Response to Review 2 (Dirk Verschuren) – CP-2013-133

We wish to thank Dirk Verschuren for the thoughtful comments provided and, that despite errors the paper 'presents valuable palaeoecological data and [subject to revision] presents a robust story of environmental change in western Uganda'. As with Reviewer 1, we have considered and, in nearly all instances, addressed the changes suggested by the reviewer. This has helped to clarify our data and has improved the paper. We address the each revision, in turn, below.

CORRECTIONS

1. The smoothing parameter chosen for this work was based on the methodology of Blaauw (2013). The age-model was run with a smooth of various values, and given the dates used in the model, produced differences of <10 years when compared. There wasn't a large difference observed when using a piecewise linear extrapolation between the dates; however the method of Blaauw (2013) was favoured due to the robust nature of the iterations used when calculating the errors associated with the age model and the determination of the fit of all dates (prior to the rejection of dates). We have re-assigned zones to the nearest century / half century (depending on whether we are in the region of Pb-210 dating [smaller errors] or C-14 dating [larger errors].

2. Lake Edward was originally omitted from the statistical analyses as the dataset we had access to stopped in the mid-1970s, so couldn't be compared to the data we had (runs up until 2007). However, we have re-jigged our datasets and rethought the statistical analyses, and by creating 2 'driver' datasets ('full' and 'reduced') we were able to include Edward in the new analyses for all samples up until AD 1975. This change to the analyses and datasets has been described in the paper. The discussion text has also been updated to reflect this. We do not suggest we can 'simultaneously' assess the changes, we suggest we can explore the various drivers of changes; even suggesting we can assess the extent may be beyond the scope of this study.

3. A change to the RDA zones and a re-run of the statistics has been undertaken for the revised version of this paper (also in response to a comment from Reviewer 1). We do not think that the time-slices are too small a time-period – especially with the new zoning. All but one zone (Ny-4) showed significant correlation with one or more predictors at a confidence interval of $p < 0.01$. We feel that it is an interesting exercise to see when drivers change through time, rather than merely suggesting that a lake responds to X number of drivers over a thousand years. There are few studies that have looked at using RDA, which 'can play a role in this exercise' and it's not without issues, but provides a different perspective when understanding and analysing our data.

4. The suggestion that '*the main text must be entirely revised*' seems unreasonable given the other comments made by this reviewer (C2904-C2906) and the comment by Reviewer 1 that the '*manuscript is clearly organized in its structure*'. Given the complex, interlinked nature of 'lake hydrological response', 'climate change' and 'diatom response', and the fact that diatoms, and the lake systems themselves may be responding to multiple drivers at any given time, it would be unreasonable to discuss these as separate, non-interacting entities. In doing so it is likely to lead to repetition and would not assist in drawing conclusions. Having now revised the quantitative analyses and discussion we hope that this has clarified the text.

5. The numerical zoning shown on the diagrams were those deemed statistically significant when compared to a broken stick model. It was decided when writing the original paper to not focus on the intricate nature of the diatom record. Whilst important, it was deemed too detailed for the nature of this specific journal. Furthermore, the detailed interpretation of the record can be viewed in the PhD thesis by Mills (2009) which is available, open access via Loughborough University library https://dspace.lboro.ac.uk/2134/13219 (this link has also been added to the reference list). Rather, we summarised the diatom records, and in doing so amalgamated the zones. This particular issue was also raised by Reviewer 1 and we have now rectified the diagrams to reflect the summary zones and have chosen not to include the diatom detail, which, by doing so, would greatly lengthen the manuscript and is not entirely relevant to the message we are trying to get across. It should also be noted that all the full diatom datasets will be available, open access, via the NOAA NCDC website. There were no plans to 'salami slice' this work and reproduce the diatom stratigraphies elsewhere – however we would like to make the data available to all researchers in this field via NOAA NCDC (link to be added) and the sites will be lodged on the PAGES Africa-2K metadata site.

6. Much of this comment should now be addressed with the re-analysis of the data and the renewed discussion provided. We thank the reviewer for the comment which has helped to clarify the interpretation / discussion from both lakes.

SPECIFIC COMMENTS

Abstract

L.6 – Yes they are less extensive, but are likely more applicable to management and understanding future climate impacts in terms of hydrology at a scale important for people. Exploratory? We disagree as these datasets can help test climate models when downscaling rather than the very generic, continent wide datasets from large lakes that show a smoothed signal.

L.19 – 'these two' inserted.

L. 25-28 – this paragraph has now been changed to reflect our final conclusion.

Introduction

P.5185 l.25-18 – as per the reviewers comment, this is the meaning and the remainder of the sentence clarifies this. No change made.

P5186 l.18-19 – a small CA:L ratio amplifies effect of groundwater (and direct P or E on lake), whilst a large CA:L makes a lake sensitive to P:E over groundwater, amplifying the local/regional P:E signal. The aim of this work was to target lakes that are sensitive to local P:E rather than regional groundwater (working on longer timescale and larger area). In this study, Lake Nyamogusingiri (the deeper lake) is an amplifier lake (compared to shallow Lake Kyasanduka) until it loses connection to the larger basin. The system then becomes isolated with non-linear response to P:E (hence the jump in DI-conductivity), and groundwater has less of an impact (does not keep the system fresh). It is likely that Kyasanduka receives a lot of fresh groundwater to stay as a lake and fresh all the time, even during substantial droughts. We have also clarified this in the text.

The precipitation regime on the rift valley shoulder is a tropical monsoonal regime with a bimodal rainfall distribution (as denoted in both instances by the dominant vegetation type).

3.1 Coring, physical analyses and radiometric dating

L.24 – changed to 'A total of sixteen dates were obtained from the 2 core sequences' to clarify.

3.2 Diatom analysis

L.10 – this is now clarified (also in response to a comment from Reviewer 1) that overlapping samples were counted to ensure core continuity and the robustness of the record, hence the higher number of samples counted.

3.3 Numerical records

L.6 – changed to 'within each site' rather than amongst.

L.15 – this had been changed to atmospheric $\Delta\ ^{14}C$ residual series which has been used as a proxy for solar (sunspot) activity and extends back to 9,600 years (Stuiver & Braziunas, 1989). We had incorrectly used this term interchangeably. It has been discussed in the literature that solar activity is linked to rainfall in East Africa, which would subsequently affect aquatic environments in terms of habitat changes, chemistry and lake level (and stratification) as a result of changing hydrology.

4.1 Core correlation and chronological analyses

Repetitive paragraph integrated and removed.

5.1 Lake-level reconstructions

P.5195 l.10-11 – in the original manuscript we only based the lake level on select taxa. In the revised version we have used the % planktonic taxa only as this seems easier to justify and hopefully goes someway to addressing a similar concern of Reviewer 1.

P.5195 l.19 – there is no reference, we are suggesting/inferring a possible extreme aridity event given the nature of the diatom assemblage at this time in Lake Nyamogusingiri. It could also be an explanation for the establishment of the dead trees in the crater. Local people also suggested (in 2007) that around 60 or 70 years ago, the larger lake Nyamogusingiri was separated from the crater. Whilst oral histories are renowned for their accuracy, the evidence pointing to a lowstand (both anecdotal and presented here) cannot be ignored.

P.5196 l.5-8 – we have clarified this and added in an alternative scenario. It is easy to assume that a 14 m deep lake would remain fresh when levels drop by only a few metres. However, with the shallow lake it may be a result of fresh groundwater springs creating pools on a drying surface, or rainfall events causing the same. This may allow freshwater taxa to bloom and the signal be recorded. It is also possible that this is coupled with ground water seepage (which is essentially an exchange of salts) or dilution of shallow water by extensive groundwater springs. We will never know for certain unless the hydrology of these systems is further explored.

P.5196 l.17-18 – this is an error on our part. Drier has been replaced by wetter. Catchment disturbance (vegetation removal) coupled with a wetter climate would lead to more catchment inwash into these systems – this is readily observed in Uganda today during the wet season in catchments with heavy human impact/clearance.

P.5196 l.20 – erroneous citation removed.

5.2 Drivers of diatom change

P.5198 l.15-18 – repetition removed.

5.3 Coherence between records

P.5199 l.15 – reference should be Gasse (2002). There is/was general agreement in East Africa that lake levels were lower during the MCA from a range of literature. Gasse (2002) provides a good summary, as few recent studies go as far back as the mid-Holocene (the statement to which the reference relates).

P.5200 l.24-26 – these references have now been added.

P.5203 l.5 – change made.

4.2 Diatom record

P.5193 l.12 – the names of these taxa have been inserted. We have also added a letter after each species name in Figures 4a, b and c which indicate the habitat preference used in this study, this should assist the reader when comparing the text to the figures.

P.5193 l.15-18 – we agree with the reviewer that soil erosion would lead to a greater flux of mineral sediments. However, in this instance, we believe that given the fertile nature of the crater catchments and the naturally high P in the soils, a large amount of nutrients/organic matter would be delivered to the system alongside the increase in mineral sediments. The reviewer also mentions a potential dilution effect even if productivity is increased. This is certainly something that is seen in some of the other crater lakes records in Uganda (work not presented here, but available in Mills [2009]) as suggested by the diatom concentration and diatom flux. However, we would expect, in a central core, to record the productivity signal as the nutrients would remain in the water column, whereas the minerogenic matter is likely to be deposited in the littoral zone, especially as the crater sides at Nyamogusingiri are not particularly steep.

P.5195 l.4 – error. *Navicula* corrected to *Fragilaria*.

6. Conclusion

Indeed it does create lots of issues! This paired lake study highlights the complexity in the lake response and we have now clarified a sentence in the conclusion about using multiple lakes, and perhaps using a landscape approach to this sort of palaeolimnological work and utilising many lakes on a simple climate / impact gradient (‘Landscape limnology’, cf. Webster and Magnusson). The possibilities of exploring drivers and response in a region such as western Uganda are huge, and may assist with teasing apart intrinsic and extrinsic drivers, and even assessing the extent to which different sites are affected (or maybe even simultaneously assessing the impacts!).