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Biogeosciences Discussions

Interactive comment on "Hypoxia and cyanobacterial blooms are not natural features of the Baltic Sea" *by* L. Zillén and D. J. Conley

Anonymous Referee #1

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This manuscript makes a strong case for human-related activities that led to eutrophication of the Baltic Sea in the last two millennia and more recently post World War II. The data post World War II are less dense and could be expanded, see below. The manuscript is quite convincing as a mechanism of the current state of cyanobacterial blooms and hypoxia in the Baltic Sea, until the treatment of climate and changes in temperature. Then the supporting evidence is thin, despite the first author having published on the subject of climate and hypoxia in the Baltic Sea.

While this paper is specific to the Baltic Sea, many of the readers are not familiar with the literature of the Baltic, re climate change and ecosystem change, terminology for climate periods, etc and may need more information than provided for what seems a Baltic audience. The case of human-caused activities would be strengthened by similar

evidence for the progression of human activity in developed countries elsewhere.

The idea of multiple stressors (brought in towards the end of the ms) and climate are not well addressed. I suggest that a basic geologic history of the Baltic basin and the climate changes in the longer geologic history would be good to provide a background for the changes in the last two millennia. Toward the end of the ms, the last two millennia are compared to the geologic history to make a point about the conditions under which human-caused hypoxia is the case now but could not have.

There are several scales of change, the geologic history, the last two millennia, and the last century, and they are not always clearly stated. For instance, the abstract stated in the first sentence that the changes are in the 1900s, while the paper is mostly about the last two centuries. I think the time scales in this paper that are the most convincing are the 0000 – 1000 period for longer changes in human population and activity and the more recent 1800 – 2000 changes, with acceleration of changes in the last 50 years of the 20th century. The data for the latter are sparse and should be included. The abstract refers to last 1000 years in first sentence and then on l 14 refers to two millennia.

The idea that the current Baltic is not similar to the geology historical Baltic is brought up at the end, which seems important enough to bring up at the beginning. If an accurate title were to be constructed it would be “Hypoxia and cyanobacteria – not natural features of the Baltic Sea in its current physiography and geologic setting.” Because the authors indicate that hypoxia and cyanobacteria may have been present in the far geologic past, but should not be compared to the present conditions.

Another issue of concern is the amount of increased P and N loads needed to affect the whole Baltic Basin. Is it the physiography that makes whatever loads have increased to have an effect, or are the loads so high that there is no escaping the effects across the broader Baltic. This is a LARGE ocean basin.

This paper is an important contribution to the Baltic Sea literature with regard to his-

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toric human activity and current hypoxia. The evidence for current versus geologically historic needs to be delineated more clearly.

ABSTRACT I suggest that the bulleted conclusions be deleted and the essence of that and what is in the abstract = a revised abstract. The conclusions do not add much to the paper, it could end with management implications, and the abstract is what a reader will focus upon for the essence of the paper. P 2, l 4, . . .severe ecosystem. . . P 2, l 6, surprised to see the use of mg/L for what the Baltic scientists usually use 2 ml/L. Not here but somewhere in the text, a definition of hypoxia or lower oxygen concentrations (which may be the case for the geologic history). P 2, l 9, delete "critically" P 2, l 18, ...9.5 million in the Baltic watersheds? Or some other cumulative area? P 2, l 20, ...yet to be demonstrated convincingly, although. . . P 2, l 23, . . .as previously deduced, but are a . . .. P 2, l 24, ...enhanced phosphorus release from seabed

INTRODUCTION P 3, l 3, . . .associated hypoxia. Think that hypoxia should be defined here. Currently the level is xxxx for determination of hypoxia. Lowered oxygen concentrations occurred in the past and the assumption from geologic history is that the geologic levels of dissolved oxygen were similar to the present levels?? Or maybe not so severe? Or more severe? Given the laminations. i.e., is current hypoxia (DO levels) similar to geologic hypoxia? This issue comes up in Osterman et al. 2009 Geo-Mar Letters, when comparing historic "low oxygen conditions" because no measurements, versus current hypoxia, defined for the Gulf of Mexico at 2 mg/L. P 3, l 6, phosphorus is not usually considered an airborne source of "new" P P 3, l 11, lower N/P ratios, where? Surface waters, water column below pycnocline, above the sediments? P 3, l 20, suggest This latter view is increasingly inserted into discussions. . .... P 3, l 26, insert comma after . . ..oxygen conditions, and how do. . ..

P 4, l 1, suggest . . ..human impact upon terrestrial and aquatic systems. Although it may be difficult. . .. P 4, l 6, et seq., mixture of palaeoecologist versus paleoecologists, just be consistent. P 4, l 12, I think that the ms provides more evidence for two millennia ago that just the one century. P 4, l 16-17, . . .the impact on sustainability of

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such impacts. . . . Suggest . . .Baltic Sea and the ecosystem functioning and resilience on both historical and . . . . P 4, l 18, I think this section would be a good place to insert something on geologic historic conditions of the Baltic Sea, climate, sills, water exchange, because these as conditions for "natural" conditions in the past come up later without adequate explanation. The explanation could also be found later in the ms when these ideas surface. P 4, l 25, suggest . . . . Explore this hypothesis further. We will also show that hypoxia. . . . [these are really two separate thoughts and should not be combined in a compound sentence.] P 4, l 27, . . .release from seafloor sediments that occurs under hypoxic conditions. We delineate. . . .

P 5, l 1, idea of hypoxia or lower DO concentrations on severe, anoxic conditions P 5, l 23, meaning of "steep" P 5, l 23, also if surface salinity increases, wouldn't this lessen the density differences and the stratification. P 5, l 8, should there be a reference to stagnation periods. If Conley et al. (2002) is the reference, it should be moved to that location. P 5, l 11, . . .there have been three major periods. . . P 5, l 14-15, an "intensification of hypoxia" is not evident in Fig 2. Just "hypoxia." P 5, l 16, "ea s. str. the opening" is unknown to most readers P 5, l 23, same on increased surface salinity and "steep" salinity stratification. Meaning of "steep" and would there be a strengthening or weakening

P 6, l 13, ...in northwestern Europe P 6, l 15, late-Medieval crisis is not apparent in meaning and especially with regard to information in this ms. P 6, l 25, add years for late Holocene (BP), most readers are not as aware as the authors on these years. Table 1 and Fig. 2, I tried to follow the various increases, decreases, stable, in the table, figures and text, and feel that there are some broad generalizations that might not be solely supported by the data, but the general information and concept of human population and landscape change are consistent with the remainder of the text. P 7, l 19, meaning of "high-Medieval" P 7, l 25, delete "detailed" why wouldn't it be. Suggest "Data from Sweden suggest that. . . .

P 8 et seq. verb tense. Series of present tense for completed studies, then a switch to

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past tense. Suggest that they should all be past tense. P 8, l 8, suggest . . ...population level (increase or. . ...

P 9, l 4, ...similar to the modern. . .. P 9, l 8, Dawson here and Dowson in literature cited P 9, l 14, this is specific to nitrate leaching. I expect that this is mostly organic N mobilization with soil erosion, and the organic N fraction is what is highlighted later on p 11. P 9, l 18-19, not sure that it is phosphate or DIP that is coming off the soils during erosion, but rather TP or organic P. The desorption of DIP from adsorbed sediments in the mixing end member of the freshwater/saline zone is where this would occur. P 9, with deforestation, in other parts of the world, there is second growth forests as agriculture lands are converted back, and there is sylviculture for which there is application of artificial fertilizers. P 9, l 28, . . .in Fennoscandia. . . Most readers will not know where this is, suggest . . .in northern boreal Sweden forests. . ...

P 10,l 2, tilling not tiling P 10, l 5-6, suggest delete last sentence, not needed. P 10, l 25, ...region was in a period. . . P 10, l 27, ...in northwestern Lithuania, eastern. . .

P 11, l 2, meaning of "sophisticated settled agriculture" P 11, l 6, ...regions likely? developed.. P 11, l 7, . . .boreal forests P 11, l 12, suggest The high living standard for the Swedish population translates to c. 0.41 ha per person. The difference between the amount of consumption and area of arable land is due to imported food from other. . .. P 11, l 17, suggest The FAO (1993) 0.5 ha per person scales up to about. . .. P 11, l 21, here organic N, and previously on p 9 nitrate. Think that the issue at this point in human activity is the loss of organic N from the landscape. P 11, l 25, can the identity of the kind of N be provided? P 11, l 28, P discharges, suggest . . ..losses. . ... There are no data in this ms on N and P loads to the Baltic

P 12, l 3, ...which is not included. . . P 12, l 4, Fig 6, why can't the doubling of arable land be included in Fig. 6? P 12, l 6, ...nutrient loss from plowing. The use of "leakage" is not appropriate, because it may be over land or below ground or erosional loss due to winds. P 12, 7-9, I would delete . . .Further studies. . ..this study. I think this

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paper should focus on the information at hand. One comment at the end regarding what specifically would future studies include. P 12, l 11, . . .northwestern Europe. . .. P 12, l 13, ...use of fertilizers(need date of acceleration) was an important. . .

******I think that this manuscript is missing an excellent opportunity to provide post WWII data on artificial fertilizer use, possibly in some cases in the 1930s as well. There should be data on fertilizer application rates and probably nitrogen water quality measurements from points in the watershed and cities in the downstream areas. *****

P 12, l 17, ...increased in the 19th century. . .

P 12, l 20, ...about three to four times. . . P12, l 13, most readers are not familiar with Sweden geography, suggest . . .rivers in the northern boreal part of Sweden.

P 12 l 24, , . . .cyanobacteria. . . P 12, l 25, no comma after spumigena P 12, l 17, ...especially for N. Spumgena, which form. . . *****P 12, the loss of the upper part of the Bianchi et al. piston core is problematic in further interpretation of their dat. Suggest that l 14 be reworded to say . . ..throughout the geological history until about c. xxxdate when the modern data were lost from the core during sampling. . ... *****P 12, the interpretation that N-fixing cyanobacteria were a natural feature of Baltic Sea phytoplankton is not supported by zeaxanthin presence. Zeaxanthin is for cyanobacteria and does not differentiate the other N-fixing forms.

P 13, l 15, suggest . . ..The presence of zeaxanthin was interpreted that N-fixing cyanobacteria were a characteristic, natural feature or the Baltic Sea. The caretenoid, zeaxanthin, however, is not specific to N-fixing cyanobacteria. P 13, l 22, it would be good to add to this paragraph something along the lines of “The work of Poutanen and Nikklilä (2001) was more definitive with regard to taxa of cyanobacteria representative of xxxxx [myxoxanthin] and xxxxxx (algal group) [echinonenone]. Zeaxanthin alone does not necessarily translate to the noxious cyanobacterial blooms currently present in the Baltic Sea in summer. I do not have this article handy to write a suggested sentence.

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P 14, first paragraph, do these data for cyanobacterail and hypoxias and thus P release correlate. The data should be available, This would nail down the P release and cyanobacterial blooms in summer. P 14, l 15-17, I think that this statement about no studies could be modified to show that by combining the results of Zinni and Bianchi and Zillen there could be a correlation among the times and cyanobacterial pigments. P 14, l 25, delete second "has"

P 15, on this page, the carefully laid out changes in population, human agricultural accomplishments and changes in the last two millennia merge with longer geologic climate changes, and the point of the former is lost in the confusion of the latter. This page assumes that the reader knows a lot about the geologic and climate history of the Baltic. The idea of Medieval Climate Optimum comes out of the blue. Either a better geologic history of the Baltic in the introduction, including climate change, or a better explanation here. P 15, l 6-10, this is full of jargon, not understandable to this reader, and P 15, l 10-13, this is not relevant, understandable, or necessary P 15, cyanobacteria blooms should be cyanobacterial blooms P 15, l 21-22, ...and decreases the mixing depth.... P 15, l 25, the basis for the statement ....demonstrated that changes in productivity have a .... is not evident P 15, the ideas of high temperature and cyanobacterial blooms in the present and climate and cyanobacterial blooms in geologic history is an important point to be made but is not provided clearly with data from completed and published papers. P 15, l 26-29, climate features do not have much of an influence on the size of the hypoxia, but earlier said that climate variability was a contributing factor.

P 16, l 1, what is "significant productivity" and was is the "control" The results of Zillén et al. 2008 need to be provided in a way that supports the case of the manuscript. P 16, it would be tremendously helpful for the argument if there were nutrient load data for a long time period, e.g. at least the 20th century. Other areas have this information, perhaps there are data for Swedish and Danish municipalities that might help. P 16, l 4, ...the anthropogenic pressures have likely played an .... P 16, l 9-12, I would

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delete, rather propose what could be done in future investigations

it would help this ms, if there were other areas from developed countries that had a similar time series of human interactions and land use changes that could be seen in the sedimentary record etc to fortify the human-influence story for the Baltic Sea.*

P 16, l 21, give years BP for early Holocene P 16, l 24, suggest . . ..the current causes of hypoxia in the Baltic to compare hypoxia. . .. P 16, l 27, would it be possible to add a pers. comm. from T.S. Bianchi that he also did not hold with his initial conclusions. P 16, l 28, ...due to the release of phosphorus. . .. P 16, l 1, ...during hypoxia (Kahru. . ..

P 17, l 1, suggest . . ..large-scale. . . P 17, l 7, "overfishing" is a new idea at the very end of the ms, how would this be a factor and how to relate to other human activities over the last two millennia. I think this aspect could be deleted in the overall sense of the ms. Otherwise provide data and reasonable conclusions re changes in cyanobacterial blooms and hypoxia.

******"The management issues are well presented and realistic. The paper could end here. The Conclusions could be wrapped into the abstract.**********8

P 18, l 3, loss instead of leakage, for here or elsewhere, P 18, l 4-7, not necessary P18, l 25 . . .Sci. . .. also south-western..

Literature Cited Many things to fix re consistent literature citations. Especially lower case and upper case for articles versus titles of books. Also the use of colons: and Capital following, should be xxxxx Xxxx P 19, l 20, phosphorus P 21, citation for Myrdal and Poulsen, have different citations re Brill P 21, l 23, British P 22, l 33, close up C.-M.

P 24, Table 1 legend, ...Baltic region has always. . . It might be helpful for an overall Europe and overall Baltic countries for population increases. More illustrative than tables.

Figure 2 legend. . . due to poor chronological control associated with . . .. This is not

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understandable. Figure 2, perhaps there should be some temperature regimes for the "climate' determinations. Figure 2, the right figure is hard to read, small font.

Figure 3, what are ....major Baltic countries..... define Figure 3, suggest make the scale up to 1000 for the left panels

Figure 5, what happened in 1500-1600? Figure 5, ...southern Sweden...

Figure 6, it is not clear in this figure whether the N is DIN or organic N, here and

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