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Interactive comment on "Salinity control on Na incorporation into calcite tests of the planktonic foraminifera *Trilobatus sacculifer* – Evidence from culture experiments and surface sediments" *by* Jacqueline Bertlich et al.

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Dear Editor,

We kindly thank two anonymous reviewers for their positive feedback, very constructive and thoughtful comments, which greatly helped to improve our manuscript. Below you find our responses to each point the reviewer's addressed and how we incorporated all suggestions in our revised manuscript, thereby following the given structure of their comments. Referee comments are written in italics and the respective answers are

given in normal font.

Yours sincerely, Jacqueline Bertlich and on behalf of all co-authors

Answers to anonymous Referee #1

Summary and general comments:

Bertlich et al., make use of earlier studies that introduced Na/Ca ratios from foraminifera as a proxy for surface seawater salinity, and they assess the reliability of Na/Ca derived from T. sacculifer as a salinity proxy. They conclude that Na/Ca can be applied as a reliable proxy for reconstructing sea surface salinity and furthermore that species-specific calibrations are necessary.

This study is one step closer towards establishing Na/Ca as a proxy for SSS. It is a well-designed study making use of culture experiments, wherein they vary salinity keeping temperature constant or vice versa and measure the Na/Ca to understand the salinity and temperature effects on Na/Ca. They further corroborate the culture studies with surface sediments from two different locations, Caribbean and Gulf of Guinea. This study has the potential to highlight the efficiency of Na/Ca as a salinity proxy which may soon be followed by other studies that may target different foraminiferal species and oceanic locations so as to develop this proxy further into a robust one. This proxy can then be utilized in unison with d18O and in some cases, Ba/Ca, to get a better handle on absolute salinity values, as each proxy has its own limitations. Here, the authors have touched a few important environmental variables that may affect and are needed in proxy validation. However I urge the authors to consider the following issues that I have raised and incorporate them in the manuscript.

Specific comments:

The authors mention that in order to avoid dissolution they have chosen sampling sites where Δ[CO32–] is >30 μmol/kg. But, if samples from water depths deeper than 2.7 km (see Table 1) are plotted against Na/Ca a clear depth dependency is noticed, Na/Ca de-

creasing with increasing depth. The authors should make this explicit to the reader by providing the Δ[CO32–] for each sample/depth and a separate paragraph discussing the depth dependency/dissolution effect on Na/Ca.

We totally agree with the referee and see the need to additionally present the Δ[CO32–] values for each sampling location to examine in detail a possible effect of calcite dissolution on foraminiferal Na/Ca. This point was also addressed in the second review. Therefore, we added the calcite saturation state for each sampling location in Table 1 (L903) and also plotted Na/Ca values with increasing water depth and the respective Δ[CO32–] values for the Caribbean and the Gulf of Guinea (Figure 6b – L1006). According to our new graphs, we would claim to see a clear depth dependence of foraminiferal Na/Ca, since error bars of all locations above 4 km intersect with each other. The issue of selective Na+-removal due to dissolution at greater water depth, nonetheless, needs further investigation, because of the limited sample set of our study. All points mentioned above are additionally added to section 2.3 in Material and Methods (L154-179) and in the results (341-363) and discussion (L532-542).

The range in spatial salinity distribution at the surface sediment locations is $\sim$1 to 1.5 salinity units. However the vertical distribution in salinity which may be encountered by T. sacculifer at its habitat, especially at the Gulf of Guinea is large, reaching $\sim$4 salinity units. Planktic foraminifera live for few weeks and so may encounter ambient conditions, which are seasonal during their life cycle (eg: Honisch et al., 2013 GCA). So when applying the Na/Ca proxy to down core samples to environments such as the Gulf of Guinea, how one does take into account such large vertical variations. This signal will also be mixed with the seasonal signal. Ideally surface samples should have covered a larger range in surface salinity.

This is indeed a very important point the referee mentioned here regarding future applicability of Na/Ca as a salinity proxy for down core records. We totally agree that seasonal shell flux patterns, which are significantly different between various planktonic foraminifera (e.g. see Jonkers and Kučera, 2015), should take into account when

applying Na/Ca as a paleo-salinity proxy. But for T. sacculifer it is well known that this species is present throughout the year and shell fluxes do not vary significantly with seasonal changes in the tropic and sub-tropic water masses, when the annual SST is >25 °C (Bijma et al., 1990a, b; Bijma and Hemleben, 1994; Schmuker and Schiebel, 2002; Lin et al., 2004; Jonkers and Kučera, 2015) (L91-93). Instead, G. ruber shows preferential seasonal peaks (Hönisch et al., 2013 GCA). But especially cold-water species show prominent peaks throughout the year, strongly dependent with seasonality and changing temperatures, respectively (Jonkers and Kučera, 2015). Further, a recent publication of Raitzsch et al. (2018) have demonstrated how information on the population dynamics of foraminiferal species can be used to reconstruct seasonal variability of environmental parameters for future application. Furthermore, the combination of foraminiferal Na/Ca and the Ba/Caforam – sea surface salinity relationship, which is limited to regions close to rivers, could provide additional information about vertical variations, especially in the Gulf of Guinea. But according to the large vertical variations of salinity e.g. in the Gulf of Guinea and also the wide range of vertical migration of foraminifera in their habitat, eventual Na/Ca results potentially represents a depth-averaged salinity, rather than that of the surface. Here, the application of a multi-proxy approach and measurements on a variety of planktonic foraminifera (covering certain depth habitat intervals) could limit the large salinity range.

Technical corrections:

Line 74: Do you mean G. sacculifer?

Actually both terms, G. sacculifer and T. sacculifer, would be correct in this case, as both morphotypes are the same biological species and genetically identical (Hemleben et al., 1987; Bijma et al., 1994; André et al., 2013; Spezzaferri et al., 2015). The previously used species Globigerinoides sacculifer just comprised both, the trilobus and sacculifer morphotype, without and with a sac-like chamber (Bijma et al., 1994; André et al., 2013).

Line 89: ‘related’ should rather be ‘correlated’? We changed it accordingly (now Line 95).

Line 92: SCUBA is written in upper case, is it an acronym?

Uppercase letters were already previously used in the initial description of culture experiments in Bijma et al. (1990b) and Nürnberg et al. (1996). But to avoid misunderstandings, as the word SCUBA does not implicate an acronym, we changed it to “scuba” (L98).

Line 95: Salinity experiments were done at salinities of 23, 26, 41, 44 and 45, which do not encompass the entire salinity range of 23 to 45. Why are the mid ranges not included?

In case you mean here that culture experiments at salinities of S = 33 and S =36 are missing, they are not listed at salinity experiments, because initially culture experiments were separated. We additionally included results of temperature experiments from both treatments S 33 and S 36, were foraminifera were cultured at the overlapping temperature of 26.5 °C. We added this information to the text (L253-254).

Line 100: ’26.5 °C to 29.5 °C’ OR ’26.5 °C and 29.5 °C’? We meant 26.5 °C and 29.5 °C and changed it accordingly.

Line 114 and 133: any reason for using the two different size fractions? 315 to 400μ and 300 to 400μ?

There is no specific reason using two different size fractions for surface sediment samples. This was simply related to slight variations in mesh sizes of sieves between different research groups, as Steffanie Nordhausen measured the Gulf of Guinea sediment surface samples.

Line 138: ‘The annual SSS varies from east to.....’. The variation of SSS from 32 to 35.9 is spatial or with depth?

This is spatial, but we also clarified this in the revised manuscript (L149-151).

Line 140 to 141: Δ[CO32–] = should be calculated for respective depths and included in tabular form.

This has been added to the manuscript. Please find the information in Table 1 (starting at L903). We additionally prepared a new Figure (6b, L 1006)

Line 221: Na/Ca increases by 0.12 mmol/mol per salinity unit. However the error on Na/Ca measurements at many instances is beyond this value (see table 1).

This point was also addressed from the second referee and we solved this issue by additionally providing the number of specimens needed to resolve a certain salinity change, based on our Na/Ca to salinity calibration, and added a figure (Appendix C, L1060) to clarify this relationship. Concluding from that, we could proof with our surface sediment samples (Table 1) that at least 20 specimens are necessary to resolve past salinity changes between 0.5 to 1 (see L441-456).

Line 273: ‘Nevertheless, it is still a ... noticeable’. Should it read as....’..... ..which is noticeable?’ Yes, we changed this accordingly.

Figure1b: As seen from the figure, the GIK samples seem to fall within 35 and 36 salinity units. However the figure 1c shows a larger range in salinity, from $\sim$31.7 to 34.7 units.

This is correct, because Figure 1b only presents the annual salinity at 30 m, the averaged water depth habitat we assumed for T. sacculifer in this study. Figure 1c shows instead the entire range of parameters within depth.

Figure 3a: Why is the 5th box, at salinity value of 44, grey in color? The text describes the salinity values for culture experiments of 23, 26, 41, 44 and 45 salinity units. The figure however shows 26, 33, 36, 41, 44 and 45 salinity units.

Maybe this was due to a converting issue, but actually the 5th box in Figure 3a should

be colored in black, equivalent to the color code in Figure 4. But we additionally added this information to the figure caption (L973-974). Further, we deleted the salinity experiment S 23, because the final, in clture newly precipitated chamber broke (too thin) and was removed due to the cleaning procedure for electron microprobe measurements. We also included the information that datasets for T = 26.5°C of both temperature experiments (S33, S36) were added to Figure 3a (L972).

References:

We changed all points mentioned below accordingly:

Line 33, 35 and 36: Rohling and Bigg, 1989 is listed as Rohling and Bigg, 1998 in the reference list. 1998 is correct.

Line 78: The reference Lin et al., 2004 is Lin et al., 2014 in reference list. Changed to Lin et al. 2004.

Line 193: Barker et al., 2003 is not listed in the references. Added.

Lines 297, 300 and 487: Dueñas-Bohórquez et al 2011 mentioned in text is Dueñas-Bohórquez et al 2011b in the reference list. Changed.

Line 469: Busenberg and Plummer, 1989 is not included in the reference list. Added.

Lines 538 and 540: Bijma et al., 1990 are two different papers and should be labelled as 1990a and 1990b, in text and reference list. Changed.

Line 682: The reference Spero, 1988 is not found in the text. Deleted the reference.

References used in the author's response:

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Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-164/bg-2018-164-AC1-supplement.pdf

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