Biogeosciences Discuss., 12, C5964–C5970, 2015
www.biogeosciences-discuss.net/12/C5964/2015/

Interactive comment on "Complexity of diatom response to Lateglacial and Holocene climate and environmental change in ancient, deep, and oligotrophic Lake Ohrid (Macedonia/Albania)" *by* X. S. Zhang et al.

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Received and published: 1 October 2015

Review for manuscript by X. S. Zhang et al.: "Complexity of diatom response to Lateglacial and Holocene climate and environmental change in ancient, deep, and oligotrophic Lake Ohrid (Macedonia/Albania)".

General comments: In this manuscript Zhang et al. aim at reconstructing Lateglacial and Holocene climate and environmental changes by using the diatom sedimentary record of Lake Ohrid. As mentioned by the authors, the ancient Lake Ohrid is a key

site for palaeoclimate research in the northern Mediterranean region. The diatom sequence presented in this manuscript includes 104 samples. The diatom analysis of the samples is of high quality, making good use of previous taxonomic works on the endemic species of Lake Ohrid. In addition to calculating diatom relative percentages and concentration in the sediment, the preservation of diatom valves was also assessed. This work represents an important diatom dataset that warrants publication. The manuscript is well written and the figures are of good quality. However, I'm concerned with the interpretation of the sequence, especially with the assumption (page 14353, lines 9-11) that the observed diatom shifts relate to changes in productivity that are themselves associated to change in temperature. 1. The relationship between diatom concentration and palaeoproductivity As acknowledged by the authors (page 14351, lines 1-4), diatom concentration data alone are not ideal for estimating palaeoproductivity. The lack of dry bulk density data prevented the authors from calculating diatom influx. However, in this dataset like in the study by Rioual and Mackay (2005) that the authors mentioned, there are very large differences in biovolume between the dominant planktonic diatoms. These differences in biovolume are actually very important when considering productivity, at least as much as the changes in diatom concentration and certainly more important than the changes in sediment accumulation rate and dry bulk density. For example, a medium-sized frustules of C. fottii with a diameter of 25 micrometers has a biovolume $\sim$240 times larger than the average frustules of C. minuscula (diameter 3-5 microns) and $\sim$50 times larger than an medium-sized C. ocellata (with a diameter of $\sim$10 microns). If one considers the size of the main diatoms, the estimates for palaeoproductivity will change a lot. For example during the Younger-Dryas (zone 1a), the diatom concentration was very low at $\sim$2 x 107 valves.g-1 but the assemblages were dominated by large-celled C. fottii. If one estimate the BVAR (by taking the bulk density as constant), one will find that the planktonic diatom "productivity" was almost as high as during the early Holocene (zone 3a) when diatom concentration peaked (80 x 107 valves.g-1) but when assemblages were dominated by the smaller diatom C. ocellata. Obviously, this changes the interpretation of the sequence. The difference in cell-size is also very important to understand the ecology of Cyclotella species (see the recent paper by Jewson et al. 2015 for details). In my opinion, the authors should estimate the Biovolume Accumulation Rate (BVAR), to improve their estimate of palaeoproductivity as the curve of diatom concentration is a rather poor proxy record for this sequence from Lake Ohrid. The authors have already split into size-class the valves of C. fottii when counting, so the biggest part of the work has been done. As I mentioned earlier, they could use a constant for dry bulk density as doing this will not change the results significantly. 2. The relationship between palaeoproductivity and temperature The second part of the assumption that relates productivity with temperature is also problematic. This is because populations of most planktonic diatoms in temperate lakes can generally grow in a wide range of water temperature and primarily respond to other factors such as light and nutrients (e.g. Anderson 2000). In any case, the temperature range in which these diatoms can grow is much larger than the variations in temperature known to have occurred during the Holocene. It is therefore very unlikely that temperature was the main factor driving the changes observed in this diatom sequence. Most likely, the availability of nutrients (and light?) was more important as driving factors behind the observed changes in productivity. As mentioned several times in the manuscript, it is likely that changes in mixing regime and their effects on the availability of nutrients were decisive factors explaining the shifts in diatom species. It is also important to remember that lake circulation is not only driven by temperature but also by wind, and seasonal changes in solar radiation. Therefore, I think that you should focus more on change in stratification/mixing regime rather than on temperature as a basis for interpreting this diatom sequence. In addition to the mixing regime, and considering the ecology of C. fottii, one would expect changes in the light regime and/or the depth of the photic zone (see Saros & Anderson 2015) to have a very large influence on the abundance of this hypolimnetic species. It is also important to consider that Lake Ohrid is a karstic system and as mentioned in the manuscript (Site description, p. 14347) it is mainly fed by karstic springs, including Lake Prespa underground outflow. According to Lorenschat et al. (2014) this hydrolog-

ical setting has a strong influence on the nutrient budget of Lake Ohrid, as water from Lake Prespa is nutrient-rich compared to that of Lake Ohrid. Therefore an increase or decrease in the outflow from Lake Prespa may influence the nutrient budget of Lake Ohrid and its diatom assemblage. Another point that the authors should consider is the possible effects of biotic interaction on the diatom assemblages. Apparent decrease in diatom productivity may be due to competition from the other primary producers in the lake. In the littoral zone, chlorophyceae including Cladophora spp and Chara spp. are the dominant primary producers. These algae can act as a sink for nutrients for nitrogen and phosphorus. Specific comments: Abstract Page 14345, line 4: I don't think you can use the term "high-resolution" for this study as the temporal resolution of the sampling is at best multi-decadal, and most often centennial. Results Page 14351, lines 21-22: change to: "with a peak in diatom concentration…"

Interpretation Page 14353, line 14: re-write such as: "… but represent real ecological shifts." Page 14353, lines 15-17. Here you should add a sentence to clearly state your interpretation for the curve of PCA axis-1 scores, something like: "Axis-1, therefore, appears to reflect a gradient of mixing regime, and opposes assemblages dominated by epilimnetic taxa associated with strong thermal stratification to that dominated by C. fottii, associated with the hypolimnion and stronger lake circulation. Page 14353, line 16: change such as: "with high positive scores associated with the dominance…"

5.1 The Lateglacial: Page 14354, Lines 3-4 you wrote: "…C. fotti indicates low temperature-dependent lake productivity…". I think this statement may not be correct. (page 14351, lines 1-4). As discussed above, the large biovolume of C.fottii largely "compensate" for the low diatom concentration. Planktonic diatom productivity was therefore already high during the YD, at least in the same order of magnitude as during the Holocene. Lines 13-15: Long duration of complete lake circulation: In my opinion, this is the most important point for the interpretation of the diatom assemblage in this interval because a large diatom like C. fottii requires turbulence to remain in suspension in the water column. Lines 21-22 you wrote: "erosion-induced external nutrient input would also have been high". This statement may not be correct. The geochemical evidence indicates more clastic delivery, but clastic material does not necessarily provide nutrients (nitrogen, phosphorus) for diatoms, except maybe silica. Line 23: again, productivity may not have been that low if you consider the biovolumes. On lines 23-27, you mentioned temperature reconstructions for the Younger-Dryas for the study region. Here it would help the reader if you could give some estimated values by how much temperature decreased in that region during the YD.

5.2 The earliest Holocene (page 14355) Line 5: add "in the epilimnion" after "reduced nutrient availability" Lines 7-9: In my opinion, the decrease in small, facultative planktonic, Fragilariaceae essentially suggests a decrease in horizontal transport from the littoral zone (where these diatoms essentially live) to the pelagic zone (from where the sediment core was retrieved). So this is associated with shorter, less intense period of lake circulation. The way it's written, it almost suggests that these Fragilariaceae are "ice-diatoms" associated to ice-rafted debris. Line 13: increase in algal organic matter contribution: would it be possible than algae, other than diatoms caused this increase? For example chlorophyceae are also present in the pelagic zone (Miho & Lange-Bertalot 2003) and in the littoral zone (Schneider et al. 2014). Lines 14-15: again, the average size of C. fottii appears to increase in that interval as shown in Fig.3 with a decrease in the percentages of cells <20 microns and an increase in the percentages of cells of large size classes (> 20 microns). So the productivity of pelagic diatoms probably increased in comparison with the previous interval.

5.3 The early Holocene (page 14356) Lines 6-7: Here the large increase in diatom concentration is mainly caused by small (C.ocellata) and very small (C. minuscula) diatoms. So overall, the diatom pelagic productivity may have in fact decreased by comparison with the previous interval. Lines 7-12: Interestingly, C.ocellata has been reported to be favored by high nitrogen concentrations including from Lake Prespa, the sister lake of Lake Ohrid (Kocev et al. 2010). Lines 19-21: Again this statement is most likely wrong, as productivity probably decreased not increased if you take into

account biovolume instead of concentration. Lines 23-25: In Lake Ohrid, calcium-rich waters that originate from subaquatic springs significantly enhance lacustrine carbonate precipitation (Matter et al. 2010). Is it possible that the observed peak in calcite was caused by increase input of spring water? Page 14357, lines 2-6: The absorption of phosphorus on calcite particles is a very interesting explanation. Page 14357, lines 19-2: Most Stephanodiscus species prefer by low Si/P conditions, which also suggests that the potential influx of silica associated with the tephra layer had no lasting influence. Is it possible that this species of Stephanodiscus was stimulated by an increase in the strength and/or length of the mixing period? Increase mixing would also promote the percentages of C. fottii.

5.4 The mid-Holocene (page 14358) Page 14358, lines 20-21. Here it is unclear how temperature would influence the abundance of the hypolimnetic Stephanodiscus transylvanicus. In general, the hypolimnion is characterized by very stable temperature conditions. Interestingly, in this interval the percentages of C. fottii of large cell-size (>20 micron) are much lower than in DAZ-1. This may indicate low nutrient availability (especially silica?), so that less cells can complete their full life cycle with sexual reproduction (see Stoermer et al. 1989 as an example of down-core variations in cell-sized of a centric species). This may be linked to shorter and/or weaker circulation period.

5.5 The late Holocene (pages 14359-60) Line 15: "It is not a predictable diatom response to high nutrient availability". Maybe the increase in epilimnetic C. ocellata and C.minuscula and the simultaneous decrease in hypolimnetic C. fottii are linked with a decrease in water transparency? Increased turbidity would be compatible with enhanced erosion. Lines 26-17: it is not clear here why you make a comparison with C.paraocellata from Lake Prespa. Please explain. Page 14360, lines 9-11: please add some reference(s) regarding the threat of invasive species.

6. Conclusions As a general comment, I think that without a better estimate of diatom productivity it is difficult to evaluate how the diatom of Lake Ohrid responded to temperature variations. With that in mind, I feel that your conclusions refers too much to

variations in temperature.

List of references mot already mentioned in the manuscript. Anderson, N.J. (2000). Diatoms, temperature and climatic change. European Journal of Phycology, 35: 307-314.

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Miho, A. & Lange-Bertalot, H. (2003). Considerations on biodiversity and trophic state of Lake Ohrid (Albanian part) from a microalgae point of view. Journal of Environmental Protection and Ecology 4/3: 543-549.

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Interactive comment on Biogeosciences Discuss., 12, 14343, 2015.