Kelp forests & biodiversity in northern Portugal

Storylines 21 & 23

NBS 1
EFFECTIVE RESTORATION

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

Marine seaweed forests, hereafter marine forests, are, together with seagrasses, the foundation of submerged vegetated ecosystems of coastal waters worldwide. Marine forests include habitat-forming primary producers such as large canopy species like kelps (Laminaria spp., Fig. 1&2) and intertidal fucoids (e.g., Fucus spp, Ascophyllum nodosum, Fig. 3). Marine forests often dominate shallow subtidal and intertidal rocky seashores, fuelling highly dynamic and diverse coastal ecosystems and providing several essential services. In Europe, marine seaweed forests extend from Arctic coasts down to the northern coastal shores of Portugal, which hosts some of the southernmost populations of cold-water species like the kelp Laminaria hyperborea and the rockweed Ascophyllum nodosum.

The Iberian upwelling is probably crucial in maintaining these seaweed communities due to the provision of cold and nutrient-enriched oceanic waters during the summer season (Franco et al. 2018). Iberian upwelling is weakening (Sousa et al. 2020) and these canopy-forming seaweeds are now declining (Franco et al. 2018, Casado-Amezua et al. 2019). Several canopy-based seaweeds are being replaced by turf-based communities with lower functional complexity (Vale et al. 2021). Functional effects are expected with several impacts at the ecosystem level (Crowe et al. 2013, Pessarrodona et al. 2021), but the magnitude of these impacts is still unknown.

Marine forest species are foundation species, providing food, shelter and habitats for a variety of organisms such as apex predators (sea mammals and seabirds), fish, invertebrates and other seaweeds, and support complex food webs in coastal zones, promoting healthy artisanal fisheries (Bertocci et al. 2015). Marine forests are highly productive systems and are considered biodiversity hotspots (Franco et al. 2020). They also provide other essential ecosystem services, such as food, raw material for bioactive compounds (e.g., Girão et al. 2019), coastal protection (Løvås and Tørum 2001), nutrient dynamics (abatement), and may be highly important for climate regulation and climate change mitigation, due to their carbon storage and sequestration potential (i.e. blue carbon, Krause-Jensen and Duarte 2016). Marine forests could also act as rescuers of climate change-sensitive species (Bulleri et al. 2018) by ameliorating environmental harshness via understory shading (Fernández et al. 2015).

Traditionally, the Northern Portuguese coast and marine forest habitats are extremely important as part of the local cultural heritage and recreation (e.g., diving, recreational fishing). Specifically, seaweed wrack has been collected for fertilising agricultural fields for centuries (Fig. 4). This activity, however, is now declining.

The Northern Portuguese Coast is within Rede Natura 2000, as a Site of Community Importance, and includes a Marine Protected Area (MPA) - Parque Natural Litoral Norte.

Within the region, the relevant stakeholders are:

- Municipalities (CMVC - Câmara Municipal de Viana do Castelo, Câmara Municipal de Esposende);
- Capitania do Porto de Viana, local users (fishermen associations - APPCE, recreational users – diving centre and ONG “Amigos do Mar”, diving centre “Cavaleiros do Mar”, “Centro Mergulho Esposende”);
- Management authorities for European communitarian funds - Portugal 2020 (Comunidade Intermunicipal do Alto Minho, Gal Costeiro Litoral Norte);
- Conservation national authorities: ICNF - Instituto para a Conservação da Natureza, DGRM - Direcção Geral dos Recursos Naturais, Segurança e Serviços Marítimos, APA - Agência Portuguesa do Ambiente)
- Local entities for environmental awareness (e.g. Esposende Ambiente, CMIA‘s de Viana do Castelo, Vila do Conde)

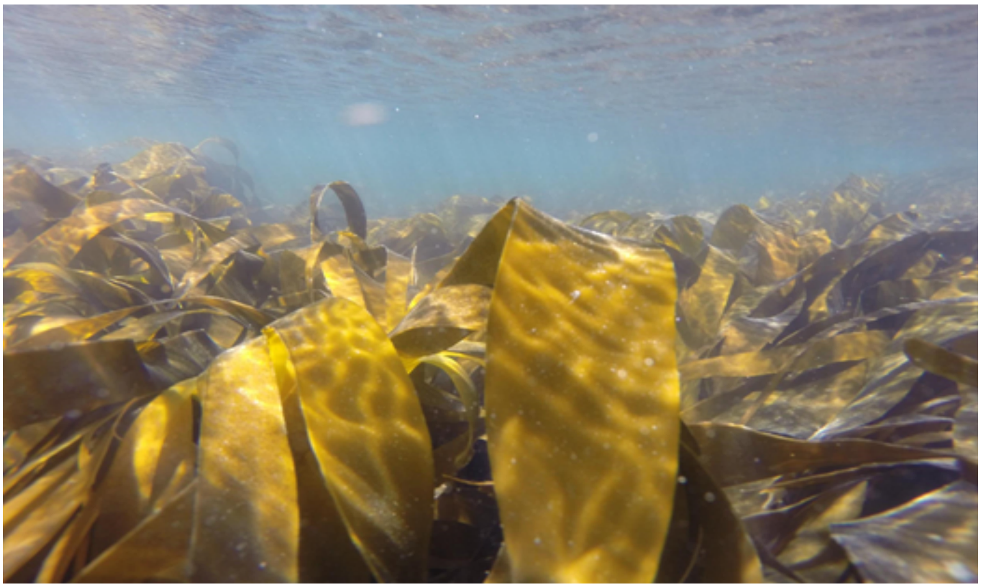

Figure 1: Kelp forests in the shallow subtidal rocky shores in the Northern Portugal (Francisco Arenas, Benthic Ecology Team. CIIMAR)

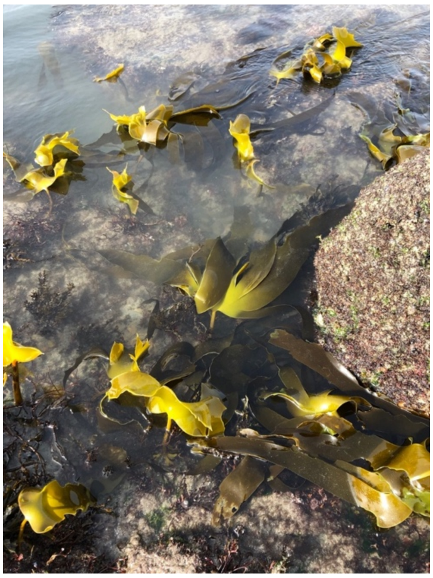

Figure 2: Kelp forests during low tide at rocky shores in the Northern Portugal Credit: Marina Dolbeth, Benthic ecology team, CIIMAR

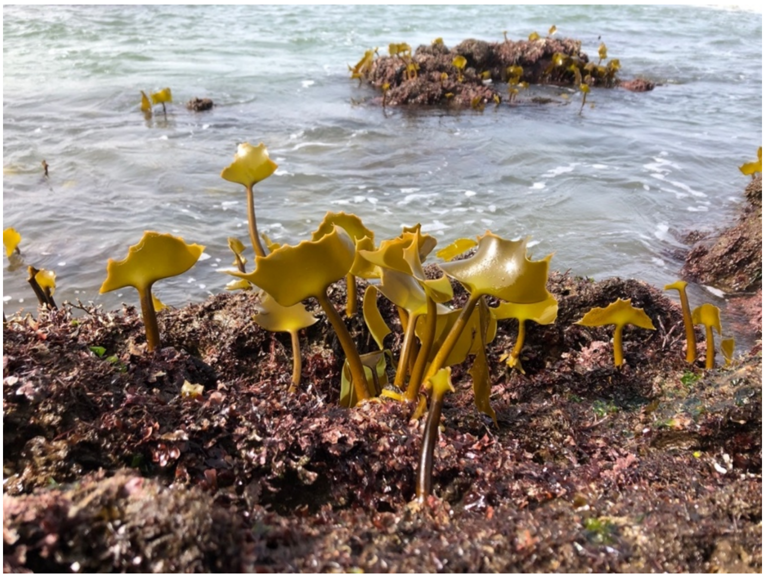

Figure 3: Detail of grazed Laminaria spp. from the Northern Portugal. Credit: Marina Dolbeth, Benthic ecology team, CIIMAR

Figure 4: Detail of *Ascophyllum nodosum* at its southern distribution limit, the Northern Portugal rocky shore. Credit: Marina Dolbeth, Benthic ecology team, CIIMAR

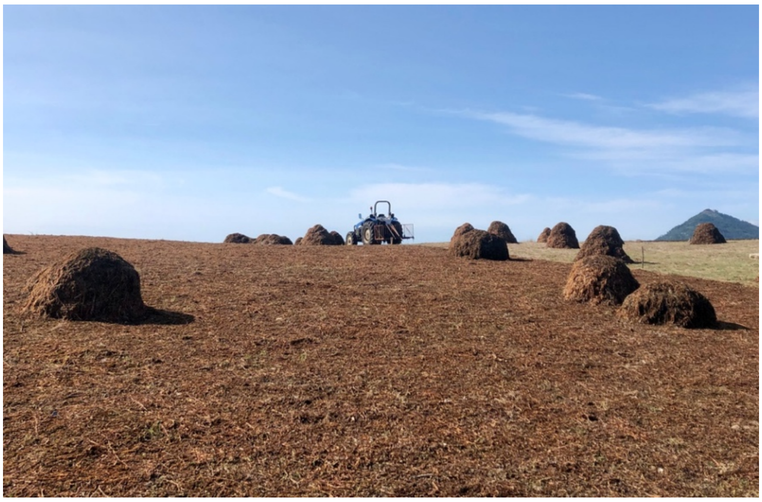

Figure 5: Collection of the seaweed wrack for fertilising agricultural fields (masseiras) in Northern Portugal (credit: Marina Dolbeth, Benthic ecology team, CIIMAR)

Projected impacts of climate change

Unlike other western boundary upwelling systems, Iberian upwelling is weakening (Sousa et al. 2020), reducing the potential of this area as a North Iberian climate refuge. Despite some previous uncertainties on the real nature of the observed seawater temperature trends (Santos et al. 2011), changes on sea surface temperatures have been confirmed by several authors suggesting that coastal warning is a real trend in North Portugal with coastal sea-surface temperature increasing at a rate of 0.01 ºC/year since 1940 (Lemos and Pires 2004) or mean increases of 0.05 ºC/year from 1985 in the same region (Gómez-Gesteira et al. 2008).

Similar to other climate-driven distribution shifts reported elsewhere in coastal areas, new biogeographic patterns associated with climate change are becoming apparent in Portugal. Local extirpation and fragmentation of populations has been reported (Casado-Amezua et al. 2019), mostly linked to recent climate change (Lima et al. 2007, Araujo et al. 2016). Oceanic ecosystems may also be affected by these changes, from the planktonic primary producers (Pérez et al. 2010) to fisheries (Teixeira et al. 2014).

Structural changes on assemblages with the new environmental conditions are expected from species tolerance variability. Empirical studies demonstrated that seawater temperature is likely the main driver of seaweed assemblages in this area (Piñeiro-Corbeira et al. 2018). However, the additive effects of other stressors like summer nutrient depletion (Franco et al. 2018) or atmospheric heatwaves should not be neglected (Martínez et al. 2012). We require a greater understanding of how species interactions vary in rapidly shifting environments and how these changes influence responses at other levels of biological organization. New diversity scenarios may substantially modify ecosystem-level aggregate functions such as energy fluxes or stability. For example, our preliminary *in-situ* results suggest a substantial reduction in the primary productivity of marine forests with the loss of these habitat-founding species.

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.

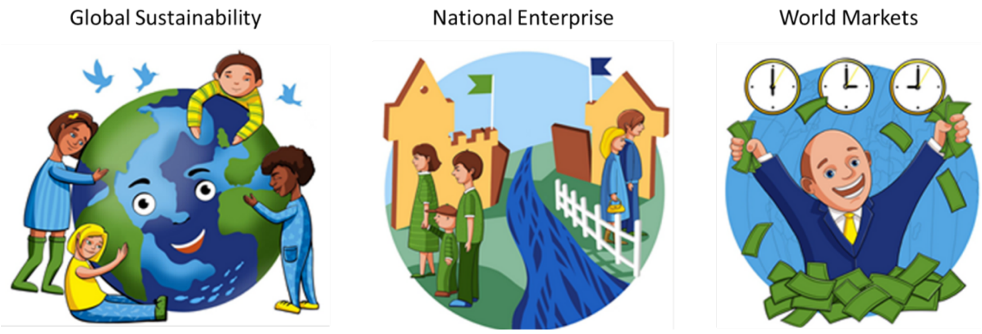

Figure 6: Representation of three, broad scenarios to be regionalised to guide activities such as model simulations in FutureMARES project. Credit: FutureMARES

FutureMARES Research needs

Research has largely ignored how vulnerable these habitat-forming species are to physical and biogeochemical changes in ocean climate and the synergistic effects of other pressures. We also do not know the ecological and societal consequences of their regional loss.

A good understanding of how multiple drivers (e.g., upwelling, sea temperature warming, indirect effects from grazing) shape the structure, dynamics and functioning of these habitats is imperative for the sustainable management of kelp forests. It is also essential to understand the actual potential of these habitats in terms of Blue Carbon (CO_2 sequestration, sink and its fate). A recognition of their importance as blue carbon would be relevant for attaining the goals of a climate-neutral society by 2050 (European Climate Law, EU - 2020/0036).

Another important topic is to explore which species (or genotypes) can persist under future climate change and, in this way, continue to provide the associated ecosystem services. This knowledge would allow conservation or restoration actions designed to foster the resilience of these important habitats to future climate change.

We also need to ensure that the stakeholders and local population recognize their importance to biodiversity and potential carbon sequestration to legitimize their conservation and restoration as nature-based solutions to cope with CC.

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

- **T1.1** Perform field sampling campaigns on intertidal and subtidal kelp forests and associated diversity to complete ecological time series needed for analyses. Calculation of a community thermal index;
- **T1.2** Compilation of data on the relevant traits, and data exploration on the trait-based analyses for use in trait-environment relationships and risk assessment;
- **T1.3** Compilation of relevant ecosystem indicators for subsequent comparative analyses;
- **T1.4** Regionalise FutureMARES scenarios using the PESTLE approach.
- **T2.1** Obtain physical and biogeochemical climate projection data from downscaled CMIP6 ensemble run;
- **T3.1** Conduct thermal performance and heatwave tolerance experiments on coastal macroalgae species;
- **T4.1** Create a kelp sub-model and perform scenario tests exploring local capacities of this biome to cope with the regional scenarios;
- **T5.1/5.2** Climate risk analyses (CRA) for kelp forests as habitats, and specific species, such as Laminaria spp., Sachorizza polyschides, in particular, those with their southern distribution limit in the region, such as Laminaria hyperborea, Fucus serratus, and Ascophylum nodosum. All these marine forests species influence associated biodiversity and other trophic levels (e.g., reef fishes, sea urchins) and several ecosystem services, so CRA should take into account both ecological and ecosystem services impacts;
- **T6.1** Identification of the bright spots for climate-smart marine spatial planning in the region, and potential conservation and restoration sites;
- **T7.1** Presentation and discussion of the project's aims and deliverables as well as the work done in Portugal with the regional policy makers: ICNF (Institute for Nature Conservation), and the APA (Environmental Association – North), as well as with the responsible for the environment of main city councils of the area.
- **T8.1-8.2** Conduct Outreach and stakeholder engagement events including talks on the importance of marine kelps and their distributional limit in northern Portugal.

Storyline Contact

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