Comment on bg-2021-160

Anonymous Referee #1

Referee comment on "Causes of the extensive hypoxia in the Gulf of Riga in 2018" by
Stella-Theresa Stoicescu et al., Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2021-160-RC1, 2021

General comments:

This manuscript investigates the underlying causes of extensive hypoxia in 2018 in the
Gulf of Riga, using data from the regular monitoring program, a continuous profiling
system at the deep part of the basin and a specific survey in September 2018. The
authors conclude that the 2018 hypoxia was caused by a combination of several factors:
1) High freshwater and nutrient inputs in autumn 2017 and January 2018 promoting high
productivity in the system, 2) inflow of saline waters from the EGB early in the year, due
to unusual wind patterns, forming a deep located halocline (deeper than normal resulting
in a smaller water volume in the NBL) that was maintained by north-easterly winds during
summer, 3) rapid warming of the surface layer strengthening thermal stratification, and 4)
reduced ventilation of the NBL during summer. These conclusions are not surprising and
basically confirmatory to our present understanding of processes governing hypoxia.

As such, I concur with the authors in their conclusions, but it really surprised me that it
takes 32 pages to underpin these conclusions. Unfortunately, the manuscript does not
keep a clear stringent structure, as it is filled with repetitions and unnecessary details not
used for supporting the conclusions. For example, the results section presents many and
elaborate analyses (17 pages) without it being clear how these results support the
conclusions. Reading the results section felt more like reading a WQ status report from an
environmental agency, where all data have to be presented – relevant or not. The weak
point is that the results section does not guide the reader towards the main conclusions!

As I see it, the main problem is that the manuscript is not structured around clearly
formulated hypotheses that are subsequently investigated in detail. The authors state that
the objective is 'to evaluate the possible role of different forcing factors leading to the
observed hypoxia'. I would strongly recommend that all the possible factors/explanations
are outlined in detail with appropriate referencing to other literature studies in the
introduction and that the M&M section describes how each of these hypotheses will be
investigated with rigorous data analyses to address each of them separately. The results

section should present only the analyses relevant to the hypotheses and finally, the discussion should centered around relevant scientific discussion points instead of repeating the results. This will require substantial rewriting, but I am also confident that the outcome will be more appealing to the readership of Biogeosciences. I estimate that the main text could be reduced by half.

In my reading I also found several unclear sentences and sentences that could be sharpened. I have listed some of these under my technical comments, but I stopped commenting on the language after the introduction, realizing that a major rewrite would be required. I do recommend that the next version of the manuscript is proofread by a native English speaker.

Specific comments:

The introduction is quite long and contains very general, and occasionally trivial, information about processes related to hypoxia (almost textbook like). This information could/should definitely be shortened to present only the most relevant information that leads to the formulation of the objectives and research questions. I suggest that the authors outline all the possible causes underlying hypoxia in the Gulf of Riga, leading to the formulation of specific testable hypotheses. Moreover, I do not think the introduction presents a stronger motivation for the study. I hope the author can present information that explains why 2018 is particularly interesting and why it is relevant to consider a single year. Are years like 2018 expected to be more frequent under current climate change scenarios – i.e. are we expecting more such events to occur in the future? Did 2018 have any ecological consequences such as fish kills, loss of benthic fauna, etc. In summary, the introduction needs to be terser.

It would improve the readability of the materials and methods section, if the different data analyses were more clearly linked with specific hypotheses stated in the introduction.

The calculation of oxygen consumption rates are based on simple box model assumptions, but these calculations are also very sensitive to small differences in salinity bw stations 114 and G1 (the divisor in Eq. 1). The authors should comment on this and how a small potential bias in using values at stations 114 to characterise the inflow of saltier EGB water could influence the calculated rates for oxygen and phosphorus.

On page 8, it is described that a decline in oxygen concentration should be expected when physical processes are taken into consideration. Does this mean that the authors discarded observations that did not exhibit a decline in oxygen after adjusting for physical processes? If yes, this would bias oxygen consumption rates to higher values, as negative values can be expected by shear randomness. This needs to be clarified.

On page 9, trends in oxygen and phosphate concentrations are investigated, but why are the authors interested in trends? What do they expect? This is one of many examples, where the formulation of a hypothesis would improve the storyline. Are the authors expecting that expanding hypoxia in the EGB will have an effect on the Gulf of Riga and increase the likelihood of spilling over?

The first paragraph of Section 3.1.2 (Page 10) presents changes over time in the physical parameters in the Ruhnu Deep. From reading, it is not clear why all this information (and with the high level of detail) is presented. Parts of the paragraph are trivial and the text could easily be reduced substantially (e.g. the two first sentences could be removed).

On page 12 first paragraph, many numbers are presented, but why are these numbers relevant for the storyline.

On page 12 second paragraph, the authors assess the uncertainty of the areal estimates of hypoxia by looking at the distribution of the depth of the hypoxia threshold value. Since the authors have many profiles that are spatially distributed, why didn't they investigate the spatial distribution of the threshold value to see if the depths are horizontally 'constant' over the domain? This would be a more meaningful analysis. Moreover, it is not clear how the authors will use their uncertainty estimate! What is the purpose of this calculation, if it is not used for substantiating the arguments later?

Section 3.2.1: why are the authors presenting all this information on wind patterns? It would be easier to read if the authors formulated a hypothesis about which wind patterns promote hypoxia and then investigate these.

Section 3.2.2: Again, explain why these data are interesting! River discharge data should be presented in a more hypothesis-driven context. Describe the expectations for the data and underpin with analyses.

Section 3.2.3: Same comment.

Section 3.3.2: The authors use 1.5 page of text to describe different profiles. This section is longwinded and should be shortened. As an example on page 18 (L. 5- 13), an entire paragraph is used to explain that stratification was stronger in 2018 than in 2017. This could be said with a single sentence. The whole section could easily be reduced to less than half size.

The discussion is primarily a repetition of the introduction and results sections, and it doesn't read like a discussion section. It is important that the authors bring up pertinent

research questions and treat these from the angle: - what do we know, what has this study shown and what can we learn? This approach to the discussion would also highlight the novelty of the study. I believe a rewriting of the discussion to follow the general style of a discussion would be needed.

Conclusion: Is there really a need for a concluding section? This section is basically a summary and not a terse concluding paragraph. It needs to be shorter and highlighting the novelties of the study. If this cannot be done, then it is not needed.

Technical comments:

Page 1, L. 12: How can something be both 'occasionally' and 'dominating'? Wouldn't it be more meaningful to just write 'due to unusual north-easterly winds'.

Page. 1, L. 14: What do you mean by 'existing stratification'? Existing relative to what!

Page 1, L. 17: 'prolonged seasonal thermocline and stronger haline stratification'.

Page 1, L. 19: Should be 'under hypoxic conditions'.

Page 1, L. 20-22: This last sentence is an exact copy of the last sentence in the conclusion.

Page 2, L. 12: Insert 'a' before permanent halocline. Moreover, I think the authors need to mention that MBIs only give a short-term relief to hypoxia, but on the long term enhance stratification and thereby reduce vertical oxygen transport (Conley et al. 2002; Carstensen et al. 2014).

Page 2, L. 14-15: This statement is only valid for the eastern Gulf of Finland, I believe. Change to 'In the eastern Gulf of Finland , the south-westerly wind forcing can change the dominant estuarine circulation pattern, leading to erosion of the halocline in the cold season ….'.

Page 2, L. 17: 'where the halocline is absent and a seasonal thermocline restricts vertical mixing, promoting hypoxia in the near-bottom layer and sediment phosphorus release in late summer-autumn (refs.).'

Page 2, L. 21: Replace with 'Sedimentation of organic matter, stimulated by nutrient inputs, can cause severe oxygen deficiency under specific meteorological/hydrographic conditions, …..'.

Page 2, L. 29: 'Water and salt budgets of the gulf are governed by the river discharge, precipitation-evaporation balance and water exchange …'

Page 2, L. 31: Insert 'surface' before precipitation.

Page 2, L. 34: '… of the gulf with the Daugava River contributing about ….'.

Page 3, L. 1-2: This sentence is unclear, please rewrite. Also, insert 'to' before 'about three years'.

Page 3, L. 6: Replace with 'while these hydrographical features are 5 m and 0,04 km2, respectively, for the Suur Strait'.

Page 3, L. 21: 'the whole water column is well mixed in winter.' The homogenous distribution is implicit.

Page 3, L. 23: Remove 'the' before 'strongest in August'.

Page 3, L. 25: Delete 'of the water column' – no need to specify this. '… occurred in years with the highest summer surface temperature and spring river discharge'.

Page 3, L. 26: Place comma after '(2017)'.

Page 3, L. 32-33: I suggest to use 'spring' consistently instead of intermixing 'spring' and 'vernal'.

Page 4, L. 8: Replace 'during the last decades' with 'in recent decades'. It should also be mentioned that the halocline position has shifted upwards in the water column, enabling

denser and oxygen-depleted waters to spill over into the Gulf of Riga (cf. Carstensen et al. 2014).

Page 3, L. 10: Be more specific! Which northern Baltic coastal basin are you talking about? Place comma after 'nutrient input'.

Page 3, L. 11-12: What does this sentence refer to? Is it needed? Delete?

Page 3, L. 14: Are the inputs in numbers really needed when all you want to say is that nutrient inputs are currently higher than required by the BSAP.

Page 4, L. 17-18: Replace with 'following by stagnation'.

Page 4, L. 18: 'Since riverine phosphorus input is <15% compared to phosphorus pool in the water column (Yurkovskis, 2004), ……'

Page 4, L. 21: 'For instance, phosphorus release in the order of …..'.

Page 4, L. 22: Replace 'poor' with 'low'. Suggestion: 'that counteracts efforts to reduce phosphorus inputs to the gulf.'

Page 4, L. 29: 'we estimated oxygen consumption and sediment phosphorus release rates under the observed hypoxic conditions.'

Page 7, L. 11: Insert 'defining' before hypoxia.

Page 7, L. 14: This in under the assumption of horizontal homogeneity and this should be specified.

Page 7, L. 21: Explain how close to the bottom the profiles get!

Page 9, L. 8: 'low sampling frequency' or 'scarcity of data'.

Page 12, L. 10: 'standard error' should be 'standard deviation'.

Fig. 4: I suggest to show (a) as a cumulative wind transport for the different years invidually. Wind transports for the years 2005-2017 could be shown with a thin line and then 2018 could be highlighted.

Page 16, first paragraph: Are all the details here really needed for making the point? Again, it would be better if these assessments were done in relation with a hypothesis. One important question to ask, which the authors haven't done, is whether the bottom water inflows from the EGB are mixed with surface water when passing across the sill, implying that the mechanism is not due to oxygen-depleted water spilling in, because the inflow gets 'oxygenated'. This would point to that respiration within the Gulf of Riga is the important process consuming oxygen, i.e. it is not imported hypoxia.

Page 21, L. 4-6: Is this relevant for the study?

Page 21, L. 12-15: This is another question about monitoring frequencies, but essentially it is not part of this study. So, why bring up that discussion here?

Page 22, L. 3-4: This sentence just repeats what was stated in the materials and methods section.

Page 22, L. 17-18: How do the authors know that outflow prevailed during this period?

Table 1+2: These data are much better displayed as a figure, showing budgets for salt, oxygen and phosphate, i.e. three budget figures with all three variables in the same plot.

Page 23, L. 9-11: Repetition from materials and methods.

Page 30, L. 12: This is not always the case! When the spring bloom sediments, diatoms are often viable and can continue living on the sediment surface for months. Furthermore, the relatively low water temperatures in spring will reduce respiration processes. Thus, it is generally believed that there will be a delayed response between spring bloom sedimentation and respiration.

Page 31, L. 15-16: Was this because the pool of Fe-bound phosphate was emptied? Worth considering.

Page 32, L. 20-22: This sentence is an exact copy of the last sentence of the abstract.