Review of „Future diversity and lifespan of metazoans under global warming and oxygen depletion" by Kunio Kaiho

Summary

In this research article, Kunio Kaiho presents novel findings on the future development of metazoan diversity in superterranean, subterranean, surface-water, and deep-water habitats based on diversity changes in the past. By incorporating seven different environmental drivers, the author projects the complete extinction of metazoans within the next 700 million years, which is 300–400 million years earlier than previously estimated.

General comments

Overall, the manuscript is well written and provides novel insights into an important field of research. The language is almost perfect, clear, and easy to follow. However, there are a few general points that should be addressed before final publication of the article.

Neither the Introduction nor the Discussion provides much context regarding previous research efforts. While the Introduction nicely explains the different environmental drivers incorporated into the current study, it is unclear what previous research entailed and what the current study adds to it. These aspects should be included in the revised manuscript. Similarly, the Discussion repeats the major results of the current study without discussing them in the context of previous findings. For example, it is repeatedly mentioned throughout the manuscript that the current study projects metazoan extinction to occur 300–400 million years earlier than previous estimates, but these previous estimates are not further specified. What differences between previous studies and the current study may cause these different results? Why are the results of the current study more/similarly realistic? These questions should be addressed in the Discussion.

In addition, I think that some parts of the Methods section are difficult to follow. Firstly, this section uses many abbreviations, but not all of them are defined in the text itself, only in figure/table captions (e.g., PAL is only defined in the caption of Fig. 1). Secondly, many terms are unclear to the reader and require further explanation (e.g., what exactly are diversity rates and what is the difference between survival rates and survival area rates?). Thirdly, the argumentation is partly difficult to follow since the required explanations are either insufficient or provided later in the Results or Discussion section. I recommend adding further explanations and revising the structure of the manuscript where necessary. I give specific examples in the "Specific comments" section.

Specific comments

- L. 29: I would replace "all known forms of life" by "**almost** all known forms of life", e.g., tardigrades can survive temperatures higher than 100°C.
- L. 32: Can you shortly explain what C_3 and C_4 plants are?
- L. 52-53: This sentence disrupts the flow of the text. Since the corresponding information was just mentioned a few paragraphs earlier, the sentence is not necessary in my opinion.
- L. 95: "These data are applied in section 2.2." – The current section is 2.2, so I do not understand this sentence.

- Section 2.3: Are only records of marine metazoans available? If yes, the possible impacts of this limitation should be discussed.
- L. 97: What exactly is meant by “diversity rates”?
- L. 98: What is PAL?
- L 106-107: I think you mean that oxygen levels drop in the habitats of metazoans and not in metazoans themselves, right?
- L. 108: Why do terrestrial metazoans require an ozone layer for evolutionary adaptation? (This is explained in l. 491-493, but I would already explain it here).
- L. 110-115: What were the main reasons for mass extinction during these events?
- L. 131: There is no red curve in Fig. 1. Do you mean the orange curve?
- L. 147: Which were the five largest mass extinction events?
- L. 152: I thought ΔTec was estimated using SST data as stated in the previous section?
- L. 163: What is sill?
- L. 167-168: How are long-term changes in CO_2 and SO_2 emissions related to short-term temperature anomalies?
- L. 191: Why do you use regions with oceanic climate?
- L. 196: Does a gradient of 15°C only apply to warm conditions or why do you explicitly mention warm conditions here?
- L. 199: Where exactly do the 5°C come from?
- L. 201: Same as l. 191 and l. 196: Why do you use data from warm coastal cities?
- L. 207: There is no section 2.3.3. Do you mean 2.6.3?
- Equation 11: What is ΔLT? (LT is only defined in the caption of Fig. 2)
- Sect. 2.7.1: This section is quite hard to follow since many abbreviations are used. Maybe it would help to spell out the abbreviations from time to time.
- L. 244-248: I think it should already be mentioned here that different scenarios are analyzed.
- L. 249-252: I think it would be helpful to provide a brief description of the different events. Some description is given in Sect. 3.2, but I believe that including such a description earlier on would give the reader a better understanding.
- L. 252: What exactly is the survival area rate and what is the difference to the survival rate?
- L. 256-257: What exactly do the rates StR, SwR, UR, and DR describe?
- L. 259: Could you explain more clearly how the SAR is calculated?
- L. 263: I cannot follow the argumentation here. Why should SAR_D approximate SAR_S?
- L. 268: How did you determine the impact of food scarcity on survival rates?
- L. 275: And the other events?
- L. 285-286: Is this reasonable? The limitations of this assumption should be discussed.
- L. 287-293: I cannot follow here. Why are metazoans extinct at 0.97 Gyr if 2% remain? And don’t you state in other parts of the manuscript (e.g., the Abstract, l. 460, and the Conclusions) that according to your calculations, metazoans go extinct at 0.7 and not 0.97 Gyr?
- L. 304: What exactly is numerical age?
- Sect. 3.1: I think this description would have been more helpful in the Methods section somewhere between Sects. 2.5 and 2.7. Then the reader could better understand the different survival rates etc.
- L. 364: What exactly do you mean by abrupt climate events? Are you referring to volcanic eruptions and meteorite impacts? If yes, I recommend stating this here again.
- L. 385-388: Could you also give current numbers for comparison?

- L. 592: Are you sure that your study is the first to reveal that?
- Fig. 1:
    - I do not understand what the green open diamond symbols denote exactly. Can you maybe explain again in other words?
    - Would it be possible to add some sort of legend to the atmospheric oxygen level graph that specifies the impact on metazoans?
- Fig. 2 (l. 630): Not only silhouettes of terrestrial plants are shown, so maybe write "silhouettes of metazoans and terrestrial plants"?
- Fig. 3: The yellowish-green is hard to distinguish from the green, so maybe use a different color?
- Table A2: What is SD? What does aftermath warming mean?
- L. 720 and 725: before or after?
- L. 727-728: Why do the underlined numbers occur just before major mass extinction events if they represent periods of recovery? Something seems wrong here.

Technical corrections

- L. 43: have ~~historically~~ triggered historical mass extinctions
- L. 61: This manuscript was written by only one author, right? I would use "I" instead of "we"; there are other occurrences throughout the manuscript.
- L. 89 and 96: I think it should be "Past records **of**"
- L. 204: LM~~m~~MT
- L. 213: 2.5 m~~eters~~
- L. 222: GATES values are ~~common~~ equal
- L. 237: where~~,~~ D_t represents
- L. 324: 1 m~~eter~~
- L. 378: "However" does not seem to fit here.
- L. 398: primary productivity?
- L. 430: estimating ~~of~~ the future diversity
- L. 504: illustrate~~s~~
- L. 569-573: This is a repetition of l. 566-569 and should be deleted.
- Fig. 2:
    - Atmospheric oxygen level relative to ~~for~~ present atmospheric level
    - Diversity rate relative to ~~for~~ the Paleozoic maximum
- L. 659 and 729: the Methods section
- L. 676: The capitalization in this sentence seems odd.
- L. 686: rate~~s~~ in the future
- L. 687-688: ~~for~~ compared to terrestrial plants
- Table 2: ~~in~~ at the family level
- Table A2: Earth's average surface temperature ~~of~~ including the long-term trend, long-term cycle, and short-term event~~s~~ with temperature anomal~~y~~ies and decreasing CO_2 and SO_2 emissions ~~decreasing rate~~ due to the decrease in mantle potential temperature during major mass extinction event~~s~~ from 0.7 billion years (Gyr) before the present to 1.5 Gyr into the future