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Interactive comment on "Ostracods as ecological and isotopic indicators of lake water salinity changes: The Lake Van example" *by* Jeremy McCormack et al.

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Response to Referee #1

Referee comment: 1 Summary and General Comments McCormack et al. present a very interesting data-set from a sediment profile (namely, Ahlat Ridge-AR) drilled in Lake Van. There already exist many published papers from the same sediment profile. Other than the previous publications, this manuscript presents abundance data of ostracod species, their temporal morphological distributions, stable isotope data from their valves and C-13 data of bulk carbonate. Accordingly, they offer that abundance of different ostracod species and changes in the morphology of limnocytherinae species

reflect the changes in salinity and/or alkalinity of the lake. This suggestion mainly depends on salinity (Tomonaga et al., 2017) and Archaeol and Caldarchaeol Ecometric (ACE) index (Randlett et al., 2017) from previous studies they also support these results with stable isotope data. My impression about the manuscript is positive. Organization of the manuscript is tidy and easy to follow. I think, the data presented in the manuscript and the efforts in interpretation are invaluable and I thank and congratulate the authors for their effort. I think the McCormack et al. ignore some of the previously published studies which should be cited and discussed according to their results. Furthermore, if possible, they should present and/or discuss morphological features of contemporary recent species as done for the fossil data. Overall, I think the manuscript should definitely be published in BG journal. On the other hand, I have major to moderate critics which you can find below.

Authors Response: Thank you for your compliments and the approval of our work. We acknowledge the very thorough and constructive feedback.

Referee comment: 2 Major/Moderate Critics 1. There is one major debate about the lake level and accordingly precipitation regime of Lake Van region, which recently Ön and Özeren (2018) made us remember. There are different lake terraces which have been dated to between 26 and 20 kyr BP (Landmann et al., 1996; Kuzucuoglu et al., 2010). These terraces have been interpreted as high stand lake level during 30-20 kyr BP and some authors claimed that the region was not arid (Kuzucuoglu et al., 2010; Ön and Özeren, 2018) as claimed by many Paleovan studies (for example, Kwiecien et al., 2014; Stockhecke et al., 2016). It is clear that McCormack et al. do not focus on LGM, however they ignore this debate and present the paleoenvironmental conditions one sided. Furthermore, faunal distribution data and their interpretations presented in this manuscript seem to me, the authors can take part in this discussion, which can be a major contribution to the precipitation regime of the region during LGM (c.f. Tzedakis, 2007).

Authors Response: As the reviewer noted, the LGM and a discussion on the regional

precipitation regime during that period are not the focus of our study. Salinity of closed lakes is inherently related to the volume of water in the lake (which can be expressed as lake level). The relation between precipitation and the volume of water in the lake is not that straightforward. The lake volume is a function of input versus output, and precipitation is only one of the input components. Aware of this fact, and having only salinity data at hand, we deliberately decide not to take part in the ongoing discussion on the precipitation regime in the region. Still, in the following we will briefly discuss some problems with the lake-level reconstruction of Ön and Özeren (2018) and why we assume a generally lower lake volume and higher salinity during the Last Glacial period (including the LGM) in comparison to Interglacial conditions as indicated by Lake Van salinity proxies (Tomonaga et al., 2017; Randlett et al., 2017) and regional humidity proxies (e.g., Pickarski et al., 2015a,b; Pickarski & Litt, 2017). We do not exclude the possibility of short-term lake-level highstands during the Last Glacial period. Ön and Özeren's (2018) reinterpretation of already published Lake Van proxy data by applying an independent component analysis (ICA) is an interesting approach. However, several issues limit the precipitation reconstruction (Van-IC7) presented by Ön and Özeren (2018) in terms of lake-level reconstructions. The main argument for using Van-IC7 as a proxy for precipitation variability is based on its similarity with normalised B* reflectance data from Stockhecke et al. (2016), assuming that sediment colour in laminated sediments mainly reflects precipitation variability. Based on the discussion presented by Ön and Özeren (2018), the authors seem to assume, that Lake Van Ahlat Ridge sediments are laminated throughout the studied interval (250 kyr), which is not the case. It appears, as if in their interpretation the authors took no account of the sedimentary facies (besides falsely stating laminated sediments throughout the studied interval) and causes of lithological changes (as described in Stockhecke et al., 2014a), which greatly affect the original data used as an input for ICA (XRF-element intensities, CaCO3 content, B* and TOC). Further arguments provided by these authors in support of the Van-IC7 as a precipitation proxy is the comparison of Van-IC7 with Lake Van bulk δ18O data. The claim that bulk δ18O profiles follow Van-IC7 trends during

marine isotope stages is questionable when comparing the records. More importantly, the interpretation of Lake Van bulk δ18O data remains ambiguous given its mineralogical complexity (discussed briefly in this manuscript and in detail in an additional now published paper: McCormack et al., 2019), and the presence of dolomite distorting the bulk isotopic signals (McCormack et al., 2018). The presence of terraces is a valid argument in regard to lake volume changes, but it must be handled with caution, due to the poorly constrained ages (some of which were recently questioned by Sumita & Schmincke, 2013) and the possibility of tectonic uplift and subsidence in this tectonically active region. Ön and Özeren (2018) do not discuss other published Lake Van records highly relevant to regional precipitation and lake-level reconstructions. These include: Seismic reflection data (Cukur et al., 2014), porewater salinity/alkalinity data (Tomonaga et al., 2017), diatom preservation-based alkalinity changes (North et al., 2017), and mineralogical documentation highlighting early diagenesis compromising bulk δ18O data (McCormack et al., 2018). Some of these data directly contradict Ön and Özeren's (2018) interpretation for the LGM (particularly seismic reflection and porewater data, Cukur et al., 2014; Tomonaga et al., 2017). Although, short-term highstands were likely during the Last Glacial period (especially during interstadials), cumulative Lake Van proxy data generally indicates a lower lake volume for most of the Last Glacial period (and particularly the LGM). Our ostracod taxonomic, morphological and isotopic data support a lower Last Glacial lake volume for Lake Van but provide no direct information on precipitation patterns.

Referee comment: According to the data presented, can the authors discuss why there is almost no noded species between 30 and 20 kyr BP?

Authors Response: There are noded valves between 30 to 20 ka BP, however, most samples do not have a sufficient number of limnocytherinae species (Limnocythere sp. A excluded as it never shows nodes) to count the number of nodes (i.e. < 20 valves per sample). This does not mean that nodose limnocytherinae valves are absent during this interval, only that we cannot obtain statistically significant results regarding the

number of noded valves (see original manuscript page 5 lines 2-4). We added a reminder of our counting method to the discussion to avoid a similar misunderstanding in the future (page 8 line 11). The reasoning for the lower number of node countable limnocytherinae valves, though speculative, is likely linked to the dominance of Limnocythere sp. A and the perhaps very unfavourable (high salinity and alkalinity) conditions.

Referee comment: Why did maximum number of noded individuals and the number of nodes per valve were attained during MIS 4 and 3 (Page 8, line 7), but nor during MIS 2?

Authors Response:See also our answer above. Interpreting noding during MIS 2 should be done with caution, given the lack of samples with a high enough number of limnocytherinae valves for node counting. Still, the samples with a high enough number of limnocytherinae valves for node counting show a significant amount of noded valves, even though the total percentage of noded valves is slightly lower than during MIS 3. There are several reasons that could explain the apparent lower percentage of noded valves during MIS 2 compared to MIS 3, all of which are highly speculative given the low MIS 2 resolution and the uncertainties regarding node formation, especially in limnocytherinae species. This study is, to our knowledge, the first to link the occurrence of noded limnocytherinae species within a geological record to proxies of past water hydrochemistry including parameters such as salinity and alkalinity. Furthermore, no study investigated the physiological process of node formation on limnocytherinae species. Therefore, we consider a discussion regarding subtle differences in the percentage of noded valves (particularly for MIS 2) as too speculative. Instead, we focus on larger variations of the relative concentration of noded valves over longer time periods.

Referee comment: At page 4, line 2 they cite Lake Xinias and Lake Urmia. That is right, Xinias seem to have low level during MIS 2, but previous conditions do not reflect the same conditions of Lake Van. Furthermore, in and around Anatolia there are other

high lake levels or evidences of high precipitation rates (see Ön and Özeren, 2018, and references therein). I don't find it fair to cite Urmia and Xinias, while there is a lake level reconstruction presented in ÇaËŸgatay et al. (2014) and a precipitation reconstruction presented in Ön and Özeren (2018). What if the authors correlate their data with these reconstructions? I can understand, they use curves of Tomonaga et al. (2017) and Randlett et al. (2017), because they are proxies of salinity. However, ACE index has very low resolution and salinity curve reflects fluctuations "over tens of thousands of years" (Tomonaga et al., 2017).

Authors Response: Please refer to our response above detailing why we do not plot our data against Van-IC7 by Ön and Özeren (2018). The lake-level reconstructions of, ÇaÄ§atay et al. (2014) rely on proxies that have been shown to be less reliable for Lake Van palaeohydrological reconstructions by more recent subsequent studies (e.g. Tomonaga et al., 2017; McCormack et al., 2018, 2019). The presence of the terraces is a clear evidence of fluctuating lake levels in the past, but their dating is still controversial (Tomonaga et al., 2017). McCormack et al. (2018, 2019) identified flaws in the traditional interpretation of bulk inorganic carbonate-based proxies (δ18O and δ13C the occurrence of dolomite and relative calcite to aragonite concentrations). Therefore, we choose to compare our data with direct proxies of salinity and original time series, rather than with fallible interpretations. Still, we find the comment justified and have implemented a sentence on the complexity of hydroclimate reconstruction in the Eastern Mediterranean region during the last glacial/interglacial cycle (page 4 lines 2-4).

Referee comment: Can the authors elaborate, why they couldn't find no ostracod species between 133 and 125 kyr? Also, if this is due to environmental conditions, they should express the ages according to Stockhecke et al. (2016) (see below comment #5)

Authors Response: Although ostracod-based palaeosalinity proxies (combined taxonomy, morphology and geochemistry) have the potential of being the highest-resolution

Lake Van salinity proxies to date, the presence of ostracods depends on bottom water oxygen content and their record is not necessarily continuous. Particularly, ostracods might be absent during short lake-level highstands (during e.g. Greenland Interstadial), due to the establishment of bottom water suboxia/anoxia. Accordingly, in this proxy-development paper, we do not discuss in detail possible short-term lake level variations within the Last Glacial period. Similarly, the termination II and the transition into the Last Interglacial likely led to an oxygen depleted bottom water body preventing or hindering a colonisation of the profundal zone by ostracods (see page 11, lines 13-17). Regarding the age model please see our response to comment #5 below.

Referee comment: 2. Why don't the authors inform us with the modern ostracod assemblage, and also, if possible, with the distribution of number of the nodes of modern Limnocythere inopinata? They still exist within the lake (Altinsaçli and Griffiths, 2002).

Authors Response: Yes, Limnocythere inopinata does still exist in Lake Van (see also KülköylüoÄ§lu et al., 2012), however, studies on the modern Lake Van ostracod assemblage (Altinsaçli and Griffiths, 2002; KülköylüoÄ§lu et al., 2012) do not focus exclusively on Lake Van and include records from different regions in Turkey (Anatolia). There is no detailed study describing the modern fauna of Lake Van that would include node counting or even a mentioning whether L. inopinata are nodose or not. Our study focusses on ICDP sedimentary material and we have no access to the modern faunal assemblage here. However, we are currently working on a manuscript describing the limnocytherinae fauna of Lake Van in more detail.

Referee comment: 3. The AR record is mentioned neither in the abstract nor in the introduction. Readers are unaware of which sediment record is being analyzed till section 3. Please name the sediment record, at least, in the introduction with proper references.

Authors Response: Done.

Referee comment: 4. I know there are too many figures in the manuscript, however

readers would want to see the geographical location with a map. This is an optional request since I don't know the restrictions on figure numbers of the journal. Maybe map or some other figures can be presented as supplementary.

Authors Response: Because the location of Lake Van is shown in so many of the cited papers dealing with Lake Van records, we decided not to show it here again.

Referee comment: 5. The chronology is only mentioned as: Composite profile depth (and age; Stockhecke et al., 2014b) was assigned to off-section samples by visual correlation based on high resolution core images. in page 4, line 24. As far as I know, there are two different age models of AR (Stockhecke et al., 2014, 2016). And these models differ a couple of thousand years during MIS-5 and 6. I know, it won't change the results substantially, however, why do authors use the old age model? Do all the data given to correlate (such as ACE index, Ca/K, salinity curve) use the same old age model? And maybe, the age model should be a little bit highlighted within the text.

Authors Response: The minor differences between these age models have no impact on our results nor our interpretations which are based on the comparison with other Lake Van proxies and therefore age independent. All data presented herein is plotted on the same age model, but also plotted against depth (mcblf, Figs. 2, 3, 4, 8), and all data will also be made available with given sediment depth, upon manuscript acceptance. In any case, the Stockhecke et al. (2014) age model remains the most commonly used age model for Lake Van ICDP Ahlat Ridge records, not only used in all publications prior to 2016 but also in most thereafter (e.g., Pickarski & Litt, 2017; Randlett et al., 2017; Tomonaga et al., 2017; DamcÄś & ÇaÄ§atay, 2018; McCormack et al., 2018, 2019; Schmincke et al., 2018; Kappenberg et al., 2019). To our knowledge, the slightly altered Stockhecke et al. (2016) age model is only used in two other publications (North et al., 2017, Ön & Özeren, 2018), while some of the data presented by the latter example are also plotted on the Stockhecke et al. (2014) age model.

Referee comment: 6. In the material and methods section: What is the sampling inter-

val? How much dry weight has been used per sample for counting ostracod valves and are these samples normalized to equal weights? I strongly suggest the authors to publish the data. Let the efforts given to this study open new doors to other researchers.

Authors Response: The sampling interval is described in the material and methods section. Sampling range covers the uppermost 68 m (56 m without event deposits) of the composite profile (page 4, lines 25-26). In this section we also detail our sampling strategy (lines 23-27). We report here the concentration of each dominant species relative to the total number of valves per sample (i.e. the relative taxonomic abundance). We have added the information that our data is presented as relative taxonomic abundance to the methods section to clarify. Naturally, all data presented here will be published alongside the article, once the manuscript is accepted.

Referee comment: 7. Why didn't the authors use the "continuous" Limnocythere inopinata species for isotope measurements, please explicitly state that.

Authors Response: For our isotopic measurements we require at least 25 to 60 μg of ostracod carbonate (clean, fully translucent, well preserved valves). Variations in L. inopinata valve abundance, size and thickness do not allow the "continuous" measurement of this species throughout the studied interval. L. inopinata valves were measured where our sample material allowed it. We have made this information clearer in the methods section (page 5 line 13).

Referee comment: 3 Minor suggestions Below you can find my suggestions. I am not a native English speaker therefore language suggestions do not have to be correct.

Referee comment: Page 1, line 10. Replace "while" with "and"

Authors Response: Done.

Referee comment: Page 1, line 22. Is the "The" at the start of the line necessary?

Authors Response: "The" is used here to avoid starting a sentence with a delta notation.

Referee comment: Page 2, lines 23-28. Why did the authors describe trace elements of valves with extensive references, is it really necessary? Maybe I am missing something.

Authors Response: Ostracod valve trace element composition is often used for salinity reconstructions. In the introduction we provide a general overview of ostracod based salinity reconstructions which include trace element compositions. Unfortunately, due to the sampling size and number of valves per sample we were not able to perform trace element measurements in this study.

Referee comment: Page 3, line 4. "well-constrained palaeoenvironmental conditions", please expand this or rewrite the sentence.

Authors Response: We have added a citation (Litt and Anselmetti, 2014 and references therein) summarising some of the earlier results of the ICDP PALEOVAN project and the environmental interpretations.

Referee comment: Page 3, line 17. No need to cite Litt and Anselmetti (2014) or any other study for this basic piece of information.

Authors Response: Done.

Referee comment: Page 3, line 19. Not "lakes", I think it should be "lake's"

Authors Response: Done.

Referee comment: Page 3, line 23. Delete alkaline.

Authors Response: Done.

Referee comment: Page 4, line 27. Is the resolution 540 years? Otherwise, check the given numbers.

Authors Response: No, it is ca. 54 years as written in the manuscript. The mean resolution of a single 2 cm thick sample is, for the studied interval in accordance with

the age model from Stockhecke et al., 2014a, ca. 54 years.

Referee comment: Page 5, line 2. Maybe it is a good idea to name the dominant species in this sentence.

Authors Response: Done.

Referee comment: Page 5, line 19. What is Van12-08? Any references and/or location? Why did you specifically use it? Frankly, I don't understand the depths given in this sentence.

Authors Response: Van12-08 is a short gravity core retrieved at the Ahlat Ridge site in May 2012. We have used its material (four samples, prepared in the same way as the ICDP samples) to complement our relatively scarce late Holocene ostracod profile. We have now added the missing information in the main text (page 5 lines 23-25).

Referee comment: Page 6, line 2. Delete "from"

Authors Response: Done.

Referee comment: Page6 line 6-7. "The highest number of noded valves appears between ca. 73- 35, 30-12 and 11-3ka BP with mean percentages of noded valves of 64, 43 and 57% respectively (Fig. 3)." Is this true for 30-12 ka BP. I see many zeros in this interval, or do the authors neglect zeros?

Authors Response: Unfortunately, not all samples had a high enough number of limnocytherinae valves ($\geq$ 20) and these samples were thus not used for node counting (page 5, lines 2-4). We repeat this information now also in the discussion. This does not mean that there were no limnocytherinae valves, or that all limnocytherinae valves were unnoded. Particularly the 30-12 ka BP interval is dominated by valves of Limnocythere sp. A, which was not included in the node counting, and therefore samples from this interval often lacked enough limnocytherinae valves for node counting.

Referee comment: Page 6, line 10. A comma after Holocene maybe, or rewrite the

sentence.

Authors Response: Done.

Referee comment: Page 7, line 23. "At the same time, Lake Van's lake level was at its lowest and the salinity concentrations at its highest (ca. 50 to 80 g kg$-$1; Tomonaga et al., 2017)". While Tomonaga et al. (2017) express temporal resolution of the fluctuations is over tens of thousands of years, is it true to use salinity to support ideas this way?

Authors Response: Yes, it is. We discuss here the general relative taxonomic abundance of Limnocythere sp. A for a longer time period between 26 to 18 ka BP. Short-term lake level fluctuations, i.e. rising lake levels or highstands, are likely during this period (coinciding with Greenland Interstadials, Stockhecke et al., 2014a; 2016). However, such short highstands are not necessarily recorded by faunal changes here (also due to changes in bottom water oxygen content), or observable at our sample resolution. Generally the lake volume was lower during this period, supported by salinity proxies (Tomonaga et al., 2017, Randlett et al., 2017), seismic interpretations (Cukur et al., 2014), and by indicators of a generally more arid Lake Van environment including arboreal pollen data (Litt et al., 2014; Pickarski et al., 2015b), Ca/K ratios (Kwiecien et al., 2014), sediment facies and TOC content (Stockhecke et al., 2014a). Our ostracod valve data (taxonomic diversity, valve morphology and δ18O values) further support generally lower lake levels, higher salinity and more arid conditions during this interval. We cannot, however, exclude short-term highstands.

Referee comment: Page 9, line 4. "the absolute size and number of nodes is smaller " it should be "are".

Authors Response: Done.

Referee comment: Page 9, line 17. Delete "In the literature".

Authors Response: Done.

Referee comment: Page 11, line 4 delete “also effect” to “affects”, or rewrite the sentence which may be a better idea.

Authors Response: Done.

Authors Response References:

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