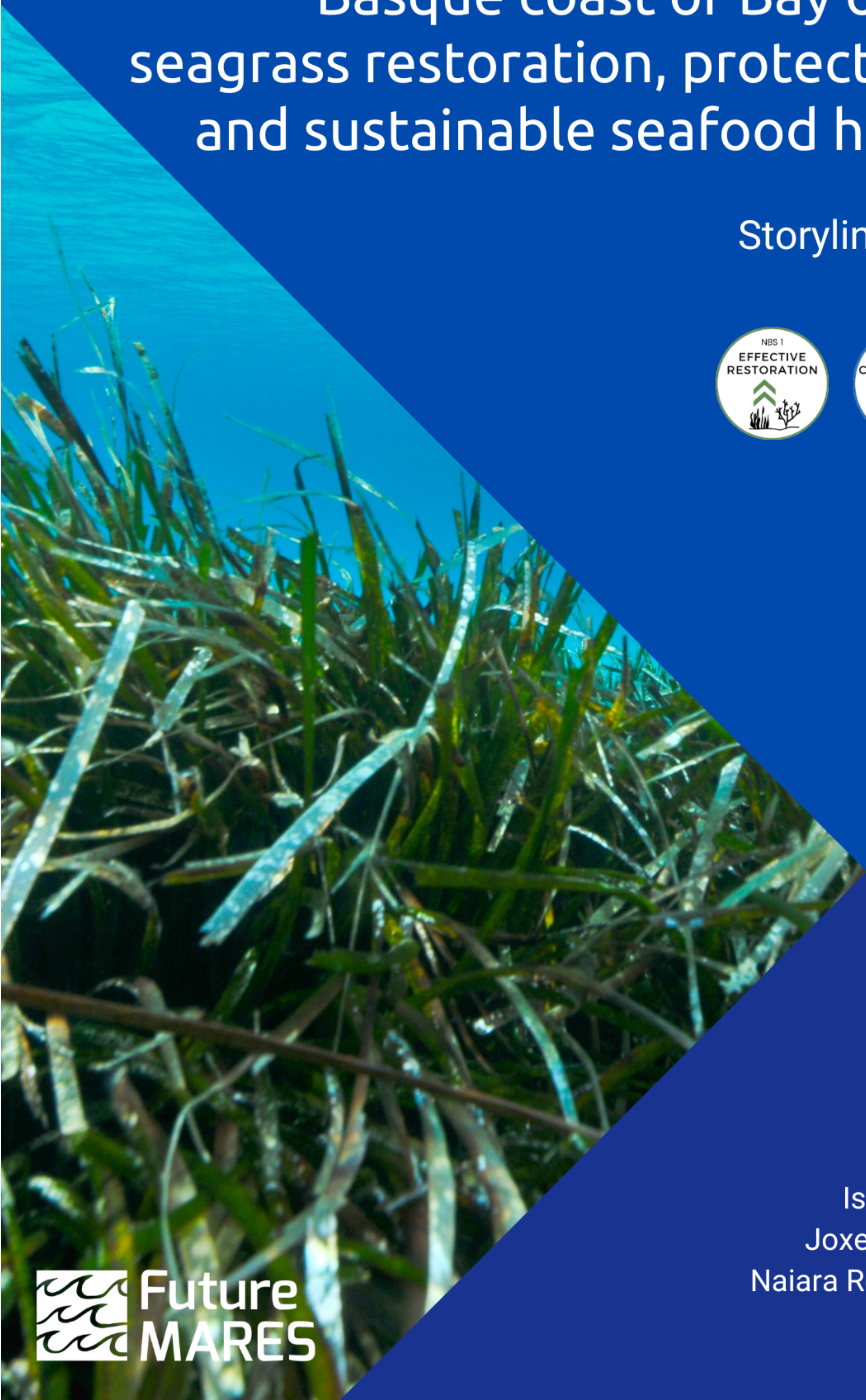
Nature-based Solutions in the Basque coast of Bay of Biscay - seagrass restoration, protected areas, and sustainable seafood harvesting

Storylines 20, 22, 24

NBS 1 EFFECTIVE RESTORATION

NBS 2 EFFECTIVE CONSERVATION

NIH NATURE-INCLUSIVE HARVESTING



Authors:
Jose Fernandes
Guillem Chust
Arantza Murillas
Ibon Galparsoro
Isabel García Barón
Joxe Mikel Garmendia
Naiara Rodríguez-Ezpeleta
(AZTI)

FutureMARES

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

Climate change exacerbated by human activities has the potential to impact on pelagic and coastal biodiversity, reducing the services provided by nature (Chust et al. 2011). In the Bay of Biscay (BoB), oceanographic conditions have changed over the last three decades (e.g., deepening of thermocline since 2007, Valencia et al. 2019) impacting on different pelagic species via spatial shifts in spawning habitats (Bruge et al. 2016) and changes on reproductive traits mediated by a trophic link (Extramiana et al. 2019), among others. Moreover, climate change is affecting the distribution of species where the BoB plays an important role since it corresponds with the northern and southern limit of several species' distribution boundaries. At higher trophic levels, climate variability affects the migration patterns of pelagic marine megafauna in the BoB, adjusted by optimal movement conditions and foraging (Louzao et al. 2015), while extreme events can increase seabird mortality (Louzao et al. 2019a).

The demographic and urban pressure on the Basque coast can lead to extensive loss, squeeze and degradation of the estuarine and marine habitats during the 20th Century. Therefore, natural capital might degrade due to the increasing anthropogenic pressure in coastal areas where multiple socio-economic activities compete for space and resources. As an example, the use of estuaries for agriculture, coastal settlements, and industry has impacted key habitats of importance for local species (e.g. *Zostera noltei*), for migratory species between rivers and sea (e.g. diadromous fishes) and for pelagic species (e.g. anchovy) that use the estuaries as nursery area before moving to other feeding areas. Estuaries and coastal areas are rich in biodiversity, but also highly interlinked with open sea (pelagic species) since many fish species spawn in coastal areas but migrate to the sea for feeding.

Figure 1: *Zostera noltei* in Basque estuaries (Source AZTI).

In terms of pelagic vertebrates, a great variety of marine mammal species are present. The seabird community is of relevance during certain periods of the year through an important migratory flyway and more than 700 species of fishes have been reported. The migration of marine megafauna (i.e., cetacean, seabirds and large pelagic fishes) is highly influenced by early stages of pelagic fishes such as the European anchovy *Engraulis encrasicolus* (Lezama-Ochoa et al. 2010, García-Barón et al. 2019a, Louzao et al. 2019b).

Regarding biotic interactions between marine megafauna and pelagic prey, schooling in prey (e.g., anchovy–sardine), local enhancement/facilitation in predators (e.g., Cory's shearwater–fin whale), and predation between predator–prey species (e.g., northern gannet–horse mackerel) have been characterised by positive associations, while predator avoidance behaviour (e.g., striped dolphin–blue whiting) has been characterised by negative associations (Astarloa et al. 2019). In relation to threats, mammals are especially vulnerable to fishing bycatch, vessel collision, and pollution-related threats, whilst seabirds are particularly sensitive to oil spills, fishing bycatch and marine litter (García-Barón et al. 2019b).

These areas are also among of the most populated and touristic areas with important socio-economic activities (i.e., Spanish maritime activities: living resources (fishing, aquaculture, processing, wholesale retail sale of fish), ship and boat building, transport and maritime tourism at BoB represent almost the 6% of the Spanish total employment and added value) that depend on the preservation of the natural capital to remain productive and attractive to the society. There is a need to minimise the potential incompatibilities between economic growth and the conservation of the natural capital needed for such blue growth, and to achieve good environmental status through effective interventions (e.g., using nature-based solutions).

Observed and projected impacts of climate change

FutureMARES climate change observatory of the Bay of Biscay has identified the following already occurring climate trends (Chust et al. 2021) and literature therein. In Basque coast, there has been a trend of sea surface temperature increase afterwards (from 15.8°C in 1980 to 16.6°C in 2020) with +0.22°C per decade. The upper water column temperature (0-100 m) shows a clear increasing pattern of 0.15 ± 0.04°C per decade (Chust et al. 2021). González-Pola et al. (2012) detected a warming trend of 0.2°C/decade from sea surface to 1000m depth for the period 1992-2009 in the southern Bay of Biscay. Thermocline depth has increased at a rate of 3.69 ± 1.86m/decade.

Winter mixed layer has deepened at rate of 21.39 ± 9.94m/decade since 1986 with extreme values in 2005, 2006, 2009, 2010, 2016 and 2018 which translates into more nutrients available for the spring phytoplankton bloom (Fontán et al. 2008, Somavilla et al. 2009, Valencia et al. 2019). Global projections indicate an increase of temperature in the Bay of Biscay in the future under climate change scenarios (Cabré et al. 2015, Le Marchard et al. 2020, Erauskin-Extramiana et al. 2019). Salinity is projected to decrease (Collins et al. 2013; Cabré et al., 2015). Recent model projections suggest that environmental change will be higher than previously forecasted (Tittensor et al. 2021).

Global projections also show a potential decline in productivity within the Bay of Biscay in the lower trophic levels (Bindoff et al. 2019; Flombaum et al. 2020). As a result of temperature changes, a faster initial growth of fish is also being induced, with a decrease in weight and size (Perry et al. 2005; Pauly et al. 2018), and expected to further continue under climate projections (Queiros et al. 2018).

This size decrease has been detected at local scale in the Bay of Biscay with anchovy (see Fig. 1.2.2). This small pelagic species has also been impacted in the timing of reproduction with an earlier spawning rate of six days per decade (Erauskin-Extramiana et al. 2019). Large pelagic tuna species are changing to an earlier migration of 2.3 days per decade (Santiago, 2004; Chust et al. 2019). All widely distributed species are showing shifts in distribution (Baudron et al. 2020), particularly small pelagic species (Fernandes et al. 2020). Mackerel is showing a northern distribution shift (Hughes et al., 2014; Bruge et al. 2016; Brunel et al. 2018) with a northward shift of spawning area in hot years (not yet published). Horse mackerel spawning timing and area is shifting eight days earlier and 164km north-west shift in hot years (unpublished).

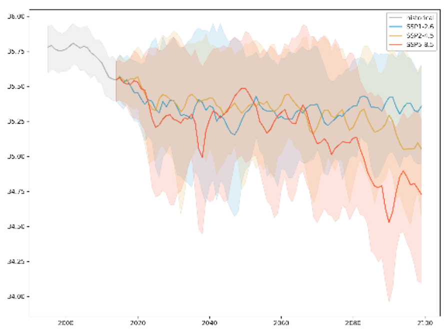
Figure 2: Great shearwaters *Ardenna gravis* during a migratory stopover in the Bay of Biscay in September. Credit: AZTI

Figure 3: Common dolphins *Delphinus delphis* in the Bay of Biscay in September. Credit Source AZTI

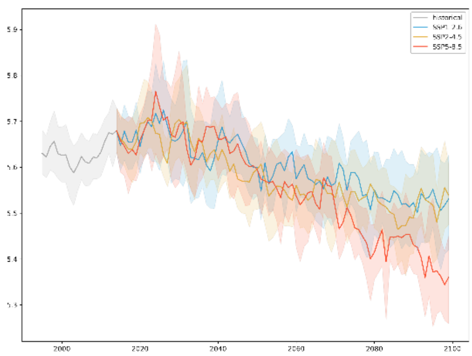
It is expected that climate change will impact directly on the populations of cetaceans and seabirds of the Bay of Biscay by modifying the physical and chemical characteristics of their environment and indirectly by affecting the distribution, availability, and accessibility to their prey (Hemery et al. 2007 Simmonds 2016). Among the different processes characterising climate change, ocean warming is believed to be forcing range shifts due to the changes in the location of thermal niche conditions (Edwards '& Richardson 2004, Gregory et al. 2009), altering food web dynamics (Hays et al. 2005), and producing a northerly shift of marine megafauna species (Hemery et al. 2007, Macleod 2009). While ocean acidification could produce trophic cascades (Lassalle et al. 2012, Sydeman et al. 2012) due to changes in primary production (Duarte et al. 2013), the sea level rise could reduce breeding grounds (Croxall et al. 2012). Extreme weather events have increased in frequency and severity (Cai et al. 2014, Ummenhofer & Meehl 2017) causing seabird mortality events due to starvation, exhaustion and drowning (i.e., cachexia) (Morley et al. 2016), lower breeding success (Zuberogoitia et al. 2016), and more cetacean stranding due to the increased incidence of rough conditions (Simmonds 2017).

The seagrass *Zostera noltei* forms meadows mainly within the intertidal zone in the BoB, leading it to be particularly vulnerable to seawater temperature increase and sea level rise. By the end of the 21st century, seawater temperature increase will trigger a northward distributional shift of 888km in the suitable habitat of the species, and a retreat of southernmost populations (Fig. 4). In contrast, sea level rise and derived changes in current velocities are expected to induce the landward migration of the species in the Oka estuary, increasing the available suitable intertidal areas (14–18%) to limits imposed by anthropogenic barriers (Valle et al. 2014).

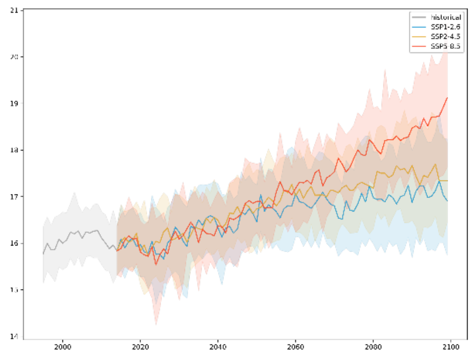
Chlorophyll (in mg m-3) at 5m depth



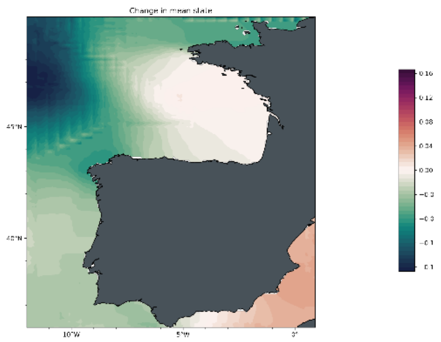
Salinity (in PSU) at 5m depth



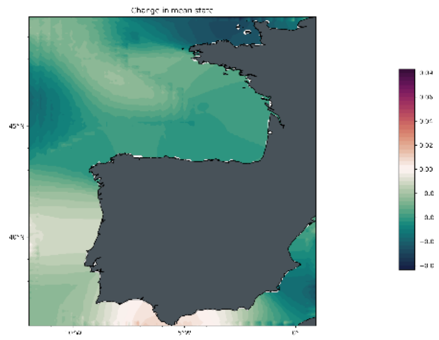
Oxygen (in ml/l) at 5m depth



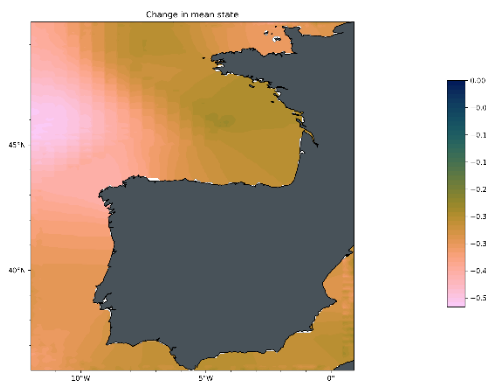
Potential Temperature (in degrees C) at 5m depth



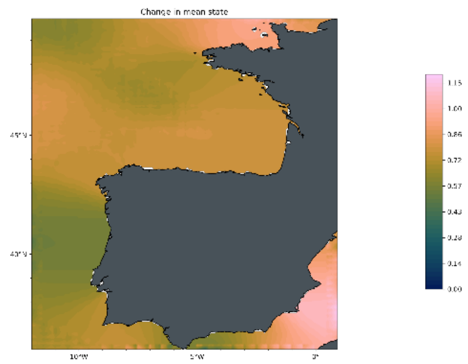
Chlorophyll (in mg m-3) changes in the mid future at 5m depth under scenario SSP5-8.5



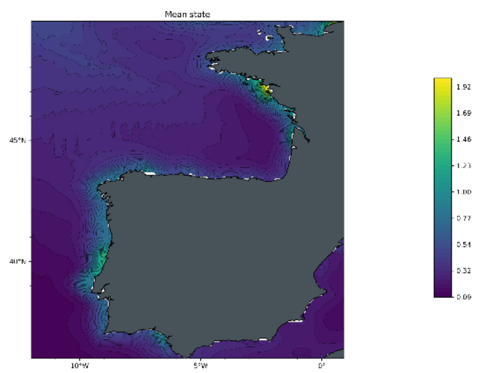
Oxygen (in ml/l) changes in the mid future at 5m depth under scenario SSP5-8.5



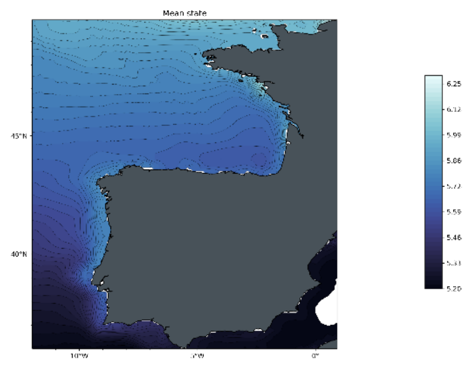
Salinity (in PSU) changes in the mid future at 5m depth under scenario SSP5-8.5



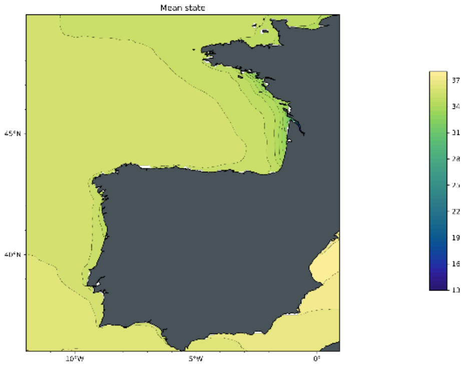
Potential Temperature (in degrees C) changes in the mid future at 5m depth under scenario SSP5-8.5



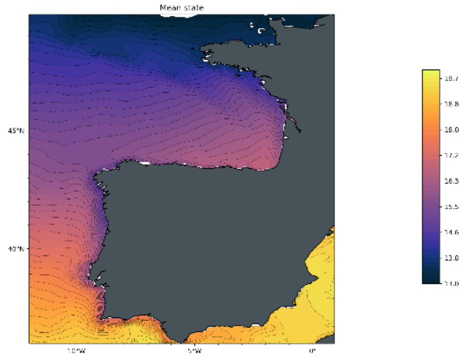
Chlorophyll (in mg m-3) at 5m depth under present day conditions



Oxygen (in ml/l) at 5m depth under present day conditions



Salinity (in PSU) at 5m depth under present day conditions



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

Figure 4: Climate projections for the Bay of Biscay and surrounds. 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 develops 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, restoration plans and protected areas definition. 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 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

Local Basque authorities, in collaboration with several local research institutions for coastal areas, consider the scenario time-slices of 2041-2050 and 2091-2100. In terms of sea level rise, the following scenarios are being considered by local authorities based on Slangen et al. (2014): two scenarios based on historical projections of tides and waves through the next 100 and 500 years, a sea level rise of 26cm by 2050 (based in the same projection in RCP4.5, RCP 8.5) and three scenarios by 2100 (+51 cm from RCP4.5, +70 cm from RCP8.5, +100 cm in case the previous estimates are too optimistic).

FutureMARES research needs

NBS1 - Restoration of engineer species needs to be demonstrated by analysing previous successful experiences in estuaries. For example, with the reintroduction of seagrass *Zostera noltei* a protected species in the Basque region. This species has value as ecosystem engineers (regulating ecosystem services), provisioning (harvested for human use) and cultural (areas of recreational fishing and touristic use).

NBS2 - Conservation needs to be effectively demonstrated by proposing a climate adaptive development of the protected areas considering existing and planned protected areas. It also needs to consider outcomes of the project in terms of climate change potential impacts and interactions with other NBS. This demonstration will consider protecting engineer species key for regulating services which are included as habitats of special relevance for conservation within the Habitats Directive or the Water Framework Directive, protection of charismatic species (e.g., mammals and seabirds) within the Natura 2000 network identified within the Bird and Habitats Directives (e.g., Pérez-Roda et al. 2017, García-Barón et al. 2019), and benefits of fish harvesting (provisioning and recreational).

NIH – Sustainable harvesting. A maximum sustainable yield (MSY) path for the fishing sector needs to be defined under considering climate change and current management (Erauskin-Extramiana et al. 2022). An aspect that to be considered is the adaptation to the landing obligation and a multispecies MSY in compliance with current Common Fisheries Policy and the MSFD. It is important to further develop a decision support system (Granado et al. 2021) to help fishermen to adapt to climate change (finding changing fishing grounds) and contribute to climate change mitigation (fuel and consequent emissions reduction).

These activities are strongly interlinked in the Basque coast of the BoB. As an example, estuaries are important nursery areas for fish species of high commercial, recreational, nutritional and conservation interest. Estuaries are also important for the conservation of migratory seabirds and Zostera noltei is a protected species. Furthermore, the protected areas definition needs to consider that at the coastal area there are highly competitive economic activities that need to adapt to climate change and their decarbonisation to contribute to climate change mitigation.

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

- **T1.1** Compile data and calculate a Community Temperature Index (CTI) for historical changes observed in key species in the Bay of Biscay;
- **T1.3** Select a set of ecosystem indicators to be used for subsequent work;
- **T1.4** Engage stakeholders to regionalise FutureMARES scenarios considering previous and ongoing scenarios used by policy makers;
- **T2.1/2.2** Compile and compare climate model runs for projections of change in physics & biogeochemistry needed for NBS assessment in the Bay of Biscay;
- **T3.3** Examine the genetic adaptation of mackerel, anchovy and sardine;
- **T4.1-4.4** Re-use or perform new model runs as necessary (incorporating new ensemble estimates available from WP2;
- **T5.1-5.3** Perform a climate risk analysis for the Zostera restoration including multiple ecosystem services;
- **T6.2** Input Output tables analysis of benefits of implementing NBSs;
- **T6.3** Create a Bayesian network (BNs) informed by risk analyses (WP5) and other data streams and finalize conceptual model and BNs via stakeholder workshops;
- **T7.1** Contribute policy information at local/national events: e.g. create a restoration plan for the Basque estuaries, MPA and decarbonisation strategies.
- **T8.1** Identify (using initial interviews and organized events) and continuously engage local stakeholders.

Figure 5: Successful transplant of Zostera noltei in a Basque Country estuary. Transplanting has physical impact on the donor area. Credit: AZTI

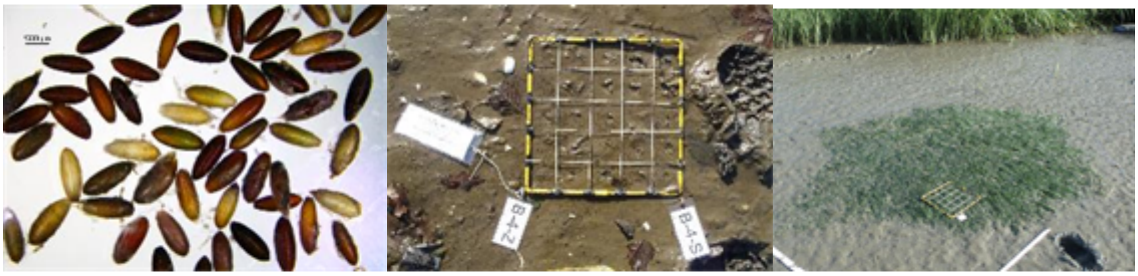


Figure 6: Successful seeding of Zostera noltei in a Basque Country estuary. Seeding is more work but less impact on donor. It also seems to lead to higher density of the plans. Credit: AZTI

Storyline Contact

Jose Fernandes (AZTI) - jfernandes@azti.es

References

Astarloa A, et al. (In press) Identifying main interactions in marine predator-prey networks of the Bay of Biscay. ICES Journal of Marine Sciences.

Atkinson D. (1994) Temperature and organism size: a biological law for ectotherms?. Advances in ecological research, 25, 1-58.

Baudron AR, et al. (2020) Changing fish distributions challenge the effective management of European fisheries. Ecography, 43(4), 494-505.

Bindoff N L, et al. (2019) Changing ocean, marine ecosystems, and dependent communities. IPCC special report on the ocean and cryosphere in a changing climate, 477-587.

Bruge, A., et al. (2016) Thermal niche tracking and future distribution of Atlantic mackerel spawning in response to ocean warming. *Frontiers in Marine Science*, *3*, 86.

Brunel, T., et al. (2018) Quantifying the influence of geography and environment on the northeast Atlantic mackerel spawning distribution. Fisheries oceanography, 27(2), 159-173.

Chust, G., et al. (2011) Climate change impacts on coastal and pelagic environments in the southeastern Bay of Biscay. Clim. Res. 48, 307–332.

Chust, G., et al. (2022) Climate regime shifts and biodiversity redistribution in the Bay of Biscay. Science of The Total Environment, 803, 149622.

Dekker, W. (2004) Slipping through our hands: population dynamics of the European eel. https://edepot.wur.nl/25418

Díaz, E., et al. (2018) Eels of southern Europe under future climate change. RIM 25 (2) UHINAK 2018., 46, 2018.

Donelson, J. M., et al. (2019) Understanding interactions between plasticity, adaptation and range shifts in response to marine environmental change. Philosophical Transactions of the Royal Society B: Biological Sciences 374, 20180186.

Erauskin-Extramiana, M., et al. (2019) Historical trends and future distribution of anchovy spawning in the Bay of Biscay. *Deep Sea Research Part II: Topical Studies in Oceanography*, *159*, 169-182.

Erauskin-Extramiana, M., et al. (2019) Large-scale distribution of tuna species in a warming ocean. Global Change Biol. 25, 2043-2060.

Erauskin-Extramiana, M., et al. (2022) Implications for Global Tuna Fishing Industry of Climate Change-Driven Alterations in Productivity and Body Sizes. Available at SSRN 4059543.

Fernandes, J. A., et al. (2020) Changes of potential catches for North-East Atlantic small pelagic fisheries under climate change scenarios. Regional Environmental Change, 20(4), 1-16.

Flombaum, P., et al. (2020) Global picophytoplankton niche partitioning predicts overall positive response to ocean warming. Nature Geoscience, 13(2), 116-120.

Fontán, A., et al. (2008) Oceano-meteorological conditions and coupling in the southeastern Bay of Biscay, for the period 2001-2005: A comparison with the past two decades. Journal of Marine Systems, 72(1-4): 167-177.

García-Barón, I., et al. (2019a) Modelling the spatial abundance of a migratory predator: A call for transboundary marine protected areas. *Diversity and Distributions*, *25*(3), 346-360.

García-Barón, I., et al. (2019b) Pressures and threats to marine predators in southern European waters. Continental Shelf Research. In press.

González-Pola, C., et al. (2012) Capítulo 2. Hidrografía y circulación. Cambio climático y oceanográfico en el Atlántico del norte de España, 69-98.

Goikoetxea, N., et al. (2009) Trends and anomalies in sea-surface temperature, observed over the last 60 years, within the southeastern Bay of Biscay. Continental Shelf Research, 29(8), 1060-1069.

Granado, I., et al. (2021) Towards a framework for fishing route optimization decision support systems: Review of the state-of-the-art and challenges. Journal of Cleaner Production, 320, 128661.

Hughes, K. M., Dransfeld, L. & Johnson, M. P. (2014) Changes in the spatial distribution of spawning activity by north-east Atlantic mackerel in warming seas: 1977–2010. Marine biology, 161(11), 2563-2576.

Le Marchand, M., et al. (2020) Climate change in the Bay of Biscay: Changes in spatial biodiversity patterns could be driven by the arrivals of southern species. Marine Ecology Progress Series, 647, 17-31.

Lezama-Ochoa, A., et al. (2010) Investigating relationships between albacore tuna (Thunnus alalunga) CPUE and prey distribution in the Bay of Biscay. *Progress in Oceanography*, *86*(1-2), 105-114.

Louzao, M., et al. (2015) The role of climate and food availability on driving decadal abundance patterns of highly migratory pelagic predators in the Bay of Biscay. *Frontiers in Ecology and Evolution*, *3*, 90.

Louzao, M., et al. (2019a) Threshold responses in bird mortality driven by extreme wind events. *Ecological indicators*, *99*, 183-192.

Louzao, M., et al. (2019b) Understanding the 3D environment of pelagic predators from multidisciplinary oceanographic surveys to advance ecosystem-based monitoring. *Marine Ecology Progress Series*, *617*, 199-219.

Nøttestad, L, Boge, E. & Ferter, K. (2020) The comeback of Atlantic bluefin tuna (Thunnus thynnus) to Norwegian waters. Fisheries Research 231, 105689.

Olafsdottir AH, et al. (2019) Geographical expansion of Northeast Atlantic mackerel (Scomber scombrus) in the Nordic Seas from 2007 to 2016 was primarily driven by stock size and constrained by low temperatures. Deep Sea Research Part II: Topical Studies in Oceanography 159, 152-168.

Pauly, D. & Cheung, W. W. (2018) On confusing cause and effect in the oxygen limitation of fish. Global change biology, 24(11), e743-e744.

Perry, A. L., et al. (2005) Climate change and distribution shifts in marine fishes. science, 308(5730), 1912-1915.

Pérez-Roda, A., et al. *(*2017) Identifying Key Atlantic Areas for the conservation of Balearic shearwaters: spatial overlap with conservation areas. Deep-Sea Research II 141:285-293.

Reuman, D. C., Holt, R. D. & Yvon-Durocher, G. (2014) A metabolic perspective on competition and body size reductions with warming. Journal of Animal Ecology, 83(1), 59-69.

Slangen A., et al. (2014) Projecting twenty-first century regional sea-level changes. Climatic Change, 124(1-2): p. 317-332.

Somavilla, R., et al. (2009) Large changes in the hydrographic structure of the Bay of Biscay after the extreme mixing of winter 2005. Journal of Geophysical Research, 114, C01001, doi:10.1029/2008JC004974.

Thurman LL, et al. (2020) Persist in place or shift in space? Evaluating the adaptive capacity of species to climate change. Frontiers in Ecology and the Environment 18, 520-528.

Tittensor, D., et al. (2021) Next-generation ensemble projections reveal higher climate risks for marine ecosystems. Nature Climate Change. In press.

Queirós, A. M., et al. (2018) Climate change alters fish community size-structure, requiring adaptive policy targets. Fish and Fisheries, 19(4), 613-621.

Valencia, V., et al. (2019) Long-term evolution of the stratification, winter mixing and θ-S signature of upper water masses in the southeastern Bay of Biscay. Continental Shelf Research, 181, 124-134.

Valle, M., et al. (2014) Projecting future distribution of the seagrass *Zostera noltii* under global warming and sea level rise. Biol. Conserv. 170, 74-85.

Villarino, E., et al. (2015) Modelling the future biogeography of North Atlantic zooplankton communities in response to climate change. Mar. Ecol. Prog. Ser. 531, 121-142.

Villarino, E., et al. (2020) Response of copepod communities to ocean warming in three time-series across the North Atlantic and Mediterranean Sea. Marine Ecology Progress Series, 636, 47-61.