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Interactive comment on “Ecosystem regimes and responses in a coupled ancient lake system from MIS 5b to present: the diatom record of lakes Ohrid and Prespa” by A. Cvetkoska et al.

Anonymous Referee #2

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Cvetkoska et al. present a diatom record of high quality, alongside various geochemical proxies, from a c. 92ka lake sediment sequence retrieved from Lake Ohrid (part of the SCOPSCO project). The main purpose of the research is to compare this record to a previously published diatom record from the adjacent Lake Prespa (to which Ohrid is hydrologically connected) in order to compare system resistance and resilience to past climate change and to investigate the potential for Prespa to influence change in Ohrid. In my view there are four substantive issues which the authors are invited to consider relating to the interpretation of the data (detailed below). This is followed by a list of specific queries / suggested changes. In addition, the manuscript would benefit from another round of proof reading to improve the clarity of prose.

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SUBSTANTIVE ISSUES

1. Diatom response to variables in Ohrid.

Temperature (I'm assuming water temperature – please clarify) is identified as the variable which chiefly accounts for the variability in diatom assemblages. This statement is based on previous research at the site. Given the importance of this statement it would be more appropriate to explain how this conclusion has been reached (rather than refer to older studies), particularly because inferring water temperature changes from diatoms is considered problematic (e.g. see Anderson (2000) European Journal of Phycology 35, 307-314). This issue is compounded by the nature of the 'end-member' species of the inferred temperature gradient. *C. fottii* is identified as a typical 'glacial' indicator (although it has not been explained why) and the only autecological information provided about this taxon is its depth preference (20-200m and which opens up the possibility that other variables such as light penetration and mixing could be driving *C. fottii* abundance). *C. ocellata* is taken to indicate a temperature-related increase in productivity. Yet this taxon is extremely cosmopolitan and is known to thrive in a wide range of conditions (including oligotrophic to eutrophic) so how can you be sure that it is only responding to increases in temperature-related productivity and / or changes in light availability? If these assumptions have not been based on contemporary monitoring of the diatom ecology of Lake Ohrid (alongside nutrient and temperature data), then these inferences are weaker, particular given the nature of the dominant taxa involved and the major influence / co-variation of temperature on other physical and chemical variables in the lake, not to mention catchment characteristics (thus making it difficult to separate temperature specifically as the major variable driving changes in the diatom assemblages). Overall, a much more convincing argument about diatom-temperature linkages must be made.

2. Diatom concentration

It appears that throughout the paper, diatom concentration (DC) is used as a proxy

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of lake productivity. This is problematic, given that DC may not necessarily reflect productivity (and thus may change independently of productivity) which could result in misleading conclusions. For example, changes in sedimentation rate will influence diatom concentrations. Although sediment accumulation rates have been calculated in the core, they are not discussed in connection with DC (or really discussed at all in the paper). There is at least scope to calculate diatom accumulation rates. Biovolume accumulation rates are a more appropriate approximation of palaeoproductivity (as it also accounts for changes in valve size (e.g. see Mackay and Rioual (2005), *Global and Planetary Change* 46, 199-219) and so the limitations of your approach need to be highlighted. More inclusion of the BSi and TOC data is required throughout in relation to your discussion of productivity, but still interpreted cautiously (because of issues of bio-volume and the potential for differential decomposition of organic matter). Occasionally in the paper (detailed below), C/N ratios are used to 'support' inferences of changing productivity, as 'revealed' in the diatom concentrations. Again this is problematic at a fundamental level; C/N ratios are not strictly a proxy of productivity, but of organic matter source (relative contribution of plankton / terrestrial vascular vegetation). Low C/N ratios are indicative of planktonic dominance, either because of an increase in productivity and/or a reduction in the delivery of organic carbon from vascular vegetation sources.

3. Lake interconnectivity

A fundamental aim of the research is to assess the degree of influence (if any) of Prespa on Ohrid ecosystem dynamics in the past. More context and detail are needed for the reader to appreciate the potential for this to occur, and to determine to what extent this can be tested given the issues with correlating the two sequences. Specifically:

(i) It is stated that the lakes are presently connected (p.15053, L 19). Do you know how long they have been connected, or are you assuming it has always been so? This is a particularly important issue during glacial / cold climate regimes. Previous stud-

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ies at Ohrid (Belmacheri et al. (2009) Palaeo3 277, 236-245) consider the potential for permafrost in the karst catchment interrupting Ca²⁺ supply to the lake, causing a reduction / cessation in calcite productivity (and it is interesting to see very low TIC during MIS 2, 3 and part of 4). They used pollen-based temperature estimates to suggest the likelihood of permafrost and also point to the evidence of past glacial activity (of MIS 2 age was suggested) extending 100m below the present level of Prespa. Such activity would be expected to disrupt the connectivity (and thus water transfer) between Prespa and Ohrid at times in the past. This needs to be considered as it is fundamental to your interpretation / conclusions – perhaps there is no apparent influence of Prespa on Ohrid for much of your record because the pathways of connectivity were simply blocked (i.e. you state that up to 50% of Ohrid water input is via karst aquifers, with up to 46% of Prespa water escaping through subsurface outflow into the karst aquifers of the Galicia Mountain – how much water would be expected to enter Ohrid from these sources at times when air temperatures would support permafrost and local glacier growth?).

(ii) Based on existing research, you state that Prespa can drive changes in Lake Ohrid, yet find no evidence that this has occurred during the time represented by your record. This is an important point and requires more context and explanation. How has the influence of Prespa on Ohrid been identified by Matzinger et al? Is it theoretical or empirical. If empirical how was this achieved? This is important because if Prespa can drive changes in Ohrid presently, but not in the past, then it begs the question why is the present so unusual? (see also potential issues with permafrost etc above). Alternatively, is it because the diatoms may be insufficiently sensitive? If this is a possibility then your inferences should be appropriately cautious (I note that this is the case in places).

(iii) The ability to correlate the two lake sequences is arguably weak (p.15059, Line 3-9), with offsets of up to several thousand years suggested. More detail is needed here to demonstrate that this approach (comparison of two independently dated diatom

records with few tie points) is viable for the purposes intended. Certainly orbital-scale climate changes are apparent in both records, but it becomes problematic to determine leads and lags between the two systems, and to correlate sub-orbital scale changes, given this uncertainty.

4. Focus of the paper

Certainly the investigation of lake resilience to change, and comparing the interconnectivity of these two systems, provide a novel contribution. Yet I found the context provided in the introduction, and the wider scope / implications of this study, as provided in the (rather short) discussion insufficient. Given the focus of the paper, it could be beneficial to review the concepts of resistance / resilience and panarchy in more detail in the context of the overall research project (SCOPSCO) and what this can potential add to the field of ecology, given the rather unique age and context of Ohrid.

OTHER QUERIES

Why is the time period up to MIS 5b the target of study? What is the significance of this?

Abstract

p.15052, L13: Suggest use terminology of both resistance and resilience in the abstract to avoid confusion (i.e. Ohrid with a high buffering capacity being resistant and Prespa resilient).

p.15052, L 16-18: Meaning unclear.

Introduction

p.15052, L23: Please clarify which terrestrial ecosystems you are referring to in this context.

p.15052, L23: query whether the use of word 'evolve' is the most appropriate. Rather than systems evolving sensu stricto, do you really mean that they change in response

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to climate forcing (patterns repeat)?

p.15054, L2 and throughout: Citations should be presented in chronological order.

p.15053, L10. There is an issue with the logic of this statement, as presented. Surely it is only through the research of lake sedimentary records in the first place that ecological collapses of the lakes mentioned has been identified.

p.15053, L20-29. The aims could be better integrated / formulated, particularly in the context of system regimes and responses (see above).

p.15054, L3-4: Which proxies are you referring to? Please state.

p.15054, L4-5: This is not a cogent statement. What independent evidence is there to make this claim? Otherwise how would you know how effective / sensitive the proxies are to change? Perhaps reword to indicate that your chosen proxies change in response to large-scale climate change.

p.15054, L7-8: The proxies to which you are referring need to be stated in each case.

p.15054, L22. Need to list these biochemical and geochemical approaches.

p. 1505, L1-3. This is one major aim of the research and so should be better integrated into the Introduction earlier.

Environmental Setting

p. 15055, L6: m.a.s.l. Write all acronyms in full on first use.

p.15055, L8: 155 and 293m respectively

p.15055, L15: average annual precipitation?

p.15055, L 17: from what P concentration? State to give some idea of scale of change.

p.15055, L27: if 100% of water input is accounted for, what proportion is groundwater?

p.15056, L6: this is rather vague – what aspect of the environment are you referring

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to?

p.15056, L10: please present TP concentrations using the same units of measurement (to allow for comparison with Lake Ohrid, p.15055, L17).

Methodology

p.15056, L16: boreholes rather than holes.

p.15056, L21: More detail required here. How many cores comprise your composite sequence?

p.15056, L20-25: Issue with sentence structure (clarity)

Results

Line 15058, L23: The suggestion that diatom species assemblages are chiefly driven by water temperature is central to the research presented here. Given the significance of this, I don't think it is appropriate to refer readings to other papers. The basis for this inference needs to be outlined here (as mentioned above).

P. 15058, L26: It has not been explained why *C. fottii* is a typical 'glacial' indicator. The only autecological information given is depth preference.

Line 15059, L2: *C. ocellata* has extremely broad tolerances, so why has it been linked to temperature-related increase in primary productivity and / or light intensity? What is your independent evidence for increases in productivity (you cannot assume DC alone will show this because of other drivers of this – see comment above).

p.15059, L3-5: please cite the study suggesting that *C. minuscula* is related to light and nutrient availability.

p.15059, L8: This is a rather thin basis to interpret Fragilariaceae. The study you refer to has a very low resolution, and no supporting modern data, so a link between Fragilariaceae peaking at the onset of the warm season (spring?) is equivocal. It would be

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more appropriate to cite research where the contemporary dynamics of Fragilariaceae in lakes which experience seasonal ice cover have been studied, or at least refer to the conceptual interpretation of Fragilariaceae in this context (e.g. Smol (1988) Verhandlungen des Internationalen Verein Limnologie 23, 837-844). Moreover, I would assume that Fragilariaceae are chiefly part of the glacial flora.

p.15059, L20: It is a gross assumption to infer productivity from DC. This is far too simplistic because of other factors which can influence DC (as detailed above). Therefore, DC cannot be used as a proxy for productivity on its own.

Ecosystem dynamics

p. 15059, L23: More details needed here, re CONISS – was this performed on transformed data? p.15060, L19. Here DC is used to infer low productivity and this may in fact not be the case because of the issues mentioned earlier. Moreover, C/N ratios are used to ‘support’ this inference. Again this is problematic at a fundamental level, but also does not follow. C/N ratios are not strictly a proxy of productivity, but of organic matter source (relative contribution of plankton / terrestrial vascular vegetation). Low C/N ratios are indicative of planktonic dominance, either because of an increase in productivity and/or a reduction in the delivery of organic carbon from vascular vegetation sources.

p.15060, L21: From the arguments presented it is unclear how ‘climate instability’ has been inferred.

p.15060, L22: You specify that the data are consistent with lower winter temperatures. Again, it is not clear how seasonality has been resolved.

p.15060, L24: For clarity, need to highlight that you are referring to Prespa here.

p.15061, L11: You suggest earlier that the diatoms in Ohrid reflect temperature. However, here you now suggest that they may also infer changes in moisture (presumably lake level). What evidence do you base this on?

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p.150061, L19: Circular argument – proxy data can be used to infer, rather than ‘correspond to’.

p.15061, L24: Presumably there is independent regional evidence for a decrease in precipitation (e.g. speleothems). If not, suggest you be more cautious here and say effective precipitation.

p.15062, L7: Phrase ‘regime of gradual transition’ unclear in this context.

p.15062, L9: If there are pollen data available, then please use this as a more robust way of inferring ‘glacial aridity and climate cooling’.

p.15062, L12-13: Please explain why *C. fottii* indicates low productivity.

p.15062, L14-15: Similarly, please explain why the dominance of *C. fottii* >30micron morphotypes in particular are indicative of low productivity. Which studies are these inferences based on?

p.15063, L5: Please explain why an increase in *C. minuscula* and *C. fottii* could indicate drier conditions (these species have not previously been linked to lake level in this study).

p.15066, L17: Again, environmental conditions are being invoked (in this case aridity) apparently without basis. Moreover, *C. ocellata* has hitherto been linked with higher temperatures, yet peaked during your inferred 8.2 ka event, with this diatom assemblage being used to infer cold winters. This does not follow, as it is presented. Please clarify.

p.15067, L2: Since there is no apparent compound-specific organic work presented in this paper, you cannot infer definitively that there is a decrease in organic matter preservation – suggest reword to include ‘and/or’.

p.15067, L2: ‘probably associated with lower temperatures’. What is the empirical evidence for this? Any pollen data? Where is your diatom evidence for lower tempera-

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tures, since it is claimed that the diatoms in Ohrid are primarily driven by temperature? More detail is needed here if there is a conflict with existing data from Ohrid, and you are trying to persuade the reader that your version of events is more likely.

Ecosystem internal dynamics and interactions

p.15068, L10: It is not clear how seasonality has been resolved in this study.

p.15068, L19: Given that you do not find evidence of lake level change in Ohrid during the study period, on what basis do you infer periods of aridity?

p.15069, L5: Please describe and explain the feedback mechanisms to which you refer.

p.15069, L29: Take care with meaning here. The lake does not have an 'ability' to change as such. In the example given, the lake level increase is what happens to the lake, driven by external forces. It's an artefact of lake morphology that it can fill quickly during wetter periods.

Lake ecosystem interactions

Be more cautious about your conclusions here. You acknowledge the uncertainty in the Prespa chronology and thus correlation to Ohrid.

The discussion overall is very short. Given the focus of the paper on regimes and connectivity, much more detail is needed in both the introduction (more context) and discussion.

No conclusions section is presented.

Figures

Fig 5 and 6. Given the issues with your assumption that diatom concentrations solely reflect productivity, these figures are probably misleading.

SAR data shown but there is no discussion of this anywhere in the text. With such a focus on productivity, sediment accumulation rates should be considered.

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Diatom concentration data, which is one of the main proxies alluded to throughout, has not been shown in Figs 2 or 4.

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