Nature-based Solutions and the Management of Coastal to Offshore ecosystems and their services in the Western Mediterranean

Storylines 30, 31, 33

NBS 1 EFFECTIVE RESTORATION

NBS 2 EFFECTIVE CONSERVATION

NIH NATURE-INCLUSIVE HARVESTING

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Future MARES

Introduction

The EU Horizon project FutureMARES (2020-2024) was designed to develop science-based advice on viable actions and strategies to safeguard biodiversity and ecosystem functions to maximise natural capital and its delivery of services from marine and transitional ecosystems in a future climate. The program investigates effective habitat restoration, conservation strategies and sustainable harvesting at locations across a broad range of European and other marine and transitional systems. The restoration of habitat-forming species (plants or animals) and habitat conservation (e.g. marine protected areas, MPAs) represent two nature-based solutions (NBS) defined by the EU as "resource efficient actions inspired or supported by nature to simultaneously provide environmental, social and economic benefits that help to build resilience to change". A third action that will interact with these two NBS and have positive effects on marine biodiversity is nature-inclusive harvesting (NIH) such as the sustainable farming of plants and animals at the base of marine food webs and ecosystem-based management practices for traditional (artisanal) and commercial fisheries. FutureMARES will advance the state-of-the-art forecasting capability for species of high conservation value, explore new and less carbon intensive aquaculture production methods, perform modelling analyses geared towards informing the development of climate-smart marine spatial planning approaches, and provide an assessment of ecosystem services based on scenarios of climate change and the implementation of NBS and NIH.

This document provides a multi-disciplinary summary of activities conducted in FutureMARES in a specific area on specific NBS and/or NIH. The activities include work across various disciplines including marine ecology (analyses of historical time series and experiments performed in the field and laboratory), climate change projection modelling (future physical, biogeochemical and ecological changes), economic analyses, social-ecological risk assessments. Many of these components and analyses, including NBS / NIH scenarios tested, were co-developed with local and regional stakeholders through regular engagement activities. The work presented in these Storylines represent activities conducted by a large number of FutureMARES project partners. Broader comparisons and syntheses (across regions and/or topics) are provided in the FutureMARES deliverable reports (www.futuremares.eu) submitted to the European Commission.

NBS regional context

The Western Mediterranean Sea basin (~ 846,000 km^2, 0-3600 m depth) includes the European Mediterranean coastlines belonging to Spain, France and Malta, as well as the portion of Italian coastlines along the Thyrrenian Sea and Strait of Sicily, and the coastlines of Morocco and Algeria. The basin includes five marginal seas: the Thyrrenian Sea, the Balearic Sea, the Sea of Sardinia, the Ligurian Sea and the Alboran Sea.

The region is relatively productive compared to the Eastern and Central parts of the Mediterranean Sea, especially the northwestern region and the continental shelves associated with large rivers and deltas (Rhone and Ebro Delta) and a counter-clock marine circulation (Bosc et al. 2004). It hosts important proportions of Mediterranean species and habitat diversity, and important percentages of endemic and at-risk species, including seabirds, marine turtles, marine mammals, chondrichthyans, finfish, invertebrates and primary producers (Coll et al. 2010).

The region is strategically positioned and is one of the principal maritime corridors in the world and the gateway to Africa for European countries. Goods transport represents close to 40% of the Mediterranean value. Marine harvests from fisheries (artisanal and industrial) and aquaculture are the second most important activity in terms of gross added value and employment. In addition, recreational and subsistence fishing are very important activities from an economic, social and cultural point of view. The region is also a traditional and consolidated tourist destination, in particular its northern rim (Katsanevakis et al. 2015).

Human activities involve a number of environmental pressures causing high or very high environmental impacts in marine and coastal ecosystems and resources. Maritime, but also land-based activities (industrial activities and a dense urbanised coastline), pose environmental pressures, including air and water pollution, waste generation and resource degradation and depletion (Coll et al. 2012, Micheli et al. 2013, Katsanevakis et al. 2015). Overexploitation of fishing resources is among the most important pressures in the region, along with biodiversity and habitat loss. Climate change (CC) is posing increasing impacts to habitats and resources, and is expected to intensify more rapidly that the average global mean (Calvo et al. 2011, Marbà et al. 2015, Moatti and Thiébault 2018, Garrabou et al. 2019, Salat et al. 2019). Current conservation actions are not enough to halt resource degradation since marine protected areas (fully, highly, moderately or poorly protected) cover less than 1% of the region (Claudet et al. 2020). This highlights the need to implement spatial-temporal management measures resilient to CC, including the mandate for protection of Vulnerable Marine Ecosystems (VMEs) and Essential Fish Habitats (EFH) (Micheli et al. 2013, Coll et al. 2015, Giménez et al. 2020).

(a) (b)

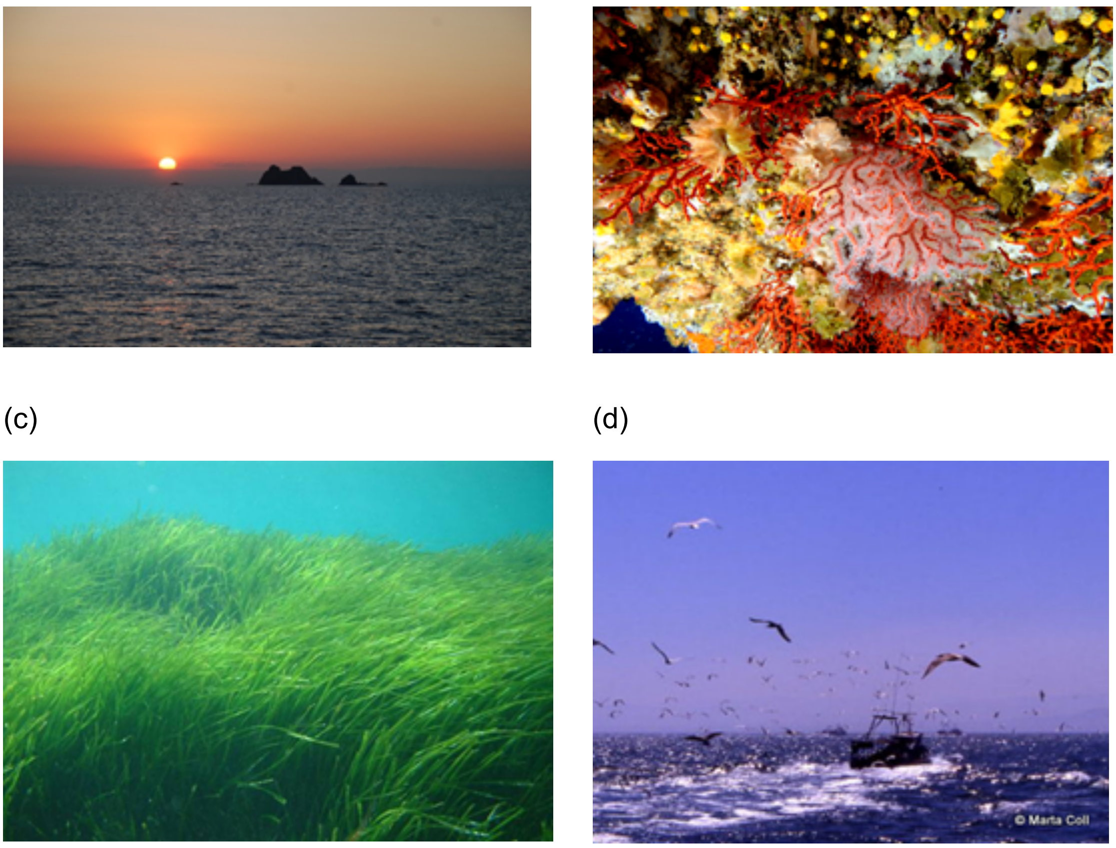

Figure 1: Photos of emblematic marine ecosystems and habitats (a) Columbretes Islands (source: M. Coll), (b) coralligenous assemblage (source: http://agricultura.gencat.cat), (c) seagrass *Posidonia oceanica* meadow (source: M. Coll) and (d) bottom Trawl fishing vessel followed by seabirds. Credit: M. Coll

a)

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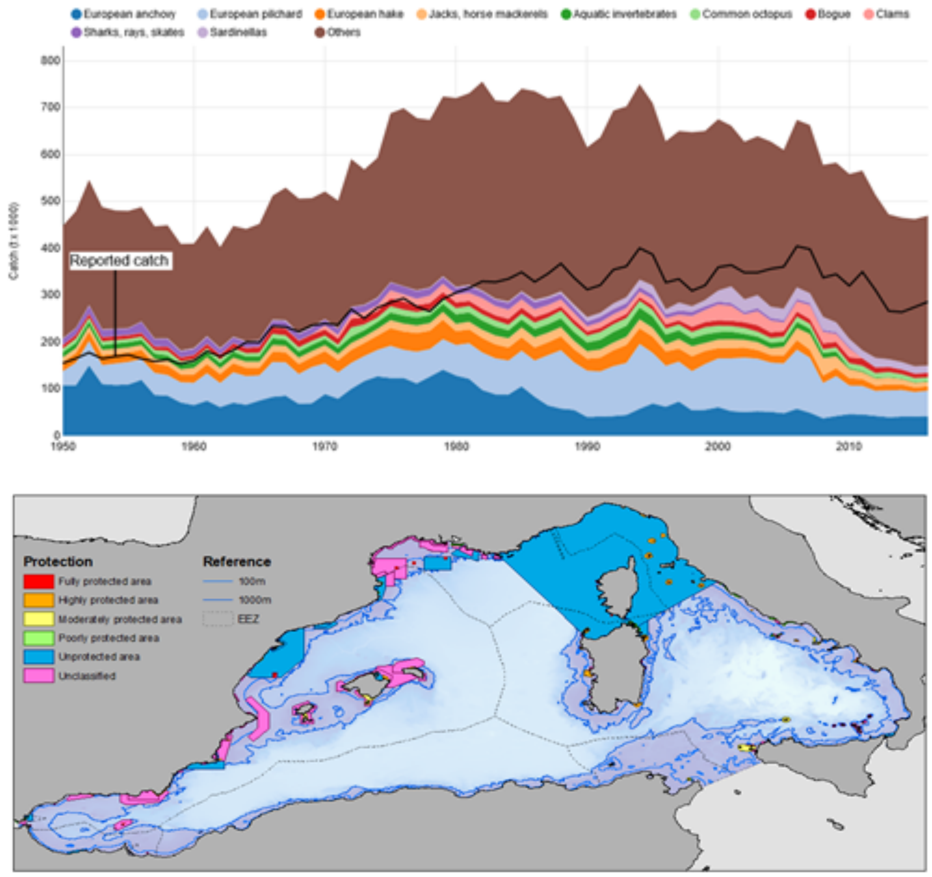


Figure 2: Figure of (a) fisheries catches (source http://www.seaaroundus.org) and (b) MPAs, Gulf of Lions (GoL) no take zones, and FRA GoL and their classification (according to (Horta e Costa et al. 2016). Credit: M. Coll

Projected impacts of climate change

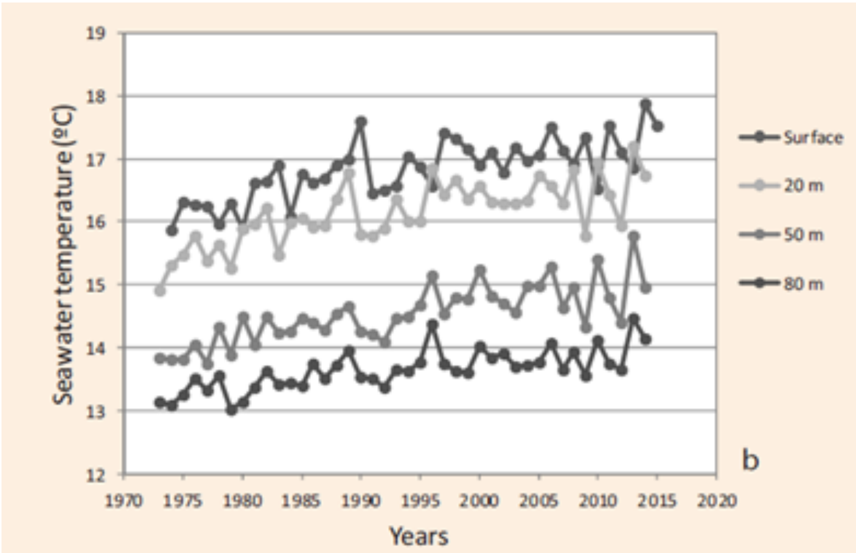
Climate change in the region is projected to intensify more rapidly than the average global mean and is already posing increasing impacts to habitats and resources.

Available trends indicate increases in sea water temperature at different depths, declines in sea surface salinity related to declines in rainfall, river run-off and wind, a prolonged stratification period and more frequent and intense marine heat wave events (Calvo et al. 2011, Marbà et al. 2015, Moatti & Thiébault 2018, Garrabou et al. 2019, Salat et al. 2019).

Several studies projected that, by increasing the vertical stability of the water column and by decreasing nutrient replenishment, seawater warming will cause changes in phytoplankton bloom phenology, biomass and community structure (Moullec et al. 2016c). The sensitivity of Mediterranean biota to warming varies across taxonomic groups (Marbà et al. 2015). However, warming is already affecting the fitness of marine biota as observed by changes in the abundance, survival, reproduction, phenology and migration of species (Marbà et al. 2015).

The large effects of CC are evident, for example, in: (1) a meridionalisation of taxa (including algal, invertebrate and vertebrate species) with the favourization of the more thermophilic species over the temperate ones (Sabatés et al. 2006); (2) mass mortality events of sessile invertebrates of the coralligenous communities (Garrabou et al. 2019); (3) increases in the small fraction of phytoplankton (Moullec et al. 2016c); (4) proliferation of gelatinous carnivores, including jellyfish (Calvo et al. 2011); and (5) a faster acidification of seawater with important impacts on many organisms, including bivalves and the coralligenous systems (Lacoue-Labarthe et al. 2016).

The effects of CC on Mediterranean marine biota most likely have synergistic effects with other anthropogenic impacts such as high exploitation (Ramírez et al. 2018, Ramírez et al. 2021). These effects may ultimately have significant consequences for ecosystem productivity, biodiversity and functioning and hence for the overall goods and ecosystem services they provide, especially the production of living resources (Moullec et al. 2016b).



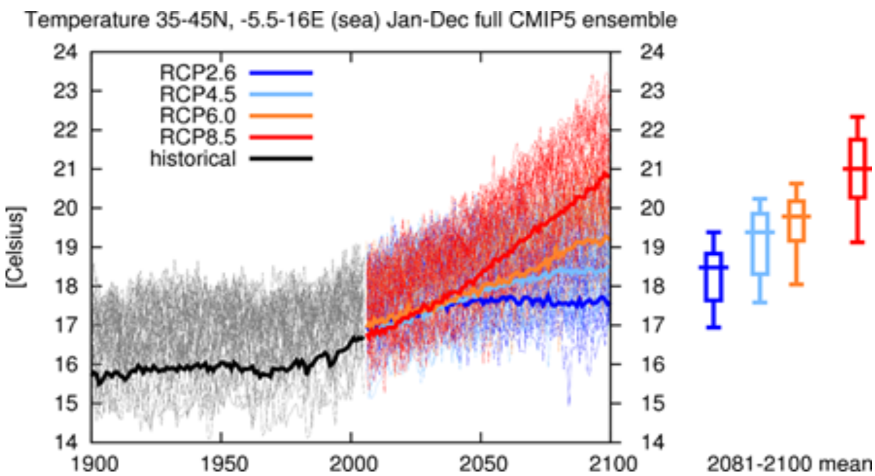
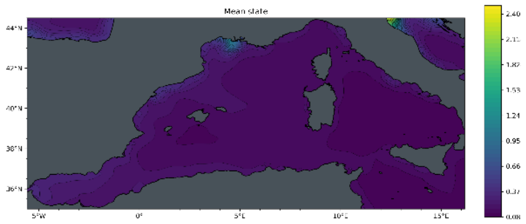
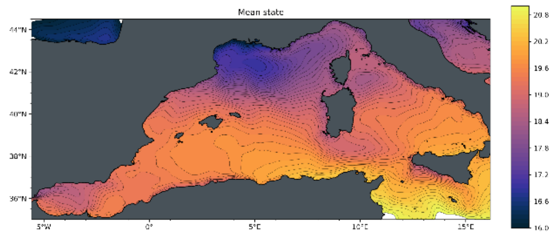


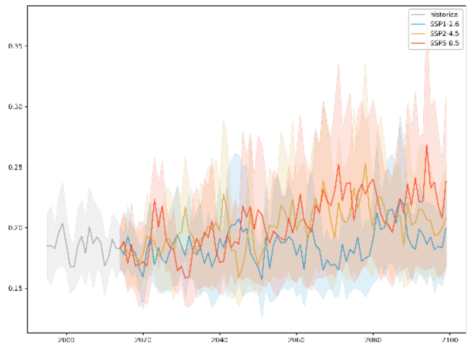
Figure 3: (Top) evolution of the mean annual sea temperature at Estartit station from 1974 to 2015. Data are shown for the surface, 20, 50 and 80 m depth, respectively. Data source: Josep Pasqual in collaboration with the Institut de Ciències del Mar (ICM-CSIC), Barcelona, and Parc Natural del Montgrí, Les Illes Medes i el Baix Ter (Moullec et al. 2016a). (bottom) temperature evolution and projections (source http://climexp.knmi.nl/plot_atlas_form.py) for the Western Mediterranean Basin and (b)



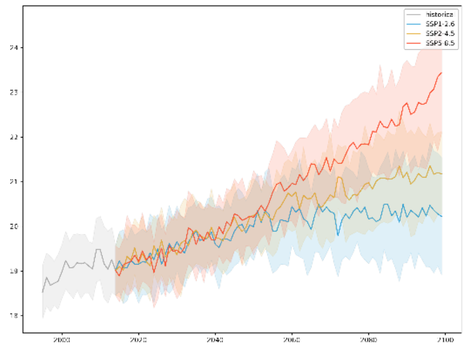
Chlorophyll (in mg m-3) at 5m depth under present day conditions



Potential Temperature (in degrees C) at 5m depth under present day conditions



Chlorophyll (in mg m-3) at 5m depth



Potential Temperature (in degrees C) at 5m depth

Figure 4: Climate projections for the Mediterranean Sea and surrounds. The figures were produced using trend preserving statistical downscaling (Lange, 2019) of a multi-model ensemble Earth System Model historical simulations and future projections from the CMIP6 archive trained on reanalysis datasets from the Copernicus Marine Environment Monitoring Service.

Geographical Maps were extracted from the full dataset by averaging over the following periods, consistent with the periods considered in the IPCC AR6 WG1 report:

- present day: 1995-2014
- near future: 2021-2040
- mid future: 2041-2060
- far future: 2080-2099

Time-series plots were produced averaging over the area of interest for each storyline and show the ensemble mean in the full lines and the range of model responses in the shaded areas as represented by the 2.5 and 97.5 percentiles of the ensemble. Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change.

Scenarios describing future society and economy

FutureMARES will develop policy-relevant scenarios based on commonly used IPCC frameworks including SSPs and RCPs. These broad scenarios are regionalised based on stakeholder perspectives to guide activities such as model simulations in specific Storylines. Each of these scenarios has implications for the three NBS examined in this program (effective restoration, effective conservation, sustainable seafood harvesting):

Global Sustainability (SSP126) - Low challenges to mitigation and adaptation

The world shifts gradually but pervasively to a more sustainable path, emphasising inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, investments in educational and health accelerate lower birth and death rates, and the emphasis on economic growth shifts to an emphasis on human well-being. Societies increasingly commit to achieving development goals and this reduces inequality across and within countries. Consumption is oriented toward lower material growth, resource and energy intensity.

National Enterprise (SSP385) - High challenges to mitigation and adaptation

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to focus on domestic or regional issues. Policies shift over time to be oriented more on national and regional security. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialised countries and high in developing ones. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

World Markets (SSP585) - High challenges to mitigation, low challenges to adaptation

The world increasingly believes in competitive markets, innovation and participatory societies to produce rapid technological progress and train and educate people for sustainable development. Global markets become more integrated and strong investments in health, education, and institutions are made to enhance human and social capital. The push for economic and social development is coupled with exploiting abundant fossil fuel resources and adopting resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Figure 5: Representation of three, broad scenarios to be regionalised to guide activities such as model simulations in FutureMARES project. Credit: FutureMARES

FutureMARES research needs

The research needs to be undertaken including obtaining a broader, more robust and integrated overview of CC impacts on the Western Mediterranean region. This entails obtaining improved CC projection data and understanding of how CC will interact with multiple stressors to influence the productivity, biodiversity and ecosystem service provision of the western Mediterranean. For implementation of Nature-based Solutions, a better understanding of the potential impact of single and the synergistic effect of multiple solutions within a CC scenario context is needed. Such scenario testing needs to include plausible alternatives for future protection (MPAs and other measures – NBS2) and sustainable harvesting of seafood (NIH) compared with status quo (spatial, temporal and spatiotemporal).
There is a lack of understanding of how to consider habitat-forming species and their recovery (NBS1) within regional assessments. Furthermore, research is needed to assess ecological risks at the regional level and changes in ecosystem services under CC and different implementations of NBS. Moreover, research is needed to understand the adaptive capacity of the socio-ecological system with respect to CC and its impacts. Finally, this knowledge needs to be implemented to emergent but still incipient initiatives for climate-ready marine and maritime spatial planning.

FutureMARES research (T = Task – see program structure at futuremares.eu)

- **T1.1** Retrieve available environmental data to track observations of climate change, compilation of historical data series about vertebrates and invertebrates (abundance, biomass, catches), and calculation of the Community Thermal Index based on selected time series for the Western Mediterranean Basin (WMB);
- **T1.2** Compilation of published data about abundance and traits (including information on the thermal limits) of selected fish and invertebrate species characteristic of the WMB and their distribution in relation to depth, impacts of fishing pressure as well as their legal protection status in the region;
- **T2.3** Identification of environmental data needed for the regional model analyses;
- **T4.1** Compilation of GIS layers about distribution of habitat forming species, such as mael, coralligenous and *Posidonia oceanica* meadows distribution, in the WMB;
- **T4.2** Compilation of GIS layers about distribution of charismatic species, such as marine mammals, seabirds and turtles, in the WMB;
- **T4.3** Modelling the fisheries activity and plausible scenarios in the WMB using a marine ecosystem model of the region (4.4 model);
- **T4.4** Modelling the WMB using a marine ecosystem model of the region with focus on testing NBS 2 and 3, and their interactions and synergies, under moderate and extreme CC projections. When modelling NBS2 we will consider the ecological consequences of recovering habitat forming species (NBS1);
- **T5.1** Climate Risk Assessment at functional group level for the WMS;
- **T5.2** Climate Risk Assessment of the ecosystem services level of the WMS;
- **T6.1** Prioritization of management sites in the WMS in the face of climate change;
- **T6.2** Estimation of planning costs of managing sites in the WMS;
- **T7.1 & 7.2** Engagement with policy makers at national, regional or EU level, and international level (IPCC, IPBES, through FishMIP collaboration);
- **T8.1** Online presentations, synergies with other projects and initiatives (e.g., INTEMARES), meetings with regional stakeholders in annual venues.

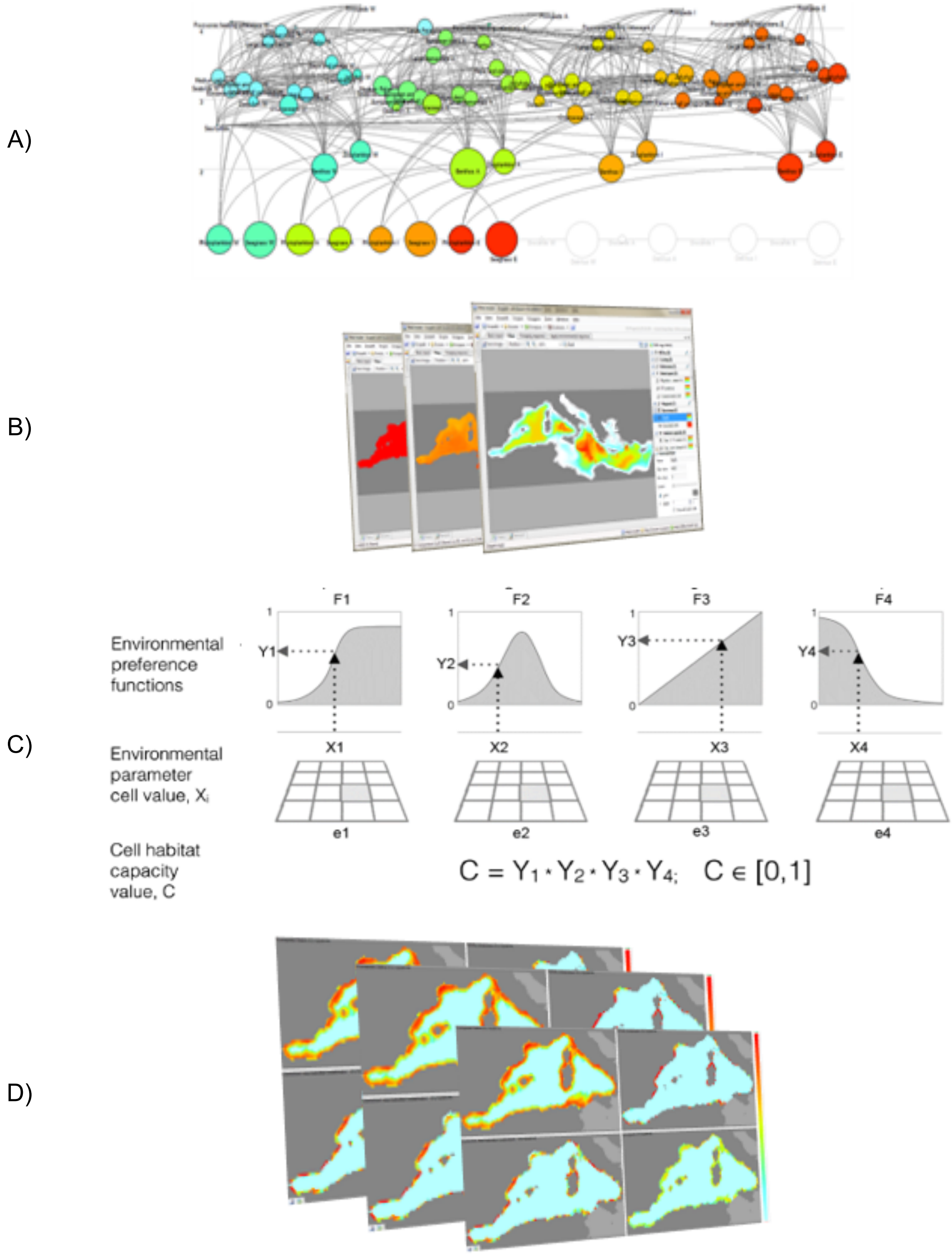


Figure 6: Methodological aspects of Task 4.4 to develop the marine ecosystem model of the WMB to test NBS2 and 3, and their interactions and synergies, under moderate and extreme CC projections: (a) baseline food web model structure using Ecopath with Ecosim, EwE (Christensen & Walters 2004), (b) spatial-temporal data to parameterize and drive the model using the spatial-temporal framework of EwE (Steenbeek et al. 2013), (c) habitat foraging capacity model to be applied to assess cell suitability (Christensen et al. 2014), and (d) example of spatial-temporal results as species distributions and ecological indicators, considering uncertainty analyses (Coll & Steenbeek 2017, Steenbeek et al. 2018).

Storyline Contact

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