Seagrass meadows and macroalgal forests in the MPA network of the Tuscan Archipelago

Storyline 28

NBS 2
EFFECTIVE CONSERVATION

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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 Tuscan Archipelago (TA) spans 150km in latitude and is composed of seven islands that are granted different levels of protection, ranging from a total (Gorgona, Pianosa and Montecristo), partial (Capraia and Giannutri) to no (Isola d'Elba, Giglio) ban on human activities. These islands host extensive seagrass meadows and macroalgal forests (Fig. 1) that support diverse invertebrate and fish assemblages and function as the pillars of a thriving economy centred on touristic activities (e.g. diving, bathing, bird-watching, boating, sailing and angling), artisanal fisheries and aquaculture.

The TA represents, therefore, an ideal model for testing future scenarios of the application of climate-ready Nature-based Solutions (NBS). Solutions such as conservation, restoration and sustainable harvesting could foster the functioning of marine ecosystems and associated economies. Seagrass meadows (Posidonia oceanica), intertidal and subtidal macroalgal forests *(Ericaria* spp.) are among the most diverse and productive ecosystems in the Mediterranean Sea. These key foundation species form habitats and sustain biodiversity at different trophic levels and provide highly valuable ecosystem services, such as productive fisheries, improvement of water quality, carbon sequestration and shore protection from erosion, thus sustaining the economic and social welfare of coastal communities.

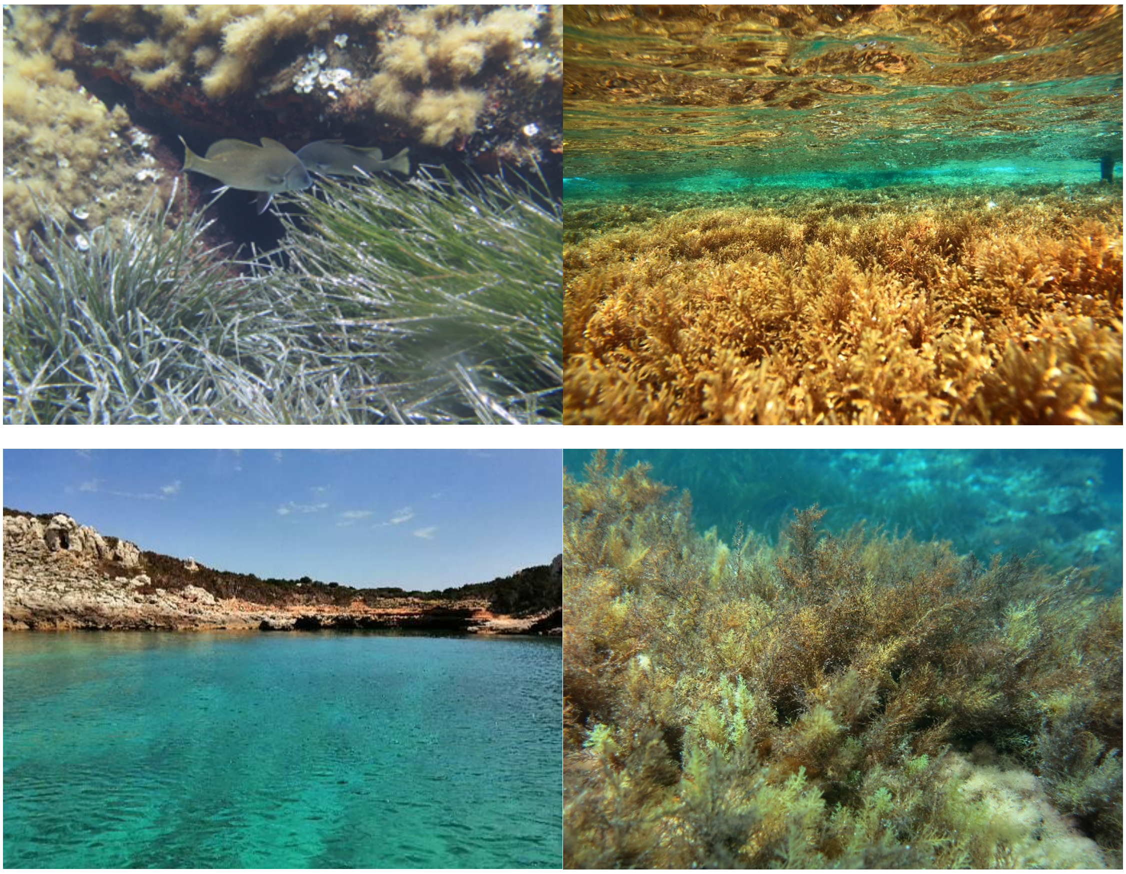

Figure 1: Top left: Individuals of brown meagre (Sciaena umbra) in a Posidonia oceanica meadow of the Island of Pianosa (Tuscan Archipelago). Photo credit: L. Benedetti-Cecchi **Top right:** The intertidal canopy-forming alga Ericaria amentacea on the rocky coast of the Island of Capraia. Photo credit: C. Mintrone **Bottom left:** The coast of the Island of Pianosa (Tuscan Archipelago). Photo credit: F. Bulleri **Bottom right:** Subtidal forests formed by Ericaria brachycarpa on shallow rocky reefs of the Island of Capraia. Photo credit: F. Bulleri

Seagrass meadows and macroalgal forests are currently well-preserved in most areas of the TA (Tamburello et al. 2012), but their persistence is jeopardised by local and regional stressors (e.g. enhanced herbivory due to the over-exploitation of predators, nutrient, sediment and pollutant inputs, trawling, invasive species, boat anchoring) and also by global climate changes (e.g. seawater warming and acidification). Recent work estimated a 34% loss of P. oceanica meadows in the last 50 years (Telesca et al. 2015). Under the worst-case (RCP 8.5) greenhouse gas scenario, projections suggest a loss of 75% of the suitable habitat for P. oceanica by 2050 and for beds to be functionally extinct by 2100 (Chefaoui et al. 2018). Likewise, declines of subtidal macroalgal forests formed by Ericaria spp. have been recorded throughout the Mediterranean Sea as a consequence of compounded effects of regional and global stressors (Thibaut et al. 2015, Strain et al. 2014, Peleg et al. 2020).

Both *P. oceanica* meadows and *Ericaria* spp. forests are included in the European Red List of Habitats and protected under several legal frameworks, including the European Habitats Directive 1992 EU Regulation 1967/2006, the Barcelona Convention (1976) amended in 1995 and the Bern Convention (1976) amended in 1996; Salomidi et al. 2012), under surveillance as vulnerable by IUCN, RAC/SPA and MedPAN and considered indicators of ecological quality within the Water Framework Directive. Effective conservation and restoration of these habitats is, therefore, paramount to sustain the natural capital of the TA.

Projected impacts of climate change

The Mediterranean Sea is considered a hotspot of climate change and projections suggest that it will warm at a faster pace than global trends, in particular during summers (Lionello and Scarascia 2018). In the last two decades, North-western regions of the Mediterranean Sea have experienced maximum daily sea surface temperature anomalies exceeding 5°C (Sen Gupta et al. 2020). In this area, Marine Heatwaves (MHWs) have been shown to cause enhanced mortality of habitat-forming primary producers, such as *Posidonia oceanica* (Marbà and Duarte 2010) or, indeed, mass mortalities in sessile invertebrates, such as gorgonians, red coral, bivalves, ascidians and sponges (Perez et al. 2000, Garrabou et al. 2009, Gómez-Gras et al. 2021).

Under the RCP8.5 scenario, there are projections for the end of the century of increased frequency of basin-wide MHWs (Oliver et al. 2018), which could occur at least once a year, be up to three months longer, four times more intense and 42 times more severe than present MHWs (Darmaraki et al. 2019). Results from T2.1, indicate that, by the end of the century and under the SSP5-8.5 scenario, the TA will be characterized by a marked increase in mean seawater temperature, up to about 4°C at 5 m of depth during summer months (Fig. 3), and by a decrease in pH, which will be more pronounced during winter months (Fig. 4). In contrast, regardless of the climatic scenario, there are predictions of minor changes in salinity (Fig. 5). The conservation of species playing a key role in sustaining the functioning of marine ecosystems (e.g. foundation species or habitat-formers) is considered a priority by the National Strategy for Climate Change Adaptation developed by the Italian Ministry of Environment. Indeed, enhancing the efficiency of Marine Protected Area (MPA) networks including no-take zones and their connectivity with areas more frequently exposed to climatic anomalies or exposed to other human disturbances is envisioned as a fundamental tool for mitigating climate change impacts on marine ecosystems at the regional level.

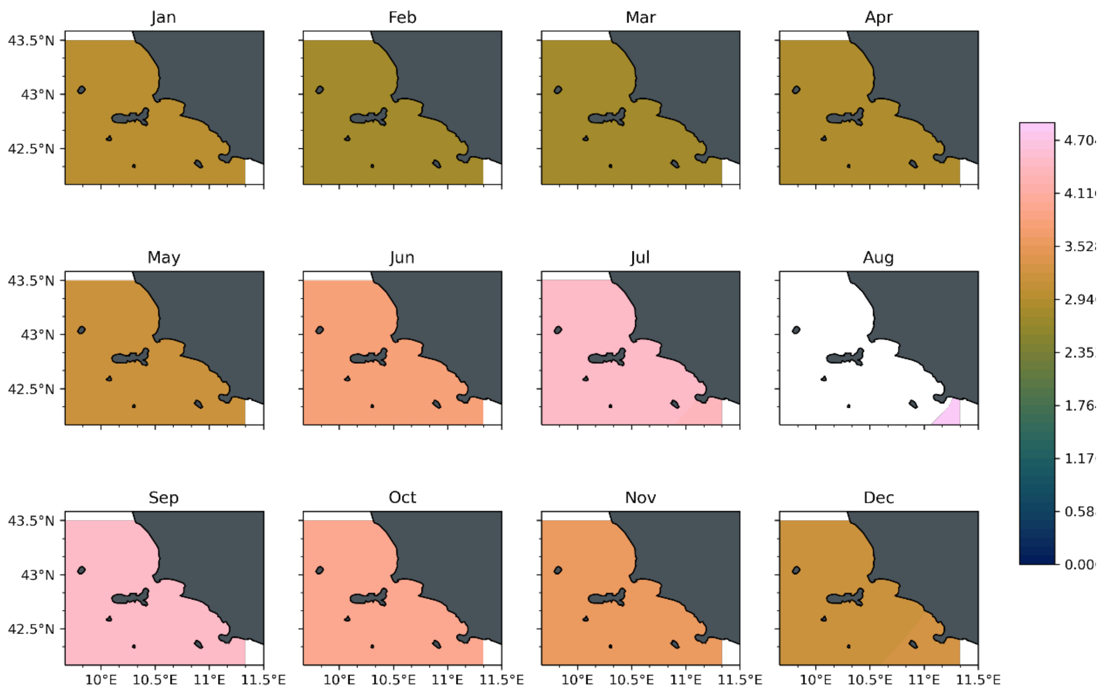

Figure 2: Monthly change in seawater temperature at 5m of depth in the TA, expected for the end of the century, under SSP5-8.5 Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change

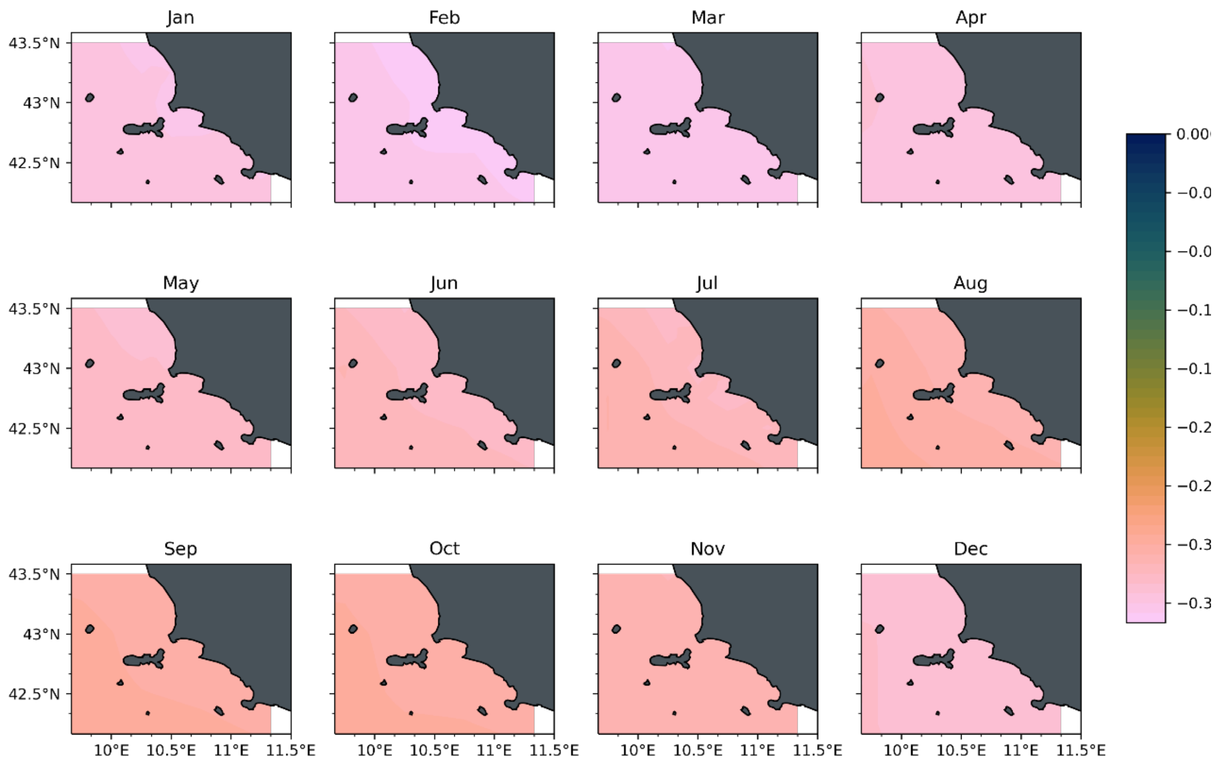

Figure 3: Monthly change in pH at 5 m of depth in the TA, expected for the end of the century, under SSP5-8.5 Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change

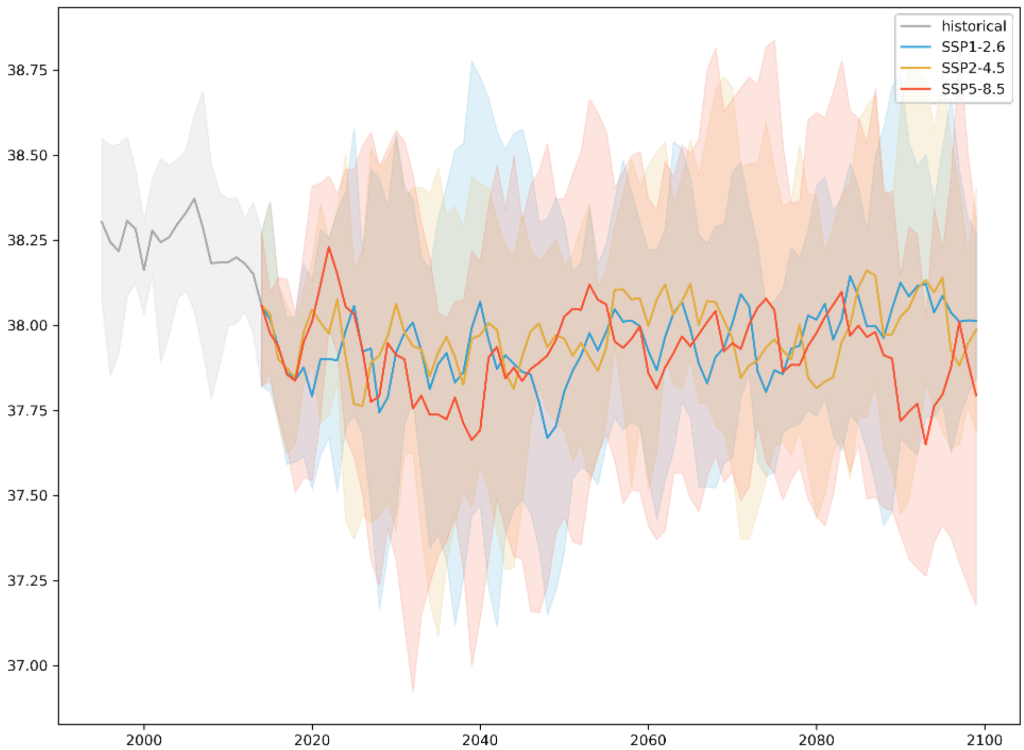

Figure 4: Change in salinity at 5 m of depth in the TA, expected for the end of the century, under SSP5-8.5 Credit: Momme Butenschön, Euro-Mediterranean Center on Climate Change

Figure 5: Wave rider in stormy weather along the coast of Livorno. Photo credit: A. Dani

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

FutureMARES research needs

Understanding how seagrass meadows and macroalgal forests will be impacted by global climate change is key for preserving their functioning and ability to sustain regional economies and livelihoods in the TA. In particular, we urgently need to: i) examine temporal trends in habitats formed by *P. oceanica* and *Ericaria* spp. and associated species and how trends relate to changing environmental conditions, ii) assess the level of risk posed by climate stressors to different populations of *P. oceanica* and *Ericaria* spp. as well as the roles of phenotypic adaptation and genetic connectivity in promoting the persistence of these habitat-forming species in the TA under future climate scenarios, iii) project the distribution of these habitats in the future in order to iv) assess where protection in the TA will be most effective in sustaining the functioning of habitats formed by these macrophytes, and vi) understand the social and economic costs and benefits of implementing such strategy.

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

- **T1.1** Compile and explore data on temporal trends in macroalgal forests and associated assemblages in the Tuscan Archipelago;
- **T1.2** Identify species life-traits responding more markedly to environmental variables;
- **T1.3** Identify Ecosystem Service indicators relevant for the management of seagrass meadows and macroalgal forests in the TA;
- **T3.1** Compare the functioning of intact and degraded benthic communities and the response of habitat-forming species to heatwaves and multiple stressors. Conduct mesocosm experiments to test whether and how P. oceanica and Ericaria spp. can dampen the effects of heatwaves and seawater acidification impacts on associated species and ecosystem functioning;

- **T3.2** Assess local adaptation of P. oceanica and Ericaria spp. by examining within-population physiological and phenological plasticity;
- **T3.3** Examine the dispersal and genetic connectivity among P. oceanica, Ericaria spp. populations and sea urchins in the TA and across the western Mediterranean;
- **T4.1** Simulate the changes in future distribution of biomass, abundance and production of P. oceanica and Ericaria spp. across the TA using physiological-based species distribution modelling;
- **T5.1** Perform a Climate Risk Assessment of P. oceanica and Ericaria spp. Communities;
- **T6.1** Generate spatial maps of climate-readiness in the configuration of the MPA network in the TA to enhance communication with stakeholders and policy-makers;
- **T6.2** Perform a cost-effectiveness analysis of the implementation of the MPA network in sustaining P. oceanica and Ericaria spp. in the TA;
- **T8.2** Engage stakeholders to co-develop activities (e.g. produce regionalised NBS scenarios, include knowledge on ecological risks) and increase policy relevance of scientific products.

Storyline Contact

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