

Abstract:

A modest 10% enhancement in the q_{10} parameter for these processes caused disproportionately big changes in nitrogen and phosphorus cycles - in the light of q_{10} creating a non-linear response of reaction rate, is that really a disproportionately big change?

strong accumulation of ammonium and depletion of nitrate in the anoxic basins, indicating stronger denitrification over nitrification in warmer conditions. The manuscript does not provide a comparison between present and warmer conditions and does not present much information on denitrification

Basin wide enhanced water column remineralization - does Basin refer to the entire Baltic Sea here, or to the Bothnian Bay?

disproportional role of the coast - this suggest that the coast had a larger impact as its small area would suggest, but most of the Sc_r values are < 1 , wouldn't that point to low impact of the coast?.

the Bothnian Bay displaying two to four fold stronger responses in nutrient cycles than basin wide perturbations – can you add an explanation?

adjacent anoxic basins - the Bothnian Bay has no adjacent anoxic basins

Accurately resolving coastal processes is therefore essential to capture the coastal filter and avoid misrepresenting nutrient transport and ecosystem responses under climate change - how does this agree with the findings of the study? For most parameters Sc_r is < 1 , so the central basins seem more important than the coast.

Introduction:

Early in the section the term "coastal" should be defined, and it should be mentioned that for this study coastal means depths < 20 m.

Line 99: The experts suggest - replace by refernece

Line 103: does this apply only to coastal processes, or would that also apply to processes at depth > 20 m?

Line 114: does the paper really investigate spatial differences in temperature sensitivity? After all, q_{10} is changed uniformly over the model domain, with the exception for the coastal zone. In addition, it also does not discuss the changes in the coastal zone compared to

Line 122: Does the paper really provide a classification of the deep basins? what are whole-basin processes - processes on the scale of the entire Baltic Sea or processes on the scale of each deep basin?

Line 124: word missing? coastal areas or deep basins?

2 Model, Data and Methodology

The entire model description could be somewhat shortened and focused towards the processes relevant for the sensitivity analysis. The model description lacks dissolved organic matter, which is essential for understanding experiments C3 and E3.

Line 142: what happens to phosphorus in detritus, is it also remineralized?

Lines 143 - 146: please improve the language

Line 152: the description of q_{10} given here is "standard" $Q_{10} = 2$, which would be $q_{10} = 0.069 K^{-1}$. Your Table 1 shows a range of q_{10} values used in the model, so there doesn't seem to be a "the" q_{10}

2.1.2 q_{10} parameterisation in ERGOM

please rewrite and shorten this section. Explain how Eq 1 relates to Eq 2, i.e. how Q_{10} and q_{10} relate to each other. In eq 2, reference temperature is 0 degC. Add the corresponding q_{10} to Figure 1, make sure that Figure 1 covers the range of q_{10} in Table 1.

Lines 180-181: you already present this information in Table 1.

Lines 201 - 204: Please provide the basic equations for the four processes in Table 1, and include basic equations for N dynamics, including also denitrification since it is discussed in the paper

2.2.1. Details of sensitivity analysis

This paragraph should include how VE and VC are calculated - I think you bring that up only very late in line 266. Please describe clearly how you generate V for the model rectangles in Fig. 2. Was V calculated based on the entire 70-year model run or only on selected years?

In your equations, subscripts E and C only seem to denote the different simulations. It would make the text clearer if you presented only one general equation.

It also seems that no selected stations (line 222) are involved and since only q_{10} is changed, it is not necessary to involve an abbreviation for parameter P and the change ΔP .

Lines 225 - 238: shorten, check for correctness, for example the rate change to a 10% change in q_{10} does not depend on whether the temperature is given in Celsius or Kelvin, since it only depends on the difference between T and T_{ref} .

Lines 239 - 250: Introducing the normalization according to the area ratio actually represents the methodology that you promised to introduce in line 220. It looks like that you are testing this methodology in your paper. Therefore lines 239 - 245 sound speculative and not really relevant to the paper. But it would

Lines 247 - 250: Please give the ratio of A_c/A for the Baltic Sea (it seems that you used 0.224?)

Line 249: factor Ac/A

Lines 252 - 255: please improve the language. And I don't quite understand from the text how you classified Scr. First of all, $Scr=0$ means that the parameter change has no impact on your non-coastal test areas. Since you didn't investigate the impacts on the coastal zone, you cannot conclude that the effect remained localized since you cannot rule out that the parameter change might have had no effect on the coastal zone either. But would $0 < Scr < 1$ would mean that the response to a coastal zone parameter change only is weaker than expected from the ratio of coastal to entire Baltic Sea area, > 1 that the response is stronger? Please explain clearly what different values of Scr imply. How do negative Scr fit in that context?

Lines 255 - 260: This might fit better into the discussion section. If you are proposing using Scr to identify sensitive processes in the coastal zone, then you should come back in the results and discussion section of the paper and show that this approach is reasonable. For the method section of the paper the content is too speculative.

Line 260: Scr values are masked when $abs(S) < 1\%$ - please correct the caption to Figure 5 accordingly

3 Results

In the results section I miss a presentation by how much a 10% increase in q10 could potentially increase process rates, given the base q10 values in the model and the ambient temperatures in the basins for which the results are presented. This is essential to understand why changes in q10 have a large impact on some processes and little effect on others.

3.1. Impact of basin wide enhanced biogeochemical process rates

what do you mean by basin-wide? Can you find precise wording throughout the paper when you are talking about the different basins you present in your model results (Fig. 3 - 5) in contrast to changes that are applied to the entire model domain?

southern, northern, western: please make sure that these terms are used consistently throughout the paper

Lines 273 - 274: This should be explained in the method section and removed here

oxic basins: Please add a statement that describes which basins were oxic in your model simulation. How were oxygen conditions in the Gulf of Finland, Bornholm Basin and Arkona Basin?

Line 283: The accumulation of NH_4 is observed with a significant decline in water column NO_3

-> please don't use the term significant outside a statistical context (applies to entire paper)

-> to which basins does that apply? Do you also see basins where both NO_3 and NH_4 increase or where both decline? Is there a difference between the response to

sediment or detritus recycling?

I realize that you present these aspects in lines 286 - 291. Can you improve the structure of the nutrient result section? Would it be easier to structure the nutrient results by the four q10 experiments?

Line 286: E1 addresses sediment mineralization rate, not detritus mineralization rate

Line 296: The Western Gotland Basin sticks out with an oxygen decline

Line 304: coastal zone should be defined only once, in the methods section

Line 304: How is "weak" in weak responses defined? Given your scaling factor A_c/A , you expect the response in the coastal zone experiment to be only about 22% of the response for the entire model domain. In the Baltic wide experiments you describe effects in the 2 - 3% range, that would correspond to about 0.5- 0.7% in the coastal experiment, whereas here you mention only effects $>3\%$ for your coastal experiment.

Would it be more informative to present where the direction of change is the same as in the Baltic-wide experiment?

Lines 308 - 316: this can be shortened/removed, the area and depth values should be moved to the method section, the weaker expected response is a recap from the method section.

3.3. Relative coastal sensitivity

Lines 318-319: Is the "clear influences of coastal parameterizations" the exception or the rule here? There are 85 Sc_r values presented in Figure 5, but only 6 are > 1 . For 10 cases, Sc_r is negative, i.e. S and Sc have opposite signs.

Lines 328 - 351: it is important and interesting to point out differences and also opposing responses of variables in S and Sc , but much of the interpretation presented here is speculative, needs to be analyzed properly and belongs into the discussion section of the paper. Further, much of the information presented is repeated in section 3.4. It would improve the flow of the paper to present the patterns in S and Sc only in Section 3.4

3.4 Ecosystem response patterns

I am not familiar with the units mol.m/kg used in Figs 5-9. Please explain or change to a more conventional unit.

Fig. 9: it should be nitrate in the caption

4 Discussion

The discussion needs to be structured more clearly. It needs to be shortened, since large parts reiterate material presented in the results and method section.

Main points that are discussed (and might help in restructuring) are

- sensitivity towards sediment detritus mineralization; impact on N and P, differences between oxic and anoxic basins
this has been found in many other studies, needs to be put into context of findings in the literature and this discussion needs to be shortened.
- using relative coastal sensitivity as a measure to identify critical coastal processes
this is an interesting aspect and is postulated as a new method
- diverging patterns in coastal and Baltic-wide experiments; role of coastal Fe-P formation, masking of coastal processes by transport from deep basins in the Baltic-scale experiment
this is an interesting finding and should be discussed in greater detail, involving more areas than the Bothnian Sea

The Summary and Conclusion section of the paper states the high sensitivity of some processes towards a 10% q_{10} change (line 580). To explain the high sensitivity of some processes, the discussion section should address the different impact of the 10% q_{10} change on modelled rates, considering the role of base q_{10} and ambient temperature.

Line 421: denitrification does not facilitate the production of NH_4 , it converts NO_3 to N_2

Line 427: if you suggest that the oxygen-rich environment in the southern and northern Baltic Sea supports coupled nitrification and denitrification, please give evidence from the literature for that

Lines 433-434: please give references

Lines 476-478: This belongs into the results section

Lines 480-482: this is the first mention of water column detritus in the discussion. Why is only water column detritus and not sediment detritus mentioned here? Perhaps it would be more interesting to discuss the different response of water column versus sediment detritus, perhaps it can be done in context with the Fe-P mechanism?

Lines 506 - 528: This largely reiterates the method section.

Lines 552 - 567: here you give an interesting explanation for the differences in the C and E experiments. Can you expand this section? Since most coastal waters are oxic, shouldn't this mechanism be visible in all investigated basins? Can you see in your model output that Fe-bound P really increases in the coastal zone?

Could the Fe-P mechanism also explain why increasing sediment recycling has a different effect than increasing detritus recycling in the water column?

Please also set your text in context to the findings of other authors about the phosphorus dynamics in Bothnian Sea and Bothnian Bay

Figure 12 could be redrawn with more focus on the coastal zone. It should show the main components in your mechanisms e.g. Fe bound P. The Bothnian Bay itself has

no adjacent anoxic basins, consider renaming the transport arrow. Perhaps it would even be beneficial to expand the figure and make a comparison to the Gulf of Finland or Gulf of Riga, where the coastal experiment increases PO₄ in the water column? Can you give any evidence from your model - fluxes, transports - that local processes, i.e. in the sub-basin itself, shape the response, or is there still an impact from changed N and P transport from the Baltic Proper, even in the coastal experiment?

Lines 565 - 567: this does not seem to apply to all systems, but is mainly restricted to the Bothnian Bay. Can you identify under which conditions the coastal processes have this large and contrasting impact? What does this imply for efforts in model calibration?

5 Summary and conclusions

The summary and conclusion section should try to answer the four questions posed as the main aims of the paper (lines 118 - 124), i.e. 1) impact of q₁₀ on Baltic biogeochemistry, 2) develop a methodology to assess coast-to-basin differences in response, 3) classify the response of the deep basins, 4) prioritise parameters for reducing model bias.

In the revised manuscript, summary and conclusions should also reflect the revised discussion.

lines 604 - 605: in the discussion you present PO₄ trapping by Fe-oxides with baseline transport of P from adjacent basins as a potential mechanism for the response pattern in the coastal zone experiment in the Bothnian Bay. The conclusions focus on the response of the nitrogen species (and phytoplankton, but here S_{cr} is negative for sediment recycling) - would addressing the nitrogen processes help in reducing model bias or should S_{cr} values be interpreted differently?

lines 614 - 618: would it be sufficient to focus on the model parameterizations in coastal areas that are sensitive to coastal q₁₀ changes?