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Biogeosciences
Discussions

Interactive comment on "Benthic foraminiferal Mn / Ca ratios reflect microhabitat preferences" *by* Karoliina A. Koho et al.

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Below we have copied the reviewer's comments one at the time and indicate how we have addressed them or (in a few cases) argue why we respectfully disagree. Our resubmission contains a typed manuscript, which is accompanied by eight figures, three tables and two appendixes.

REVIEW 2: Anonymous referee#2

The manuscript "Benthic foraminiferal Mn/Ca ratios reflect microhabitat preferences" by Koho et al. presents new data on the link between pore water Mn concentrations which are related to dissolved oxygen content, and benthic foraminiferal Mn/Ca. Mn/Ca is receiving a lot of attention recently as it may be a suitable proxy to reconstruct past dissolved oxygen concentrations in the water column/pore water. Using several differ-

ent species and linking the data with pore water measurements has resulted in a very nice dataset, which partly provides evidence for existing ideas but also points out some issues that still exist. Especially the discussion on these possible issues could still use some more extensive consideration as described below in detail. But in general, the manuscript is well-written, easy and clear to follow, and definitely fitting within the scope of Biogeosciences. I recommend that this manuscript is suitable for publication after moderate revisions have been made.

RESPONSE: The authors thank reviewer#2 for the time spent reviewing the manuscript and the positive feedback on the study.

My main issue is that I feel that the discussion on the part where pore water Mn/oxygen and Mn/Ca in the forams are not fitting, can be explored further. Currently, it is partly contradicting, i.e. living labradorica and fimbriata were found at 0-1 cm but are generally deeper-living species (unless maybe in conditions where the bottom water is already close to anoxic), so that would imply habitat migration. But then the lack of a trend in Mn/Ca in the chambers would indeed point to no migration. In station 8, both species have the highest Mn/Ca again and are deepest, but there is no Mn in the pore water. So under the anoxic conditions all the available Mn has either diffused upwards when reduction took place or it precipitated as $MnCO_3$. How then can the forams have high Mn/Ca? For me this either means that they did migrate and picked up the Mn at a shallower depth; or that pore water oxygen and thus Mn are changing through the seasons, having higher pore water Mn when the forams calcified (assuming they were not calcifying at the moment of collection); or finally that the test Mn/Ca is biased by $MnCO_3$ precipitation. You did write that contamination on in- and outside bits (high Al and or Mn) was discarded, but it would be interested to know if especially in these deep station 8 forams there was indeed a Mn-coating. Because if a coating forms, crystals may as easily form somewhere inside the test to bias the bulk Mn/Ca.

RESPONSE: A discussion dealing with the influence of foraminiferal migration has been added to section 4.2, 4th paragraph. Although, no systematic ontogenetic migration was observed, it is possible that foraminifera move in the sediment during their life. As the study of Fontanier et al (2014) shows some deep infaunal foraminifera, including N. labradorica, are also found in low abundances at surface sediments, although their ALD and maximum density is deeper. The migration of intermediate and deep infauna foraminifera in sediment may also explain the larger scatter seen in the Mn/Ca ratios of these species, whereas specimens from the surface dwelling E. batialis had relatively similar Mn/Ca ratios. Two typical laser ablation profiles are now given in new Figure 2. In all cases any contamination was excluded, and specimens with relatively high final Al content were discarded prior to further statistical analyses. In addition, all specimens used in the study were rose Bengal stained and therefore alive at the time of sampling, or dead very recently. Hence, high Mn/Ca ratios due to diagenetic coatis can be neglected.

Even though that in general the relation between oxygen and Mn/Ca seems to follow the expected trends, the species-specific correlations are not very good or non-existing. What do you think could be the reason for that? How could the impact of habitat migration be determined? Seasonality may be resolved of course by extra sampling, which is always welcome. As a side note, I do like to point out that it would have been great to have had pore water profiles for stations 7 and 9 too.

RESPONSE: We suspect that part of this is due to lack of pore water data. Unfortunately the team responsible for the pore water analyses could handle only three stations within the time available. The oxygen free sampling (slicing), porewater extraction and subsampling of porewaters is very labor intensive, resulting in the sampling of pore waters from 3 stations only. In addition, foraminiferal migration and seasonal changes in pore water could explain some of the discrepancies seen in the data. This is now discussed in section 4.2 4th paragraph.

Minor Comments: 2.1 add some of the main currents and water masses to figure 1.

RESPONSE: The pathway of Tsugaru warm current (based on Oguma et al., 2002) is

now added to the Figure 1. As the position of the currents shifts during the year, we do not feel confident placing the Oyashio current on the map. The dysoxic water mass is indicated in figure 1. As the North Pacific intermediate Waters (NIPW) mixes gradually with saline Deep Pacific Water (DPW), entering this area between a water depth of 800-3000 m, it is not possible to accurately place the water mass boundaries on the Figure 1C.

p.4, 16: part of the previously mentioned loop of possible explanations why not everything fits. Could it be that some of the deeper specimens in the anoxic sediment are stained despite being dead? They would still classify as recently-alive, but that may be enough to have them buried a couple of cms.

RESPONSE: It is true that foraminifera could be recently dead, and hence buried. However, it should be noted that the pore water profiles provide a snap shot in time, and hence the conditions may have been slightly different at the time when the foraminifera calcified. This is now discussed in section 4.2 4th paragraph.

p.5, 6: Mg? Mg/Ca data would of course also be interesting to present. But to stick to redox elements, were any other redox elements like Fe or U analyzed?

RESPONSE: Focus of this study is Mn/Ca. Fe was analyzed but the data does not seem good enough for any robust inferences. Measuring Fe with laser ablation is challenging due to interferences with other masses (e.g Ar-O). This can be overcome by measuring the samples at intermediate resolution with the SF-ICP-MS, but is not possible with the quadrupole. Uranium was measured. However, previous studies have also shown it to vary with carbonate saturation (e.g. Raitzsch et al. 2011 G3). Thus, adding U-data to the manuscript would reduce the focus of the paper.

p.5, 26: Internal reproducibility is good, but how was the comparison between both lasers?

RESPONSE: As shown earlier, these systems provide consistent results (De Nooijer et al., 2014a). We have added this reference to the manuscript (Section 2.5. paragraph 3), which is also reflected by the similarity in precision/ accuracy of the ablated standards at both instruments.

p.6, 23: shell size; can a trend in different chambers automatically be related to shell size? I am not sure if this is a correct way of naming it.

RESPONSE: Chamber number refers to the ontogenetic stage, F- being most recent, F-1 being penultimate chamber and so on.

p.7, 29: rations, delete n

RESPONSE: mistake not found on p. 7 line 29 or elsewhere in the document.

p.10, 20: where the TROXCHEM, add the; still be, add be

RESPONSE: done

p.12, 2: foraminferal

RESPONSE: done

table 2: change comma's for decimals to points.

RESPONSE: done

Figure 1: add currents and watermasses

RESPONSE: The pathway of Tsugaru warm current (based on Oguma et al., 2002) is now added to the Figure 1. As the position of the currents shifts during the year, we do not feel confident placing the Oyashio current on the map. The dysoxic water mass is indicated in figure 1. As the North Pacific intermediate Waters (NIPW) mixes gradually with saline Deep Pacific Water (DPW), entering this area between a water depth of 800-3000 m, it is not possible to accurately place the water mass boundaries on the Figure 1C.

Figure 5 caption: in indicated, change to is

RESPONSE: done

Figure 6 caption: this is exactly the same as the one for figure 5, which I assume should not be the case.

RESPONSE: done

—END OF REVIEW 2—–

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/bg-2016-547/bg-2016-547-AC2-supplement.pdf

Interactive comment on Biogeosciences Discuss., doi:10.5194/bg-2016-547, 2017.

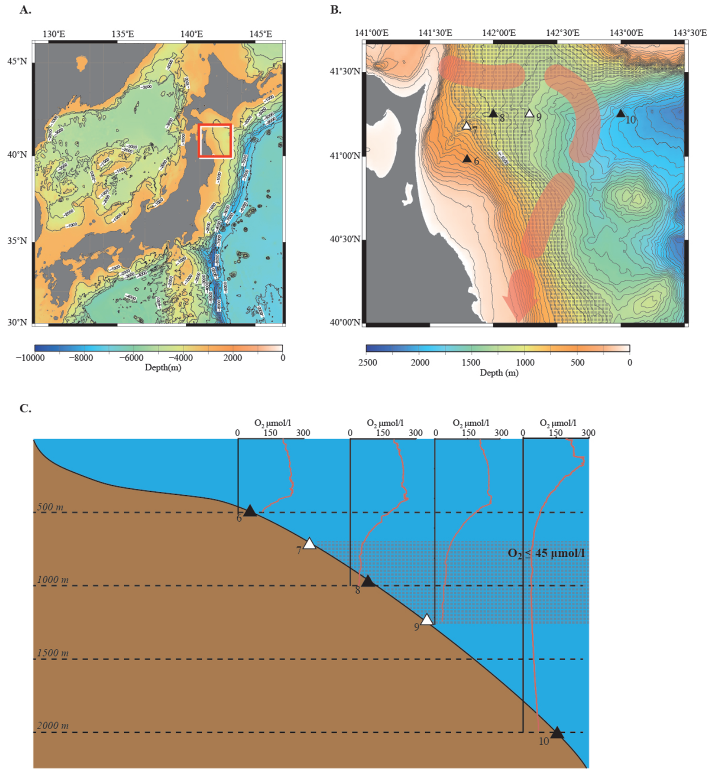

Fig. 1. A Regional map of the study area B: Bathymetric map of the study region, showing the position of Tsugaru warm current (Oguma et al., 2002) and multicore sampling sites. C: Schematized study

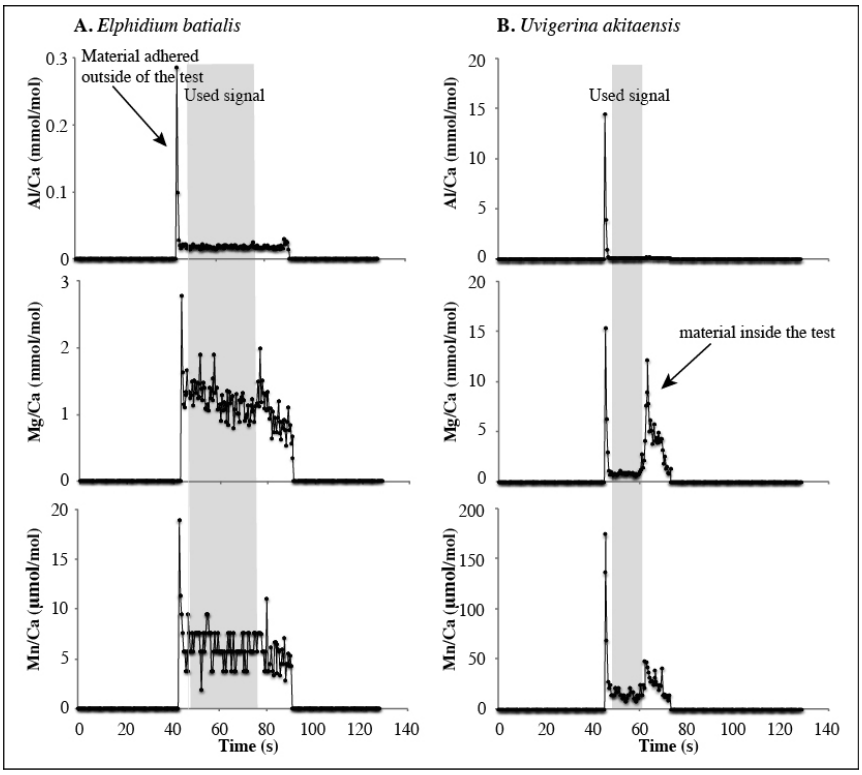

Fig. 2. Laser ablation profile for Al/Ca Mg/Ca and Mn/Ca measured in (A) E. baliatils (station 8, 0-0.5 cm depth) and (B) Uvigerina akitaensis (station 7, 0-0.5 cm depth) benthic foraminifera The se

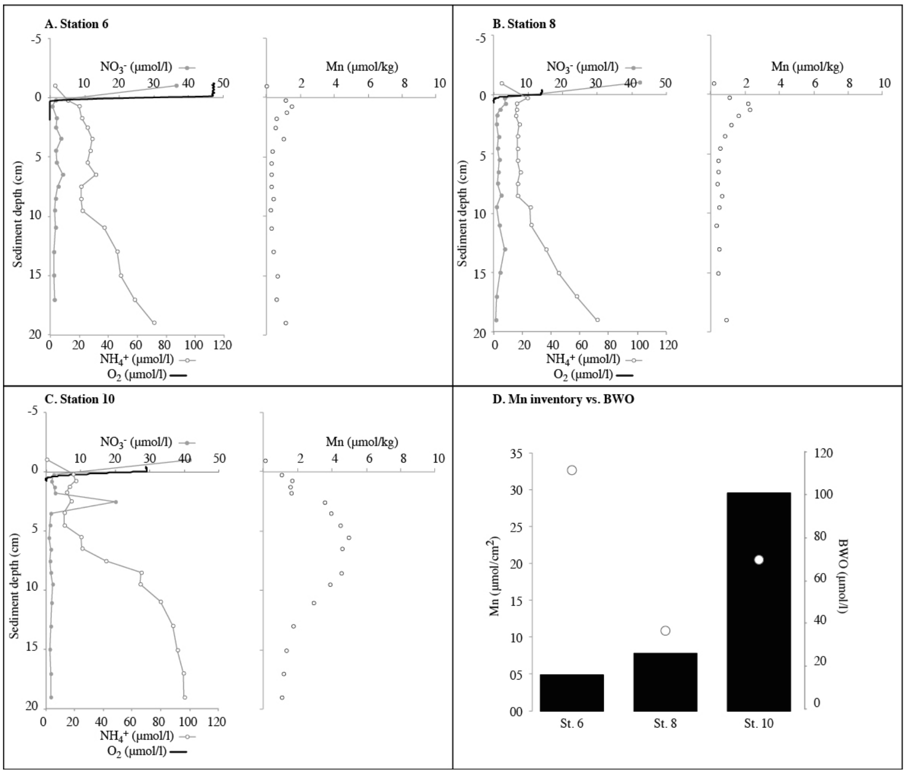

Fig. 3. Pore water profiles of dissolved oxygen, nitrate, ammonium and manganese at station 6 (A), 8 (B) and 10 (C). (D) Pore water manganese inventory in the top 10 cm of sediment and bottom water oxygen con

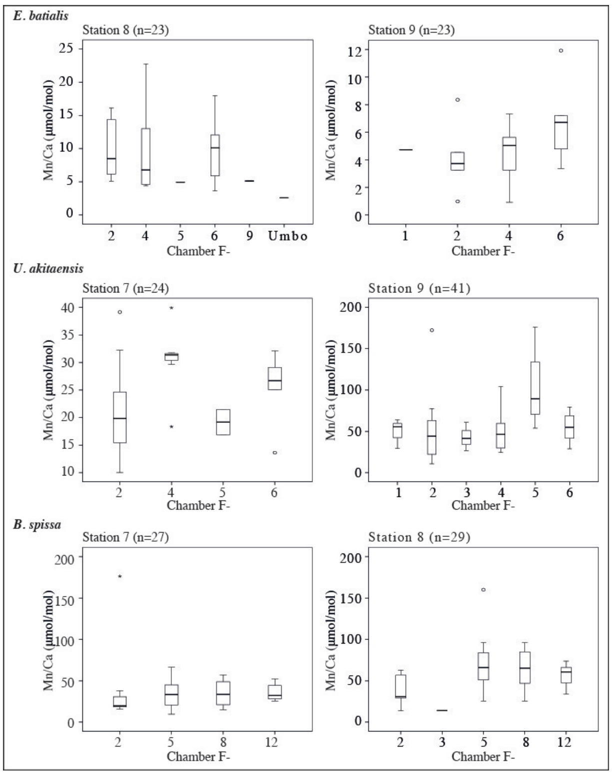

Fig. 4. Box-plots showing chamber-to-chamber variability of Mn/Ca. Error bars display the full range of data variation (from minimum to maximum). Data outliers are represented with an astrix.

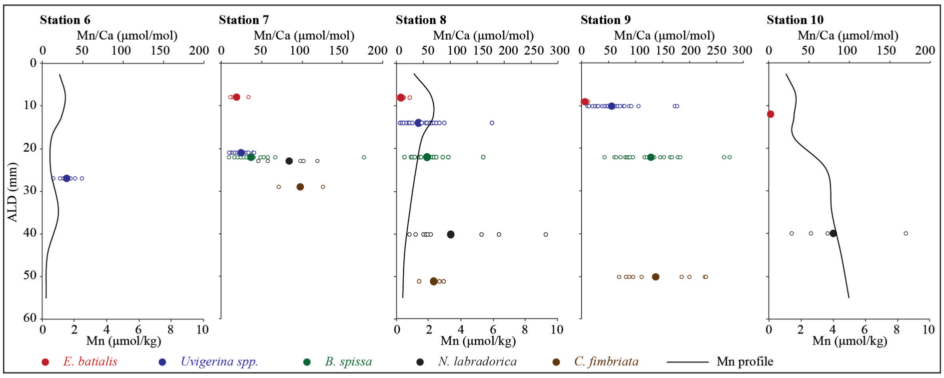

Fig. 5. Individual laser ablation measurements of Mn/Ca in foraminifera versus sediment depth where the specimens were collected.

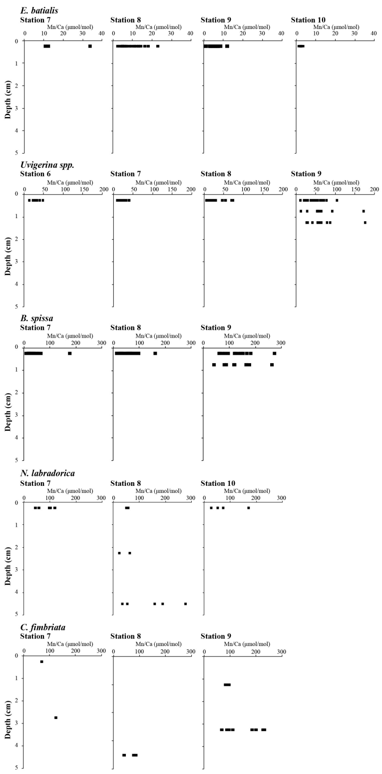

Fig. 6. Mn/Ca ratios in foraminifera as a function of the average living depth of each species. The average of all measurements is indicated with a solid symbol and the individual measurements with open symbo

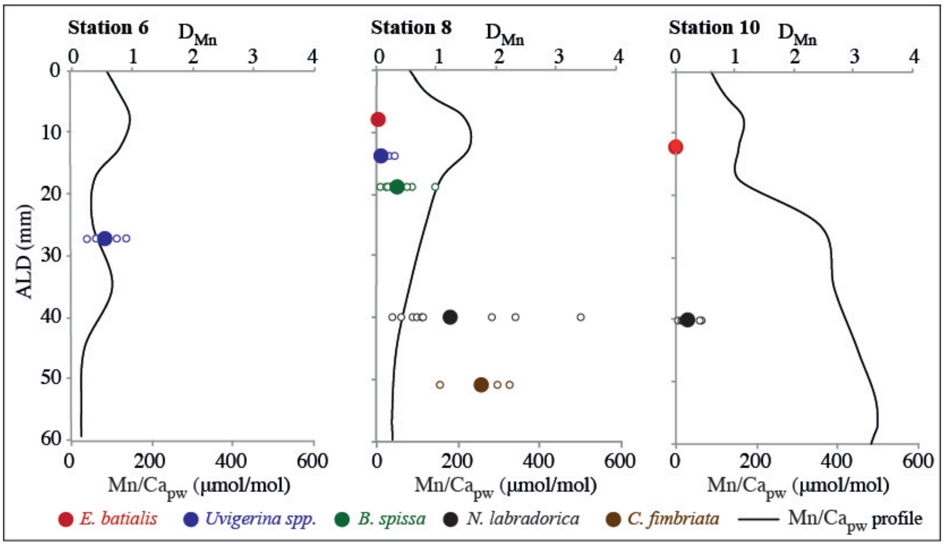

Fig. 7. Manganese partition coefficient DMn in foraminifera as a function of average living depth of each species. In addition, the pore water (pw) Mn/Ca profile is shown.

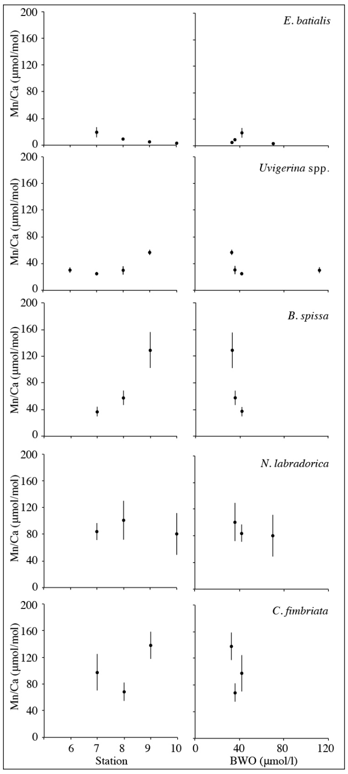

Fig. 8. Variability of average Mn/Ca ratios of each species plotted against the study transect from station 6 to station 10 (left), and along the bottom water oxygenation (right). The error bars represent the