TOOLBOX AQUACULTURE

NIVA

Mapping regional sustainability for offshore salmon and mussel aquaculture in the North Atlantic and Nordic Seas using the A20 ROMS-ERSEM model

SUGGESTED USERS	PLANNING PROCESS	TYPE OF AQUACULTURE
Governmental and EU planners and policy developers	Location Pre-application	Marine fish pens Shellfish

SUMMARY

A20 ROMS-ERSEM predicts the 3D evolution of seawater hydrography, currents, and biogeochemistry (nutrients, oxygen, organic matter, plankton concentrations) over a pan-Arctic domain at 20 km resolution.

In our case study the model was used to assess past and future environmental suitability for offshore salmon and mussel aquaculture in the North Atlantic and Nordic Seas, but the same model could be used to assess offshore aquaculture potential for other species and in other regions within the domain shown above.

DESCRIPTION

A20 ROMS-ERSEM is a coupled ocean model based on: the ROMS physical model (Shchepetkin and McWilliams, 2005), the ERSEM biogeochemical model (Butenschon et al., 2016) adapted for the Arctic (Wallhead et al., in prep.), the FABM coupling framework (Bruggeman and Bolding, 2014), and a 20 km pan-Arctic grid (A20) developed by the Norwegian Meteorological Institute. It predicts the 3D evolution of seawater hydrography, currents, and biogeochemistry (nutrients, oxygen, organic matter, plankton concentrations) over a pan-Arctic domain at 20 km resolution.

The model was applied to assess the regional-scale sustainability of offshore salmon/mussel aquaculture sites in the North Atlantic and Nordic Seas, over the past 3 decades and the next 3 decades under the RCP8.5 scenario. Such assessments are needed for long-term planning and policy development in regard to economic development and food provision and within the European Economic Area (e.g. expansion into offshore areas as potential regions of future blue growth and sustainable exploitation).

Our results suggested that large regions of the European/Nordic shelf seas could be utilized for offshore salmon and mussel aquaculture, assuming that logistical and administrative constraints can be overcome, and that the total suitable area will likely remain stable over the coming three decades even under a pessimistic climate change scenario.

THE ISSUE BEING ADDRESSED

The A20 ROMS-ERSEM case study addresses the issue of assessing the present and future potential for oceanic offshore salmon and mussel aquaculture in the North Atlantic and Nordic Seas. With the arrival of Ocean Farm 1 from SalMar (https://www.salmar.no/en/offshore-fish-farming-a-new-era/), oceanic offshore aquaculture is becoming a realistic prospect for future economical development and food provision, and one that may provide significant advantages over inshore (fjord) and onshore aquaculture, such as reduced disease transmission and area-use conflicts, and better welfare conditions (larger cages, more natural environments).

THE APPROACH

We applied the A20 ROMS-ERSEM model to assess the regional-scale sustainability of offshore salmon/mussel aquaculture sites in the North Atlantic and Nordic Seas, over the past 3 decades and the next 3 decades under the RCP8.5 scenario. This analysis focuses on scoping and spatial planning for potential offshore facilities. Sustainability of Atlantic salmon aquaculture was based on environmental windows for seawater temperature, oxygen concentration and maximum current speed (corrected for the presence of the fish farm), and engineering constraints on water depth at the farm site. Sustainability of blue mussel aquaculture was based on a thermal window for favourable grow-out, a potential food supply index based on current speed and ambient particulate organic carbon, and mooring feasibility constraints on water depth (see TAPAS D6.3 for full details). These constraints were combined into sustainability indices and averaged over past and future decades to generates maps of sustainability over the North Atlantic and Nordic Seas.

While similar broad-scale “macro-siting” analyses have been performed using only observational data (e.g. Kapetsky et al., 2013; Gentry et al., 2017), the use of an ocean biogeochemical model (such as the A20 ROMS-ERSEM model used herein) has two major potential benefits: 1) The model can provide complete time series of variability at all depths and horizontal locations, not subject to gaps or sampling biases, and may thus provide more robust estimates of e.g. annual minimum oxygen concentrations; 2) The model can provide future projections, thus allowing us to investigate how different scenarios of anthropogenic change may impact conditions at a regional scale, allowing policy-makers to identify potential zones that could be used for aquaculture into the future, subject to local-scale assessment.

THE RESULTS

The model output suggests that, in lieu of administrative, technological, or logistical constraints not considered here, water depth and thermal tolerance are the primary constraints on offshore salmon aquaculture, with a secondary role played by oxygen concentration and current speed. On this basis, vast areas of the European/Nordic continental shelves would have been suitable for offshore salmon aquaculture in recent decades, if the appropriate technology had been developed. For blue mussel aquaculture, all constraints appear to be of comparable importance, and the primary driver of spatial variations in potential food supply appears to be the horizontal current speed. The combined sustainability index suggests that regions off Brittany, Northern Ireland, Scotland, the northern North Sea, the Faroe Islands, Iceland, the Norwegian coast especially in the south, and parts of the Barents Sea and western Svalbard shelf, would be suitable for offshore mussel aquaculture (again, if the technological challenges can be overcome). For both aquaculture types the overall area with potential for offshore aquaculture appears to have been stable over recent decades.

In the future, under the RCP8.5 scenario, the A20 projections suggest that regional-scale sustainability will remain stable over the coming 30 years for both salmon and mussel aquaculture. A caveat to these results is that they represent the downscaled projections from only one driving climate model (the Norwegian Earth System Model NORESM) and this particular climate model show relatively weak warming over the next 30 years, compared to other climate models. A more rigorous analysis would consider ensemble downscaled predictions using multiple climate models.

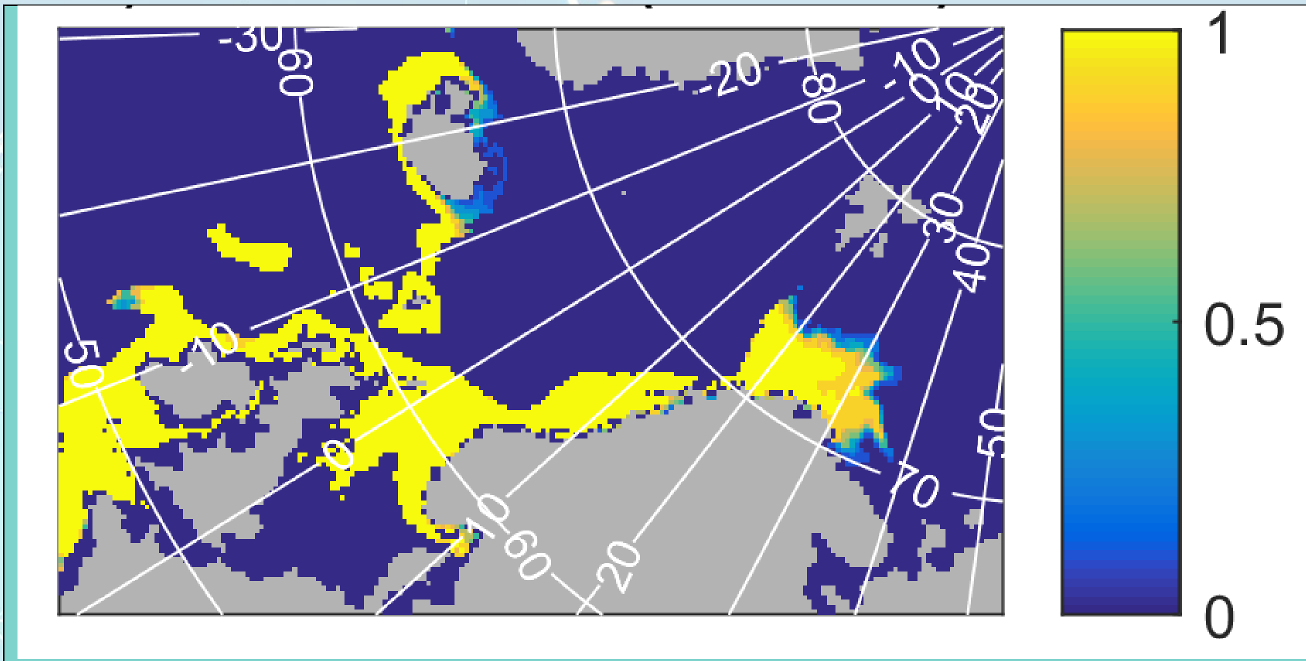

Figure 1: Combined sustainability index for offshore Atlantic salmon aquaculture in the North Atlantic and Nordic Seas during the period 2005-2014 (1 = suitable, 0 = not suitable). This combined index is based on water depth, temperature, and dissolved oxygen conditions inside a hypothetical fish cage at each location in the plot.

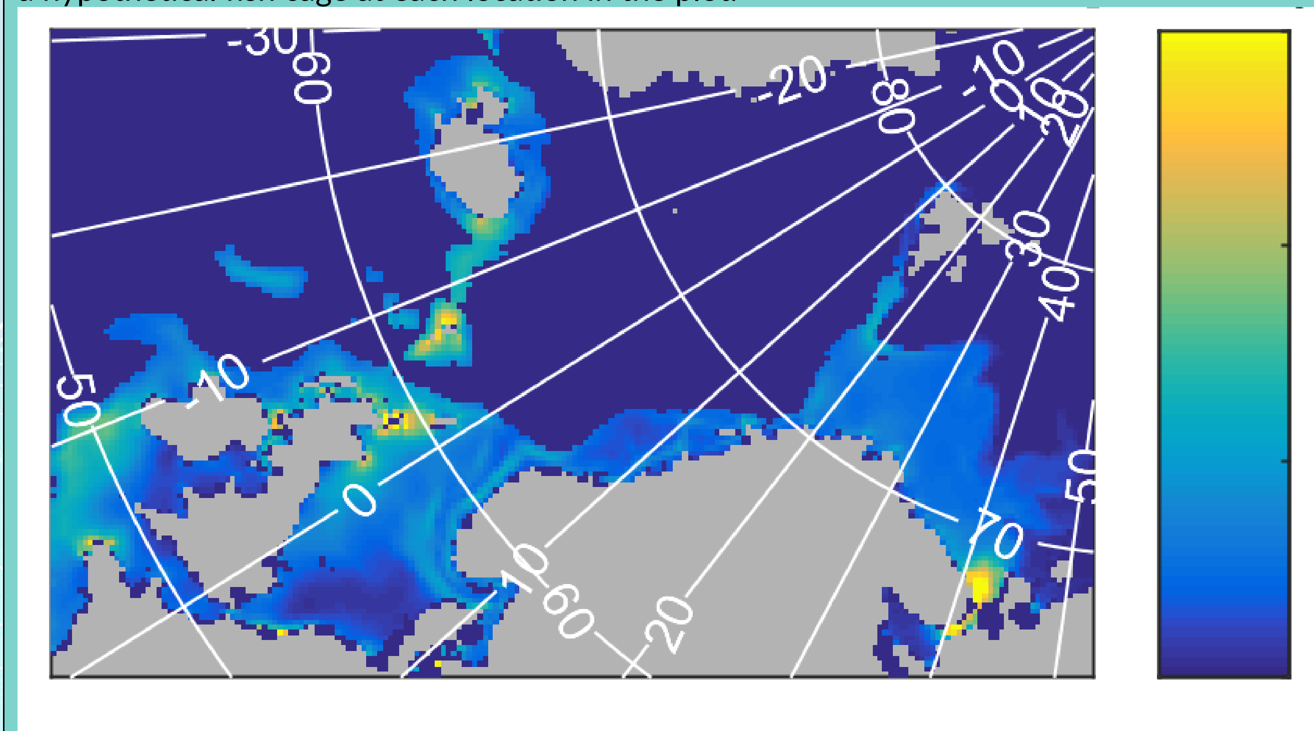

Figure 2: Combined sustainability index for offshore blue mussel aquaculture in the North Atlantic and Nordic Seas during the period 2005-2014 (yellower colours more suitable). This combined index is based on water depth, temperature, particulate organic carbon, and horizontal current speed at a hypothetical mussel longline each location in the plot.

SWOT ANALYSIS	
STRENGTHS	The A20 ROMS-ERSEM model synthesizes a vast amount of data and process knowledge (physics, chemistry, and biology) to create mechanistic and mass-conserving predictions of ocean environment and productivity It can produce estimates and predictions of ocean environment and productivity that are regular and free of gaps to sampling coverage and measurement/remote-sensing artefacts.
WEAKNESSES	The A20 ROMS-ERSEM predictions will be affected by inaccuracies due to various modelling limitations, such as spatial resolution and process parameterization, which may impact projections despite the application of bias-correction methods The model does require extensive specialist skills for preparing data input, running the simulations, and post-processing the model output, which may imply significant expense in terms of personnel man-hours.
OPPORTUNITIES	The A20 ROMS-ERSEM model offers the prospect of better informing and improving long-term planning and policy development in regard to offshore aquaculture by providing broadscale projections of the response of ocean environment and productivity to climate change. The case study demonstrates a “macro-siting” approach for identifying broad regions of interest, that could subsequently be further investigated using more focused models with higher spatial and process resolution but more limited geographic scope (“micro-siting”, Jansen et al., 2016).
THREATS	

CONTACT INFORMATION	Norwegian Institute for Water Research (NIVA) Phil Wallhead pwa@niva.no
LINK	NA