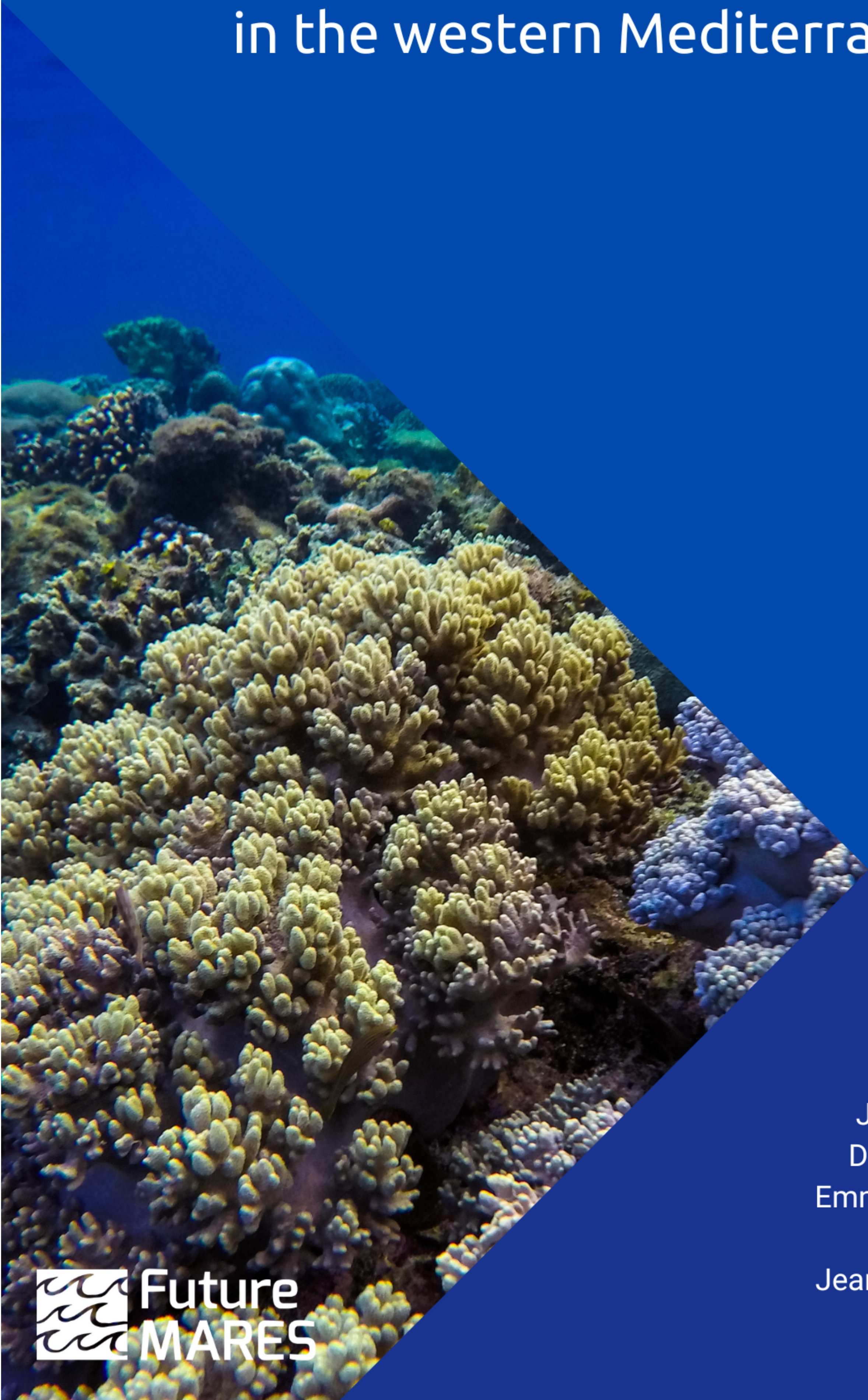
Habitat-forming macroalgae / corals in the western Mediterranean Sea

Storyline 29

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

This Storyline will focus on the subnetwork of marine protected areas (MPAs) located in the northern Catalan coast, located in the NE of the Iberian Peninsula (NW-Mediterranean region). This subnetwork is composed of three protected areas; the Natural Parks of the Cap de Creus and the Montgrí, les Illes Medes i el Baix Ter and the Natura 2000 site Litoral Baix Empordà. Together, the three areas span over a geographical scale of 60 km and cover more than 65 km^2 of marine coastal waters. The area is protected to different extents from the reinforced protection no-take no-use zones (e.g., in Illes Medes and Cap de Creus), no-take zones (e.g. Illes Medes) to partial protection areas (some specific regulations for fishing modalities and recreational uses) up to similar regulation as in non-protected zones. This protection heterogeneity is the result of different processes adopted for the declaration of the MPAs, as well as the specific socio-ecological context of the area, in which fisheries and multiple tourist interests exist.

From an ecological perspective, the three MPAs contains a great diversity of coastal benthic habitats, including the coralligenous assemblages and the macroalgal forests dominated by *Ericaria crinita*. The macroalgal forests dominated by *E. crinita* are also recognised as a hotspot of diversity and a source of food and habitat to diversified assemblages of understory species. They also enhance coastal primary productivity. These macroalgal forests are distributed throughout the entire Mediterranean Sea (as *Cystoseira crinita*; Ribera et al. 1992, Sales et al. 2012) where they are mainly restricted to the upper sublittoral zone in relatively wave-sheltered and well-illuminated environments (Molinier 1960, Sales and Ballesteros 2009, 2010, 2012). Unfortunately, these marine forests are also threatened by multiple stressors, including urbanisation, eutrophication and increasing sediment loads in coastal areas, as well as climate change.

The coralligenous assemblages are hard-bottom habitats of biogenic origin that are mainly produced by the accumulation of calcareous encrusting algae growing at low irradiance levels (15-120m depth). Coralligenous habitats are highly biodiverse (hosting around 10% of Mediterranean species) (Ballesteros et al. 2006). They tend to be dominated by long-lived algae and sessile invertebrates such as sponges, corals, bryozoans and tunicates (Ballesteros 2006). However, because most of the structural species of the coralligenous are long-lived and exhibit slow population dynamics (Caragnano and Basso 2009, Garrabou and Ballesteros 2000, Garrabou and Harmelin 2002, Linares et al. 2007, Teixidó et al. 2011), they are also very sensitive any disturbance that increases adult mortality rate. As a consequence, coralligenous assemblages are currently threatened by several pressures such as nutrient enrichment, invasive species, increased sedimentation, mechanical impacts such as damage from fishing activity, and climate change (Ballesteros 2006, Balata et al. 2007, Garrabou et al. 2009 & 2021, Piazzi et al. 2012, Verdura et al. 2019, Gómez-Gras et al. 2021).

Coralligenous assemblages and *E. crinita*-dominated macroalgal forests both provide important ecosystem services to human societies (e.g., fishing, tourism, active compounds, carbon sequestration). Due to these services and the current threats to these habitats, the subnetwork of three MPAs represents an ideal study area for exploring scenarios of how NBSs (e.g., better designing the MPA network to increase climate resilience) could sustain the functioning and services provided by these habitats in different climate futures.

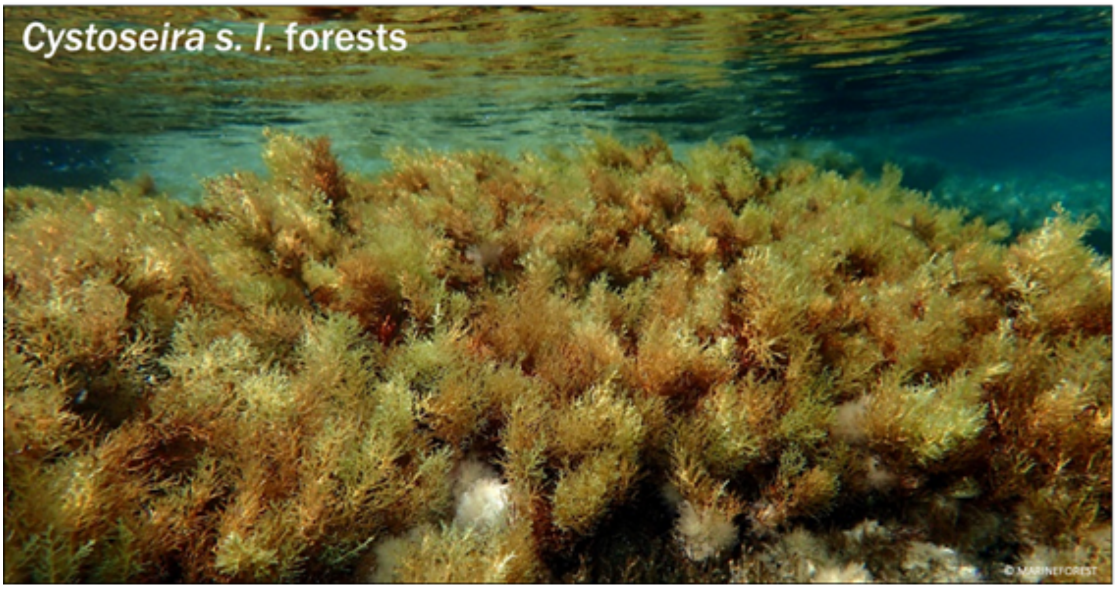

Figure 1: Typical shallow 0-3m macroalgal forest dominated by *Cystoseira sensulato* species in the study area. Photo by Enric Ballesteros

Figure 2: Typical deep (20-50 m depth) coralligenous formation dominated by the red gorgonian *Paramuricea clavata* in the study area. Photo by Josep Clotas

Projected impacts of climate change

The Mediterranean Sea is considered a hotspot of climate change that is warming faster than the average surface of the world's oceans (Pisano et al. 2020). In particular, the western basin is warming at a rate of 0.03ºC per year, which is almost three times faster than the global oceans (average 0.012ºC per year; Pisano et al. 2020). Moreover, the frequency of extreme events has doubled in recent decades, with marine heatwaves becoming longer, more frequent and intense (Darmaraki et al. 2019).

Since the Mediterranean is also a biodiversity hotspot (Bianchi and Morr, 2000), the convergence between rapid warming trends and exceptional biodiversity has resulted in widespread evidence of climate change impacts on Mediterranean biota at all levels of biological organization (Lejeusne et al. 2010, Marbà et al. 2015). In particular, extreme warming events such as marine heatwaves (MHWs) are triggering devastating mass mortality events (MMEs) that are impacting Mediterranean benthic communities across hundreds to thousands of kilometres of coast (Cerrano et al. 2000, Garrabou et al. 2009 & 2019, Linares et al. 2005). During these events, thousands of organisms from a great variety of species and phyla are experiencing temperatures that exceed their thermotolerance limits, suffering extensive tissue necrosis (partial and total mortality) and subsequent population declines. There is evidence of these species impacts are cascading to the community and ecosystem levels in some cases, causing structural and compositional changes, as well as changes in the ecosystem functioning (Verdura et al. 2019, Gómez-Gras et al. 2021). However, there is also evidence that local-scale climatic refugia exist that, if clearly identified, could be protected to safeguard the persistence of Mediterranean benthic communities (Verdura et al. 2021).

High-resolution projections (10- to 20-km spatial and daily temporal scales) using IPCC RCP scenarios 2.6, 4.5 and 8.5 revealed a sustained increase in the frequency and intensity of MHWs over the next century in the NW Mediterranean Sea (Garrabou et al. 2021). Specifically, the number of MHW days will probably reach levels far above what occurred in 2003, an exceptional year, during the next decade in all RCP scenarios. By 2050, and under RCPs 2.6 and 4.5, MHWs are expected to last for ca. 60% of the period (3.5 months) vs. 73-85% (4.5 to 5 months) under the worst-case RCP 8.5 scenario. In addition, MHW frequency is projected to further increase during the second half of the century, up to 80-100% of the period from June to November, except under RCP 2.6 where a decreasing trend occurred after 2070. In addition, MHWs are expected to increase their maximum intensity by two to three-fold during the second half of the 21st century depending on scenarios.

Overall, these projected warming trends suggest an increased number of winner and loser species, a loss of habitat complexity due to the loss of habitat-forming species, and the potential occurrence of changes in ecosystem structure, composition and functioning (Ben Rais Lasram and Mouillot 2009, Ben Rais Lasram et al. 2010, Sala et al. 2011, Verges et al. 2014, Azzurro et al. 2019, Montero-Serra et al. 2019 Gómez-Gras et al. 2019 & 2021). It is, therefore, urgent to identify and preserve the mechanisms of ecosystem stability that maintain essential functions and services in NW Mediterranean benthic ecosystems. In this sense, NBSs such as the conservation and/or restoration of key habitat-forming species will be critical.

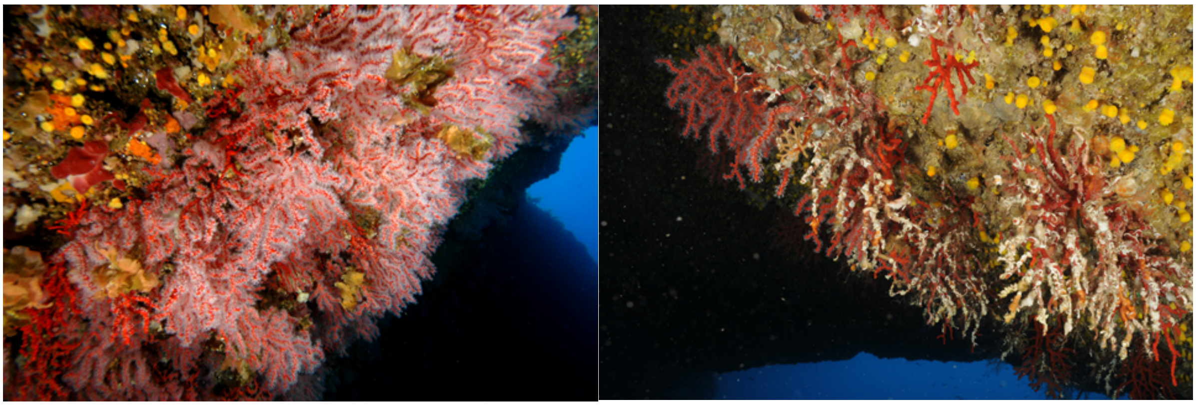

Figure 3: A healthy population of red coral Corallium rubrum (above) and affected by amass mortality event (below). Photos by Joaquim Garrabou

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

FutureMARES research needs

The main research questions that need to be address focus on understanding the processes and mechanisms enhancing the resilience of targeted rocky benthic habitats in the face of climate change.

Key research needs include:

1) Improve our understanding the factors and processes that shape intra-specific and inter-specific sensitivity to warming in benthic species to improve our ability to assess climate change risks. Field and experiments (in and ex situ) are required along with next generation genomic approaches.

2) Better support and coordination is needed in coastal observatories to track climate change effects in Mediterranean coastal areas. Sustained coastal observation networks are essentially lacking and the implementation of harmonised monitoring protocols is needed across the three MPAs. This will better inform MPA managers on ongoing climate impacts in their specific areas.

3) Newly availability technologies in data acquisition and analysis need to be implemented to better study and characterise benthic communities in structurally complex rocky benthic habitats. These new techniques can help quantify patterns across relevant spatial and temporal scales. Such advances are a crucial step forward to enhance our understanding in the relationship between the structure and functioning of benthic communities.

4) There needs to be a better implementation of marine citizen science activities in the MPAs. Community engagement strategies are being developed to take full advantage of this emerging activity and platforms (e.g. Observadores del Mar www.observadoresdelmar.es coordinated by CSIC) to improve the conservation status of marine ecosystems.

5) Climate adaptation strategies need to be developed to enhance the role of MPAs as Ocean Based Solutions to climate change. The lessons learnt in the development of operational climate adaptation strategies for the managers of the 3 MPAs will help establish tailored action plans to confront climate change in other MPAs.

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

- **T1.1** Analysis and supporting long-term monitoring series including calculation of Community Thermal Index;
- **T1.2** Collect species traits for macroalgal and coralligenous habitats needed to examine climate risk;
- **T2.1** Provide the T-MEDNet high-resolution temperature series to explore agreement with ensemble model hindcasts with potential bias correction for near shore environments;
- **T2.3** Spatial and temporal analysis of physical and biogeochemical model runs bias corrected with T-MedNet measurements to identify climatic hotspots and refugia;
- **T3.1** Perform field measurements on macroalgal habitats to understand their role in biogeochemical cycling and potential carbon budgets;
- **T3.3** Analyse population genetic datasets and analysis of octocorals and potentially other key members of the MPA habitats;
- **T4.1** Perform spatial distribution projection modelling under different scenarios of climate and MPA network management;
- **T5.1** Provide input to estimate ecological climate risk to thee habitats (thermotolerance data available);
- **T6.1** Create spatial maps identifying options for implementing climate-ready conservation (NBS2) within the NW Mediterranean given multiple users, sectors and services (particularly fisheries);
- **T7.1-8.1** Engage local MPA managers to co-develop project activities and present FutureMARES activities to broader, MPA network through other, ongoing programs.

Storyline Contact

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