Point-by-point description of changes made to the revised manuscript

"Calcification response of reef corals to seasonal upwelling in the northern Arabian Sea (Masirah Island, Oman)"

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We would like to thank the editor and reviewer #3 for commenting on our manuscript. Their supporting comments and ideas have substantially improved the scientific significance of our work. In line with the reviewers' and editors' comments, minor changes have been made to our revised manuscript. Generally, all suggestions for the improvement of language and grammar were implemented. Detailed responses to the specific comments made on our manuscript are given in a point-by-point manner in the following.

1. Editor comments:

1.1 *"Lines 62-64: This is a bit confusing as written, please rewrite to make clear that eutrophication along the off-inshore gradient is inhibiting calcification where there are more nutrients."*

We have revised the sentence to clarify that increasing eutrophy causes a "stretching modulation of the skeleton". This modulation in the patterns of calcification can result either in reduced, constant (Carricart-Ganivet and Merino, 2001; Carricart-Ganivet, 2004) or enhanced (D'Olivo et al., 2013; Manzello et al., 2015) rate of calcification.

The revised the sentence is to read: "In general, increasing eutrophy is considered to cause reef corals to sacrifice skeletal density for increased extension rate ("stretching modulation of skeletal growth"), which can either lead to enhanced, constant or reduced rate of calcification (Carricart-Ganivet and Merino, 2001; Carricart-Ganivet, 2004; D'Olivo et al., 2013; Manzello et al., 2015).

1.2 *"Line 136: Is "tournament" the correct word here?"*

The word "tournament" was replaced by the word "rotation".

1.3 *"Line 327: Reduce the use of acronyms, these get very confusing."*

Acronyms for the individual seasons (i.e. SWM, AIM, NEM, SIM) are now written out as whole words for better readability.

1.4 "Line 365: I would refrain from citing personal communication about seawater chemistry data, you could rephrase as a hypothesis."

In this sentence, we refer to an unpublished dataset, which provides sub-annually resolved Ω_{cf} (based on combined δ^{11}B and B/Ca analyses) derived from a *Porites* collected within the upwelling zone of Panama (Saboga). Annual means in Ω_{cf} of the same coral are published in Mollica et al., 2018 (see Fig.1; Saboga). The unpublished sub-annual data demonstrate Ω_{cf} to be relatively low all year round, even during the non-upwelling season. These data are an important contribution to our hypothesis suggesting the year-round low skeletal density of corals from the Arabian Sea upwelling zone to be the result of a constantly low Ω_{cf}. After consultation with N. Mollica, we have provided the data on the sub-annually resolved Ω_{cf} as a supplement on which we refer to within the text (see supplementary material, Fig. S3).

1.5 *“Line 367-370: This sentence is very confusing. Rewrite, and maybe break into two sentences.”*

We have revised the sentence to read: “A similar finding is reported from two sites located within the Galapagos upwelling zone (n = 7-8 cores per site) (Manzello et al., 2014). Poor replication of *Porites* calcification data from the upwelling areas of Panama and the South China Sea (n = 1, respectively) does not enable a proper comparison (Mollica et al., 2018).

1.6 *“Line 378-380: Wording is a bit strange here, rewrite this portion.”*

We have revised the sentence to read: “Hence, a stimulating effect of nutrients on extension rate during the non-upwelling seasons is possible, since moderate nutrient concentrations with high PO_4^{3-} to NO_3^- ratio exist year-round in the Arabian Sea (Dunn et al., 2012; Kleypas et al., 1999; Koop et al., 2001).”

1.7 *“Line 386-387: Awkward wording.”*

We have revised the sentence to read: “Accordingly, we hypothesise the year-round relatively low skeletal density of the Masirah corals to be also related to a constantly low Ω_{cf}.”

1.8 *“Line 414: Add a sentence after describing how future work may confirm this hypothesis.”*

We added the sentence to the end of the conclusion section to read: “Further research should include combined analyses of $\delta^{11}B$ and B/Ca ratios in order to confirm the hypothesis of a year-round relatively low Ω_{cf} in reef corals from sites affected by seasonal upwelling.”

2 Reviewer comments (RC #3):

General comments:

2.1 *“Unfortunately, there is low sample size for the sub-annual measurements. This results in high variability of the calcification data. Even though the authors have included additional samples showing similar annual bulk density, extension rate, and calcification rate, without the sub annual data it does not help to clear up many uncertainties..*”

Intra-reef variability in the patterns of calcification between individual coral colonies is largely related to differences in locational conditions (e.g. depth, illumination, nutrients, etc.). These locational differences are negligible when comparing internal, sub annual growth patterns of one single coral. Sub-annual variability in calcification performance within a single specimen reflects seasonal changes in environmental conditions at a particular site.

Consistently, all three sub-annually resolved specimens from Masirah Island reveal lower extension (calcification) rates during the upwelling season compared to the winter months (northeast monsoon) (with approximately similar SSTs) (see table 3). We have no doubt on this being a seasonal environmental signal rather than being an artefact of intra-reef variability. Therefore, we have no reason for concern about "many uncertainties".

2.2 *“One of the major flaws in its current form is that most conclusions are derived from data that is not included or were not measured i.e. calcification fluid carbonate chemistry, seawater conditions for turbidity, light, or complete carbonate chemistry..”*

We agree to reviewer #3 that assumptions about Ω_{cf} in the discussion section and conclusion section of our manuscript cannot be backed up by analytical data. For this reason, assumptions concerning Ω_{cf} will appear as hypotheses in the revised version of our manuscript (see changes made to line 387 and following). However, we strongly feel that there is no necessity to measure turbidity, light levels, nutrient concentrations or seawater carbonate chemistry since information on these parameters are available in published literature (please see Quinn and Johnson, 1996; Takahashi et al., 2014; Garcia et al., 2019).

Detailed comments:

2.3 *"Line 54-55: Incomplete sentence"*

We have revised the sentence to read: "Eutrophication can have both beneficial as well as detrimental effects on coral growth, depending on the kind of available nutrients and their concentration (Tomascik and Sander, 1985; Tomascik, 1990)."

2.4 *"Line 55-56: Consider rewording this sentence"*

We have revised this section to read: "In general, reef corals are highly adapted to oligotrophic waters with micro-algae symbionts to allow an efficient use of essential nutrients (Muscatine and Porter, 1977). This enables outcompeting other fast-growing biota on a reef whose growth is inhibited by the undersupply of nutrients (Vermeij et al., 2010; Barott and Rohwer, 2012)."

2.5 *"Line 98-99: But still supersaturated with respect to aragonite during the upwelling season?"*

Indeed, the seawater remains supersaturated with respect to aragonite even during the upwelling season. However, saturation drops below critical values assumed to be required for coral growth (Kleypas et al., 1999).

2.6 *"Line 120: I feel there is a lack of description from where/how the cores were collected since position on the reef can be a big factor for many of the points measured here."*

We strongly feel that the origin and collection of the specimens is adequately addressed in section 2.2.

2.7 *"Lines 139-140: How were these 3 corals selected out of the 6?"*

We have revised this section to read: "Corals 5.10, 5.13 and 5.21 were selected for Li/Mg and Ba/Ca geochemical analysis based on optimal orientation and traceability of the corallites adjacent to the density measurement transects."

2.8 *"Line 327-328: "All specimens show lower SWM calcification rates compared to NEM." is this accurate? I would argue that coral 5.13 is identical in SWM and NEM and coral 5.21 shows too much variation to say its different."*

According to seasonal means and standard deviations shown in Table 3, both, coral 5.13 as well as coral 5.21 have lower calcification rates during the southwest monsoon than during the northeast monsoon.

2.9 *"Lines 369: What identical results?"*

We have revised the sentence to read: "A similar finding is reported from two sites located within the Galapagos upwelling zone (n = 7-8 cores per site) (Manzello et al., 2014). Poor replication of *Porites* calcification data from the upwelling areas of Panama and the South China Sea (n = 1, respectively) does not enable a proper comparison (Mollica et al., 2018).

2.10 *"Lines 386-387: But skeletal density shows an increase to SWM upwelling? And based on your summary of how skeletal density might be related to Ω_{cf} – this would mean Ω_{cf} is increasing in response to an external decrease, potentially to offset negative effects?"*

All three sub-annually resolved coral specimens show a high-density band during the upwelling season. No evidence exists, however, that the density bands are driven by up-regulation of the Ω_{cf} during the upwelling season. Instead, figure 7 shows the high skeletal density during southwest monsoon to be a function of decreasing extension rate ($r^2 = 0.88$, $p = 0.0002$) (see also line 270 – 275). As an explanation, we refer to the work of DeCarlo and Cohen (2017), showing that with decreasing extension rate, more carbonate is precipitated in less space, which leads to higher skeletal density (line 351 – 357).

2.11 *"Line 388-389: I see what you are saying but this is not a strong argument. Highly suggest to remove an Li/Mg ratio offset as evidence that pH_{cf} is constant"*

We have revised the sentence to ensure the reader is aware that the high Li/Mg ratios support, but do not confirm the hypothesis of a low Ω_{cf}. The revised sentence reads: "This hypothesis is further supported by the Li/Mg ratios of the Masirah corals, which are offset to higher values than those expected from the literature".

2.12 *"Lines 393-394: the statement "not capable to adapt completely to ocean chemistry change on a quarterly scale" seems to not have much basis on the limited data you provide, particularly since there is no internal saturation data. It would rather seem that external saturation state is not a good determination for calcification in general since you show that overall calcification is indistinguishable from calcification data in non-upwelling zones elsewhere."*

The sentence annotated provides an approach to explain the absence of an immediate response in the intra-annual density variability to temporary low Ω_{sw} during the seasonal upwelling. Although no immediate response to the upwelling is observed, the mean annual skeletal density is lower than in corals from sites unaffected by upwelling. According to actual literature, we therefore propose Ω_{cf} of the Masirah corals to be kept relatively constant by modification, but to be less upregulated than in corals from regions without upwelling (McCulloch et al., 2017; Mollica et al., 2018).

2.13 *"Line 395: I agree, Ω_{cf} is probably held constant throughout the year, however it is more likely another constant factor such as high year round nutrients, which at relative high levels promotes extension/limits density (as you cite from Manzello et al 2014) and then is reversed under upwelling either from turbidity as you suggest or extreme high nutrients or both."*

As shown in Figure 9c, the skeletal density of *Porites* from upwelling areas is consistently lower compared to those unaffected by upwelling. In contrast, extension rates at the same sites are highly variable, with relatively slow growth in Panama and fast growth at a site off Galapagos (Fig. 9b). We therefore consider both the seasonal dynamics of seawater nutrients (as discussed in lines 339-349; 361-362; 385-390) and a constantly relatively low Ω_{cf} to determine the density patterns in corals from upwelling areas.

Further evidence for low skeletal density in corals from upwelling areas being linked to a relatively low Ω_{cf} was also demonstrated by combined analyses of $\delta^{11}B$ and B/Ca for specimens from Saboga and the South China Sea (Mollica et al., 2018).

3. References

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