

Interactive comment on “Light and temperature effect on $\delta^{11}\text{B}$ and B/Ca ratios of the zooxanthellate coral *Acropora* sp.: results from culturing experiments” by D. Dissard et al.

Anonymous Referee #3

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Review of Dissard et al. BGD

Dissard et al. report findings from a thorough study of the effects of temperature and light intensity on boron isotopes ($\delta^{11}\text{B}$) and boron/calcium ratios in the coral *Acropora*. This work is topical, the experiments are thorough, and the data is interesting, and I recommend publication after some minor revisions.

General comments

Explanation of light effect on $\delta^{11}\text{B}$

One of the most interesting findings of the study is the fact that with increasing light

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intensity, $\delta^{11}\text{B}$ decreases. This is unexpected, as increasing light intensity increases photosynthetic rate, which might be expected to increase CO_2 uptake, and thus increase pH in the coral epithelium and microenvironment; this would be expected to increase $\delta^{11}\text{B}$ (and B/Ca) in the coral skeleton, rather than cause the decrease that is observed. Furthermore under high light intensity, calcification rate increases (an effect known as light-enhanced calcification - LEC), which has often been attributed to an increase in pH due to increased photosynthetic rate. However what the authors show is that the opposite seems to take place: high light does increase photosynthesis and does enhance calcification, but that pH seems to be lower.

The authors' description of possible reasons for this is currently very confusing. I think this stems, in part, from taking the summary given by Moya et al. (2006) as a starting point for this discussion (5985, 25 - 5986, 7). I don't think this summary is clear, even having read the original references in question. Point 2 is too vague, as several carbon concentrating mechanisms have been suggested, and the main finding of the study of Furla et al. 1998 is similar to point 1: that enhanced light causes an increase in epithelial pH (with the addition that this may have relationships with enhanced ion channel transport). Point 3 describes a feedback between calcification and photosynthesis, with calcification removing alkalinity relative to DIC in a 2:1 ratio, and thus shifting the carbonate system towards CO_2 , which may then be used for photosynthesis. This removal of CO_2 (DIC) then increases pH (and CO_3^{2-}) again, and thus may promote calcification. However as admitted by the authors (5987, 2): "this seems more a consequence than a cause" of light enhanced calcification. More importantly, I don't agree with the authors that this process will lead to a net lowering of pH in the calcifying environment. The calcification step will lower pH, but this is the case in all these examples. The step linking in photosynthesis (i.e. that the CO_2 produced during calcification may be reabsorbed during photosynthesis), will cause an increase in pH, and is thus just the same as point 1.

The authors don't need to solve light enhanced calcification in one fell swoop. As none

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of the explanations really seem to work, they should just clearly describe this and leave it as an interesting result, deserving future study. Alternatively, if I've made a mistake in the logic above, and the authors think that mechanism 3 really does work to cause a net decrease in pH in the calcifying environment, they need to show this much more clearly, ideally with some modelling, or at least graphically.

Description of culturing

This work will be of interest to the isotope geochemistry and paleoproxy community. As such, I think the description of the culturing could be made slightly clearer. I'd suggest making a table or schematic that describes the 3 steps within the culturing process. I was also confused about the pieces of coral used for metabolic measurements - were they kept in the same culture tank as their associated nubbin, and just brought out for the metabolic measurements? And do coral pieces grown on wires behave the same as those grown on slides? Finally please annotate Fig. 1 to show the new growth of aragonite in culture, and here and in Section 2.2 describe how skeleton grown in step 1 was distinguished from skeleton grown in step 2.

Shorten description of other work

I think there are several places where this manuscript loses flow by too much detailed description of previous studies, with little reference to the new work in this paper. Shortening these sections (for instance 5988, 18 - 5989, 9) would make the paper more focussed and much more readable.

Reviewer 1's comment on a temperature effect on α

I disagree with reviewer 1's comment that: "rigorous evaluation of temperature effects on aqueous boron fractionation should be performed. For instance. Zeebe (GCA, 2005) and Hönisch et al. (EPSL, 2008) provide guidelines for how this could be done". In the only thorough study of this effect (the Zeebe (2005) paper referred to by this reviewer), Zeebe states that: "Given the range of outcome for α_{B3-B4} at 300 K cal-

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culated in the current paper, no recommendation will be made regarding α 's temperature dependence, which equally depends on the frequencies/methods chosen." i.e. although there is likely to be a temperature effect on α , we don't know it yet (and it may be extremely small over this temperature range). This being the case, adding a temperature effect on α is likely to only add confusion and uncertainty. The reviewer is, however, right that changes in pK_b with temperature should be evaluated.

Specific comments and technical corrections

5971, 9: mention in the abstract the finding that increased light causes a decrease in d11B, the opposite to what is expected in most models of light-enhanced calcification.

5971, 11: it would be helpful to give example real world conditions or environments that this change in light intensity represents, i.e. "equivalent to the summer vs. winter light intensities in the natural environment of these corals".

5971, 12: replace "between 22 and 25 C" with "with an increase from 22 to 25 C" and "enhancement" with "an increase" for clarity.

5971, 16: replace "confirming" with "consistent with" as B/Ca and d11B may have different controls.

5971, 19: replace "ions" with "ion"

5971, 25: replace "(actual)" with the year this value applies to.

5972, 3: insert "past" before "seawater"

5973, 1: as the authors discuss in this paragraph, these NMR measurements record trigonally coordinated boron in a crystal, which is not necessarily the same as boric acid and doesn't necessarily imply boric acid incorporation (see Klochko et al. 2009 Figure 9). So please replace "boric acid" at line one with "trigonally coordinated boron", and in line 3 say something like "if this reflected incorporation of boric acid in this proportion..."

5973, 17: refer to Juillet-Leclerc references as submitted, rather than giving it a year,

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which implies it is already published.

5975, 1: indicate new skeleton growth in Figure 1.

5976, 8: replace "steps" with "step"

5976, 9: how many nubbins per experiment?

5976, 16: how was skeleton grown in step 1 distinguished from that grown in step 2?

5976, 24: give a reference for the respirometry technique, and replace "consists in" with "consists of"

5977, 6: what is LT?

5977, 8: what is "nitrogen-bulld"? Grammar here doesn't seem quite right.

5977, 12: replace "weighted" with "weighed"

5977, 13: replace "were" with "was" and provide a reference for this formula (or if original give rationale for its use).

5977, 19: what type of replicates are these - fully separate samples from different nubbins, separate samples from the same nubbin, replicate analyses of the same coral sample, replicate analysis of the same dissolved solution etc.?

5977, 23: what sample size was analysed?

5978, 5: does this 0.5 permil refer to the size of the blank expressed as a fraction of the total sample, or to the effect of the blank on isotope composition? Make this clear.

5978, 12: replace "than" with "to"

5981, 1: give references for these values. Bt has been remeasured by Lee et al. 2010 (432.6 $\mu\text{mol/kg}$), more precisely than this measurement by Uppstrom 1974. Ideally the value of Lee et al. should be used. However as the value of Uppstrom is still given in the best practices guides by EPOCA and Dickson 2007, I suppose it is OK to use the

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Uppstrom value.

5984, 17: replace "important" with "high" or some such.

5984, 20: this is not necessarily the case - kinetic effects or some other fractionation of the two molecular species could occur during incorporation of boron into carbonate. This needs to be stated clearly.

5985, 12: replace "up-regulation" with "pH up-regulation"

5985, 15: see discussion of this section in major comments above.

5988, 2: replace "paleo-pH reconstructions are still..." with "paleo-pH reconstructions from corals are still...", as reconstructions from other species may be better or worse than this.

5988, 18 - 5989, 9: much of this section could be cut.

5989, 5: cut "By definition". Could replace with "Carbonate system equilibria are such that CO_2 is more soluble in cold water" or some such.

5989, 12: I don't understand what is meant by "carbonate availabilities" - please be more clear.

5990, 3: change section title to "Comparison of the impact of light vs. temperature"

5990, 3: Currently not really sure what this section adds. Could be improved by clearly stating at the start of this section that despite seeing an increase in calcification under both increased temperature and increased light intensity, these conditions have the opposite effect on d11B.

5990, 10: again, this mechanism doesn't really work.

5991, 5: B(OH)_4^- doesn't become the dominant species at these pHs and pKbs - it just increases in abundance. B(OH)_3 is still the more abundant species.

5991, 18: replace "confirm" with "are consistent with", as B/Ca and d11B may have

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different controls.

5994, 22: state the interesting result that increased light intensity results in lower $\delta^{11}\text{B}$.

5995, 4: again replace "confirming" with "consistent with"

Table 2: Give units for Calcification Rate, and maybe use "Calc'n rate" as abbreviation, rather than "Ca rate".

Fig. 4: replace "Oranges crosses" with "Orange crosses".

Fig. 5: again, reference to Juillet-Leclerc should be submitted, not 2012.

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