Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2020-74-AC4, 2020

Biogeosciences Discussions
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EGU

Interactive comment on "Changes in population depth distribution and oxygen stratification explain the current low condition of the Eastern Baltic Sea cod (*Gadus morhua*)" *by* Michele Casini et al.

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Received and published: 10 June 2020

We thank the reviewer for the helpful comments.

Reply to the general comments:

- The paper is interesting, and the patterns are convincing. Inevitable any conclusions drawn from parallel changes in two or more metrics without a test will be speculative. Nevertheless, I think the authors do a good enough job of highlighting hypoxia as a contributor to decreasing cod condition. However, I think the description on confounding

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effects and other contribution factors could be improved. For example, although hypoxia may well contribute greatly to low growth of cod in the current system the drivers of a decrease in condition are the triggers of a change in depth distribution and the cause of low oxygen.

The reviewer asked about other factors that drive the poor condition of cod. In fact, we presented briefly the potential other factors contributing to the cod condition patterns in the Introduction to provide some background, specifying that in literature deoxygenation has been advocated as one of the major drivers of the condition decline (e.g. Casini et al. 2016). Our present manuscript is focusing on showing the processes (deepening of cod population and shallowing of low-oxygen layers) explaining the link between the general Baltic deoxygenation and condition (as shown by Casini et al. (2016)) and putting in a population context what found previously in the cod otoliths by Limburg & Casini (2019). We appreciate the reviewer's point, and thus we can add some text in the Discussion section about the alternative factors that could contribute to the patterns in cod condition, especially before the mid 1990s when the cod population seemed outside the sub-lethal oxygen layers but condition was quite low. We can also add some sentences about the reasons of the shallowing of the low-oxygen layers, from literature. On the other hand, the reasons for the deepening of the cod population have not been investigated, only speculated about in other papers (Orio et al. 2019). These are beyond the scope of our paper, but we have suggested that this is an important question to answer in futures studies.

- Furthermore, there is no description of any statistical analysis. Mostly the patterns are "analyzed" by eye and described in the results chapter (related note referring to ïňĄgures as you describe results). This approach may occasionally be valid – and the patterns described are convincing enough - but at least some sort of quantiïňĄcation of the size of effects across time should use when describing them (reduced from x to x). A statistic test is used for the otolith data, but this is not included in the methods. The results from the otolith analysis is interesting yet this part of the paper is referred

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to as an afterthought throughout the paper. I think this analysis warrants increased value, both by adding to the introduction enough background material to allow readers to evaluate the validity of the methods on know of any prior ïňĄndings and in the a fuller description of methods including how the otoliths were selected.

In the revised manuscript we will be more quantitative, spelling out the most important changes across time. We now also estimated the actual oxygen that the population has been experiencing over time (not only the overlap with low-oxygen levels below a certain threshold) and we perform statistical analysis relating this with fish condition. The otolith analysis is a modification of the analysis done in Limburg & Casini (2019), so we thought not to explain the method too much in detail but just refer to that paper for further information for example about the sampling. However, we have now opted to delete the part on otolith chemistry form the main body of the text but add it in Supplementary material.

Reply to the specific comments:

- 26+28: Is “processes” the right word?

We believe yes, we could say also “mechanisms”.

- 100: What is the sample size?

We have added it.

- 101: is this data stable once entered, or is it subject to change? In the last case, a date of retrieval would be handy to include.

We have now added the date of data extraction for the years after 1990, which can undergo slight updates in the ICES DATRAS database. The years before 1990s are from historical databases and therefore not subject to change.

- 105: there are different ways to measure ‘total length’, maybe explain in more detail how it was done in this study.

Done.

- 107: why is SD26-28 chosen and not for example not 29?

We have now explained the reason.

- 108/109: why is the subdivision of big and small cod made and why those speciïňĄc lengths? What happens with ïňĄsh between 29 and 40 cm?

The two length groups for condition were selected to represent small and large fish, as stated in the paper. The small fish can also be seen as juveniles even though the size at maturity has declined with time for this population. The large fish on the other hand can all be considered adults. Currently, there are very few cod above 50 cm and therefore we could not use larger size-classes. We have now edited a little this part.

- 109: Quarter 4 also includes part of the winter. Why not mentioning the exact months instead of season or quarter 4?

Done

- 117: why are those class divisions different from row 108?

The population distributions, divided in < 30cm and $\geq$ 30 cm, come from Orio et al. (2019). In the condition estimations, we did not want to use too large ranges of fish sizes in one group because Fulton condition factor (used in the paper we refer to and compare to ours) can be affected by fish size. Moreover, cod start to become piscivorous around 30 cm and therefore fish below 30 cm (but larger than in the plankton- and nektobenthos-feeder phase, around 15 cm) can be considered occupying similar ecological niche. Therefore, the 20-29 and 40-49 size groups were chosen for condition estimation just to represent the small and large sizes with different ecological niches and therefore likely different behavior and food requirements. We have now added information into this part.

- 135: it is later explained, but I would rather put here the <0.8 (Eero et al 2012),

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explaining the ‘very low’ condition

Done

- 160-191: I see many statements as ‘more’ and ‘lower’ and ‘deeper’, but it is very descriptive, and I miss actual numbers in some places and statistical tests to prove these statements. Also, how many data points were retrieved, how big was the sample size?

We do not think we need statistical tests to explain the long-term patterns, what is important is the overlap between the cod population and low-oxygen layers. However, we tried to add some more quantitative information in the text and not only percentages. We now also estimated the actual oxygen that the population has been experiencing over time (not only the overlap with low-oxygen levels below a certain threshold) and we perform statistical analysis relating this with fish condition. We have also added the samples sizes in the Methods.

- 171: which depth?

Done, we have improved this description.

- 186: The oxygen layers are almost the same, but not totally. I understand this is because they are weighed with the SD-speciïňĄc distribution of the cod, but I think it makes things clearer if you write somewhere that this means that it differs between the big and the small cod (it took me a while to understand).

Done

- 267: I miss a note about that it is not 100% sure that the cod are actually in those low oxygen waters, because that was not directly measured. However, the additional otolith results make it very plausible that this is the case.

We agree, fish can move and therefore we cannot be sure that those with very low condition spent most of their time in low-oxygen waters (even if they were caught there)

from the time-series, but as the Reviewer #2 also says, this is very plausible also considering the otoliths' analyses in Limburg and Casini (2019) (and the modified analyses now in Supplement).

- 273: Was there a way to directly link otolith chemistry with body condition? (e.g. from the same individual?) Why do you think the overlap between cod and oxygen layers is oscillating? (why is the oxygen stratiïňĄcation oscillating?)

Yes, it is possible analyzing the Mn/Mg elements ratio in the otoliths of individual fish, see Limburg & Casini (2018, 2019).

- 475/476/481/486: you use here the whole word 'subdivision', while in the previous description (472) you al-ready used SD

We have edited this to be more consistent.

- 490 post-2000? This is differently described throughout the text.

We have edited this to be more consistent.

- Figure 3: Is there a possible explanation for the high condition in 1996 in SD25

In general, the mid 1990s are characterized by good oxygen conditions (low extent of hypoxic areas) and a large increase in the sprat stock, probably boosting condition. We feel that going into these details bring us out of the paper's scope and we prefer not to focus on single annual values but on the general patterns.

- Figure 6: 2000 onward is called 'post 2000' in the text. Why are there squares in the boxes

We are now more consistent in the terminology. In the caption we have now also specified what the squares and the boxes are.

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