

Dear Aninda Mazumdar,

We kindly thank you for your effort in reviewing our manuscript. In the following we refer in detail to the three minor issues you finally raised in your last correspondence to us from September 17th, 2018. These comments, which have also been previously addressed by the anonymous reviewers, were carefully considered and answered in detail in the current version of our manuscript. Below you find our point-by-point reply, complemented by the according text passages in the manuscript. We hope that this will find your support, and will help the manuscript to get finally accepted at Biogeosciences. Please let us know in case of further questions.

Yours sincerely,

Jacqueline Bertlich and on behalf of all co-authors

Answers to the editor's comments:

- A. I think the effect of alkalinity on surface sediment Na/Ca ratio is quite apparent in case of Caribbean samples. In fact the change in Na/Ca is almost of the same magnitude as in figure-4. This issue may be a little bit more clarified.*

We totally agree that there is a possible effect on foraminiferal Na/Ca values with changes in the carbonate ion concentration and increasing water depth at different locations, especially obvious at Caribbean surface sediment samples below 3.5 to 4 km water depth (Figure 6b). We pointed out this more clearly and as already written in the revised manuscript, the dissolution effect on Na/Ca at deeper water depth definitely needs more study and elaboration due to the limited sample set. Further, Na/Ca values of surface sediments (Fig. 6b) have indeed the same variation/magnitude as in Figure 4, since we used the same values, but just plotted against salinity in Figure 4 and 6a, in comparison to the influence on Na/Ca of changes in the calcite saturation state with increasing water depth.

Line 531-546: For instance, planktonic foraminiferal Mg/Ca values start to decline linearly below the critical $\Delta[\text{CO}_3^{2-}]$ threshold of $\sim 21.3 \mu\text{mol kg}^{-1}$ (Regenberg et al., 2006, 2014, see Sect. 2.3 for details). Evidently, we cannot see the same trend for Na/Ca_{T. sacculifer} values from Caribbean surface sediments, albeit Na/Ca seems to decline at 3.5 to 4 km water depth, below a $\Delta[\text{CO}_3^{2-}]$ level of $< 13 \mu\text{mol kg}^{-1}$ (Figure 6b). In the Gulf of Guinea, the critical $\Delta[\text{CO}_3^{2-}]$ threshold value is at even shallower water depth (~ 2.5 km), but no significant Na/Ca change with water depth is obvious, matching the Caribbean values (Table 1, Figure 6b). Therefore, Na/Ca seems to be less affected by dissolution than Mg/Ca, which could be linked to different incorporation mechanisms of both elements into foraminiferal calcite (see Sect. 4.4). The issue of Na/Ca removal due to calcite dissolution at greater water depth, nonetheless, needs further investigation, because of the limited sample set of our study.

Although the calcite saturation state is quite different in bottom waters and differs regionally in depth

(Brown and Elderfield, 1996; Dekens et al., 2002; Regenberg et al., 2006, 2014), we suspect that foraminiferal Na/Ca, similar to foraminiferal Mg/Ca dissolution, is not changing above the critical calcite saturation state of $>\sim 21 \mu\text{mol kg}^{-1}$ in the Caribbean and the Gulf of Guinea at least over the last ~ 3000 years (ages of Caribbean and Gulf of Guinea surface sediments; Regenberg et al., 2009). Although lowest Na/Ca values of surface sediments are possibly affected by calcite dissolution at respective water depths below 3.5 km, all foraminiferal Na/Ca values match the 95% confidence interval of culture experiments, not affected by dissolution (Fig. 4, 6a). This confirms the robustness of Na/Ca as paleo-salinity proxy over time.

L617-623: We observed no significant calcite dissolution effect on Na/Ca in foraminiferal calcite with changes in the calcite saturation state above 2.5 km water depth in the Gulf of Guinea and 3.5 to 4 km in the Caribbean, while Na/Ca values decline below. However, Na/Ca is not changing above the critical $\Delta[\text{CO}_3^{2-}]$ threshold of $\sim 21 \mu\text{mol kg}^{-1}$, established for the onset of Mg/Ca dissolution in planktonic foraminifera (Regenberg et al., 2006, 2014). Further, Na/Ca values of surface sediment samples lie within the 95 % confidence interval of our salinity culture experiments, which are unaffected by calcite dissolution. Therefore, our new data support that foraminiferal Na/Ca potentially serves as a direct and reliable proxy for significant changes in ocean salinities, e.g. exceeding 0.5 salinity units.

B. The dispersion (error bar) in the Na/Ca data from surface sediments are quite large (Fig. 6A). Authors may suggest how much error in paleosalinity measurement is expected using T. succulifer based Na/Ca ratio measurements? and how this will be advantageous to Mg/Ca based measurement currently used since the author has suggested multi-proxy approach at the end.

Both reviewers addressed previously the same points that the Na/Ca variability within specimens is quite high in respect to paleo-salinity reconstructions. Therefore we calculated additionally, based on our culture experiments and surface sediment samples, the smallest salinity range we could reconstruct, while considering the standard error of culture experiments and surface sediments. As written in the manuscript (L462-463), it is necessary to analyze at least 20 specimens to get a standard error of 0.18-0.36 mmol/mol, which in fact would reflect a salinity change of 0.5 to 1 at respective standard errors. Here we would kindly refer to the section 4.2, starting at line 441 onwards.

Further, the advantage of a combined multi-proxy approach in combination with Mg/Ca is simply linked to the fact, that Mg/Ca in combination with $\delta^{18}\text{O}$ just give indirect estimations and no absolute salinity values. We clarified this accordingly in the revised manuscript.

L464-468: With a sensitivity of 0.5 salinity units, reconstructions of paleo-river discharge (e.g. see Weldeab et al., 2007) as well as glacial meltwater discharge (e.g. in Flower et al., 2004) should become possible, independent from stable oxygen isotope approaches. Therefore, the application of $\text{Na/Ca}_{\text{foram}}$ in multi-proxy approaches, as already suggested in Vetter et al. (2017) to combine e.g. foraminiferal Mg/Ca- $\delta^{18}\text{O}$ with Ba/Ca, could infer more confidence of such reconstructions by providing absolute salinity values instead of previous indirect estimations.

C. In a routine measurement, an aliquot of multiple well preserved shells are expected to be used for Na/Ca measurement, which I believe represent an homogenized number than the point specific measurements using EPMA which is bound to show a lot of dispersion. Author may kindly clarify how an EPMA based calibration line would work for aliquot based measurement?

As already written in lines 458-462, we could show that Na/Ca values of fossil foraminifera (bulk/aliquot samples of around 20 to 30 specimen, homogenized and measured by wet-chemical analysis – ICP-OES) from respective surface sediments reflect the same inter-test variability and have the same standard error as single map analysis by the electron microprobe. This proves the reliability of our EPMA based calibration line. For our Na/Ca to salinity calibration we averaged Na/Ca values of at least 3 to 5 specimens, so it is comparable to the application routine for paleo-reconstructions. Electron microprobe results just additionally provide insights into the intra-test variability (which is the higher “dispersion” compared to bulk samples) and element distribution patterns with a higher spatial resolution than observed with bulk analysis.