Risk of regime shifts and changes in ecosystem dynamics in the future Baltic Sea

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Background

- **Regime shifts** are described in global marine ecosystems in increasing numbers.
- Baltic Sea, the world's largest brackish water basin, has experienced one of the fastest rates of sea surface temperature (SST) increase during the past decades.
- The **future projections** of global climate models (GCMs) suggest fast increase in air temperature in the Baltic Sea region.
- In late 1980s, changes in climate, eutrophication and intensive fishing resulted in a reorganisation of the Central Baltic Sea food web.

Aim

The aim of this study was to evaluate how different combinations of external drivers (climate, nutrient loads, fishing) may affect the possible risk of ecological regime shifts in the Baltic Sea marine ecosystem under future climate conditions.

Regime shifts. We consider regime shifts as abrupt changes between alternative states, which show profound differences in ecosystems structure, functioning and feedback.

Results in short

- Model projections suggest that eutrophication makes the Baltic Sea ecosystem more susceptible to abrupt change in response to climate change (especially change in salinity).
- Return towards ecosystem recovery takes place only when both the cod fishing and nutrient loads are low, i.e., best-case scenario.
- Even in the best-case scenario, the ecosystem is projected to become increasingly vulnerable to bottom-up forcing, including climate.
- Every abrupt change detected by statistical methods doesn’t coincide with changes in food web control; need for complementary analysis.

Fig 1. The key external drivers affecting the Central Baltic Sea ecosystem.

Fig 2. Environmental forcing (anomalies) we used to drive the food web model with: (a) spring temperature (T, 10-50m), (b) August T (0-10m), (c) salinity (sal, 60-100m), (d) cod reproductive volume (RV) and (f) primary productivity. Forcings (d)-(f) are dependent of nutrient loads (BAU and BSAP).

The temperature values projected for the future Baltic Sea (2100) are higher and the salinity values lower than ever measured (since 1850s).

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Results

climate fishing nutrients

Fig 3. (right) Future abrupt changes in the ecosystem state detected by STARS in (a) BAU-F1.1 (worst-case), (b) BAU-F0.3, (c) BSAP-F1.1 and (d) BSAP-F0.3 (best-case) scenarios.

Fig 4. (down) Changes in food web control in the BAU-F1.1 and BSAP-F0.3 scenario. Red: top-down control (i.e., negative predator-prey relationship), blue: bottom-up control (i.e., positive predator-prey relationship).

if Δ abrupt + Δ food web control = regime shift 2043, 2084 (worst-case) 2034 (best-case)

Regime shift analysis

REGIME SHIFT ANALYSIS. We used the PC1 of Principal Component Analysis as the proxy of ecosystem state for future food web projections and the Sequential T-Test Analysis of Regime Shifts (STARS) to detect potential shifts in this state. If these shifts were accompanied by CHANGES IN FOOD WEB CONTROL, we defined them as regime shifts. Otherwise we address them as abrupt change.

Fig x. The working team (from left): Susa Niiranen, Johanna Yletyinen, Saskia Otto and Thorsten Blenckner (Markus Meier is missing from the photo).

Acknowledgements

This study was enabled by the following research projects: ECOSUPPORT (BONUS+), Regime Shifts in the Baltic Sea Ecosystem, Baltic Ecosystem Adaptive Management (BEAM, Stockholm University) and Nordic Centre for Excellence NorMER.