Baltic Sea Coast - Restoration of Eelgrass (Zostera marina) in the South-West Baltic Sea

Storyline 6

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.

Introduction & NBS regional context

Danish coastal waters are located in the transition zone between the brackish Baltic Sea and the saline North Sea. The region is characterised by extensive areas with shallow sandy seafloor in relatively protected microtidal, brackish waters, which offer ideal conditions for eelgrass (*Zostera marina*). The region is and, even more so, used to be a key distribution area for this habitat-forming species with an historical (1900) distribution area estimated at about 6700 km^2 with coastal areas covered by eelgrass to maximum depth of 11 m depth and fjords to depths of about 5.5 m.

The wasting disease decimated the eelgrass populations in the 1930s and, although some natural recovery occurred in the following decades, stress from eutrophication and bottom trawling still constrains the distribution and growth of meadows, especially at the deep edge, and prevents recovery to historical levels, and warming is emerging as an additional stress factor. The current distribution area is not quantified but the potential distribution area is estimated at 2200 km^2. Although management efforts have reduced nutrient loads over the past 30 years, eelgrass meadows are generally still constrained to much shallower waters than in the past due to eutrophication combined with other stressors. The depth limit of eelgrass meadows, which is a key indicator of ecological status under the Water Framework Directive, signals that the vast majority of Danish coastal areas do not fulfil the requirement of good ecological status.

Active restoration (NBS 1) is increasingly explored as a means to accelerate eelgrass recovery in target habitats. This is to assist natural recolonisation, which can be challenging especially if there is a long distance to the mother populations. The early phase of natural recolonisation is also vulnerable because the new scattered shoots are exposed to high mortality e.g. by uprooting via physical exposure since they do not possess the protective capacity of the larger patches. Effective eelgrass restoration must be accompanied by alleviation of stressors via protection and conservation (NBS2), which also involves sustainable fisheries (NBS3) to limit trawling damage and ensure proper top-down control of opportunistic algae via well-functioning food webs. The recovery of eelgrass in Danish coastal waters hence involves all three NBS examined in the FutureMARES program.

Healthy, large eelgrass meadows support C-sequestration (blue carbon) and coastal protection by dampening wave action and reducing storm surges. Moreover, eelgrass stimulates biodiversity by serving as a habitat, and improves water quality by filtering and storing nutrients and particles from the water column.

Figure 1: Seagrass beds serve in climate change mitigation (natural carbon sinks), climate change adaptation (coastal protection, sediment accretion, buffer against ocean acidification) and stimulate biodiversity and water clarity (photo Peter Bondo Christensen).

Projected impacts of climate change

Danish coastal waters have experienced a warming trend of 0.5°C per decade over the period 1985–2018 (Krause-Jensen et al. 2020). Continued warming and associated heat waves may potentially hamper eelgrass meadows in the region as temperatures above 25°C cause a negative carbon balance and increased mortality. Warming is most severe in shallow turbid waters, while clear-water areas offer eelgrass refugia from warming in deeper, cooler waters (Krause-Jensen et al. 2020). Increased run-off and associated nutrient loading following projected increases in precipitation would increase the need for management efforts in a warmer future.

Moreover, increased storminess associated with climate change may exert physical damage on shallow eelgrass populations and, thereby, also increase the need for climate-ready management to facilitate deeper, resilient meadows that can support the shallow populations.

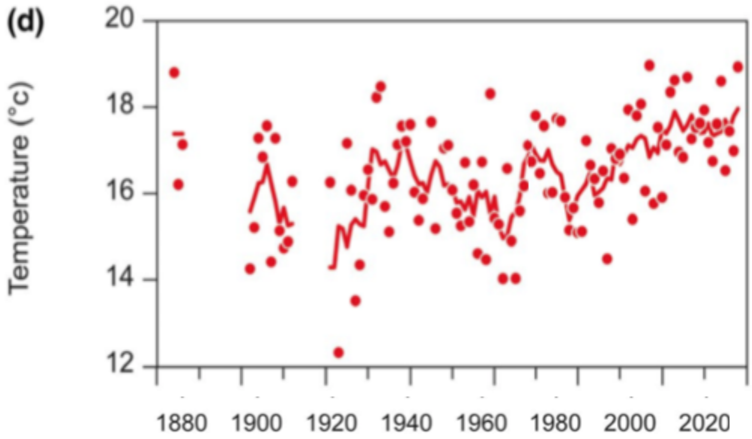
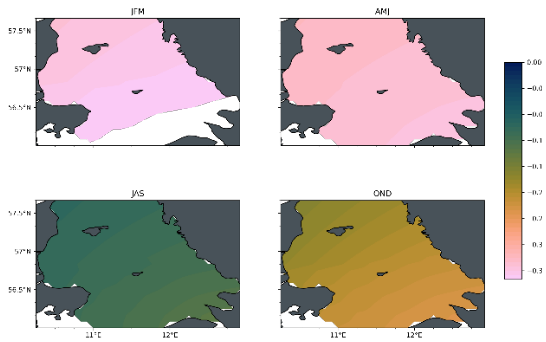
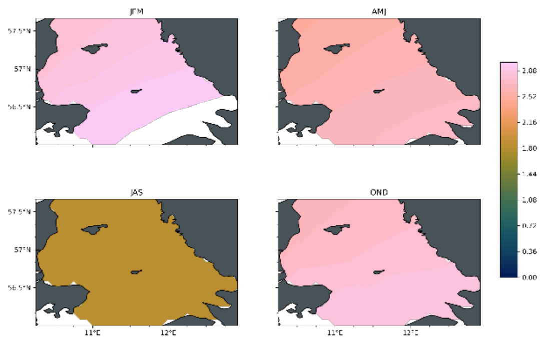


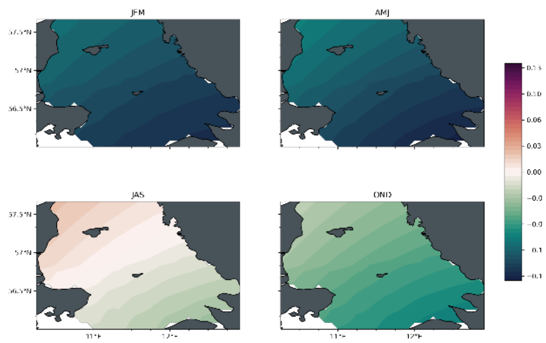
Figure 2 Long-term means of summer (June– August) surface water temperature in Danish waters. Lines are 5-year moving averages. From Krause-Jensen et al. 2020.



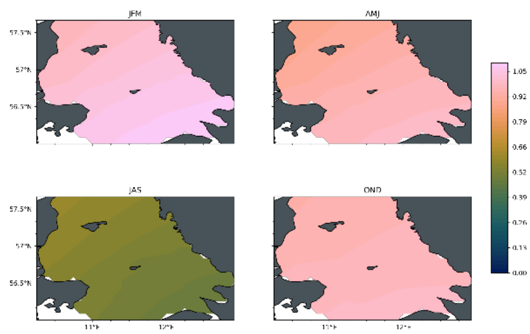
Oxygen (in ml/l) changes in the far future at seafloor under scenario SSP5-8.5



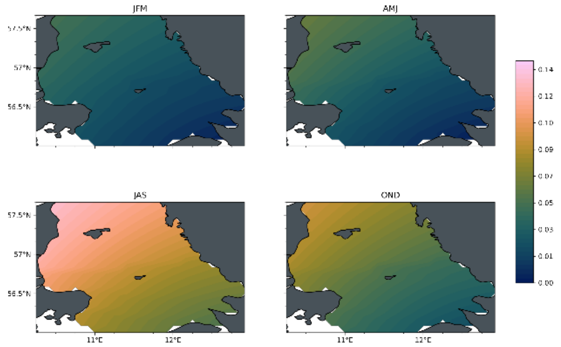
Potential Temperature (in degrees C) changes in the far future at seafloor under scenario SSP5-8.5



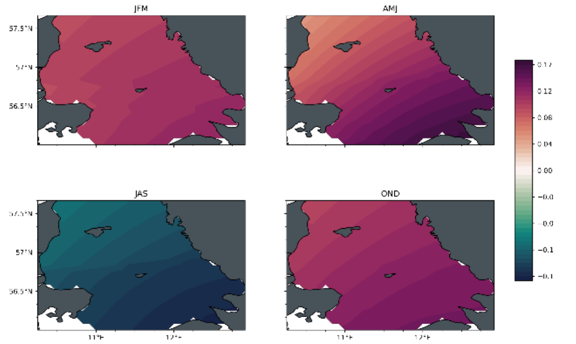
Oxygen (in ml/l) changes in the mid future at seafloor under scenario SSP5-8.5



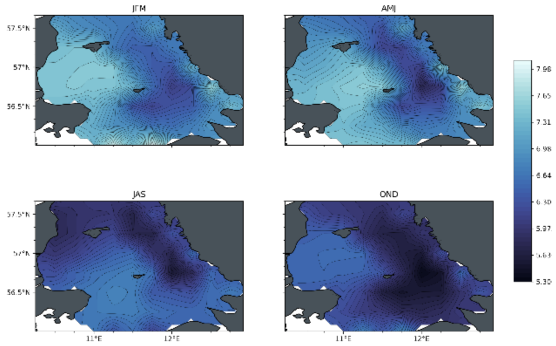
Potential Temperature (in degrees C) changes in the mid future at seafloor under scenario SSP5-8.5



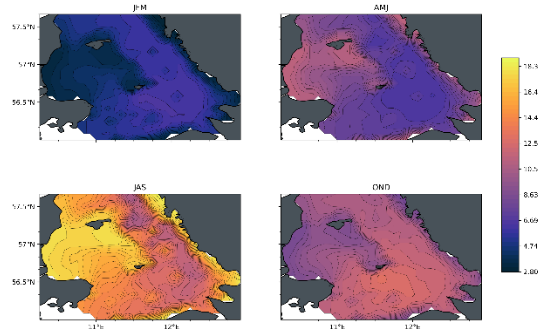
Oxygen (in ml/l) changes in the near future at seafloor under scenario SSP5-8.5



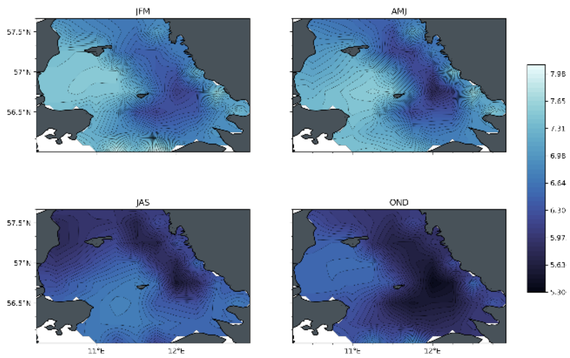
Potential Temperature (in degrees C) changes in the near future at seafloor under scenario SSP5-8.5



Oxygen (in ml/l) at seafloor under present day conditions



Potential Temperature (in degrees C) at seafloor under present day conditions



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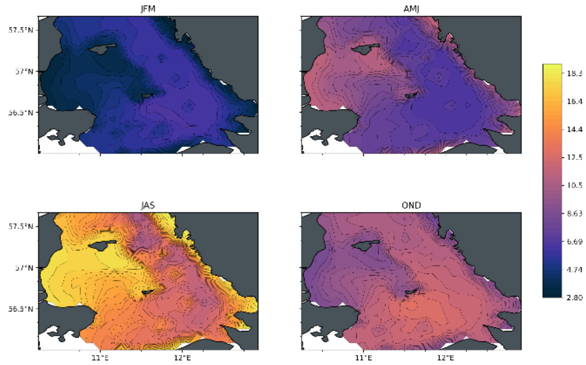
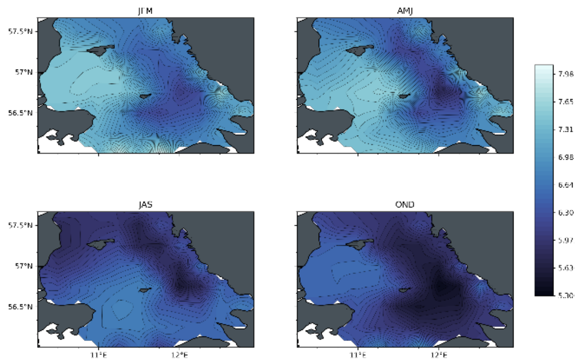


Potential Temperature (in degrees C) at seafloor under present day conditions



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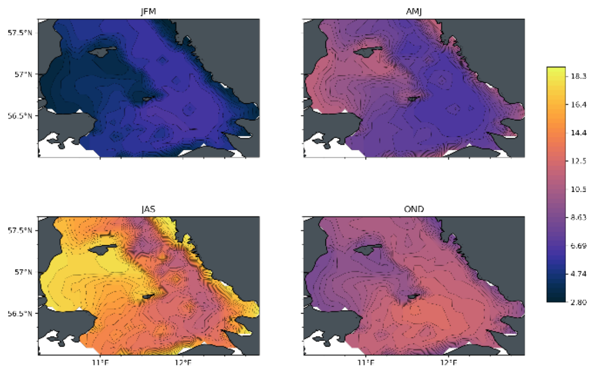

Potential Temperature (in degrees C) at seafloor under present day conditions

Figure 3: 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.

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

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.

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

The main research questions addressed here are:

- What are the effects of key abiotic factors (climate-related and other) on the distribution (and associated functionalities) of eelgrass in the SW Baltic Sea?
- Which eelgrass populations are particularly vulnerable to climate change?
- How well-connected are eelgrass populations and how may targeted restoration improve connectivity among meadows in selected Danish coastal waters?.
- In addition to the blue carbon sinks within eelgrass habitats, exported eelgrass detritus contribute to blue carbon sinks beyond the habitats. Where are the largest eelgrass C-sinks beyond the habitats located?
- How do the research findings translate to climate-ready management of eelgrass meadows in Denmark and what are the overall benefits to ecosystem services?

FutureMARES research

Key research by the AU FutureMARES team:

- **T1.1** A data base on current status & climate-driven trends compiled via the study "Century-long records reveal shifting challenges to seagrass recovery" (Krause-Jensen et al. 2020);
- **T2.3** CMIP6 downscaled projections will be used to identify climate hotspots and refuges for Danish waters;
- **T 4.1** A seagrass sub-model will be produced to examine connectivity of meadows based on potential distribution combined with a hydrodynamic model and information on seagrass propagules. The study will target NW Kattegat on Jutland's east coast where eelgrass is currently absent and a planned eelgrass restoration (conducted via a collaborative project) is, hence, expected to be particularly effective. Connectivity modelling will also allow the export of eelgrass detritus to potential C-sinks beyond the eelgrass habitats to be estimated.
- **T5.1, 5.2. 5.3** The risks of climate change (and interacting stressors such as eutrophication and trawling) to eelgrass restoration and loss of associated ecosystem services, and socioecological vulnerability in DK will be examined. The work will combine relationships between eelgrass and stressors, overviews of restoration efforts and stakeholder engagement to support co-implementation holistic management to minimize risks to targeted restoration goals;

- **T6.1** Guidelines for climate-ready eelgrass management will be based on identified interacting effects of stressors combined with information on hotspots of eelgrass connectivity
- **T6.3** Produce recommendations for climate readiness of eelgrass management illustrating the associated positive effects on the natural capital that the eelgrass meadows support.
- **T7.1** Engage with regional and national-level policymakers to co-develop activities on eelgrass restoration and communicate FutureMARES results;
- **T7.2** Contribute international engagement of marine habitat restoration (e.g. communicating the role of 50 UNESCO Marine World Heritage sites as custodians of the globe's blue carbon resources stores in seagrass, salt marsh and mangrove sediments (UNESCO 2020));
- **T8.1** Engagement of relevant stakeholders on the benefits (and costs and trade-offs) of NBS implementation and other parts of the FutureMARES program (e.g. regionalization of scenarios). A national marine restoration centre in DK has been proposed to deliver coordinated support for implementation of marine restoration strategies involving stakeholders at municipality-, regional- and state/ministry-level, private foundations.

Storyline Contact

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