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Discussions

Interactive comment on "Secondary calcification and dissolution respond differently to future ocean conditions" *by* N. J. Silbiger and M. J. Donahue

N. J. Silbiger and M. J. Donahue

silbiger@hawaii.edu

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We thank you very much for your helpful review. Below are responses to your comments and specific questions.

General comments: As a more general question though I wondered the following: since the organisms being studied here are described as "secondary calcifiers" how do their responses impact coral reefs directly, which I'm assuming is thought of in this context as "primary calcification"?

While secondary calcification contributes significantly less to the overall growth of coral reefs than primary calcifiers (such as corals), secondary calcifiers still play several key

ecological roles on coral reef ecosystems. For example, they help to cement the reef together which maintains reef stability, and they produce chemical cues that induce the settlement of many types of invertebrate larvae (including corals). I have added this information to the introduction.

Specific points:

1. (12802, 20) – Is it "increase to 557 ppm by the year 2100" (rather than "increase by 557 ppm the year 2100")?

The increase actually is "by 557", not "to". RCP 8.5 is a high-emissions scenario, but one that we are currently tracking. Meinshausen et al., 2011 states that under the RCP8.5/ECP8.5 scenario pCO2 is predicted to be 936ppm by 2100, which is 557ppm above current levels (379ppm).

2. (12804, 9) – How long were the aquaria monitored without rubble to establish the stability conditions in Table 1? How many measurements were made to determine the mean values in this table?

The data presented in Table 1 are from one 24 hour cycle: each aquarium was measured in the light and then, again, in the dark. Each entry in the table is the average of 12 measurements: day samples and night samples for each of the six aquaria. This is now clarified in the text and the table caption. We have also changed the wording to reflect that these measurements demonstrate the consistency of the treatments within each rack between day and night, but not temporal stability, persay. The temporal stability of the mesocosm system was measured over a 26 day period and is reported in Putnam (2012). We have added this citation to the ms.

3. (12807, 2) - Is there a reference for the technique used to determine pH?

Yes, the reference is Dickson, A. G., Sabine, C. L., and Christian, J. R.: Guide to best practices for ocean CO2 measurements, 2007. This was referenced later in the paragraph, but we have added it to the end of line 3 for clarity.

4. (12808, 5) – I think there must be some words missing here in this description of how things were normalized to DIN.

This sentence now reads, "TA was normalized to a constant salinity (35 psu) to account for changes due to evaporation and then corrected for dissolved inorganic nitrogen and phosphate to account for their small contributions to the acid-base system (Wolf-Gladrow et al., 2007)."

5. (Eqn. 1) - I think a little more detail is needed for how the 3 measurements made per experiment (12805, 7-11) were specifically used in this equation (i.e., which values were used to determine the F values, and which were used for dTA/dt). The same is true for Eqn. 2 although I assume the same general approach was used in both cases.

We added some additional text to describe the equation. "F_TAin is the rate of TA flowing into an aquarium (= average TA in the header tank times the flow rate), F_TAout is the rate of TA flowing out of an aquarium (= average TA in the aquarium times the flow rate), and , d"TA" /dt is the change in TA in an aquarium during the measurement period (change in TA normalized to the volume of water and the surface area of the rubble). The rates are measured in mmol CaCO3 m-2 hr-1 (specific calculations are given in the supplemental material)." Additionally, we added the specific calculation for F_TAin, F_TAout , and d"TA" /dt to the supplemental files. These calculations follow Andersson et al. 2009, as referenced in the text.

6. (12810, 5) – I'm not sure I understand why a simple product of temperature and pCO2 was used as the independent variable (i.e., the one sentence explanation here seems inadequate to me).

We agree with the reviewer that a simple product of pCO2 and temperature was not straightforward to interpret. We have revised the manuscript so that the Standardized Climate Change (SCC) axis is a simple linear combination of ∆pCO2 and ∆Temperature that puts ∆pCO2 and ∆Temperature on the same scale. The results and interpretations of our study are the same with this new axis (indeed, any of several

choices of synthetic axes produced similar results). Further, we added figures to the supplement showing G and NCP versus ∆pCO2 and versus ∆Temperature to show that the relationships between G and NCP versus ∆pCO2 and ∆Temperature are similar to the relationships using the combined axis (Standardized Climate Change). Here is the explanation of our new version of the SCC axis in the text:

"Although we imposed four discrete temperature-pCO2 scenario treatments on each tank (Table 1), random variation between treatments and the feedback between the rubble communities and the water chemistry resulted in near-continuous variation in temperature-pCO2 treatments across aquaria (Figures 2 and A1). To capture this continuous variation in temperature-pCO2 in the analysis, we used the measured temperature-pCO2 seawater condition as a continuous independent variable in a regression rather than the four categorical treatment conditions in an ANOVA (an analysis of G and NCP using the ANOVA approach is included in Figures A3, A4 and Tables A1, A2). The regression approach allowed us to better capture the quantitative relationships between net calcification (G) or NCP and the temperature-pCO2 treatment. We created a single, continuous variable, Standardized Climate Change (SCC), from a linear combination of temperature and pCO2 values in each aquarium. A simple linear combination was used because pCO2 increased linearly with temperature (Figure 2), as imposed by our treatments. We first calculated the relationship between ∆Temp (Eq 3) and ∆pCO2 (Eq 4) using linear regression. The coefficients from this regression (slope: α = 0.0031; y-intercept: β = - 0.078) were used to combine pCO2 and temperature onto the same scale, as a measure of Standardized Climate Change (Eq 5):

∆Tempi= Temp(trt,i)- Temp(cont,i) Eq. 3

∆pCO2i = pCO2(trt,i) - pCO2(cont,) Eq. 4

SCC_i=∆Tempi+ α*∆pCO2i+β Eq. 5

This synthetic temperature-pCO2 axis, SCC, is centered on the ambient (control) conditions such that a value of 0 corresponds to present day Kaneohe Bay conditions, a negative value corresponds to water that is colder and less acidic (pre-industrial) and a positive value corresponds to water that is warmer and more acidic (future conditions) compared to background seawater. (The independent relationships between G and NCP with ΔTemp and $\Delta p CO_2$ are shown in Figures A5 and A6 and are similar to the relationship with SCC.)'

7. It also occurred to me that if calcification rates vary differently in response to changes in temperature versus changes in pCO2, then this might explain the non linear response seen in Fig. 3A. I would think that this might be considered a bit more explicitly in the discussion starting on line 24, p. 12812.

Yes, we agree. We have added a section to the discussion about the impact of temperature on daytime calcification, specifically focusing on metabolic response.

8. (12811,15) – Which G values were used in Figs. 4 and 3A? Since Gnet = Gday + Gnight, using Gnet here (along with Gday and Gnight) would seem to be "doubledipping" with the data.

Gnet is the sum of Gday and Gnight. We thought that it was critical to show our readership the response of net calcification over a 24 hour cycle. Figure 3e highlights the aquaria that were net calcifying or net dissolving over the entire experiment. It is difficult to elucidate this from figures 3a and c alone. We added a line at the zero point in 3e to futher highlight that there is a shift from net calcification to net dissolution over the 24 hour cycle. The data shown in Figure 4 are simply the day (squares) and night (circles) data. The figure legend reads: "Squares are data collected during the light (day) conditions and circles represent data collected during dark (night) conditions".

"Double dipping" typically refers to an iterative analysis where initial analyses or preprocessing of data guides subsequent analyses and increases the likelihood that the subsequent analyses are signficant. Here, the separate and planned analyses of day, night, and net are critical because each analysis gives distinct information to the reader

about the community response to climate change when (day) photosynthesizers are active and (night) when all members of the community are respiring, and (net) whether there is net calcification or net erosion over a diel cycle. Although Gnet is not statistically independent of Gnight and Gday, it is still appropriate to analyze the sum separately from the components: for example, consider if Gday had a positive relationship with SCC and Gnight had a negative relationship with SCC and, when summed, Gnet had no significant relationship with SCC. Each of these results would tell us something different and important about the relationship between calcification and SCC (daytime calcification increases with SCC, nighttime calcification decreases with SCC, and daily net calficifation is unaffected by SCC). Although the actual results of this study are somewhat more complex, all three analyses must be presented for the reader to understand the dynamics of the system.

9. (12811, 21) –Maybe I'm getting caught up in semantics but referring to changes in carbonate system parameters due to calcificiation, dissolution, photosynthesis and respiration as "feedbacks" seems to imply a bit more complexity than is really occurring. I'm not sure I would use this word here and throughout the manuscript to describe how these biological processes affect carbonate chemistry.

We disagree. As CO2 is added to the water it impacts the biology of the organisms, and those biological responses then also change the water chemistry. For example, increased pCO2 decreases pH which may result in increased erosion/dissolution, or increased pCO2 may enhance photosynthesis, which could increase erosion/dissolution by autotrophic microborers (Tribollet et al. 2009). The enhanced photosynthesis then also alters the seawater chemistry. This interaction between the biology and chemistry causes a feedback loop. The term "Feedbacks" has been used in the literature (e.g., Jury et al 2011, Anthony et al 2011) to describe the interaction between increased CO2 from the atmosphere and biological responses (e.g. calcification, dissolution, respiration, and photosynthesis) in altering the chemistry of the seawater. In our study, we saw a positive relationship between the amount of CO2 that we added to the mesocosms and the deviation in CO2 from the intended concentration (Figure A1). If there were no feedbacks, then the relationship between pCO2 with rubble and pCO2 without rubble from each aquarium would have a slope of one with a fixed offset (change in y-intercept) due to increased respiration by the organisms. With feedbacks, we would expect that as pCO2 increases, feedbacks would increase resulting in deviations from the 1:1 slope. During the day, we saw a slope of 1.1 while during the night, the slope was much greater than one (slope = 1.4, Figure A1b). This relationship suggests that there were feedbacks in our mesocosms. We added regression lines to Figure A1 to better illustrate these feedbacks.

10. (12811,17) - I think it would help if the data described here as “exceptions” were explicitly indicated on Figs. 4 and 3A (perhaps circled on the figure ?). This concern is also relevant to discussions on p. 12813, line 24 [‘This hypothesis . . .].)

We have changed the text to explicitly call out the points in the upper left quadrant with the points in the upper right and lower left quadrants of Figure 4. We have also added y = 0 lines to Figure 3 to make it easier for the reader to identify the net positive versus net negative values. We have shied away from circling these specific points on the graph so as not to distract readers from their own interpretations of patterns in the data. However, we have called out these points much more descriptively and specifically in the text to help orient the reader to the plots – thank you for highlighting the need for this direction.

11. In section 4.2, please don’t switch flux units. Mixing ‘per day’ flux units with ‘per hour’ flux units makes it very difficult on the reader. If necessary, convert data from the literature to the units you wish to use in the manuscript.

We switched the units to mmol m-2 d-1 in the text.

12. (12813,10) – “In the present study . . .”. Where is this shown? Is “net photosynthesis” actually NCP?

We added a panel with the NCP data to figure 3 and associated references, in the text; we also changed "photosynthesis" to "NCP".

13. (12813,18) – ‘We saw a decline . . .”. Again, where is this shown? We added a citation to Figure 3 after this sentence.

14. (12814, 7) – How exactly is “strongly affected” defined here?

We changed the wording to be more precise: “Standardized Climate Change explained more of the variance in dissolution than in calcification in our rubble community: (R_(G_night)ˆ2=0.64> R_(G_day)ˆ2=0.33; Table 2) this result is not surprising”

15. (12814, 15) – Talking about “distinct” responses here seems a little vague.

We added ": Gday had a non-linear response while Gnight declined linearly with Standardized Climate change" for clarification.

16. Figure 4 – Why is the color scale for standardized climate change multiplied by 10ËĘ4?

This has been corrected in the revised manuscript using the new Standardized Climate Change axis.

17. Figure A3 – Is the y-intercept listed here (0.0016) correct? Also, it might be worth mentioning somewhere that you would expect the slope here to be roughly 2x that of the slope in Fig. 4 (which is what is actually seen), based on the way G and NCP are defined.

Figure A3b has now been added to the main text as Figure 4b. The y-intercept is 1557.4, and this has been changed in the text. We also note in the Figure 4b caption, "As expected, the slope of TA versus DIC (0.31) is approximately twice that of G versus NCP (0.14). "

Interactive comment on Biogeosciences Discuss., 11, 12799, 2014.