverse environmental and ecological conditions, as well as by fisheries activities and management actions. These spatially-explicit results highlighted that tailored management interventions will be crucial to ensure favorable ecological and socioeconomic outcomes for European marine ecosystems in the future.

Figure 5. Marine biodiversity within Mediterranean MPAs. Photo credit: left-mid: Joaquim Garrabou; right: Fabio Bulleri.

CONTEXT & BACKGROUND

FutureMARES tested the ecological and socioeconomic effects of climate change and management measures in three scenarios (with their associated climate change only scenarios, RCP2.6 and RCP8.5).

First, general scenarios were translated into downscaled narratives and mechanistically implemented into Marine Ecosystem Models (MEMs) representing both regional and sub- regional areas (Fig. 1). These models were used to run contrasting scenarios that considered different management interventions (including a range of options for protection, restoration and ecosystem-based management of fisheries) across a range of differing regional contexts, current legislations and future developments of relevant legal frameworks.

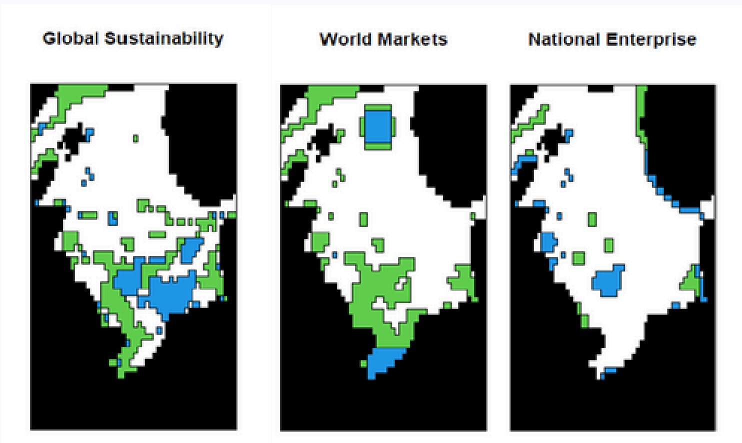

Figure 6. Placement of protected areas (areas where artisanal fisheries only are allowed – green - and no-take zones –blue) used in the digital laboratory scenarios for the North Sea.

Spatial-temporal impacts of climate change and human activities on the biomass of key commercial and key conservation species, spanning different trophic levels of the marine food web, were assessed for each scenario. Ecological indicators that integrated changes in multiple species and multiple fisheries were also included. Trade-offs between management strategies were investigated, contrasting changes in whole-system diversity, ecosystem structure and service delivery, and its resilience to climate change.

-**Global Sustainability**: digital labs tested the effects of reaching EU & international legal regulations and targets for restoration of habitat-forming species (flat oysters, blue mussels, seagrass, corals), for protection (Marine Strategy Framework Directive - MSFD, Habitats Directive, Biodiversity strategy, Green Deal) with priority for connectivity and climate-ready solutions, and for a full implementation of EU fisheries directives (Common Fisheries Policy, MSFD), Regional Sea Conventions, and Ecosystem Based Fishery Management principles. These included establishment of fisheries restricted areas, reductions in discarding and bycatch rates, and reduction of fishing effort to achieve values of fishing mortality below F_{MSY} (Fishing mortality at the maximum sustainable yield).

- **National Enterprise**: experiments tested the effects of prioritizing restoration of high-value species according to food security, job security or coastal protection within EU exclusive economic zone (EEZ), according to national targets.

Regarding protection actions, the scenario included small MPAs focusing on national interests with little to no connectivity and high levels of fishing operating in national EEZ following economic subsidies to ensure food security and maximum landed volumes.

- **World Markets**: priority was given to restore high-value species (key commercial species) with limited-scale interventions, to establish small MPAs with economic value and no connectivity and to prioritize large-scale fisheries over small scale fisheries, with the aim to achieve a maximum landed value.

NE and WM scenarios considered lower targets of discard reduction and bycatch, while the three contrasting scenarios also differed in terms of fish price and fuel costs that alter the distribution of vessels. Finally, status quo scenarios simulated baseline conditions for management interventions with climate change only.

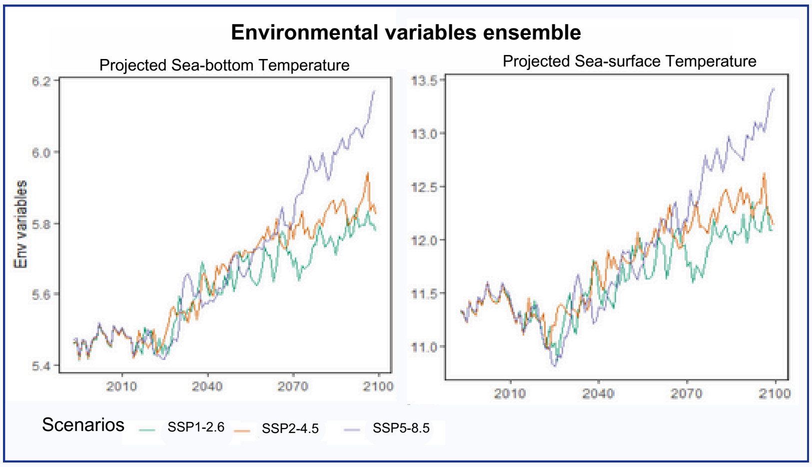

Figure 7. Temporal changes in future surface and bottom seawater temperatures (SST, SBT) used to drive the spatial-temporal simulations of the digital laboratory in the Bay of Biscay.

KEY RESULTS

Results showed distinct ecological and fisheries socioeconomic outcomes by the mid-term (2050) and long term (2100) according to the three simulated scenarios. The final results were shaped by contrasting environmental conditions (RCP2.6 and RCP8.5) as well as the pivotal influence of the various management strategies (encompassing protection, restoration and ecosystem-based fisheries management) in each **FutureMARES** scenario (Figure 8). This study illustrates that **NBS can yield clear benefit when the greenhouse gas emissions is reduced**.

1) Global Sustainability (GS) scenario.

Several positive outcomes were projected, including the rebuilding of cod stocks as well as other commercially important fish species in the Baltic and the North Sea, the recovery of habitat-forming species such as corals, mussels and kelp in the Bay of Biscay, the Baltic Sea, the Portuguese shelf and the Western Mediterranean, or the rebuilding of Mediterranean seagrass, small pelagic fish and predators in the Mediterranean Sea and flat oysters and predatory biomass in the North Sea. Interestingly, indicators of ecosystem degradation, such as the increase of gelatinous zooplankton and of cyanobacteria, were predicted to stabilize or decline under GS conditions.

2) National Enterprise (NE) and World Markets (WM) scenarios.

Declines of several important commercial and conservation species were projected. These declines were associated with important changes in ecosystem structure and functioning, and the occurrence of ecological changes in the food web, with trophic cascades and predation release effects in a diversity of species. In this context, several trade-offs and synergies were identified.

Fisheries outcomes depended strongly on the status of the ecosystem, on the fisheries activities projected to occur in the areas, and on future changes in environmental conditions. In some cases, higher catches were projected under NE or WM scenarios, despite depletions of important commercial and conservation species. However, in other cases, higher catches were projected under the GS scenario.

Overall, the status quo scenarios tended to project lower catches than historical levels due to climate effects and, in some cases, than the **FutureMARES** scenarios.

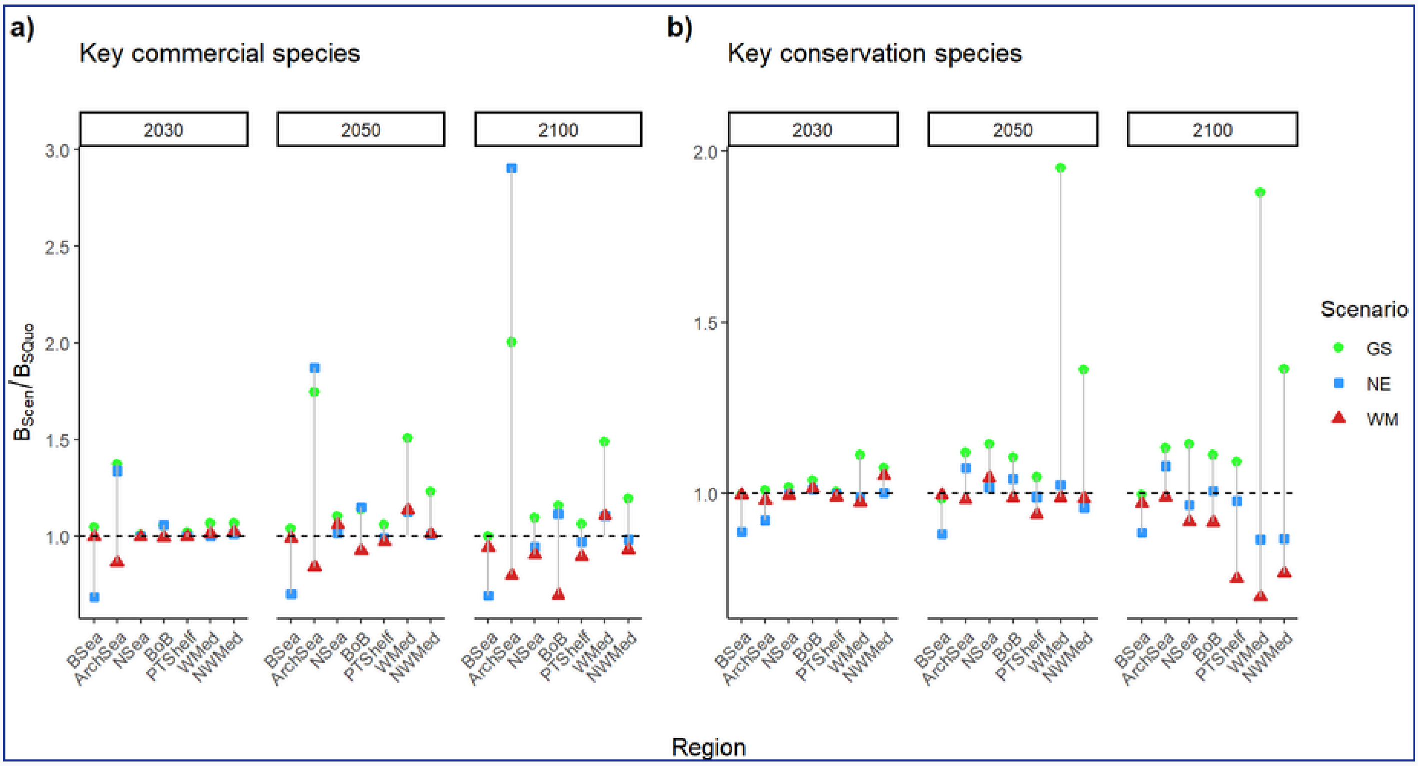

Figure 8. Biomass change due to additional management action of key commercial species and key conservation species in 2030, 2050 and 2100 in multiple regional seas. Outcomes are given for the three FutureMARES scenarios (Global Sustainability, GS, National Enterprise, NE, and World Markets, WM) once standardised to the status-quo simulation incorporating climate change but no new management (B_{Scen} / B_{SQuo}).

Regions reference: BSea: Baltic Sea, ArchSea: Finnish Archipelago Sea, NSea: North Sea, BoB: Bay of Biscay, PTShelf: Portuguese Shelf, WMed: Western Mediterranean Sea, NWMed: Northwest Mediterranean Sea.

Policy Recommendations

- In a context of climate change, with expected further increases in temperature and potential changes in primary production, management interventions should be implemented now to maintain biodiversity and support productive, sustainable fisheries in the future.

- Proactive ecosystem-based management interventions that combine actions to restore, protect and conserve marine ecosystems, in combination with sustainable fishing practices, are crucial to shape the future ecological and socioeconomic status of European Seas, under all climate change scenarios.

- Overall, our results show that proactive, regionalized interventions can ensure resilience and attain Good Environmental Status in the future, contributing to the recovery of both the ecological integrity and the socioeconomic benefits of marine ecosystems for generations to come.

Figure 9. FutureMARES projected climate change impacts on diverse marine species.

References

Coll, M., C. P. Lynam, X. Corrales, L. Espasandín, M. Ortega, R. Puntila-Dodd, J. Steenbeek, D. Szalaj, M. Tomczak, M. Butenschön, E. Andonegi, M. D. Castro, S. Heye, T. Kristiansen, L. van Duren, V. Vilmin and M. A. Peck (2024). "Mechanistic projections for changing species and ecosystems: preliminary projections and report." FutureMARES Deliverable Report 4.4

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