Biogeography and biodiversity change on coastal communities at continental scales

Storyline 36

NBS 2
EFFECTIVE CONSERVATION

Author:
Fernando P. Lima
(Research Centre in Biodiversity and Genetic Resources)

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

There is mounting awareness about the threat that climate change poses to global biodiversity, and that addressing it requires a better understanding of the link between climate and biodiversity. This is certainly the case of marine thermal refugia – which organisms can exploit to escape from the effects of climate change. The extent to which thermal refugia matters for biodiversity at continental and decadal scales remains largely unaddressed, thought, because of a lack of simultaneously detailed and wide coastal temperature and biodiversity datasets. Temperature data at scales matched to those of organisms is lacking due to previously unsurmountable technical limitations, severely reducing the impact of most analyses and forecasts (Helmuth et al. 2014). We have, however, recently developed a new family of miniaturized autonomous loggers (Chan et al. 2016, Lima & Wethey 2009, Gandra et al. 2015) which are key for collecting temperature at organismal scales over continental spans.

Intertidal systems, located in the area between the high and low tide levels, offer unparalleled advantages to address these questions. They are inhabited by marine organisms which must withstand terrestrial conditions during low tide (Harley 2008, Denny & Wethey 2000), and which are regarded as especially sensitive indicators of the effects of climate variability and climate change (Helmuth et al. 2006). In the intertidal, solar radiation is the dominant component of the energy balance, and during low tide its influence can exceed that of seasons or latitude (Seabra et al. 2011). Thus, geomorphology determines the availability of refugia and influences metabolic costs and sublethal and lethal stress (Lima et al. 2016). Coastal upwelling further increases thermal complexity (Seabra et al. 2019). During summer, cold and warm-water pockets alternate at regional scales, and owing to wind stress variability, sea temperature may experience oscillations of 5-10 ºC in a few days.

Figure 1: Extraordinary biodiversity in the low intertidal of NW Iberia. This sort of luxuriant algae cover was once abundant towards the south, but many of the canopy-forming algae are now retreating, leaving behind much less diverse communities. In some, few locations, however, these highly diverse communities are still present. We want to understand why. Are they exploiting thermal refugia? Credit: Fernando Lima

Interestingly, along the European coast, there is an alternation between stressful and non-stressful environments across a variety of scales, ranging from a few meters to hundreds of kilometres. Often these patterns overlap across spatial scales, amplifying or dampening their combined effect. Quantifying the availability of thermal refugia and understanding how it can buffer the deleterious effects of climate change is fundamental for understanding the mechanisms setting biogeographic limits and forecast changes in biodiversity. This information is extremely valuable to prioritize conservation efforts and to inform on the ideal spatial arrangement of marine protected areas.

In this storyline, we are compiling quantitative abundance data of more than 200 species of rocky intertidal organisms (e.g., algae, molluscs, crustaceans) collected by our research team more than 15 years ago at a series of microhabitats at 22 locations on the Atlantic coast of Europe (from Morocco to Scotland). We are downloading and compiling long-term temperature profiles measured at the scale of the organisms and at the same microhabitats by autonomous data-loggers developed specifically for this purpose by our team. These loggers have been installed in 2010 and have been collecting temperature at 1h resolution since then. Additionally, we are currently re-assessing biodiversity in the field at the same coastal locations surveyed in the past. Biodiversity changes are being compared with temperature patterns and with temperature changing trends. We are looking at changes in the temperature affinity of native and invasive species, changes in their geographical span, abundance, and co-occurrence, at the same time we quantify thermal heterogeneity and identify and quantify thermal refugia from micro to continental scales.

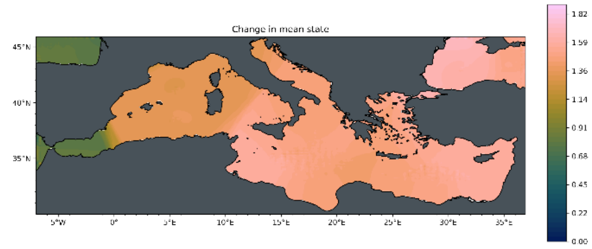
Figure 2 (left): The cold-water adapted canopy-forming foundation species Himanthalia elongata, which has suffered a dramatic retreat of the southern distribution limit along the coast. It moved more that 400 km over ~150 years. Notably, in the last decade the species disappeared from the entire coast, with the exception of the relict population here depicted. Is it because this location provides refugia from warming? Credit: Rui Seabra.

Figure 3 (right): Field testing of a new smartphone app developed by us to aid on the acquisition of photo-quadrat data and metadata, important to contextualize biodiversity measurements in the field. Credit: Fernando Lima

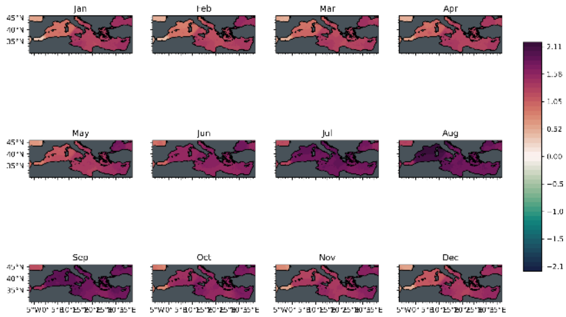
The evaluation of current and future distribution of thermal refugia along the European Atlantic coast will help us to generate robust forecasts of ecosystem sensitivity or resilience to climate change and, consequently, inform on the optimal placement of MPA in relation to climate change.

Projected impacts of climate change

Climate change has already been linked to the global redistribution of species and biogeographical boundaries, a process with deep ecological, economic, and social consequences (Pecl et al. 2017). Our ability to address the processes that drive these changes is deeply dependent on a better understanding of the links between the spatial and temporal structures of temperature and community changes (Waldock et al. 2018). Despite the fact that a substantial number of studies have been reporting major biodiversity changes in European intertidal communities in response to climate change (Lima et al. 2007, Burrows et al. 2020, Hawkins et al. 2009), few have focused on the importance of thermal refugia as a modulator of the effects of climate change (Lima et al. 2016, Lourenço et al. 2016, Bates et al. 2018). Thermal refugia may allow species to extend their distribution to areas otherwise uninhabitable, and may act as thermal buffers overriding the long-term warming trend. When acting upon key species (e.g., foundation species, Fig. 2) these processes have the potential to influence the entire community and drive (or prevent) pervasive change.



Potential Temperature (in degrees C) changes in the mid future at 5m depth under scenario SSP5-8.5



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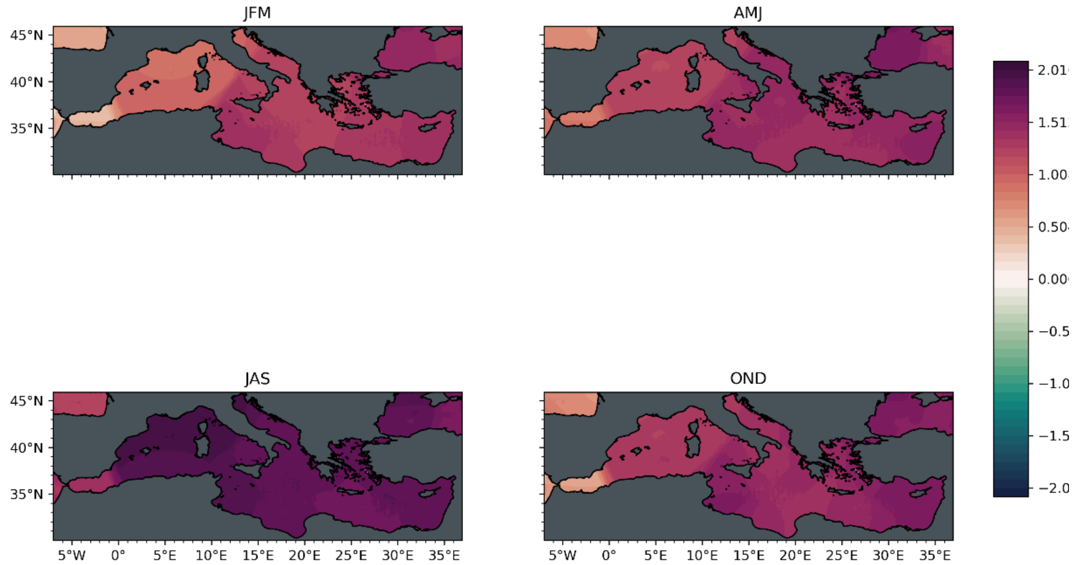

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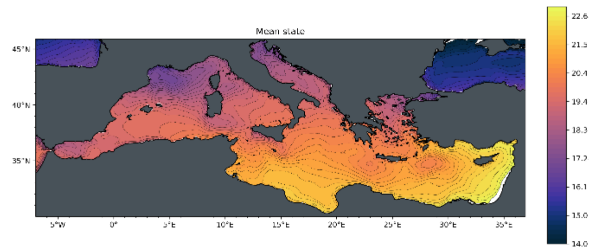
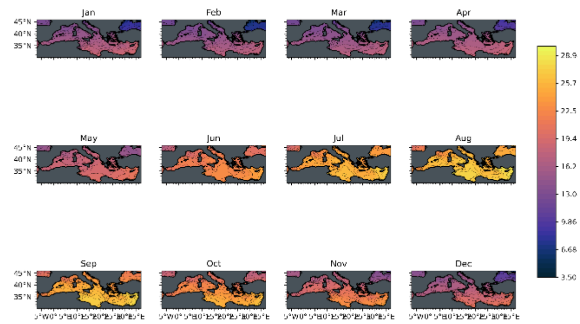


Potential Temperature (in degrees C) at 5m depth under present day conditions



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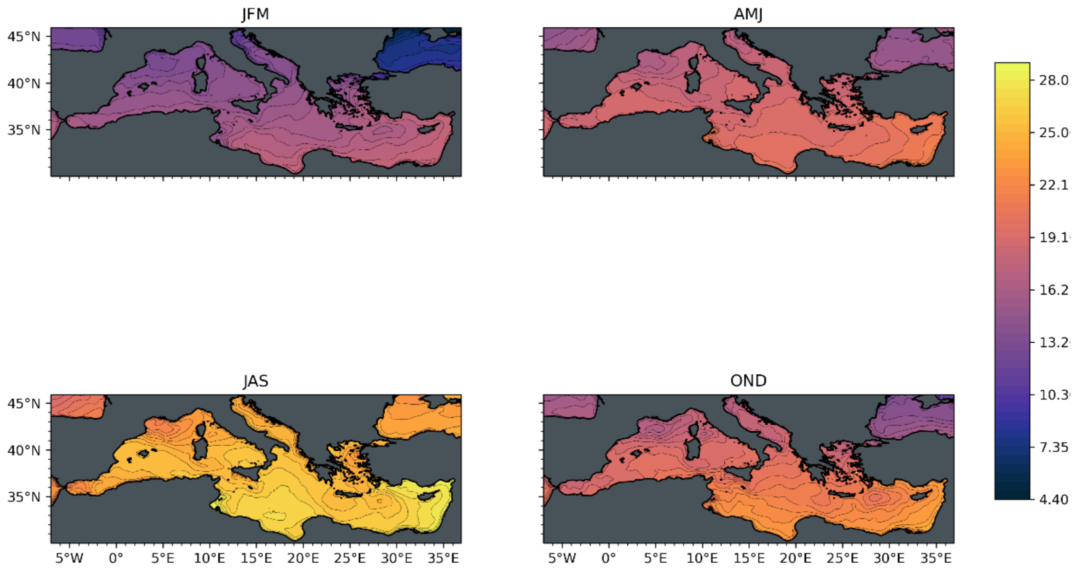

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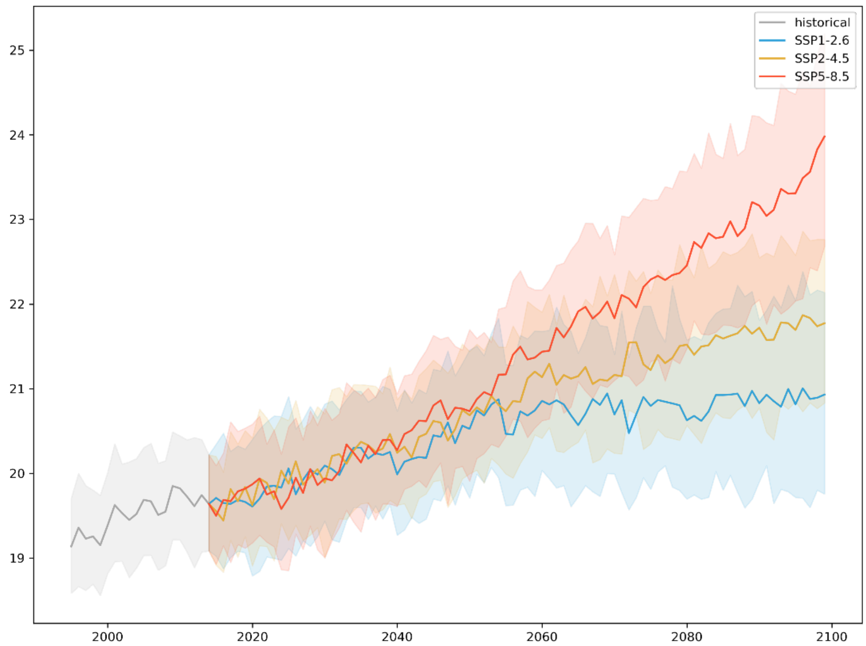

Potential Temperature (in degrees C) at 5m depth

Figure 4: 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

While large amounts of data are available on large-scale temperature patterns, comparatively little is known about near coastal and intertidal zones that are crucial for a wide variety of ecosystem services. Obtaining temperature data at scales matched to those of organisms is crucial because it ultimately drives organism's physiology and performance (17). The consequences of those performances are then scaled-up to the community level. Thermal refugia, in particular at scales that effectively matter, still needs to be quantified. Those data need to be accompanied by simultaneously detailed and geographically-wide biodiversity datasets collected at decadal scales from which change and stasis can be accurately assessed.

Figure 6: Downloading a year's worth of hourly temperature data from an autonomous miniaturized logger previously deployed in the intertidal. These data are crucial to identify and, more importantly, quantify the distribution of thermal refugia along the entire geographical span of species. Credit: Rui Seabra.

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

- **T1.1** Temporal trends in macroalgae and macroinvertebrate distribution and abundance across the Atlantic coast of Europe
- **T1.2** Identification of functional groups whose change can be associated with warming
- **T1.4** Engage stakeholders on FutureMARES scenarios to help define projection simulations
- **T2.1** Contribution with in-situ temperature data series for forecasts and hindcasts
- **T2.2** Contribution with in-situ temperature data series for uncertainty analyses
- **T2.3** Combination of biodiversity and temperature data to identify biodiversity hotspots and climate refugia in the Atlantic coast of Europe
- **T3.1** Team-up with CIIMAR to run experiments looking at the functions provided by canopy forming macroalgae at the southern limit of their distribution

- **T3.2** Team-up with CIIMAR to build a standardized experimental chamber that accurately replicates the intertidal thermal environment to assess the potential for local adaptation of selected species across the European Atlantic
- **T4.1** Provide data on range and abundance of seaweeds
- **T6.1** Produce climate readiness maps

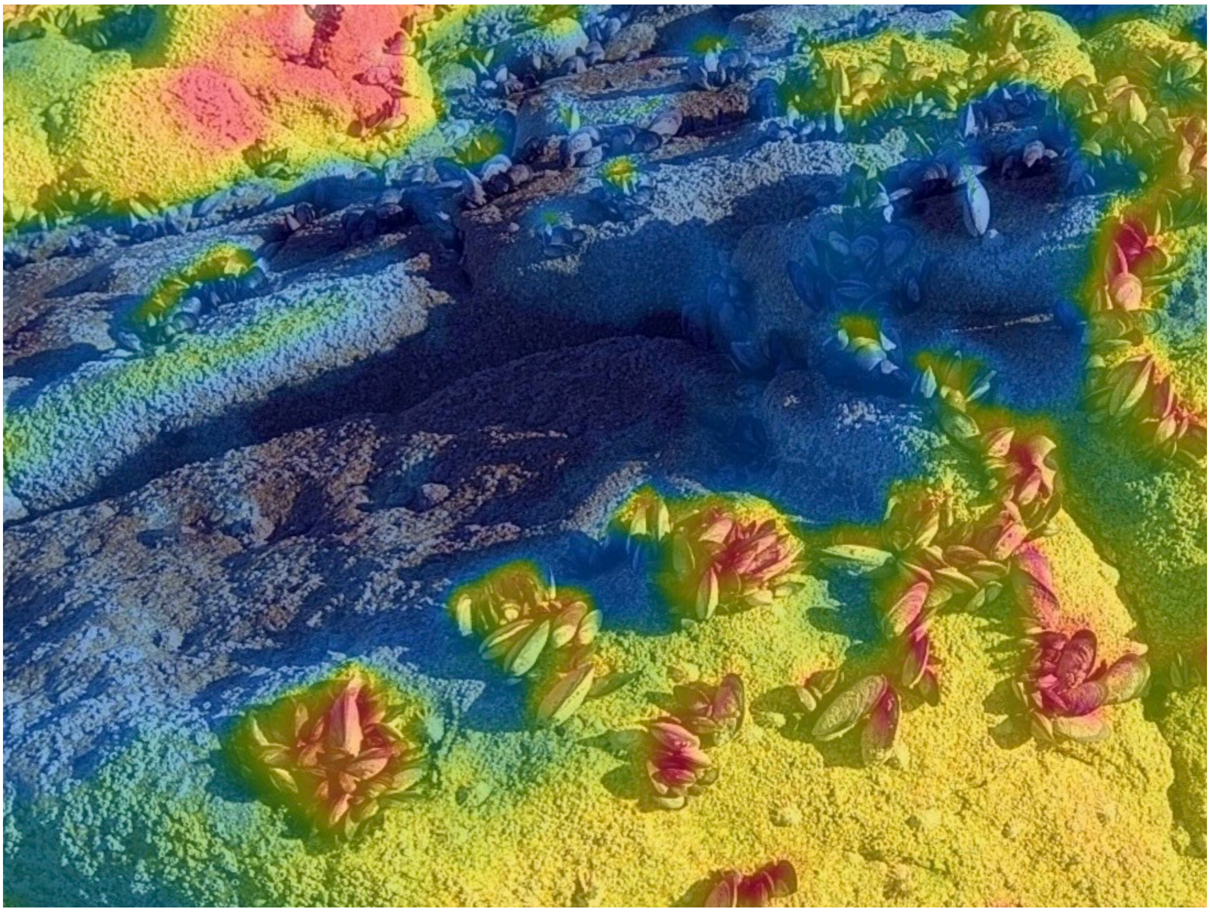

Figure 7: Thermal picture of the intertidal showing its immense thermal variability. We are quantifying how much thermal refugia and hotspots exist at a variety of scales from a few cm to continental scales, and their importance for the inhabiting life. Credit: Fernando Lima.

Storyline Contact

Fernando Lima (BIOPOLIS) - fplima@gmail.com

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