Baltic Sea Coastal Areas - Sustainable mussel culture in the Limfjorden, SW Baltic Sea

Storyline 9

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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

The Danish Limfjorden is a shallow, semi-enclosed system with mean depth of 4.5 m with narrow connections to the North Sea and the Kattegat/Baltic Sea. It suffers from eutrophication with algal blooms, low water clarity, seasonal bottom hypoxia and loss of benthic flora and fauna. Despite the decadal implementation of land-based nutrient reduction measures, the nutrient loads are still exceeding the reduction targets for achieving a good ecological status according the EU Water Framework Directive. Dredging of blue mussels (*Mytilus edulis*) is the most important fishery in the Limfjorden since the1990ies with annual landings of 8-17,000 tons (2016-2020). The market price is on average €0.3 to €1.3/kg. However, dredging can have negative effects on the ecosystem, e.g. on the eelgrass depth distribution and recovery (NBS1).

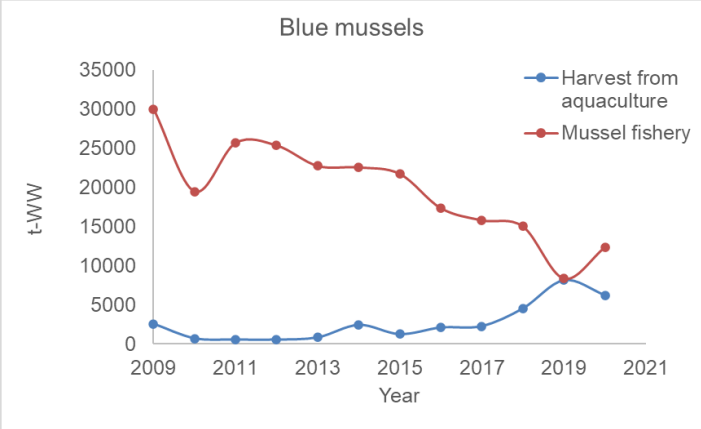

Figure 1: Data on annual harvest from suspended cultures and fishery of blue mussels (t-WW) in the Limfjorden 2009 to 2020. Credit: Danish Fishery Agency.

Suspended mussel aquaculture has been suggested as a more sustainable way of producing mussels. Mussel aquaculture is a relatively new activity in the area and has increased to an annual production of 2,100 - 8,100 tons (2016-2020) and an average market price of €0.6 to €1.1/kg for human consumption. Mussel cultures can reduce the effects of eutrophication directly within the marine environment by extracting nutrients through mussel harvest and provision of ecosystem services related to large-scale filtration and immobilization of organic particles (Timmerman et al. 2019). Opposed to the commercial farms, mussel mitigation cultures are designed to give the highest possible nutrient extraction in the cultivation area, but are not suited for food products. They must therefore be used for other purposes such as feed for husbandry or fish farms and is not economically feasible without substitutes. The mitigation farms have been tested in several projects, but is not yet implemented as a management tool.

A future expansion of the mussel aquaculture will occupy space at sea and may be in conflict with other economic and recreational activities and interests. The introduction of more farms must also consider the carrying capacity of the area and not reduce the wild mussel population that e.g. provides spat for settlement in the farms. Hence, in the site-selection process of mussel aquaculture, marine spatial planning is needed to optimise production or/and nutrient removal, minimize conflicts between users, minimise negative (maximise positive) environmental impacts and support co-existence of different activities (von Thenen et al. 2020).

Figure 2: Natural blue mussel beds in the Limfjorden. Credit: Jens Larsen.

Projected impacts of climate change

Climate change is expected to worsen the eutrophication effects (e.g. hypoxia, algae blooms) through increased run-off with nutrients and higher temperatures. By changing the production from bottom to suspended mussel cultures, the climate change impacts can be mitigated through nutrient extraction and higher water clarity from mussel filtration, which is beneficial to e.g. eelgrass beds and carbon storage (NBS1). Mussel proteins also have a lower carbon footprint compared to terrestrial sources and can help to accommodate the increasingly demand for seafood. Climate change can, on the other hand, also reduce mussel production due to lower salinity (or Ca^{2+}) and heat waves causing physiological stress, higher mortality, and detachment and loss of mussels in the suspended cultures (Buer et al. 2020).

Figure 3: Suspended long-line mussel cultures in the Limfjorden. Credit: Marie Maar

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

FutureMARES research needs

- How would an increase in suspended cultures influence water clarity, nutrient cycling, benthic impact and carrying capacity?
- How do conservation targets interact with large scale nutrient and phytoplankton extraction by aquaculture?
- How will the suspended cultures respond to climate change (heat waves, salinity, hypoxia)?
- How much aquaculture can the ecosystem sustain given other activities?
- Can suspended cultures mitigate climate change impacts?

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

Key research in this Storyline includes:

- T1.4 Regionalise scenarios for use in mussel farms in the Limfjorden social-ecological system (number of farms in the future and location);
- T2.1 CMIP6 downscaled projections of the Limfjorden ecosystem with and without mussel culture;

- T4.3 Model the effects of large-scale suspended cultures on ecosystem dynamics, mitigation of CC impacts (e.g. hypoxia, water clarity), estimate carrying capacity, estimate impacts of CC on mussel recruitment and growth.
- T5.1 & 5.3 Using trait-based information and projection model results, perform an ecological risk assessment and add information to produce a social-ecological risk assessment
- T6.1 Produce maps of sustainable aquaculture under different CC scenarios and multiple uses of Limfjorden
- T7.1 Communicate storyline results to national environmental (EPA) and fishery policymakers as well Danish Aquaculture sector and regional policy bodies (e.g. Submariner network, EUCC Coastal and Marine Union, HELCOM Aquaculture Correspondence Group, ICES).
- T8.1 Effective engage relevant national and regional groups (see above) including local fishers and marine managers (Foreningen MuslingeErhvervet, Limfjordsrådet) using a variety of approaches (targeted online and physical meetings, meetings coupled to Danish Sea Research meetings)

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References

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