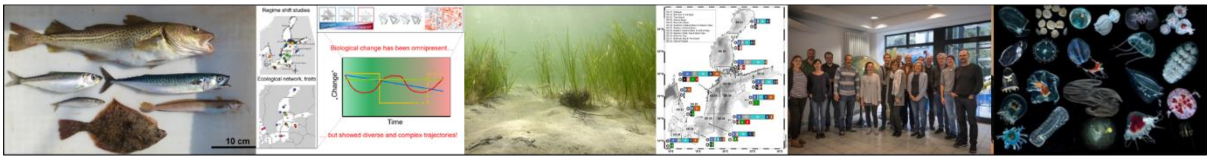
BONUS XWEBS policy brief no. 1[1]



Managing marine resources in a sea of change - Lessons from past trajectories of biological change in the Baltic time machine

Highlights

The Baltic Sea is a sea under strong anthropogenic pressures and experiencing rapid environmental changes. It has therefore been called a "time machine" representing conditions only expected in the future in other coastal seas (Figure 1).

Synthesis of existing knowledge in BONUS XWEBS showed that biological changes in this time machine have also been pronounced and omnipresent, but at the same time diverse and complex, with widely varying trajectories among regions, timepoints and food webs. Further analysis highlighted that processes related to biodiversity and food webs, have a context-dependent potential to buffer but also amplify pressures, thus contributing substantially to this complexity.

From a management perspective, the past trajectories of biological change suggest that future management needs to be adaptive to account for change in the Baltic Sea system, conservative to provide a buffer against unpredictable tipping points, and account for food web knowledge to move towards ecosystem-based management. Finally, targeting the key regional pressures in the Baltic, such as eutrophication and fishing, has a high potential to lead to big payoffs and conservation success stories despite ongoing global change.

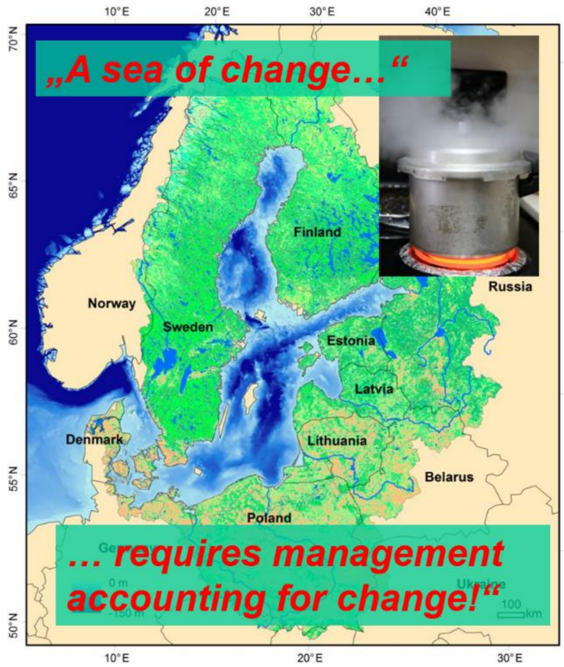


Figure 1. Map of the Baltic Sea and its drainage basin (in green). The characteristics of the Baltic – large, highly populated drainage basin, shallow depth, low water volume, narrow connection to the North Sea, slow water turnover – make it an amplifier of environmental changes and anthropogenic pressures. Processes such as eutrophication, warming and de-oxygenation have been pronounced, which makes the Baltic a "time machine" reflecting levels of change only to come in the future in many other coastal seas (Reusch et al 2018). The question is now: *which biological changes have resulted from these pressures, and what does this means for resource management?*

[1]*Our policy briefs are summaries of scientific knowledge produced in the BONUS XWEBS project, connected to current management and policy needs concerning the Baltic Sea.*

The problem

The Baltic Sea has experienced particularly strong levels of anthropogenic pressures, such as fishing and eutrophication, and of environmental changes including warming and de-oxygenation. As a consequence, it has been identified as a "time machine" reflecting levels of change and conditions to come in many other coastal seas only in the future (Figure 1, Reusch et al 2018). Projections show that pronounced changes, such as warming, will continue into the future (BONUS BLUEWEBS policy brief). The question is now:

How have biological systems reacted to the major changes in pressures in the Baltic Sea?

Which evidence is there for biological changes, and what have been the trajectories of change?

Which lessons do the patterns of the past hold for resource management of the future?

To address these questions, BONUS XWEBS synthesized current knowledge about past biological changes in the Baltic Sea, including individual case studies and all published community trait, regime shift and ecological network studies. We then characterized the observed trajectories of biological change and analyzed which underlying processes could explain what we saw. Here, we summarize these observations and use them to derive recommendations for future resource management in the Baltic sea of change.

Key results and conclusions

Our synthesis revealed that biological change in the Baltic Sea has been omnipresent over the past 30 years. However, the specific trajectories of change differed substantially among regions, periods, food webs and systems that were assessed, ranging from rapid directional change, to fluctuations, to sudden abrupt regime shifts, to no detectable system-level change at all (Figure 2).

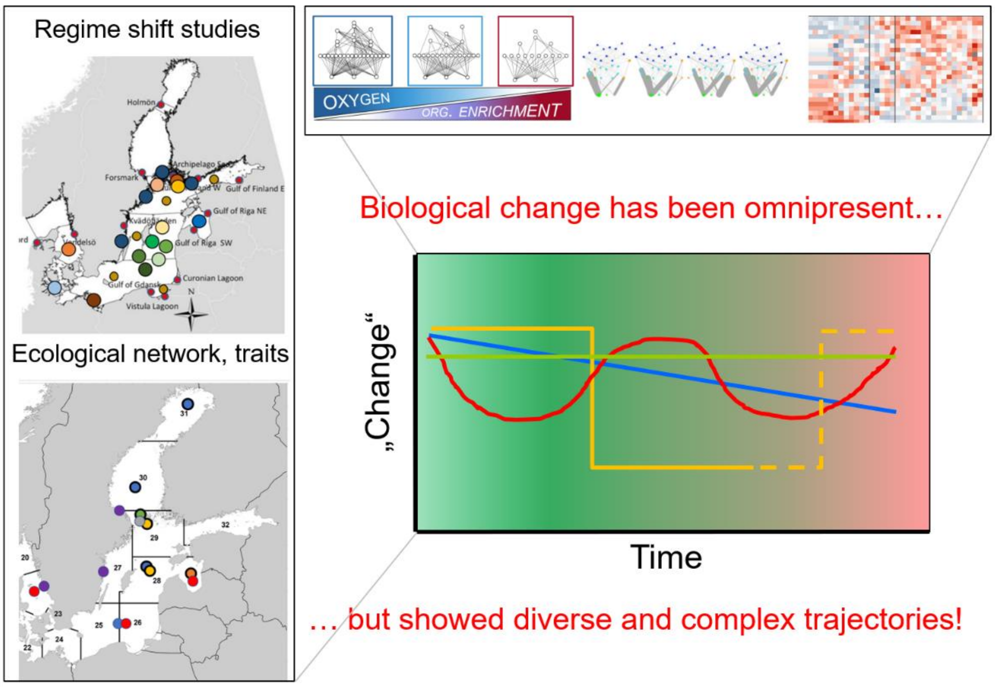


Figure 2. Trajectories of biological changes in the Baltic Sea: the systematic review of regime shift (top left panel) and ecological network and community trait studies (bottom left panel) in BONUS XWEBS revealed that biological change has been omnipresent, but also that trajectories of change have been diverse and complex. The schematic illustration at the center of the figure summarizes types of observed trajectories. Three examples from the published literature illustrating differences are shown in the top right panel (from left to right: type "gradual trend", Nordström and Bonsdorff 2017, type "fluctuation", Kortsch et al in review, type "regime shift", Möllmann et al 2009). Figure based on Dierking et al (in preparation).

Regarding our understanding of these changes there are good news and bad news:

Firstly, our assessment showed that processes related to biodiversity ("eco-evolutionary dynamics") and food webs have the potential to buffer but also amplify and propagate external pressures. For example, functional redundancy and weak links in trophic networks can maintain functions even if species abundances shift or non-indigenous species become established. At the same time, trophic cascades and spillover to adjacent systems can amplify initial changes, e.g., in the abundance of roving top predators. Predicting the biological implications of changing pressures is therefore not an easy task, and requires in depth food web understanding.

Secondly, few to none of the past Baltic regime shifts were predicted *a priori*, underscoring the complexity of the issue at hand, and stressing that we should not be overconfident about our ability to predict changes to come in the future.

Thirdly, some key species such as the top predator cod, the foundation species eelgrass, or the non-indigenous round goby, have had a disproportionate potential to initiate trophic cascades and thus, large scale-shifts.

Finally and encouragingly, independent of the diverse trajectories, it is evident that past changes were oftentimes related to regional-scale pressures, in particular eutrophication (and related oxygen problems) and fishing, and can thus be managed on the regional level.

These observations can help direct future research directions (Nordstroem et al. in preparation), but also lead to a set of applied recommendations (see text box).

Recommendations

- Management in the Baltic sea of change needs to account explicitly for change!
- More specifically, it has to be …
  - …adaptive (i.e., not based on stationary baselines).
  - …conservative to provide a buffer against tipping points, considering our bad past track record in predicting their occurrence.
- Encouragingly, many biological changes and resource management problems in the past can be linked to regionally manageable pressures, most importantly eutrophication (also promoting de-oxygenation) and overfishing. This means that managing regionally manageable pressures matters and can substantially benefit future Baltic states!
- We need to better understand the fates of key Baltic Sea species under changing conditions, and design management options that promote and safeguard the integrity of their populations. This has the potential for overproportionate management payoffs, in limiting unwanted system-wide cascading effects.
- Food web knowledge matters! Food webs have played a central role in mediating initial pressures to ecosystem-level consequences in the Baltic Sea. Successful ecosystem-based management will therefore depend on the explicit incorporation of food web processes and on the availability of dedicated food web knowledge.

This policy brief is based on synthesis work and thoughts developed in XWEBS WP1 “Food web knowledge synthesis”, and the corresponding WP1 manuscript:

Dierking J, Blenckner T, Bonsdorff E, Salo T, Jonsson P, Rosell EA, Herrmann J-P, Jacob U, Köster F, Kotta J, Kuosa H, Lindegren M, MacKenzie B, Margonski P, Meier M, Müller-Karulis B, Oesterwind D, Ojaveer H, Reusch T, Sommer U, Temming A, Tomczak M, Tomkiewicz J, Winder M, Nordström, M (to be submitted to the journal Global Change Biology in Q1 2021) Food web complexity and eco-evolutionary dynamics underlie diverse biological trajectories in a sea of change.

Please cite this policy brief as:

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BONUS XWEBS - For more overarching information on Baltic food webs and other project output and policy briefs, visit our XWEBS website.

Further literature cited:

Nordström, M., Dierking, J. and EU BONUS XWEBS team (2021) BONUS XWEBS policy brief No. 2.: A perspective for Baltic Sea food web research – How food web knowledge can be integrated in adaptive ecosystem-based management of marine resources. EU BONUS project XWEBS, Kiel, Germany, 5 pp. DOI 10.3289/XWEBS_Policy_brief_2.

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Nordström MC, Salo T, Eero M, Neuenfeldt S, Blenckner T, Bonsdorff E, Eglite E, Häubner N, Jacob U, Jonsson P, Köster F, Kotta J, Lindegren M, MacKenzie B, Margonski P, Möllmann C, Oesterwind D, Ojaveer H, Otto SA, Reusch T, Sommer U, Temming A, Tomczak M, Tomkiewicz J, Uusitalo L, Winder M, Dierking J (to be submitted to AMBIO in January 2021) Gap analysis and a future perspective for Baltic Sea food web research.

Reusch TBH, Dierking J, Andersson HC, Bonsdorff E, Carstensen J, Casini M, Czajkowski M, Hasler B, Hinsby K, Hyytiäinen K, Johannesson K, Jomaa S, Jormalainen V, Kuosa H, Kurland S, Laikre L, MacKenzie BR, Margonski P, Melzner F, Oesterwind D, Ojaveer H, Refsgaard JC, Sandström A, Schwarz G, Tonderski K, Winder M, Zandersen M (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances 4

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