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Interactive comment on "Effect of carbonate ion concentration and irradiance on calcification in foraminifera" *by* F. Lombard et al.

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We are grateful for H. Spero's comments. As he noted , the calcification process in planktic foraminifera is a complex mechanism in which symbiont may help the calcification process, making it light-dependent . This is discussed briefly in the manuscript (page 8597, line 10-19; page 8598, line 18-28). These sections have been expanded in the revised version of the manuscript (see below).

"I recommend that the authors consider the potential impact on their calculations if day-precipitated calcite was not influenced significantly by changes in ambient pH, and that the dominant effect was on the amount of calcite precipitated at night. Given that O. universa adds much more calcite at night then G. sacculifer, such a rationale could explain why the data analysis indicates a much larger decrease in shell mass for O.

universa vs G. sacculifer by the end of the century. If indeed the primary impact of ocean acidification is on night calcite, I wonder if a reanalysis of these data would help reconcile the magnitude of the effect of seawater pH change on the non-symbiotic species Globigerina bulloides that has appeared in the literature recently."

Response: Our data do not allow to go very deep into the potentially different calcification response to CO3 between night and day (both conditions are subject to day-night cycles with different daylight intensities). Separating the effect of [CO32-] on day, night or light to dark calcification would need specific experiments and is not within the scope of this manuscript. Symbionts may help calcification by increasing the pH in the vicinity of the foraminifera in the light (Rink et al 1998), but they are also suspected to act as competitors for inorganic carbon which they used for photosynthesis (ter Kuile et al 1989, Erez 2003). Calcification in foraminifera is a quite complex process in which ambient water is vacuolized and then chemically modified (pH, calcium) prior to calcification (Erez, 2003). Water vacuolized during day time (with high pH) may reduce the metabolic cost of water modification in vacuoles significantly. In both light and dark conditions, any change in water [CO32-] will also modify the final [CO32-] in the vicinity of the foraminifer, modify the energetic cost of calcification and then have potentially an impact on the calcification rate. Based on the hypothesis that calcification depends linearly on [CO32-, day calcification should be easier than night calcification (as shown by the larger amount of calcite precipitated during the day time). However, in both high light (HL) and low light (LL) calcification should be equally impacted by a change in bulk [CO32-]. We find indeed that the response to changes in [CO32-] is identical in LL and HL (the slopes of the two relationships in Fig 3B are not significantly different; $F_{1,191} = 0.9$; $P=0.34$) and hence do not allow to separate the potential effect of [CO32-] on dark calcification to light calcification. One part of text discussing this night and light calcification has been added to the manuscript.

"My second issue is a question for the authors. A part of the analysis is a presentation of the data in terms of foraminifera organic carbon content. This calculation is based

on an assumption that the cytoplasm volume is the same as the cumulative chamber volume within a shell. From observations on many living foraminifera, we know that cytoplasm does not instantly fill a chamber, but requires ∼1 day for G. sacculifer and 3-5 days to fill the sphere of O. universa. In both species, the shells do not completely fill with cytoplasm until just before gametogenesis when the foraminifera has ceased ontogenetic calcification. How does this issue affect the calculations?"

Response: Our estimation of calcification rate is based on a calculation that is based on an estimate the foraminiferal organic content. This calculation was motivated by the fact that calcification rates need to be normalized in order to be able to compare the different individuals that have different sizes. Larger individuals produce more CaCO3 than smaller individuals, and the absolute amount is certainly related to their "bioreactive content" (i.e. enzymes). This normalization is effectively a gross estimation as we do not have a direct estimation of the relevant "bioreactive content" and can only estimate it as "biomass". For the final organic weight of foraminifers, it is possible that the calculation is biased but usually the cytoplasm fills entirely the shells of both species prior to gametogenesis, when ontogenetic calcification has ceased but gametogenetic calcification is still in progress. In contrast, the variability in the cytoplasm filling of the shells at t=0 may in fact partly explain the variability observed between individuals. This is mentioned in the revised version of the manuscript. However, as primary, secondary and gametogenic calcite productions cannot be separated, we can only relate to the average amount of calcite precipitated over the course of the experiment.

Literature cited:

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