NE Atlantic & North Sea - Restoration of oysters in Dutch coastal waters

Storyline 10

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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/NIH regional context

The restoration of habitat-forming species is a Nature-based Solution (NBS) that is being applied throughout the world's oceans to halt the loss of biodiversity, combat climate change and help sustain the provision of ecosystem services (Steven et al. 2020). Native (flat) oyster (*Ostrea edulis*) beds, once a major component of the North Sea covering > 25,000 km2 (Fig 1), largely disappeared from the region in the late 19th century due to a combination of overfishing, habitat degradation, introduction of invasive species and appearance of parasitic organisms.

Habitats created by native oyster beds support biodiversity by providing natural refugia, substrate and feeding grounds for many co-existing species. Moreover, by filtering phytoplankton, oysters play a key role in nutrient cycles of shelf seas and can mitigate poor water quality caused by excess nutrients (eutrophication). Also, deposition of SPM from the water column is relevant, especially in increased storminess and elevated SPM. Oyster reefs along coasts can also function as wave barriers that grow with sea level rise and reduce coastal erosion which will help with adapting to sea level rise and weather extremes. Finally, the shell formation and silt capture of oysters may contribute to carbon sequestration. These important roles of oyster beds have long since been recognised and large-scale restoration efforts are now underway to help safeguard future biodiversity and various provisioning, supporting, regulating and cultural ecosystem services for humans.

Shellfish reef restoration is of specific interest for delivering the services mentioned above and for contributing to enhanced ecosystem integrity, functionality and resilience.

Storyline 10 has a focus on natural and restored (>10-year old) Pacific oyster reefs which occur in the Oosterschelde estuary (Figure 2) and flat oyster reefs in the southern North Sea, where restoration efforts concentrate on Gemini wind farm and Borkum Reef Ground (four years old) to enhance biodiversity and carbon storage.

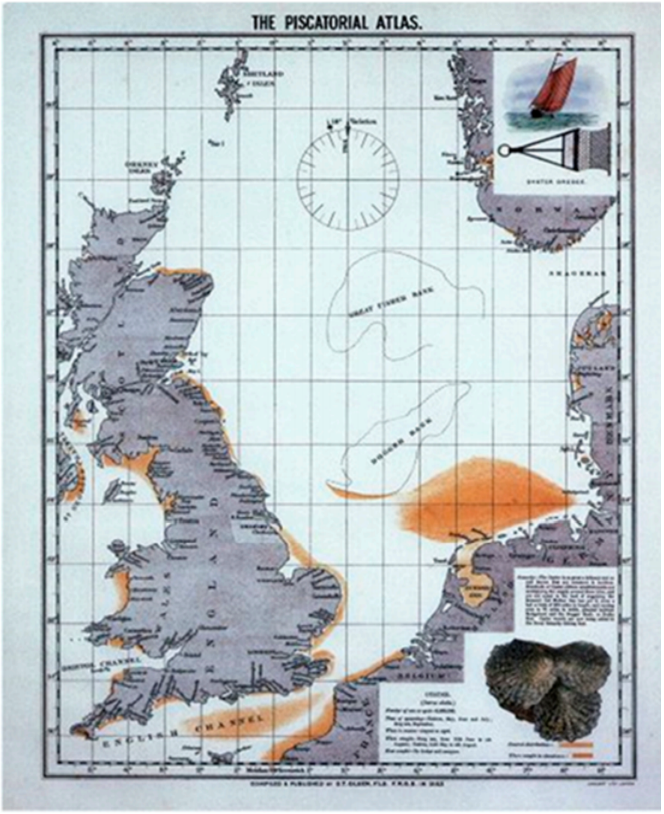

Figure 1: Historic distribution of *Ostea edulis*. Note: although the general indication of the extent of oyster distribution is likely correct, there are topographical inaccuracies in the central North Sea. Credit: Olsen, 1883

Figure 2: Artificial oyster reef blocking waves. Credit: Brenda Walles

Projected impacts of climate change

Effects of climate change in the North Sea region are sea level rise, coastal erosion, general temperature increases, changes in stratification patterns and hence in timing and amount of primary production and more weather extremes such as heat waves and severe storms in summer. There are also potential effects of acidification, mostly impacting the survival and settlement success of pelagic oyster larvae to bottom habitats Changes in primary production will impact the carrying capacity of the North Sea for extensive shellfish beds. Changes in the timing of the spring bloom (generally linked to the timing of onset of stratification) can interfere with food availability at times of spawning. Oysters have specific tolerance ranges for temperature. If temperatures shift substantially the habitats with suitable temperatures are likely to shift.

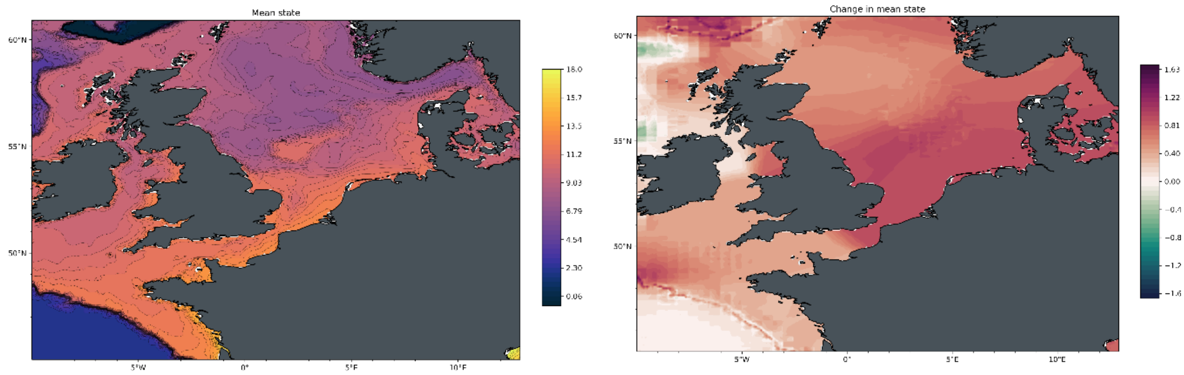

Figure 3: Potential Temperature (in degrees C) changes in the mid future at seafloor under present day conditions (left) and under scenario SSP5-8.5 (right). The figures were produced using trend preserving statistical downscaling (Lange, 2019) of a multi-model ensemble Earth System Model historical 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

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 (Figure 3). 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. The implementation of NBS is embraced as part of climate mitigation and adaptation actions.

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. The implementation of cross-national NBS is hampered due to a lack of cooperation and agreements among countries.

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 such as air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary. The implementation of NBS is guided by economic incentives.

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

In the past oyster reefs yielded several key ecosystem services. E.g. provisioning services (yield of oyster fisheries) as well as regulating services such as nutrient recycling, habitat provision and hence biodiversity. As climate change may alter the locations with suitable habitat as well as the carrying capacity of the North Sea to sustain large oyster populations, the possibilities for restoration of the species and its associated ecosystem services may also be affected.

A key question is how adaptive and resilient these populations are to climate change. Specifically, the adaptation potential of the flat oysters used in restoration projects in the North Sea is of interest, as they come from other areas. Genetic diversity of the source populations could help identify climate change resilience. It is important to understand if oysters can adapt to temperature change and survive extreme events such as heat waves. With increasing temperature, a change in the timing and level of food for oysters is also expected.

In many cases, it is unclear if shellfish reefs are a net sink or source of CO_2. This is another key research need. By taking habitat modification beyond the boundaries of reefs (CO_2 burial in the sediment) into account, a better estimate can be provided. And finally, biodiversity development on natural and restored Pacific oyster reefs.

Figure 5: A. In-situ incubation apparatus used in FutureMARES to determine how oyster reefs impact the biogeochemistry (e.g. oxygen respiration rate) and the adjacent sediment an B. Incubation experiments on oyster reefs during the night. Credit: Brenda Walles

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

- **T2.3** Provide projections of climate change impacts on potential oyster habitats to potentially identify climate refugia or areas most suitable for using the restoration of oyster reefs to enhance biodiversity;
- **T3.1** Conduct in-situ incubations to determine carbon sequestration on oyster reefs, sediment affected by Pacific oyster reefs, and reference bare sediment (Figure 4) and determine biodiversity of reefs;
- **T3.2** Perform common garden experiments to assess sensitivity (survival, growth, metabolism and behaviour) to temperature effects (heat waves) of flat oysters from three populations covering a large latitudinal gradient (Meditarranean, Netherlands, Norway) and time of adult reproduction and temperature and food on larvae;
- **T3.3** Identify genetic diversity of the populations used in the common garden experiment to assess adaptation and recovery potential;
- **T4.3** Develop a bioenergetics-based model (DEB) that includes the sensitivity of flat oysters to changes in temperature, suspended particulate matter (SPM) and food (including nutrients), as well as the interaction of oyster restoration with changes in nutrient availability due to increased extractive aquaculture (offshore seaweed and mussel cultivation);
- **T4.3** Utilise new models to make projections of the effects of climate change on the future distribution of flat oysters in the North Sea.

- **T6.2** Perform a cost effectiveness analysis of establishing Pacific oyster reefs in coastal areas of the southern North Sea
- **T1.4 & 8.1** Engage local and national-level stakeholders to co-create aspects of the FutureMARES program including regionalising NBS scenarios for oyster bed restoration to be tested and other knowledge gaps to be filled.

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