

Interactive comment on “Freshwater pearl mussels from northern Sweden serve as long-term, high-resolution stream water isotope recorders” by Bernd R. Schöne et al.

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First of all, we wish to thank the reviewer for his/her thoughtful comments and suggestions that greatly improved the quality of the manuscript. We have added the revised version of the manuscript with all changes highlighted red as a supplementary file to this author comment.

RC1: L51: (rephrasing suggested) AC1: Rephrased as suggested: "underutilized"

RC1: L62: Has any other study verified this in *M. margaritifera* ? AC1: There is currently no long-term $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ record of *M. margaritifera*. However, there is a

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$\delta^{13}\text{C}$ record (not subannually precisely aligned) by Geist et al. (2005). Citation added.

RC1: L66: ...and limited existing environmental data, right? AC1: Added as suggested

RC1: L68: (rephrasing suggested) AC1: Rephrased as suggested: "occurs"

RC1: Last paragraph of section 1: What are your hypotheses? AC1: Hypotheses were added.

RC1: First paragraph of section 2: Add this information above to the introduction when you're talking about shells precipitating near isotopic equilibrium with their environment. AC1: Moved as suggested.

RC1: L83: (rephrasing suggested) AC1: "were used" deleted as suggested

RC1: L88: What kind of material? AC1: "Material" substituted by "bivalves"

RC1: L96: (rephrasing suggested) "soft parts" replaced by "soft tissues"; Rephrased as suggested: "air-dried"

RC1: L101: "... mounted onto glass slides with the mirroring sides facing upward. The latter facilitated...". Why? AC1: The reason for mounting the shells slabs like this is given in the following sentence: "This method facilitated the temporal alignment of isotope data measured in one slab to growth patterns determined in the other shell slab." The addition that the adjoining portions of the shell slabs need to face upward is relevant because patterns in one slab can otherwise not properly be crossdated with the same portion in the other shell slab.

RC1: L111: (rephrasing suggested) AC1: "ca." deleted as suggested

RC1: L125: How did you micromill at a constant sampling resolution by hand? AC1: We have a long experience with this technique and conduct the sampling at higher magnification under the binocular microscope. We feel that available micromilling robots are not very suitable, because they do not offer enough control in three dimensions, which is necessary when a curved growth front is sampled.

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RC1: L135: Given this is your analytical precision, I would report all isotope values to the tenths place, not the hundredths place. AC1: It is common usage to report isotope values to the second decimal, also because precision error is far better than 0.10 permil.

RC1: L141: Did you define this? AC1: Yes, to distinguish oxygen isotope values of river water from shell etc.

RC1: L162: (rephrasing suggested) AC1: space added between “21” and “July”

RC1: Section 2.6: I find this section difficult to follow, so if there's any way to simplify and/or clarify I recommend doing so. AC1: We did our best to slightly rephrase individual sentences, but find it difficult to simplify this section further.

RC1: L192: (rephrasing suggested) AC1: “ca.” deleted as suggested

RC1: L235: (rephrasing suggested) AC1: “ca.” deleted as suggested

RC1: L236: (rephrasing suggested) AC1: Rephrased as suggested: “The largest. . .”

RC1: L242: (rephrasing suggested) AC1: “long” deleted as suggested

RC1: L243: (rephrasing suggested) AC1: Rephrased as suggested: “The δ 18Os* . . .”

RC1: L254: n values? AC1: We added “values” after δ 18O; corrected throughout ms, likewise for δ 13C.

RC1: L257: (rephrasing suggested) AC1: Number of values added in parentheses

RC1: L260: You use this phrase a lot, do you mean dampened? AC1: According to Miriam Webster, “damped” (= attenuated, truncated) is synonymous to “dampened”; therefore, adjective left unchanged

RC1: L261: (rephrasing suggested) AC1: Rephrased as suggested: “ δ 18Op”, corrected in most other instances

RC1: L266: I would break this out into two sentences. It's confusing as written. AC1:

As suggested, split in two sentences

L273: RC1: (rephrasing suggested) AC1: Second “and” deleted; “values” added (see above)

RC1: L277: Reference table with statistics. AC1: Reference to Table 3 added

RC1: L280: (rephrasing suggested) AC1: Rephrased as suggested: “ $\delta^{18}\text{O}_{\text{w}}$ ”, corrected in most other instances

RC1: L282: (rephrasing suggested) AC1: “further” deleted

RC1: L301: (rephrasing suggested) AC1: “likewise” deleted

RC1: L304: (rephrasing suggested) AC1: “values” added (see above), “the” added

RC1: L305: (rephrasing suggested) AC1: “The” added

RC1: L310: Do you mean through ontogeny? AC1: “youth” replaced by “ontogeny”

RC1: L330: Really you’re discussing the benefit of using shell archives rather than sedimentary archives, and I suggest that the title of this section reflect this. AC1: Modified as suggested: “Advantages and disadvantages of using bivalve shells for stream water $\delta^{18}\text{O}$ reconstruction; comparison to sedimentary archives”

RC1: L333: This does not make sense. Please clarify. You repeatedly say that data are damped relative to precipitation, but what does that mean? AC1: Rephrased with explanation of the term “damped” as suggested: “Since $\delta^{18}\text{O}_{\text{w}}$ values have a much lower seasonal amplitude than $\delta^{18}\text{O}_{\text{p}}$ values (i.e., $\delta^{18}\text{O}_{\text{w}}$ signals are damped relative to $\delta^{18}\text{O}_{\text{p}}$ data as a result of the water transit times through the catchment of the stream), the...”

RC1: L334: (rephrasing suggested) AC1: Added “values” after $\delta^{18}\text{O}$ (see above)

RC1: L337: This section should be discussed in the context of other studies that use bivalves as paleoenvironmental archives. There are many other studies that have in-

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vestigated this and they should be discussed within the context of this study. AC: Since the paper is already quite long and not a review, and similar reconstructions presented here (= reconstruction of $\delta^{18}\text{O}_{\text{water}}$ from $\delta^{18}\text{O}_{\text{shell}}$ and temperature) have not been done, we prefer not to extend this section further.

RC1: L342: This needs to be cited with other relevant publications that have demonstrated similar results. AC1: Citations added; text slightly rephrased. "This is possible by solving the paleothermometry equation of Grossman & Ku (1986) for $\delta^{18}\text{O}_{\text{wr}}^*$ (Eq. 2) and compute the oxygen isotope values of the water from those of the shells and river water temperature."

RC1: L344: (expansion requested) AC1: Slightly expanded as suggested: "Similar studies in which the oxygen isotope composition of microfossils or authigenic carbonate obtained from lake sediments were used to infer the oxygen isotope value of the water, however, merely relied on estimates of the temperature variability during the formation of the diatoms, ostracods, abiogenic carbonates etc., and how these temperature changes affected reconstructions of $\delta^{18}\text{O}_{\text{w}}$ values (e.g., Rosqvist et al., 2013). In such studies, it was impossible to reconstruct the actual water temperatures from other proxy archives."

RC1: L348: But there are other archives that precipitate in oxygen isotope equilibrium with their environment. I would expand this bullet point and compare the freshwater bivalve archive directly to other archives in the region that have been problematic for paleoenvironmental reconstructions. AC1: To our knowledge, no attempts have been made to reconstruct river water isotope data in that region.

RC1: L352: Why is high-res data significant??? AC1: Explanation added: "Such high-resolution isotope data can be used for a more detailed analysis of changes in the precipitation-runoff transformation across different seasons."

RC1: L367: Combine bullet points 3 and 5. AC1: Done: "If required, a refined sampling strategy and computer-controlled micromilling could ensure that time-averaging

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consistently remains below one year. Such high-resolution isotope data can be used for a more detailed analysis of changes in the precipitation-runoff transformation across different seasons. Furthermore, the specific sampling method based on micromilling produced uninterrupted isotope chronologies, i.e., no shell portion of the outer shell layer remained un-sampled. Due to the high temporal resolution, bivalve shell-based isotope chronologies can provide insights into inter-annual and decadal-scale paleoclimatic variability. With the new, precisely calendar-aligned data, it becomes possible to test hypotheses brought forward in previous studies according to which $\delta^{18}\text{O}$ signatures of meteoric water are controlled by the winter and/or summer NAO (e.g., Rosqvist et al., 2007, 2013)."

RC1: L373: Expand. Summarize the above points and discuss specifically how the benefits of using freshwater mussels can complement new and existing sedimentary archives. AC1: We have followed this suggestion and added: "In summary, bivalve shells can provide uninterrupted, seasonally to annually resolved, precisely temporally constrained records of past stream water isotope data that enable a direct comparison to climate indices and instrumental environmental data." and "For example, once the low-frequency variations have been reconstructed from sedimentary archives, a more detailed insight into seasonal to inter-annual climate variability can be obtained from bivalve shells. As long as the date of death of the bivalves is known, such records can be placed in absolute temporal context (calendar year). Although the same is currently impossible with fossil shells, each absolutely dated (radiocarbon, amino acid razemization dating) shell of a long-lived bivalve species can open a seasonally to annually resolved window into the climatic and hydrological past of a region of interest."

RC1: L389: (rephrasing suggested) AC1: L380: "if the shells were precipitated near oxygen isotopic equilibrium" was rephrased into "if the bivalves precipitated their shells near oxygen isotopic equilibrium"

RC1: L383-384: The thoughts in this sentence and the one above it seem disconnected. AC1: To accommodate the comment, the previous sentence was shortened,

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detailed information on the Water Resources Program deleted.

HESSD

RC1: L389: (rephrasing suggested) AC1: Suggested rephrasing (“high-resolution”) does not capture exactly what we intended to say. Therefore, we rephrased the sentence as follows: “Due to the micromilling sampling technique, ...”

RC1: Section 4.3: This needs to be expanded upon and the freshwater studies should be discussed in the context of your study. AC1: We feel that a more detailed discussion of why the studied rivers differ with respect to $d_{18}\text{O}_w$ would be far beyond the scope of the present study. Moreover, this would require detailed monitoring. We added references for listed potential influences on $\delta_{18}\text{O}_w$.

RC1: L406: But can you speculate using existing data sets? Can you explain the differences between rivers based on the set of physiographic characteristics you mention? AC1: Reviewer suggested to speculate what could have caused the differences in isotope signatures of the studied rivers. Given the number of potential variables (which we listed) that can contribute to such differences as well the complex interplay between them, we prefer to stick to the notion that an explanation for the isotope differences would require detailed monitoring. The difference in absolute values among the studied rivers is also not the main scope of the present study.

RC1: L434: do you mean $d_{18}\text{O}_w$ values? AC1: We indeed meant a winter precipitation signal (snow) was recorded by the bivalves during the following spring (meltwater). Slightly rephrased to make things clearer: “The specific isotope signatures in the rivers were controlled by the snowmelt in spring. Essentially, the bivalves recorded the (damped) isotope signal of the last winter precipitation in their shells.”

RC1: Paragraph starting at L440: This paragraph needs to be clarified and expanded. AC1: We followed the suggestion and clarified the text, but refrained from expanding this paragraph significantly, because the ms is already quite long.

RC1: L450: (rephrasing suggested) AC1: We prefer to keep “further”, because this

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provides a better transition between paragraphs.

RC1: L481: Do you know this or are you speculating that this is the cause? AC1: It is a hypothesis. To make this clearer we rephrased as follows: “The attenuated variance on inter-annual time-scales can possibly be explained – amongst others – by inter-annual . . .”

RC1: L484: How much is ‘not massive’? AC1: Rephrased: “. . . so that the net effect on $\delta^{18}\text{O}_{\text{W}}$ in spring was less severe than the isotopic shift in $\delta^{18}\text{O}_{\text{P}}$.”

RC1: L490: Citation? AC1: Except one study that we now cited (“. . . , yet in *M. margaritifera* the seasonal timing of shell growth is remarkably invariant across large distances (Dunca et al., 2005).”), there is no other citation to back this assumption, because no studies exist on the seasonal timing during different life stages of this species. However, an unchanged seasonal growth trait can be deducted from the fact that chronologies of ontogenetically young and old specimens can be successfully crossdated. We have slightly rephrased the sentence: “. It was further assumed that the timing of shell growth has not significantly changed through the lifetime of the studied specimens. In fact, if ontogenetic changes of seasonal growth traits had occurred . . .” and added more references on crossdating of *M. margaritifera* shell chronologies.

RC1: L494: Citations to back this assertion up? AC1: Citation added.

RC1: L498: Citations to verify this? AC1: Added

RC1: L499: Is this a valid assumption? AC1: See reply to comment in L490. If the timing would differ through ontogeny, and old shells grew several weeks or months less per year than young specimens, it would be impossible to combine these chronologies by means of crossdating. Crossdating requires that the timing of seasonal growth remains unchanged.

RC1: L508: Why? AC1: We amended that the contribution of metabolic carbon dioxide to the shell carbonate “likely remains nearly constant through lifetime as it does in other

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long-lived bivalve mollusks (Schöne et al., 2005c, 2011; Butler et al., 2011; Reynolds et al., 2017”)

RC1: Table 3: formatting issue AC1: Table 3: Not a formatting issue, but we forgot a notation in the captions: Isotope values next to months represent the multi-year averages. Statistically significant values are bold.

RC1: (thicker lines suggested) AC1: Fig. 2: As requested, thickness of white lines and line of white box was increased.

RC1: Fig.4: (write out d.o.g.) AC1: Fig. 4: As requested, “direction of growth” was written out. CHECK ELSEWHERE

RC1: Fig. 5: LARGER TEXT POSSIBLE??? AC1: The text will appear larger in the final version, because the figure will be on a single page

RC1: Fig. 8: ENLARGE EQUATIONS AC1: As requested, size was increased

Please also note the supplement to this comment:

<https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-337/hess-2019-337-AC1-supplement.pdf>

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2019-337>, 2019.

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