Restoration of seagrass (Posidonia oceanica) in the Balearic Islands (North-west Mediterranean)

Storyline 25

NBS 1
EFFECTIVE RESTORATION

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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

Posidonia oceanica is a Mediterranean seagrass endemism that forms underwater meadows up to 45 m depth (1). These meadows provide habitat, nursery and feeding grounds to a high diversity of organisms, act as filters of suspended particles and dissolved nutrients, reduce sediment resuspension and attenuate wave energy, and are important carbon and nutrient sinks. They also contribute to maintaining good conditions in the marine environment that are at the base of important activities (fishing, beach enjoyment, coastal recreational activities such as diving) in the economy of Mediterranean countries. *P. oceanica* is a slow growing species (2) with low and highly variable sexual reproduction (3) and limited capacity to recover from disturbance (4). Present in about 50% of Mediterranean coastline, between 13% and 38% of the area extent of meadows has been lost during the last decades mostly due to local impacts of anthropogenic activities (5-7). Restoration of lost or disturbed *P. oceanica* meadows is a nature-based solution that, if successful, may facilitate the recovery of the ecosystem services that these meadows provide (e.g., carbon sequestration, coastal stabilisation, sand generation, nursery function and cultural services among others) (8-10). Of paramount importance is the CO_2 sequestering capacity of *P. oceanica* meadows (up to 1.6 tCO_2/ha yr; 11) and its possible role in climate change mitigation (12-14), as well as their role in supporting commercial fisheries (15). The value and fragility of *P. oceanica* meadows is reflected by their inclusion as a priority habitat in the European Union's Habitat Directive (92/43/EC) and on be considered a characteristic to assess the good environmental status of the marine environment by the EU's Marine Strategy Framework Directive (2008/56/EC).

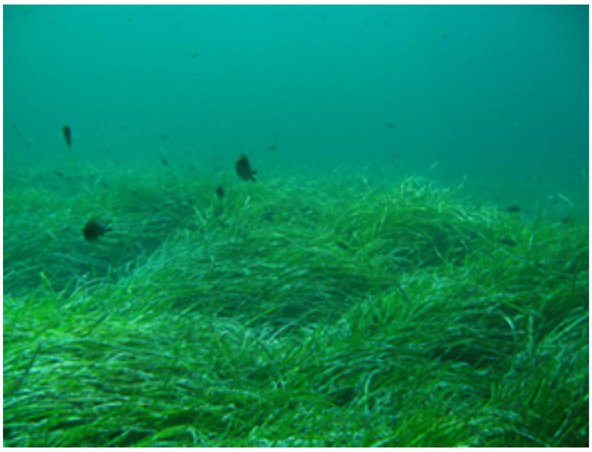


Figure 1: Posidonia oceanica meadow. Credit: Jorge Terrados, IMEDEA (CSIC-UIB)

Figure 2: Fish capture in a *P. oceanica* meadow. Credit: Ignacio Catalán, IMEDEA (CSIC-UIB)

Projected impacts of climate change

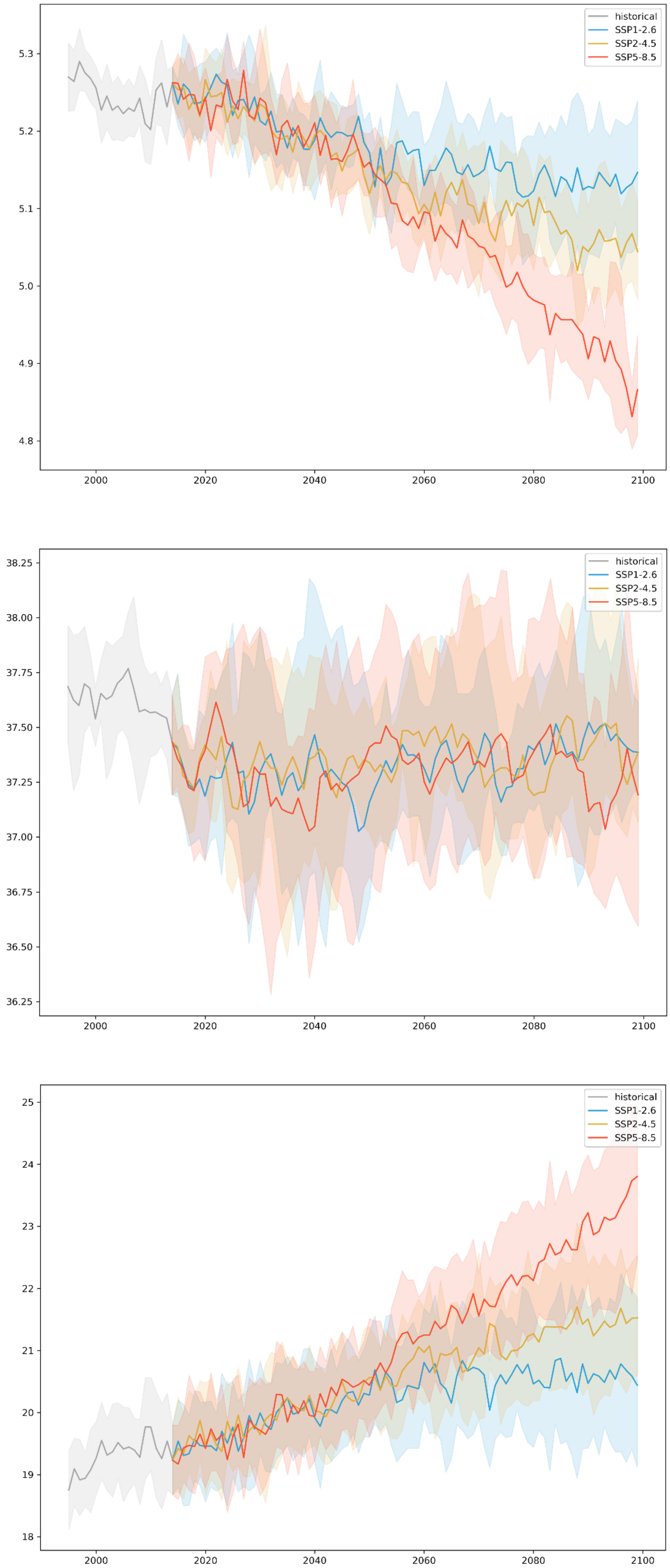
The main direct negative effects of climate change (CC) on *Posidonia oceanica* meadows are expected to be mainly associated with the increase of seawater temperature. An upper thermal limit of 29ºC for the presence of *P. oceanica* has been suggested based on correlative evidence between species distribution and local temperatures (16). In the laboratory, this species maintains near-to-optimum leaf growth between 20.1ºC and 29.6ºC and shoot survivorship is reduced to only 50% at 28.9ºC (17).

Different experimental short-term (weeks) and mid-term (months) studies show that negative effects of seawater temperature on plant performance become significant at temperatures of 28ºC (18), 29ºC (19-22) or 30ºC (23-24) compared to temperatures of 24ºC-27ºC. In situ monitoring of plant performance and seawater temperature provides correlative evidence of the onset of negative effects at temperatures above 28ºC (25). However, *P. oceanica* is able to tolerate short-term (days) exposure to temperatures of 30ºC (23). Hence, the interval 28ºC-30ºC would represent the transition from a within-physiological limits *P. oceanica* development to a deleterious condition that will drive plant loss. In theory, this contention imposes limits to the feasibility or long-term success of *P. oceanica* meadow restoration that should be considered.

CC may impact other services associated with the relatively high biodiversity associated to *P. oceanica* (26-27). Although largely untested, CC effects might affect some components of the exploited fish and cephalopods using *P. oceanica* as a key component of their habitat (28-30). Projected CC effects on the community might be either direct (e.g. thermal limits), derived from habitat degradation, or combined. Further, CC effects will interact with other anthropogenic stressors (19, 23-24, 31-32) that may ultimately override CC effects.

Figure 3: Wastewater outfall near *P. oceanica* meadows. Credit: Manu San Felix, Vellmarí Foundation

Figure 4: Anchoring in *P. oceanica* meadows. Credit: Jorge Terrados, IMEDEA (CSIC-UIB)



A

B

C

Figure 5: Projections for (A) Oxygen (in ml/l) at 5m depth (B) Salinity (in PSU) at 5m depth (C) Potential Temperature (in degrees C) at 5m depth

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.

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

Techniques for the planting of *Posidonia oceanica* meadows are increasingly assessed and currently it is feasible to address meadow restoration under specific conditions (33-34). The recovery of ecosystem function in restored areas and the consequent recovery of the ecosystem services they provide is a major gap in knowledge that needs to be addressed if restoration is to be considered a component of coastal zone management and climate change mitigation.

Ecosystem function and the provision of ecosystem services by *P. oceanica* meadows are dependent on the habitat structure that *P. oceanica* plants create. The recovery of ecosystem functionality and services is presumed to be slow considering the slow growth rate of the species. Some key questions to be answered include i) what functions and services are recovered first? ii) what are the recovery rates of the different functions and services? iii) are there any thresholds of habitat structure (or any other condition) that should be achieved for the recovery of a given ecosystem function/ service? iv) do specific ecosystem functions and services have specific constraints or thresholds for recovery?, v) how would climate change affect restoration success? vi) under what circumstances is ecosystem restoration an effective tool for climate change mitigation?

Successful *P. oceanica* plantings provide the opportunity to address these questions. Addressing these questions provide a unique opportunity to identify policy and socio-economic frameworks that facilitate restoration actions at spatial scales that are suitable for practical demonstration and management.

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

- **T1.1** Compile field data and initiate new field data collection: i) 2019- survivorship and vegetative development of planted *P. oceanica,* and of the abundance and diversity of epifauna and fish in the planted area. ii) historical (c.a. 100 yrs, with gaps) data series on the fish community of *P. oceanica* meadows in the Balearic Islands, iii) newly initiated (2021) annual data on the fish community of *P. oceanica* in Palma Bay, Mallorca. Iv) Calculate Community Thermal Index based on selected *P. oceanica* associated fish species and cephalopods;
- **T1.2** Compile of published data about abundance and traits of selected fish and cephalopod species characteristic of *P. oceanica* meadows, in relation to depth, cover/fragmentation of *P. oceanica* meadow, fishing pressure and legal protection

status in the Mediterranean. Compile published data on the thermal limits and effects of seawater temperature on the performance of *P. oceanica*

- **T2.2** 2019-initiated data series of seawater temperature in a shallow (5 m depth) *P. oceanica* restored area in Pollença Bay, Mallorca;
- **T2.3** Identify response function of *P. oceanica* performance to seawater temperature based on published studies;
- **T4.1** Compile GIS layers about distribution of *P. oceanica* meadows and create a training data set for modelling of *P. oceanica* distribution as a function of current and projected seawater temperature in the Balearic Islands;
- **T4.1** Perform simulations of *P. oceanica* propagule connectivity at high resolution (4.1) within the Balearic Islands;
- **T5.1, 5.2** Conduct a Climate Risk Assessment at species level for *P.oceanica* and associated community selected species and for selected ecosystem services;
- T**6.1** Prioritize *P. oceanica* restoration sites in the Balearic Islands in the face of climate change;
- **T6.2** Estimate the costs of planting *P. oceanica* in the Balearic Islands
- **T8.1:** Engage stakeholders using face-to-face interviews and workshops with relevant stakeholders in the Balearic Islands.

Figure 6: Planting of *Posidonia oceanica.* Credit: Jorge Terrados, IMEDEA (CSIC-UIB)

Figure 7: Sampling of *P. oceanica*-associated epifauna.
Credit: Jorge Terrados, IMEDEA (CSIC-UIB)

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