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Biogeosciences Discussions

Interactive comment on "Sources, fate and geochemical dynamics of nitrate in an oligotrophic lake" *by* U. Tsunogai et al.

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Review by Wayne S. Gardner, The University of Texas at Austin Marine Science Institute

I find this paper to be a strong contribution as it takes some new and innovative approaches to examine nitrogen dynamics in the cold, relatively pristine, oligotrophic Lake Mashu. It derives important information about the dynamics of nitrogen, particularly nitrate, in the lake. The elegant and sophisticated analytical approaches for examining isotope ratios, combined with clever mathematical and biogeochemical methods and holistic interpretations, provide interesting and useful evidence to help describe the biogeochemical sources, dynamics, and fate of nitrate in this deep oligotrophic lake. The authors tell an interesting story about the fate of nitrogen in the lake and the changes

experienced by the lake over the past several decades. I believe that the following issues should be addressed to make it more accurate and improve interpretations. 1. The most important issue, in my opinion, is that the pivotal role and importance of ammonium dynamics in relation to nitrate biogeochemistry is not emphasized sufficiently in the paper or in the conceptual model that is presented. For example, the schematic diagram presented in Fig. 6 does not even include ammonium as a crucial component but implies that organic nitrogen is converted directly to nitrate. My understanding of the mineralization process is that organic nitrogen is not mineralized directly to nitrate but is mineralized to, or excreted as, a reduced nitrogen form (usually ammonium) before being taken up by phytoplankton (or N-starved bacteria) and/or converted to nitrate. I do not know of evidence indicating that reduced organic nitrogen is mineralized directly to nitrate as implied in the figure and parts of the text. Essentially all nitrate produced internally in the lake must have been regenerated first as ammonium so inclusion of ammonium dynamics is crucial to understanding the internal cycling of nitrate. Also, much of the ammonium that is produced in surface waters may be taken up by phytoplankton directly without being nitrified by bacteria/Archaea. Regardless of the mechanism, the authors' observation of low levels of inorganic nitrogen in the euphotic zone of this oligotrophic system makes sense because phytoplankton can assimilate available nitrogen in either form. To the authors' credit, they say that ammonium dynamics should be examined more thoroughly, but my point is that ammonium dynamics is critical to the model they present and should be discussed conceptually, whether or not it was measured directly. I.e., the model presented in Fig. 6 and the text should include ammonium dynamics to give the reader a more realistic picture of what is going on with regard to nitrogen cycling. 2. Lake Mashu provides a suitable environment for nitrification when ammonium is available, but the authors suggest that denitrification is not important in the lake due to the low rates of carbon burial. It is reasonable that denitrification may not be a major process in this type of lake because it requires anoxic conditions and labile organic matter. This observation is important for deep oligotrophic lakes, such as Lake Mashu and Lake Superior. They may also want

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to mention that most of the labile organic matter in small particles of a deep oligotrophic lake can decompose while settling slowly through the oxygenated water column, rather than at the sediment water interface, and therefore does not cause much oxygen demand at the sediment-water interface. As a result, as they already infer, the oxygen demand in the sediments will be low and not cause much oxygen to be depleted in the upper sediment layers. 3. The results of this paper show strong resemblances to those found in Lake Superior, another cold and oligotrophic lake, and the authors make some nice comparisons with previous publications on gas exchange in Lake Superior. However, I believe that it would be useful for them to also compare their results with some previous papers regarding internal nitrogen dynamics in Lake Superior. Their final conclusions about the fate of nitrate and much of their conceptual model seem strikingly similar to those made by Komar et al. about Lake Superior (see references below) using completely different methodologies. I suggest that the authors incorporate some of the concepts presented in those papers into the current manuscript as I believe that it would strengthen the ideas and conclusions of both investigations.

Kumar, S. et al. 2008. Nitrogen and carbon uptake dynamics in Lake Superior. JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, G04003, 15 PP., doi:10.1029/2008JG000720 Kumar, S. et al. 2010. Isotopic composition of nitrogen in suspended particulate matter of Lake Superior: implications for nutrient cycling and organic matter transformations. Biogeochemistry. DOI 10.1007/s10533-010-9441-6

Question: Page 7233, second paragraph. How long were samples stored in refrigerator before analysis?

Small grammatical details: In several instances, including the first sentence of the abstract, I think the writing would be improved by reversing the order of presentation of phrases in the sentences. I.e. start that sentence as “The stable isotope compositions of nitrate, including the 17O anomalies (Δ17O), were determined twice in one year (June and August 2007) in the water column of Lake Mashu, Japan, to trace the fate of atomospheric. . ...” Same idea for second sentence of last paragraph of page 7235, first

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sentence of last paragraph of page 7236, the last sentence of the first paragraph on page 7233, the last sentence of the second paragraph on page 7238, and the second sentence of the second paragraph on page 7241. Page 7230, first line. Insert “ammonium and converted to” after “remineralized to” Page 7242, second paragraph, first line. Replace “was” with “occurred” Page 7244, last paragraph. Should not “reducing” be replaced with “subtracting”? Overall, I find the paper to be innovative and interesting and recommend that it be accepted for publication after minor revisions.

Interactive comment on Biogeosciences Discuss., 7, 7227, 2010.