

Earth Syst. Dynam. Discuss., referee comment RC1  
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## **Comment on esd-2021-73**

Anonymous Referee #1

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Referee comment on "Global climate change and the Baltic Sea ecosystem: direct and indirect effects on species, communities and ecosystem functioning" by Markku Viitasalo and Erik Bonsdorff, Earth Syst. Dynam. Discuss.,  
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This review by Viitasalo and Bonsdorff offers a timely overview of the scientific evidence for effects of climate change on the ecosystems of the Baltic Sea. Both authors are in a good position to deliver a comprehensive review of this complex field, and Erik Bonsdorff is probably the researcher with the broadest knowledge on Baltic ecosystems. The review covers most ecosystem components except for marine birds and mammals. With 177 included references the coverage is impressive.

The authors give a balanced account of the wide range of studies applying many different approaches including observational, experimental and modelling studies. The emerging picture is complex where ecosystem components show different sensitivity to ongoing and anticipated climate-change effects. This review also highlights the great challenges involved in the interpretation of effects on the ecosystem from studies on the species level considering feedbacks and indirect effects through biological interactions like trophic links, cascading effect and the potential capacity for plastic acclimation and adaptation. The review honestly points out the great difficulty in predicting major changes in ecosystem functions with possible regime shifts. This is also viewed in the perspective of the uncertainties involved in climate model projections of how the climate may change across this century.

This review should be a very useful introduction to the field of climate-change effects on the ecosystem to many researchers as well as in higher education.

The review is well-written and concise. It may be argued that the review is a bit short considering the scope, but this may be an advantage if the aim is to offer a brief summary of the current knowledge together with an extensive collection of relevant literature. I only have a few comments below.

### **Major Comment**

The only major comment is that the section on "Knowledge gaps" could be more extensive. There are questions how to best approach climate-change effects through experimental studies. There may be a lack of experimental infrastructure of sufficient scale in terms of the ability to control multiple environmental factors, sufficient replication, and not least technical staff to maintain also long-term studies. There is the question of more extensive habitat-mapping and also the development of more advanced Species Distribution Models (partly mentioned), e.g. the inclusion of biological interactions, plasticity and capacity for adaptation. A major knowledge gap (likely deserving a different paper) is also how to interpret the present, rather sprawling, knowledge about climate-change effects into Marine Spatial Planning and conservation efforts, e.g. the design of Marine Protected Areas.

### **Minor Comments**

Page 4, line 63. Climate change may also affect the opportunities for freshwater biota, e.g. vegetation.

Page 5, line 112. More sunlight because of less cloudy conditions?

Page 5, line 114. *Mesodinium* should be considered mixotrophic (e.g. Stoecker DK, Hansen PJ, Caron DA, Mitra A. 2017. Mixotrophy in the Marine Plankton. Annual Review of Marine Science 9: 311-335).

Page 5, line 119. A change in N/P ratio? with more P favouring the N-fixing Cyanobacteria?

Page 6, line 140. So what is causing that nutrient reduction? This sentence links poorly to the previous sentence about *increased* nutrient loading.

Page 6, line 155. What competitive advantage? Higher levels of toxins that defend against predation?

Page 7, line 173. There is an experimental study "Karlsson K, Winder M. 2020. Adaptation potential of the copepod *Eurytemora affinis* to a future warmer Baltic Sea, Ecology and Evolution 10: 5135-5151". This Experimental study suggests that copepod populations from warmer environments can at present adapt to a future warmer Baltic Sea, whereas populations from colder areas show reduced adaptation potential to high temperatures.

Page 8, line 216. There is a recent study by "Kinnby A, Jonsson PR, Ortega-Martinez O, Töpel M, Pavia H, Pereyra RT, Johannesson K. 2020. Combining an ecological experiment and a genome scan show Idiosyncratic responses to salinity stress in local populations of a seaweed. Frontiers in Marine Science. 7: 470". This study shows the possible presence of locally adapted populations of *Fucus vesiculosus* in the Baltic with different tolerance to salinity and with different genetic backgrounds.

Page 8, line 230. A typo: "algae" should read "alga".

Page 9, line 239. It may be pointed out that *Zostera* in the Baltic proper may consist of some few clones making the total genetic diversity low with less capacity for adaptation to a changing environment, although it has been found that somatic mutations may increase overall diversity (Yu et al. 2020. Nature Ecology & Evolution 4: 952).

Page 9, line 241. A particular concern is the potential loss of marine, canopy-forming macroalgae (*Fucus*, *Furcellaria*). There is here no freshwater vascular plants that can replace that type of vegetation on hard substrata.

Page 9, line 273. In the paper "Meier et al. 2020. Future projections of record-breaking sea surface temperature and cyanobacteria bloom events in the Baltic Sea. Ambio 48: 1362-1376", they showed how the frequency of heatwaves may dramatically increase under some climate change scenarios.

Page 12, line 369. "IpcC" should read "IPCC".

Page 12, line 375. The previous sentence states a projected increase in stratification, while this sentence refers to enhanced mixing. I guess that this enhanced mixing is caused by more intense wind speeds during the spring when the thermocline is weak. Please, rephrase to avoid confusion here.

Page 12, line 378. Do you know what is the projected P/N ratio for the external loading?

Page 13, line 386. Species names should appear in italic.

Page 13, line 386. Note that also *Cyanothece* (supposed to increase) is a nitrogen fixer.

Page 13, line 401. What is the mechanism behind this negative effect on flux?  
Stratification?

Page 13, line 410. What may be the consequence of this shift apart from lower food web efficiency? Lower export to benthic biota?

Page 14, line 449. A detail: *Myrionecta* is regarded as a junior synonym to *Mesodinium* (and not the other way around). Also, *Mesodinium rubrum* is now considered a complex of several species.

Page 14, line 450. Note that Dinophyta (e.g. *Dinophysis acuminata*) is a PREDATOR on *M. rubrum*.

Page 17, line 542. The word "through" should be omitted.

Page 17, line 558. A bottle-neck for high-resolution 3D circulation models is the availability of high-resolution pan-Baltic bathymetries, and forcing data (e.g. wind fields).

For species distribution models (SDM) a major constraint is the poor habitat mapping in many areas (with exceptions in Finland and Estonia). There is also a need for the inclusion of biological interactions (e.g. predator-prey) into SDMs.

Page 18, line 574. The word "While" can be omitted.

Page 18, line 581. Better start this sentence with "However, some common...".