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Manuscript “Global climate change and the Baltic Sea ecosystem: direct and indirect effects on species, communities and ecosystem functioning”
by Markku Viitasalo and Erik Bonsdorff, submitted to Earth System Dynamics.

Author comments for reviewer no. 2 (esd-2021-73-referee-report.pdf).

All author replies to reviewer comments in red font.

Anonymous reviewer #2

General comments

In general, the compilation of results are more distinct and text easy to read.

All the “To sum up,..” paragraphs are much appreciated. Significant improvement.

The fact that many more mesocosm studies relevant for climate-change effect has been reported need to be clarified and preferably some references added. Also, clarify that just a selected number of studies using defined test variables are presented in table 1.

Some correction of terminology and language is required as suggested below.

I recommend publication after these minor revisions.

We thank the reviewer for the positive comments. We have now taken improved our review on mesocosm studies and added the suggested references.

In the *Review methods* we mention that “...we have not reviewed all experimental studies that have dealt with environmental variables that may change with climate change.” In Table 1 caption we also mention that the Table concerns “selected variables”.

Terminology and language have been corrected as suggested. Some typos and linguistic corrections have been made.

We have also taken all specific comments into account (see below).

Specific comments

r. 150 Variation between year is weather variations as climate variations are defined as differences between 30-year periods.

Good point, and changed accordingly. We agree that “climate change” mainly refers to climatic variations in the scale of decades. We however retain the possibility to review studies considering slightly shorter-term variations (taking “several years”). Such changes, often associated with cyclic phenomena such as NAO, may give valuable information on responses of organisms to longer-term climatic variation as well.

Edited text: "We are not considering short-term (between-year or seasonal) weather variations, but mainly include studies that attempt to reveal organisms' responses to longer term (several years – decades) variability in climate."

r. 293 The reported period is wrong.

Typo on line 297 corrected.
Edited text: "Although data on biogeochemical parameters was not available for the period 1**9**03-1911..."
[Note: The period referred to on line 293 is correct. Hällfors et al. (2013) refers to periods 1903-1911 and 1993-2005.]

r. 467 I would avoid "loop" as having an unclear and even misleading meaning (instead "microbial (part of the) food web". How is "loop" justified? Microorganisms constitute the original food web in the biosphere and is an integral part of the modern food web. It both contribute to biomass flow and remove biomass by respiration. As most organisms.

We agree, and we have now replaced "microbial loop" to "microbial food web" throughout the ms.

r. 481 Correct to "betaproteobacteria". Indeed, all "proteo" phrases need correction.

"Prototer**r**obacteria" changed to "proteobacteria".

r. 506 Please correct to "In the northern Quark, …"

Thank you for the comment. Following HELCOM vocabulary we now use "the Quark" to refer to "Kvarken" or "Norra Kvarken" (in Swedish). In this sentence we do not use the wording "in the northern Quark", because the study area of Nydahl et al. (2013) (and the Öre River, from where the freshwater of the study was taken) are located in the *southernmost* part of the Quark.

r 907-909 This is likely relevant for the Baltic proper and Kattegat but less for the Gulf of Bothnia. The potential effects of simultaneously increasing DOC discharge is neglected in the scenario proposed.

We agree, and define the basins we are speaking of. In Kattegatt, Cyanobacteria will probably not increase due to too high salinity.

New text: "This hypothesis concerns especially the Baltic Proper and the Gulf of Finland, perhaps also the southern Bothnian Sea."

r.970-973. If flagellate pressure is released bacterioplankton would increase. Please match with the scenario proposed in the last sentence. Also, "loop" preferably changed to "food web".

A valid comment. New text: "On the other hand, decreasing of bacteria would also decrease competition for nutrients between bacteria and phytoplankton, which could counteract the negative effects of diminishing remineralization on phytoplankton."

r. 979. More correctly expressed "… maintained bacterial biomass production despite reduced phytoplankton production…".

We agree. Edited text: "This provided additional substrate for bacteria, which maintained bacterial biomass production despite reduced phytoplankton production (Wikner and Andersson,

2012). This suggests that increased humic-rich river inflow may counteract climate change induced eutrophication in the coastal waters (Andersson et al., 2013).”

r. 1182-1185 There are more valuable mesocosm studies so a “(e,g, Lindh et al. 2015….)” would be appropriate or better adding some more examples covering larger parts of the food web (some suggested below).

A valid comment. We have changed the text accordingly.

New/edited text: “A few mesocosm studies have exposed the communities to near-natural environmental conditions and have been able to shed light on the complex dynamics of the Baltic Sea ecosystem, e.g., the responses of the microbial food web to changes of environmental variables affected by the climate change. In studies made in the Gulf of Bothnia, bacterial, phytoplankton and zooplankton production increased with additions of inorganic carbon, and the systems remained net autotrophic. In contrast, when both nutrients and DOC was increased, only bacterial and zooplankton production increased, driving the system to net heterotrophy (Andresson et al., 2013; Båmstedt and Wikner, 2016). Increased heterotrophy led to a decreased fatty acid content and lower individual weight in the zooplankton (Dahlgren et al., 2011). With the combined treatment of elevated temperature and terrestrial nutrient loads, also fish production (of three-spined sticklebacks) increased, with terrestrial and not autotrophic carbon being the main energy source (Lefébure et al., 2013). The complex responses indicate that, to provide useful inferences about physiological and population-level responses of organisms to climate change, experimental work should use full communities, apply naturalistic exposure regimes, and investigate effects of stress at spatial and temporal scales appropriate to the species studied (Gunderson et al., 2016).”

r. 1216 Please add “ , microbial food web….”. Typically overlooked in current models.

We agree. Edited text: “...there are major gaps for key trophic groups, such as macrophytes and macrozoobenthos (Korpinen et al., 2022) as well as the microbial food web.”

r. 1308 I suggest to add: “Continuation and expansion of long term ecological studies in collaboration with environmental monitoring programs is also crucial for validating experimental results and advance our knowledge of environmental and meteorological drivers on large spatial and temporal scales.”

A very good suggestion, thank you. We also note the importance of spatial mapping programs, since they can also be used for validating both experimental results and models.

New text: “Also, continuation of both spatial mapping programs and long term ecological studies will be crucial for validating experimental results and for developing ecosystem models, advancing our understanding of environmental and meteorological drivers of the Baltic Sea ecosystem on large spatial and temporal scales.”

r. 1340 Please change to “…the Gulf of Bothnia (…” as demonstrated also in the Bothnian Sea.

We agree that the studies investigating the role of DOC discharge refer to an area covering the Bothnian Bay, the Quark and the northern Bothnian Sea (at least River Öre discharge area). Changed as suggested.

Edited text: “Increase of DOM flowing via the rivers may decrease both primary and secondary production, at least in the Gulf of Bothnia (Wikner and Andersson, 2012; Andersson et al., 2013).”

r.1388-1390 Should ecological safe fish catches be added here as a reliable and required measure?

A good point. Edited text: "Despite the many uncertainties concerning the effects of climate and eutrophication on the state of the Baltic Sea (Munkes et al., 2021), it can be stated that continued abatement of anthropogenic nutrient loading, combined with sustainable fisheries, seem to be the most reliable, albeit slow, measures to solve the grand challenges of the Baltic Sea (Meier et al., 2018; Murray et l., 2019).

r. 1427 I suggest to specify "…in the Baltic Sea for selected test variables". Several studies referred to in the text, and some covering other test variables, are omitted

Yes we agree. We however do not speak of "selected *test* variables" but "selected variables", as we also summarize long term studies.

Edited text: "Summary of research findings and conclusions on the anticipated effects of climate change (CC) effects in the Baltic Sea for selected variables. The table only shows studies published in 2011-2021 and a part of studies referred to in the text are not included."

Suggested selected mesocosm references

Amin, R. M., et al. (2012). "Partition of planktonic respiratory carbon requirements during a phytoplankton spring bloom." Marine Ecology-Progress Series 451: 15-29.

Andersson, A., et al. (2013). "Can Humic Water Discharge Counteract Eutrophication in Coastal Waters?" Plos One 8(4): 13.

Bamstedt, U. and J. Wikner (2016). "Mixing depth and allochthonous dissolved organic carbon: controlling factors of coastal trophic balance." Marine Ecology Progress Series 561: 17-29.

Dahlgren, K., et al. (2011). "The influence of autotrophy, heterotrophy and temperature on pelagic food web efficiency in a brackish water system." Aquatic Ecology 45(3): 307-323.

Lefebure, R., et al. (2013). "Impacts of elevated terrestrial nutrient loads and temperature on pelagic food-web efficiency and fish production." Global Change Biology 19(5): 1358-1372.

We have now included these references in appropriate places, also in Table 1. We however did not include Amin et al., 2012, since this paper does not specifically concern effects of climate change.