Biogeosciences Discuss., 11, C2687–C2695, 2014
www.biogeosciences-discuss.net/11/C2687/2014/

Biogeosciences
Discussions
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Interactive comment on "Relative roles of endolithic algae and carbonate chemistry variability in the skeletal dissolution of crustose coralline algae" *by* C. Reyes-Nivia et al.

C. Reyes-Nivia et al.

catalina.reyes@uq.edu.au

Received and published: 19 June 2014

Thanks a lot for your valuable comments on the Discussion paper by Reyes-Nivia et al. We are please you found this study exiting and significant to increase our understanding on erosional processes in coral reef ecosystems. On behalf of all co-authors, I would like to answer your comment and methodological questions. Please also find attached our response as a PDF document to be able to see complex formats highlighting how we have changed particular sections of the paper.

Comment: You state that 'dissolution rates of skeletons without photo-endoliths were dramatically higher (200%) than those colonised by endolithic algae'. This statement

is misleading since the recorded rates are only about 100% higher, thus 'rates double' or 'rates twice as high' would express your results in a more intuitive manner.

Answer: There are several ways to present relative differences in dissolution rates between types of CCA substrates, but we choose percentage change as we found it meaningful in the context of our variable and for the message to send across. We carefully investigated what this percentage is relative to and found it is actually relative to an initial/control value, in our case to those CCA colonized by endolithic algae. Thus, an increase of, for instance, 100% in dissolution measure of CCA under dark conditions means that the final change is 200% of the 'initial amount'. In other words, that measure has doubled. If after this explanation the Editor considers that the message is unclear in any way then we will reword such sentence as follow:

Abstract: Dissolution rates of skeletons without photo-endoliths were dramatically higher (100 %) than those colonized by endolithic algae across all CO2-T scenarios.

Methodological matters:

Comment: 1) You prepared your recently dead CCA substrates by immersion of live CCA samples 'in hot seawater (50 °C) for 10 min to kill the algae'. What is your reasoning for such a short and mild treatment? How can you be sure that this treatment did actually kill not only the CCA but also the microendoliths hidden within the substrate where they are able to buffer short-term environmental changes to a certain extend? In any case, this treatment did not remove the killed tissue of both the CCAs and the microbial endoliths, likely leading to bacterially mediated maceration of the dead organic matter during the course of your experiment and resulting in a drop in interstitial pH – a fact that should be considered in the discussion

Answer: We used a short and mild treatment in an attempt to obtain dead CCA substrates without potentially compromising the mineralogy of CCA. Tolerance of endolithic algae to "reef" elevated temperatures (31 °C) has been demonstrated (Fine et al., 2005), so the endoliths may or may not survive short exposure to 50 °C. Whether these

organisms were killed or not did not affect our objective as the experiment was carried out long enough to allow a re-colonization (Kobluk and Risk, 1977). An important point is that all samples were subjected to the same experimental conditions including the hot water treatment and any potential variability among substrates was spread across CO2-temperature treatments. Microbial decomposition of the remaining organic matter, which may lower the interstitial pH, might have occurred across all samples under different CO2-temperature treatments. Yet, as you mentioned it, it is also possible that the warmer more acidic conditions may stimulate microbial decomposition, affecting such pH levels. Therefore, the following information will be added to the last paragraph of the discussion (in bold style):

Discussion P9: Combined, our results indicate that endolithic algae play ecologically relevant roles in the carbonate balance of coral reef ecosystems as they act destructively on high-Mg calcite substrates but also reduce the effect of seawater carbonate chemistry in the dissolution of CCA skeletons. This suggests that particular processes mediated by endolithic algae further contribute to the stability of reef frameworks. Because of this, dissolution of high-Mg calcite carbonates within the reef matrix, which is mostly driven by changes in seawater saturation state, appear to be stronger than that of surficial reef components containing photosynthetic microborers. The lowered dissolution of surficial substrates will be relevant for recently dead and/or constantly grazed CCA skeletons in which the epilithic component is reduced and thus the metabolic activity of endoliths is not limited. Irrespective of the presence/absence of endolithic algae, exposure to the "business-as-usual" CO2 emission scenario increased the dissolution of CCA skeletons. Models also project that Mg-calcite carbonates will undergo significant environmental dissolution under OA and/or warming scenarios as they are currently surrounded by slightly supersaturated seawater (Andersson et al., 2008). Since elevated CO2-temperature levels appear to stimulate microbial biomass (Dove et al., 2013) and our experimental samples retained coralline and endolithic algal tissue, this may have intensified microbial decomposition of the organic matter, promoting seawater undersaturation with respect to high-Mg calcite (Morse et al., 2006) and

increasing the dissolution of CCA skeletons under such conditions. This suggests that weakened carbonate deposits are at increased risk of further erosion through wave impact generated by storms or cyclones. Despite the potential ability of endolithic algae to reduce the dissolution caused by declined ΩHMC under warmer and acidic oceans, reef frameworks with a high proportion of Mg-calcite carbonates (e.g. fringing shallow reefs and algal ridges) may experience significant dissolution threatening the architectural complexity and persistency of these ecosystems.

Comment: 2) You address the replicates kept in constant darkness as 'without photo-endoliths' and thus showing an 'environmental effect' only. While the former is correct, the latter might not. Why do you exclude the possibility of colonisation by organotrophic fungi and other non-phototrophic bioeroders (endolithic bryozoans or foraminiferans for in-stance)? Did you quantify the biomass of replicates kept in total darkness as you did for the light/dark ones, which would allow you to demonstrate the absence of such bio-eroders? The contribution of endolithic fungi (also in a light/dark treatment) is easy to underestimate since these fungi are quite difficult to detect and to identify.

Answer: We acknowledge the reader has made a fair and interesting comment but we did not quantify the biomass of samples in dark tanks because our study did not aim to separate every single component, in which case we would have to use a different approach and inhibitors to prevent bacterial/fungal growth for instance. In addition, a different methodology to estimate biomass is definitively necessary since after few trials with dark samples we realized almost no organic matter could be recovered. Nevertheless, in the 4th paragraph of the introduction, we indicated that the biological role of photosynthetic microborers on dissolution of CCA was isolated from the environmental effect of seawater (driven by CO2-T conditions, or by local CO2 production/consumption from the thermal stimulation of metabolism). Such statement therefore includes the potential contribution of non-phototrophic bioeroders. If the Editor considers this is not completely clear, we will reword such sentence as follow:

Introduction P4: Here, we used an experimental outdoor system designed to assess

the relative contribution of endolithic algae and carbonate chemistry variability on skeletal dissolution of dead CCA fragments exposed to combined OA and warming. Endolithic algae abundance, metabolism, and bioerosion rates increase under OA conditions in corals, therefore we hypothesized that similar responses will occur in CCA skeletons. Further, as endolithic algae contribute considerably to carbonate dissolution, we also hypothesized enhanced dissolution rates when they are present. The biological role of photosynthetic microborers on skeletal dissolution was isolated from the environmental effect of seawater carbonate chemistry (driven by CO2-T conditions, or by local CO2 production/consumption from the thermal stimulation of metabolism, i.e. ΩHMC < 1). To achieve this, half of the experimental CCA substrates were kept under dark conditions (without photo-endoliths) and thus their responses represent the 'environmental effect' potentially enhanced by background microbial populations. Ocean chemistry variability included past and present CO2-T conditions following scenario projections by the Intergovernmental Panel of Climate Change (IPCC) (Meehl et al., 2007).

Further, considering a related comment by Reviewer #1, we have included a new sentence in paragraph 7 of the discussion on the need to assess microbial erosion in future studies:

Discussion P7: Exposure to full dark conditions revealed that dissolution of CCA skeletons within the reef matrix is largely mediated by changes in seawater ΩHMC across all CO2-T treatments. Since CCA exposed to seawater supersaturated with respect to high-Mg calcite (ΩHMC > 1 for preindustrial, present-day and medium scenarios) also dissolved, this suggests that acidic and undersaturated interstitial seawater were likely generated by heterotrophic microbial metabolism (Dupraz et al., 2009; Andersson and Gledhill, 2013). Processes such as microbial respiration and/or sulfide oxidation have been related to the dissolution of reef carbonate sediments, with a preferential dissolution of the more soluble high-Mg calcite and aragonite phases (Burdige et al., 2010; Rao et al., 2012). Our results also indicated that CCA high-Mg calcite skeletons might

undergo persistent environmental and/or heterotrophic metabolic dissolution across a range of CO2-T levels. Given that coral skeletons may experience no dissolution under dark conditions, as aragonite undersaturation was neither chemically nor metabolically reached even under the "business-as-usual" scenario (Reyes-Nivia et al., 2013), this suggests that alterations in seawater saturation state of different carbonate phases play a critical role in the susceptibility to dissolution of major reef components. Future work should quantify the metabolic microenvironmetal control by non-phototrophic microborers and their potential relative contribution to the dissolution processes under changing climatic conditions.

Comment: 3) In your experiment you record the pioneer phase of microbioerosion on a partly previously bioeroded substrate, hence a shift from dead (but already bioeroded) substrate (in both the dark and light/dark replicates) to the density recorded at the end of the experiment. This fact could be considered in the discussion since the observed effect would have possibly been even more pronounced if you would have worked with a mature and live microbioerosion community in the light/dark replicates from the start.

Answer: This is again a very interesting aspect raised by the reader. We agree with this point as early microbioerosion rates (pioneer successional communities) appear to be lower than those caused by more mature endolithic communities under natural conditions (Tribollet, 2008).Yet, it is also true that elevated CO2-temperature levels can alter community structure of endolithic microborers (Reyes-Nivia et al., 2013 and this paper) and likely natural successional processes. In addition, the abundance of epilithic components, such as turf algae, can be modified when CO2 and temperature interact (Connell and Russell, 2010). Given this information, we decided not to make further predictions as successional processes of endoliths are associated with both, epilithic algae and grazing (Chazottes et al., 2002). Therefore in our paper we have stated that: "The lowered dissolution we observed in surficial substrates (harboring endolithic photo-autotrophs) will be relevant for recently dead and/or constantly grazed CCA skeletons in which the epilithic component is reduced (we removed it regularly)

and thus the metabolic activity of endoliths is not limited" (see last paragraph of Discussion section). We have, however, added a new sentence in paragraph 6 of the discussion to address such comment:

P6: We found that the endolithic community structure was altered under the high CO2-T scenario with a particular increase in the relative abundance of the cyanobacterium M. testarum (figure 4). This boring alga is a pioneer colonizer of dead CCA substrates and exhibits a moderate abundance at the early stages of bioerosion (Ghirardelli, 2002; Tribollet and Payri, 2001). M. testarum largely accounted for the increased abundance of endolithic micoborers in dead portions of living CCA under elevated CO2-T conditions (Diaz-Pulido et al., 2012). Here, we further quantified the abundance of major endolithic microborers and found a positive response of M. testarum to high CO2-T levels, which may also be associated to the increased dissolution rates of CCA skeletons under this scenario. It is also likely that higher density networks formed by M. testarum linked to environmentally weakened high-Mg skeletons may also explain the increased amount of CaCO3 removed in the high CO2-T treatment. Since rates of microbioerosion may change depending on the successional stage of the endolithic community (Gektidis, 1999; Tribollet, 2008), the observed rates of dissolution may be lower than that of more mature endolithic communities under OA and warming conditions.

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Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C2687/2014/bgd-11-C2687-2014-supplement.pdf

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Interactive comment on Biogeosciences Discuss., 11, 2993, 2014.