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Biogeosciences Discussions

Interactive comment on "An isotopic (Δ^{14}C, δ^{13}C, and δ^{15}N) investigation of particulate organic matter and zooplankton biomass in Lake Superior and across a size-gradient of aquatic systems" *by* P. K. Zigah et al.

Anonymous Referee #1

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The manuscript by Zigah et al. (Biogeosciences Discuss. 9, 4399, 2012) exploratively investigates the elemental and isotopic composition of 'zooplankton' (everything caught by 300 μm mesh size nets) and bulk particulate organic carbon (POC) in Lake Superior. By using a 1-isotope (Δ14C only) Bayesian mixing model, the authors conclude that algal carbon consistently contributed to a significant share of the zooplankton biomass, while terrestrial POC, sediment material or bacterial carbon did not. Allochthony calculations showed that the overall terrestrial contribution to zooplankton was occasionally high, with values up to 54%, and that the grand average of zooplankton allochthony

was 10-20% depending on choice of model parameters (Table 5). Further, the Lake Superior data was compared with data from other lakes, showing that the discrepancy between zooplankton Δ14C and algal Δ14C increased with increasing basin:lake area and decreasing hydrologic residence time.

The ms convincingly shows how Δ14C can be used to determine allochthony and to some extent discriminate between algal and other sources of zooplankton biomass. The Δ14C datasets that are presented are in many ways unique, and allow for novel conclusions about zooplankton reliance on different food sources in Lake Superior. Thus, this study makes a significant contribution to the field of biogeoscience.

General concerns

1. My major concern is that a single isotope ratio (Δ14C) is used to model the contribution to zooplankton by as many as four different sources. Recent Bayesian mixing models such as MixSIR and SIAR have tremendously increased the possibility to discriminate between multiple sources. However, the whole idea of working with more than two sources is based on the simultaneous use of multiple isotope ratios. If there is only one isotope ratio, but multiple sources, the two sources that represent the highest and the lowest 'endmember', respectively, can be mixed in different proportions, creating combinations that perfectly resemble all other sources. My recommendation would be to include more isotopes in the MixSIR model (at least δ13C), remove sources from the MixSIR model or to abandon the MixSIR model.

2. Radiocarbon data from a set of lakes in Québec (Canada) is presented as original data. However, as far as I can see, these data were already published by McCallister & del Giorgio (2008, Limnol. Oceanogr. 53:1204). The sampling in these lakes was also following a different protocol, e.g. using plankton nets with a much smaller mesh size (50 μm). My primary suggestion would be to bring in this data from the Québec lakes as published data, using the McCallister & del Giorgio (2008) reference. Alternatively, the authors need to motivate the choice of considering this data material as original.

However, if the 'McCallister & del Giorgio' data can be considered original also here, I would seem logical that P. A. del Giorgio is at least acknowledged (or perhaps even included as co-author) in the present manuscript.

3. In the methods description, lines 13-17, p. 4404, a previous study is cited, indicating that 90% of the zooplankton in Lake Superior is likely to be consisted by copepods. The manuscript needs to be much more specific here, by considering different groups of copepods that have fundamentally different feeding styles. It could be argued that the feeding styles within the copepod community (e.g., cyclopoids vs calanoids) in fact show bigger differences than those shown between cladocerans and copepods. Therefore, a more detailed description of the Lake Superior zooplankton community would be preferable. Further, the discussion could be strengthened by addressing the possible role of shifting zooplankton communities for the observed patterns in allochthony. For example, it could be argued that the allochthony was higher in the small lakes because these happened to have a high proportion of relatively non-specific filter feeders such as Daphnids.

Specific comments

1. p.4400 l.5-7 The abstract reads: 'these subsidies [i.e., terrestrial carbon subsidies]... play major roles in determining the fate of organic carbon'. I am not sure what this means. Is the terrestrial carbon determining the fate of itself?

2. p.4400 l.7 Perhaps a reference that supports the claim that terrestrial carbon subsidies may support economically important fisheries should be included somewhere in the manuscript

3. p.4402 l.10-11 'neither ... or' should be changed to 'neither ... nor' or 'either ... or'

4. p.4403 l.15 'of' is missing between 'abundance' and 'radiocarbon'

5. p.4404 l.6-9 The choice of zooplankton sampling protocol might need to be motivated. For example, a 300 μm net will not retain protozoan zooplankton, small meta-

zoan zooplankton such as rotifers or even small crustacean individuals. Further, since the zooplankton were not hand-picked, it can be argued that coarse POC might have contaminated the samples. These issues are presently not addressed.

6. p.4404 l.13-17 It is not clear what the 90% refers to. Is it out of total zooplankton, metazooplankton or only crustaceans? Adults or including nauplia and juvenile cladocerans? Is it 90% by numbers or by biomass?

7. p.4410 l22 MixSIR is using the standard deviations of source isotope signatures to obtain reasonable estimates of uncertainties in the contribution by different sources to a consumer. Section 3.2.1 focuses on the endmenbers themselves, but not explicitly on the standard deviations of these endmenbers. It needs to be clarified how the standard deviations were managed.

8. p.4412 l.16 suggestion is to remove 'a little'

9. p.4413 l.14-17 It is not clear how the 1-isotope modeling approach gives any advantage in terms of being able to use other isotope ratios as independent checks on the robustness of the model output. First, a multi-source 1-isotope model can never be robust (see general concern #1). Second, the authors do not consider that these other isotopes (δ13C and δ15N) contain important information about sources. Thus, it seems a contradiction that they can be used to check model robustness.

10. p.4414 l.5 remove 'then'

11. p.4414 l.22 a suggestion could be to replace 'vs.' with 'or'

12. p.4415 l.27 This is an intriguing result that that is unexpected considering the close correlation between the δ13C of zooplankton and POM that have been reported, e.g. by Mohamed & Taylor (2009). It raises a few questions that could be addressed in the discussion: Is the studied ecosystem different than those previously studied? Is it rather the choice of using Δ14C that helps reveal that there in fact is no connection between the sources of POM and the sources of zooplankton biomass? Could it be

that the zooplankton community in Lake Superior is dominated by very specific grazers that use only certain components of the bulk POC pool?

13. p.4416 l.1-2 Here and elsewhere: The results section includes interpretations of what the results suggest etc., which makes it discussion-oriented. Other parts of the results are clearly methods-oriented, like section 3.2.1. As a consequence, the results section span over more text pages than it would need to do.

14. p.4432-4433 Tables 3-4 An alternative to the 'median contribution' is to use the modal contribution. Often the probability distributions that are generated by Bayesian models are complex and the median may not represent the contribution that is most likely. Thus, the mode has been suggested to be a better measure of central tendency (Parnell et al. 2010 PLoS One 5:e9672). On the other hand, the sums of the different contributions are relatively close to 1 in Tables 3-4, indicating that the median is working fairly well in this case.

15. p.4432-4433 Tables 3-4 There is conceptual overlap between the different sources. If the bacteria have a high degree of allochthony, the bacteria are, in principle, part of the terrestrial POC pool. Further, also the sedimentary OC and Bacterial carbon/DOC can be of algal origin

16. p.4433-4434 Tables 4-5 There is typically a 20 units of percentage off-set (in either direction) between zooplankton autochthony (Table 5) and algal carbon contribution to zooplankton biomass (Table 4). This big difference needs to be adequately discussed.

17. p.4438 Fig 3b I would remove the regression lines as no regression model exists here (the regression is almost as far from significant as it can be).

18. p.4439 Fig. 4b Perhaps this correlation should be denoted 'marginally significant'

19. One recently published paper of seemingly relevance is not cited:

Karlsson et al. (2012) Limnol. Oceanogr. 57(4): 1042-1048, DOI: 10.4319/lo.2012.57.4.1042

Just like the present manuscript, this study shows that autochthonous organic matter contributes 'disproportionally' to zooplankton biomass

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