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Interactive comment on "A novel paleo-bleaching proxy using boron isotopes and high-resolution laser ablation to reconstruct coral bleaching events" *by* G. Dishon et al.

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Anonymous Referee #1

Abstract: The authors should mention/discuss that understanding the frequency of bleaching events is critical for determining the relationship between natural and anthropogenic causes of these events

We agree that this is an important aspect that should be stated. It is now included in the abstract.

Introduction:

1. **The authors provide a pretty brief/incomplete review of the stressors that may cause bleaching events. Please expand.**

2. **P. 8134 Line 5, authors mention previous papers that have discussed dating of coral bleaching events but not how these events were identified.**

3. **P. 8135 Line 5, utilize 'ambient' instead of 'surrounding' and 'pH' instead of 'pH level'**

4. **P. 8135 Line 18, please quantify what you mean by 'beyond the natural vital effect'**

5. **P. 8135 Line 17-24, is there a citation for when/how this was previously proposed? not clear as written. In general, this section is written very awkwardly, needs to be clarified.**

   (a) We intended to keep this part of the introduction as concise as possible. However, we agree that other possible environmental triggers for coral bleaching should be mentioned. We added the other factors with a reference to a review dealing with this topic. It now reads: *" Coral bleaching occurs when environmental stress, primarily increased water temperature and high irradiance (but also decreased temperature, decreased salinity and pathogenic infections), induces breakdown of the coral-algae symbiosis and the host initiates algae expulsion (Brown, 1997)."*

   (b) The suggestion that coral bleaching caused mortality events by the end of the 19th century (Yu et al., 2006), was made by correlating SST and coral mortality, and speculating that a coral that died during high SST years was probably bleached. Even though this speculation is not a strong one, it is part of the body of knowledge to which we aim to add our new findings. We rewrote this sentence and it now reads: *" By correlating isotopic dating of*

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massive corals and concomitant SSTs, it was speculated that coral bleaching may have already caused mortality events by the end of the 19th century (Yu et al., 2006)."

(c) Corrected.

(d) pH up-regulation by "healthy corals" reaches ca. 0.3-0.6 pH units above ambient pH ((McCulloch et al., 2012). Photosynthesis termination (e.g. in darkness) was documented to reduce pH up to 0.7 pH units below "healthy" pH (Al-Horani, 2005). These quantification was added to the text.

(e) The effect of coral bleaching on d^{11}B values has been a debated topic for some years already. Hemming et al. (1998) raised the question whether d^{11}B is largely influenced by coral productivity. Wei et al. (2009) suggested a pH drop in coral record to be the outcome of coral bleaching. However, trying to "catch" short bleaching events (ca. 2 weeks) using d^{11}B, failed (Schoepf et al., 2014).

Methods:

1. **Items that are in the Supplemental table should still be discussed to a greater degree in the text.**
2. **Please summarize experimental conditions further in your methods section, and use Supplemental Table only as supporting evidence.**
3. **Instead of "Experimental Set Up" consider "Experimental Design" or "Coral Culturing" as the heading here**
4. **Were salinity, pH, turbidity, held constant in the experiment?**
5. **Section 2.1.2 seems slightly out of order. The first sentence of the 2nd paragraph logically belongs at the top of this section.**

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6. **What was the depth of ablation?**

7. **Similar to comment above, the description of Naturally occurring bleaching events should also go before the description of analytical d11B methods.**

8. **Section 2.3 I wonder if this entire paragraph belongs in the results/discussion. This methodology relies on the reader being convinced that the d11B proxy works before moving forward to a review of previously published records.**

   (a) Corrected

   (b) Corrected

   (c) Corrected

   (d) Due to the direct connection with the nearby sea, sea water parameters reflected the natural characteristics of the Gulf of Aqaba's waters. Salinity and pH varied 8.20 +/- 0.01 (SD) pH units and 40.60 +/- 0.08 (SD) ppt respectively. Turbidity was not measured but is considered low due to the oligotrophic nature of the Gulf. Overall, both control and heat stresstreatments were fed with the same water source and experienced the same (little) variation in water features.

   (e) Corrected

   (f) Ablation depth was ca. 20 um. it is important to note, however, that ablations were made on coral slices perpendicular to growth axis, which means that ablated material belongs to the same calcified layer.

   (g) Following the referee's suggestion we transferred the description of analytical $\mathbf{d}^{11}\mathbf{B}$methods to section 2.3 after the section describing experimentally and naturally bleached specimens.

   (h) We consider paragraph 2.3 a methodological one, explaining the methods of "data crunching" which its results are in section 3.3 and 3.4. It is true that

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this methodology relies on the reader being convinced that the $d^{11}B$ proxy works, but we believe that placing these explanations inside the discussion (before section 3.3) will make the flow of the article more difficult to follow.

Results:

1. **This section should be renamed Results and Discussion, or "Discussion" materials should be pulled out as a separate section.**

2. **P. 8140, paragraph at top of page: the question is whether these timescales are environmentally relevant. These results require a discussion of what temporal scales may be resolved in the paleo record, and what events might be missing. This is key to the importance of the proxy.**

3. **This may just be a wording preference, but I am not enamored with 'footprint'. Why not... proxy (as used in title), or signature, or indicator, or quantitative threshold? I found myself wanting to replace 'footprint' at every usage with one of these words. Also, in the title you state it is a paleobleaching proxy. So, why the "" around every usage: "born bleaching footprint"? I would clarify the language here and be consistent.**

4. **Section 3.4 You state that ocean surface pH paleo records exhibit more "acute and radical changes": isn't this a result of sampling resolution or averaging? In the modern ocean these two parameters are very linked in variability, so why wouldn't they be in the paleo record? Also - please be more precise in language - I think you mean to say "variability" and "amplitude" not "acute and radical changes".**

5. **For the discussion of the paleo intervals - this is a pretty limited discussion of each of the events. I am not sure if this is tremendously useful - the**

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main point is that these events exist and appear to be related to changes in temperature. I would suggest either a) streamlining this section of the paper so it is a brief review of previous events or b) strengthening this section with a more thorough analysis - why are these events occurring at these times? Might there be other, shorter term events that are missing? How should investigators proceed with utilizing the d11B bleaching proxy?

(a) Corrected

(b) Time scales of the phenomena addressed are highly important. A researcher interested in reconstructing paleo-pH record inspecting glacial cycles, does not have to measure $d^{11}B$ in a weeks-month high resolution technique, but he should be aware that if one sampling point represents ca. 1 year of calcification, $d^{11}B$ may contain the bleaching signature leading to underestimation of pH_{sw}.

For biological phenomena that occurs at time scales of weeks-months (such as coral bleaching), high resolution sampling is necessary (as can be seen in (Schoepf et al., 2014)). The boron bleaching proxy is apparently an indicator of only pronounced long bleaching events which are indeed environmentally significant.

Section 3.2 was added with a discussion of temporal resolution significance.

1. Corrected

2. Our data compilation showed that paleo-pH record contains higher magnitude variations than pCO2 through the last 130 K yr. This decoupling of pHsw and pCO2 atm is indeed different then the familiar relation in modern measurements, and can be explained by:

   (a) **There is no real decoupling**: pCO2 averaging of ca. 150 yr in ice cores gasses measurements missed short term pCO2 fluctuations that resulted in

severe pHsw changes recorded in the higher resolution (ca. 1 yr scale) $d^{11}B$ in coral skeletons. This interpretation is quite radical, implying that in the smooth, continuous and well explained pCO2 record, major climatic events are hidden (e.g. 6Kyr ago, where no sharp change in pCO2 is evident).

(b) **In specific oceanographic settings, decoupling occurred** : changes in ocean circulation may cause local pH decrease due to upwelling of deep low pH waters. This is the path chosen for example by Douville et al. (2010) to explain the sharp decrease in $d^{11}B$ at the end of the Younger Dryas.

(c) **The apparent decoupling is actually coral bleaching**: **$d^{11}B$** drops that were interpreted as low pH values, are actually a coral bleaching signal. In this case, the pH-pCO2 decoupling is just an artifact of misleading $d^{11}B$ interpretation.

The last one (c) is the approach suggested in this paper and this is exactly why we consider it is important to highlight the different variabilities of pH and pCO2 records. This is also part of the reason why we believe that presenting each potential bleaching event in regard to oceanographic settings and previous interpretations is of high importance (sections 3.4.1-3).

Following the advide of Reviewer 1, this paragraph now reads: *"Ocean surface's pH paleo-records exhibit higher magnitude variations in comparison to atmospheric pCO_2"*

3. As stated before, in order to demonstrate how $d^{11}B$ are better explained using the boron bleaching proxy, we believe that presenting each potential bleaching event in regard to concomitant oceanographic settings and previous interpretations is of high importance (though fairly technical in nature). In all cases we suggest that either high SST (paragraphs 3.4.1-2) or rapid increase in SST (paragraph 3.4.3) is the main cause for these coral bleaching events.

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In order to put these paragraphs in a clearer context, we expanded the opening section 3.4 with a clearer explanation.

Conclusions:

1. **2nd paragraph of the conclusions seems out of place. I think it should be modified and moved up to be the 1st paragraph of this section.**
2. **Also, I suggest that the authors include a statement that examination of additional modern, known bleaching events will be necessary to understand the temporal dynamics of when/how these events are recorded in coral skeletons.**
   (a) Corrected
   (b) Corrected

References:

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