POLICY BRIEF

Reaching Good Environmental Status and Blue Growth – in a novel future

The potential to reach both Good Environmental Status (GES) and Blue Growth (BG) in the Baltic Sea rests heavily on how human-induced pressures such as nutrient loading and fishing are managed in relation to climate change. A new decision support system developed within BLUEWEBS displays possible consequences of different nutrient and fisheries management objectives in various future climate scenarios. It also shows that the future will require a more adaptive and ecosystem-based management, which accounts for uncertainty due to novel, not previous observed, conditions.

The overall objectives for the Baltic Sea are since long set: reach GES according to the Marine Strategy Framework Directive (MSFD), and develop the long-term EU strategy of BG. The question is, can these objectives be reached in parallel to future climate change? Is it possible to reach both GES and increased profits from ecosystem services in the Baltic Sea under future novel conditions?

To answer these questions, the project BONUS BLUEWEBS has designed a probabilistic Decision Support System (DSS) that allows for simultaneous evaluation of both BG and GES objectives in different future climate scenarios, thereby faci-

Recommendations

- Continue and enforce the BSAP, as further nutrient reductions will benefit both water quality and total fishery profits.
- Provide greater scope for adaptability in regional and local management using the BSAP and multi-species, ecosystem-based fisheries management.
- Maintain extensive environmental monitoring in order to enable adaptive management, and ensure that all the environmental and ecological data are swiftly and easily accessible in the same database.
- Introduce procedures for constantly assessing the nutrient and fishery management targets under novel conditions, to be able to adjust management strategies if needed.

BLUEWEBS scenarios for climate change, fishing and nutrient loading

- Two **climate change** scenarios, Representative Concentration Pathways (RCP), by the Intergovernmental Panel on Climate Change (IPCC), include:
  - RCP 4.5. Moderate rise in CO2 emissions reaching a plateau around 2040.
  - RCP 8.5. Steeper rise in CO2 emissions, with continuous increase.
- **Nutrient loading** includes two scenarios:
  - REF (reference). Nutrient loads are similar as in the late 1990s.
  - BSAP. Lower nutrient loads as outlined in the Baltic Sea Action Plan (BSAP).
- **Fisheries management** includes 3 scenarios:
  - Sustainable Baltic Sea (Sus). Sets healthy states of all three major fish stocks in the Central Baltic Sea (cod, herring and sprat) as management objective, exploits stocks at current maximum sustainable yield (MSY) fishing pressure.
  - Pelagics first (Pel). Prioritizes and aims to benefit fisheries on herring and sprat.
  - Open Access (OA). Explores largely unregulated, open access fisheries.

litating discussions and decision-making regarding the many trade-offs and synergies of these two objectives.

In addition to presenting the tool – and launching a user-friendly application in support of it – the scientists behind the project have also explored different combinations of nutrient and fisheries management strategies under future novel conditions (see Factbox). The analysis is coupled with a set of overarching recommendations for the future management of the Baltic Sea (see the recommendations below).

Novelty – a management challenge

Worldwide, marine ecosystem services are threatened by rapidly changing environmental conditions such as ocean warming and changes in circulation patterns that alter food web dynamics. This is particularly noticeable in the Baltic Sea, were environmental changes have occurred more rapidly than in most other seas (Reusch et al 2018), including sea surface temperature warming of 0.6°C per decade in the recent past.

As climate change progresses, the cumulative impacts on the marine ecosystem will continue to expand, leading to combinations of oceanographic conditions never encountered before, so-called novel conditions. At the same time, the ecosystem is affected by anthropogenic pressures such as eutrophication, fisheries exploitation, invasion of non-indigenous species and accumulation of hazardous substances. This highly complex system, with multiple and novel interacting factors, poses a major coming challenge for managers and decision-makers.

What does BLUEWEBS do?

BLUEWEBS has developed a probabilistic decision support system (DSS) that allows resource managers and policy-makers to explore how future climate scenarios, together with changing nutrient loading and different fisheries policy options, can affect both the Baltic Sea ecosystem and the opportunities to benefit from ecosystem services. The aim is to create a clearer understanding of how different combinations of policy decisions and future scenarios may affect the ecosystem, and what combinations would result in optimal ecosystem health and profit to humans under future novel conditions.

The DSS integrates the results of several analyses and modelling runs, including ecosystem change and novelty research, ecosystem simulation model studies and

The Baltic Sea will change

The Baltic Sea is one of the fastest warming seas in the Northern Hemisphere. In the future, water salinity might decrease, but the uncertainty is high and dependent on the future climate scenario. Increasing temperature accelerates nutrient turnover, and will most likely also accelerate eutrophication effects. However, nutrient load reduction measures will still be able to reduce algal blooms and improve bottom oxygen conditions. The exact magnitude of future changes in the Baltic Sea ecosystem due to climate change is still highly uncertain, depending also on future global greenhouse gas emissions. But regional management of the seas – i.e. mitigating nutrient loads, establishing an ecosystem-based fisheries management, and providing a greater scope of adaptability – also play a key role in safeguarding the future Baltic Sea ecosystem.

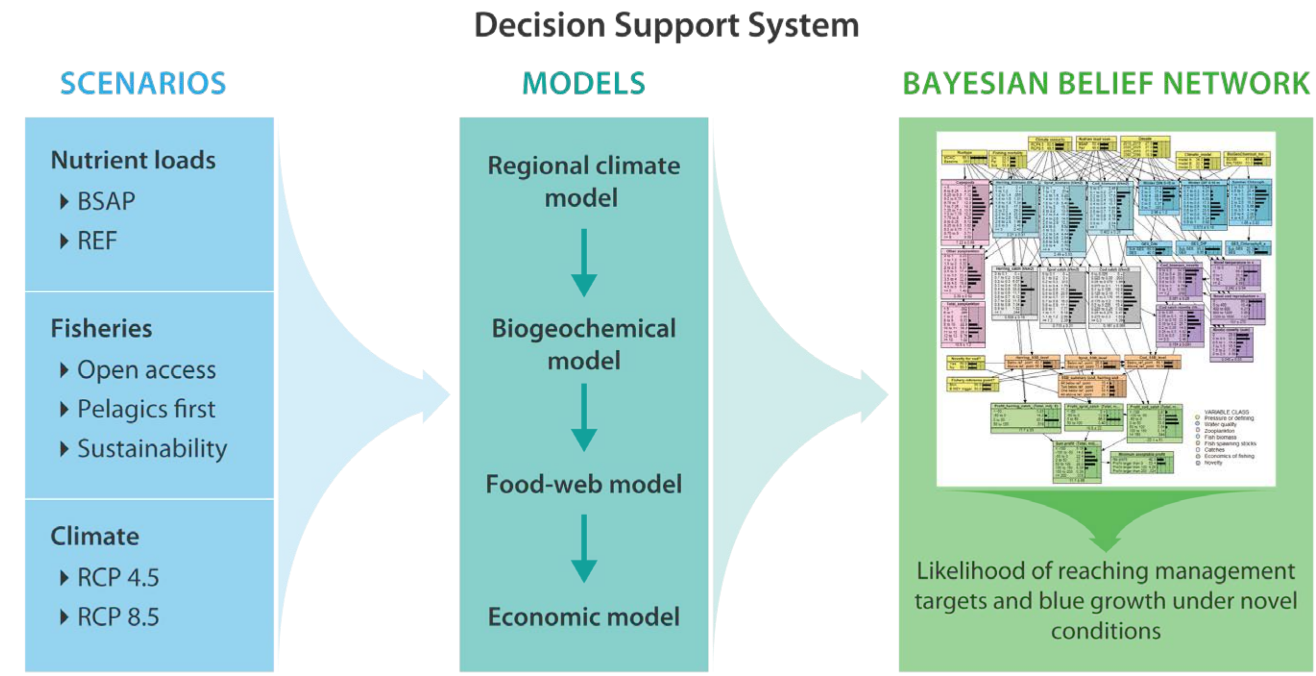
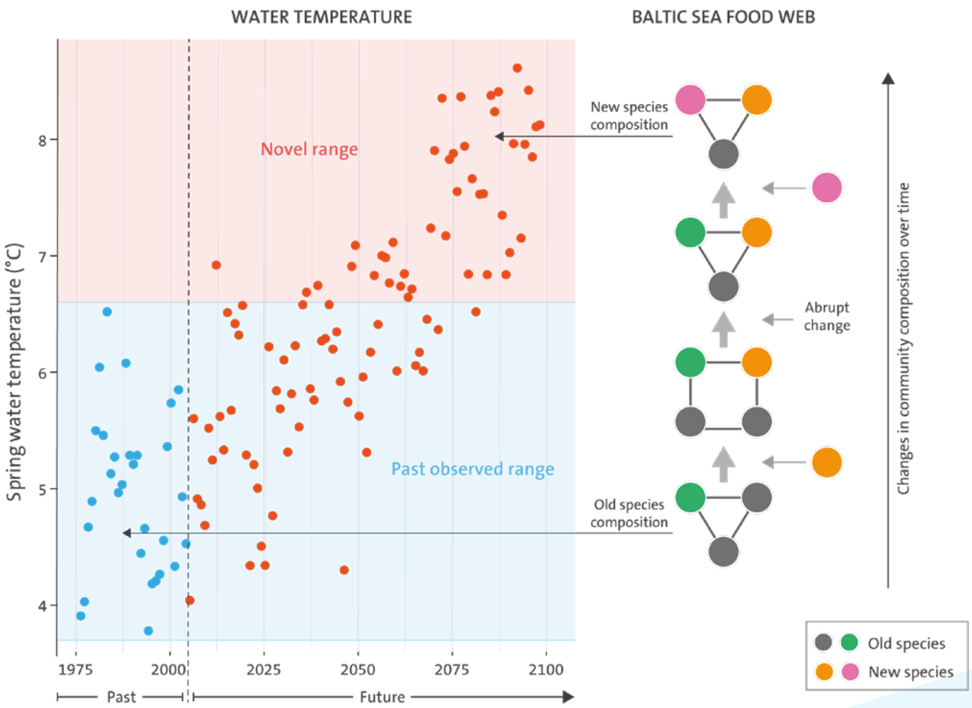


Figure of the Decision Support System (DSS). Illustration: J Lokrantz/Azote

Small-scale coastal fishery in the Baltic Sea. Photo: T Svensson/Azote

economic and social benefit analyses for the Finnish Archipelago and the Central Baltic Sea. The model results, forced by different climate, nutrient and fisheries scenarios, capture changes in:

- water quality (i.e. nutrients and water clarity)
- the marine food web, i.e. biomasses of important ecosystem components (plankton, benthos, fish and birds)
- fish catches and other ecosystem services
- profits and/or stakeholder benefits.



Example of how increased water temperature creates novel conditions that can affect the food web in the Baltic Sea. Illustration: J Lokrantz/Azote

Dealing with novelty

Novel conditions in the marine ecosystem are a challenge for both scientists and managers, as they introduce something unprecedented and therefore highly uncertain. With increased novelty comes greater uncertainty. Thus, most likely, reference conditions that have been used to calibrate environmental models will no longer apply in the future, making it more difficult to project future states of the ecosystem.

By adding scientific expert knowledge about uncertainty on top of the numerical modelling, BONUS BLUEWEBS can explore the uncertainty of the modelling results. Because the DSS includes the best available estimates of uncertainty related to the various decision options, it e.g. allows a decision-maker to see the uncertainty in the scenarios linked to different management choices.

ANALYSIS

One aim of the project was to use the DSS in estimating the consequences of different management strategies for eutrophication and fishing under two climate scenarios (see Factbox) for the Central Baltic Sea.

Based on the results, a series of overarching conclusions were drawn regarding the likely future management characteristics of the Baltic Sea ecosystem:

a) Change is inevitable

Even if nutrient inputs are kept at levels specified in the Baltic Sea Action Plan (BSAP), and fisheries are kept at sustainable reference levels for the three major commercial stocks (cod, herring and sprat), climate change will still bring about novel and never-before-observed environmental conditions in the Baltic Sea.

For example, climate change will increase water temperatures and perhaps also lower salinity. While warmer waters will benefit fish species such as sprat and herring, implementing the BSAP will lead to a less productive system, with less algal blooms and improved bottom oxygen conditions, which restores cod reproduction in the Central Baltic. Most likely, food web dynamics in this warmer, less productive system will differ from its present state. Some species are favored by these novel conditions while others will be stressed, leading to new species interactions.

b) Novelty calls for precaution

Projections about the impacts of climate change are uncertain. Future novel environmental conditions in the Baltic Sea will certainly affect management strategies for achieving both GES and BG. The future climate and management scenarios indicate that due to novel conditions it is likely that for many Baltic regions, not all nutrient and fish management targets will be reached even when applying sustainable nutrient (BSAP) and fisheries management. However, the effects of novelty may vary locally.

c) Future management needs to be adaptive

Climate change and the uncertainties surrounding novel environmental conditions require both constant monitoring to detect ecosystem changes, and reliable modelling of the ecosystem function – which should be used to implement a more adaptive management. For example, climate change might increase rainfall and therefore also nutrient loads from rivers. Continuous monitoring, combined with adaptive management, will be needed to adjust load reduction measures to reach nutrient load targets even in a changing environment. And fishing quotas need to be adapted to the productivity of fish stocks and the food webs supporting these.

The BLUEWEBS app

The web app (https://bluewebs.shinyapps.io/decisiontool/) simplifies the user interface and shows the key messages of the results in an interactive form.

BLUEWEBS

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Manuscripts on which the policy brief is based

Blenckner et al (in prep) Integrating novelty into ecosystem management using future model projections
Uusitalo et al (in prep) Interdisciplinary, integrated decision support model for a socio-ecological system of the Baltic Sea

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Reference

Reusch TBH, et al (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances 4. DOI: 10.1126/sciadv.aar8195