

Production and accumulation of reef framework by calcifying corals and macroalgae on a remote Indian Ocean Cay.

Response to RC2: 'Comment on egosphere-2022-467', Anonymous Referee #2

In this paper led by James McLaughlin et al., the authors investigate the rates of CaCO₃ production and O₂ production/consumption (i.e., photosynthesis and dark Respiration) on different species (green algae, red algae, and corals) to scale up to the community level in a remote island in the Indian Ocean on the west coast of Australia. I greatly appreciated the efforts made by this team to study the functioning of benthic communities, and it is undeniable that much work was done to write this study. However, the writing of the article is still a bit shaky, especially in the references, which are not up-to-date. I do not doubt that this study will be significantly improved after revision and make an excellent reference in benthic functioning.

We thank RC2 for the time spent providing constructive criticism and comments on our manuscript. We greatly appreciate the reviewers suggested additional reference material for us to consider implementing into this manuscript. We feel in addressing the comments below, the effort has added considerable value to our work resulting in a much more impactful summation for our study of the reef at Browse Island.

Abstract.

There is a lot of information missing. Especially on the M&M. I mainly see the introduction and the results in this abstract. It would be wise to reduce the results to keep only the key results, add at least two sentences about how you did the experiments (and when), and a sentence in the discussion/conclusion. For example, your M&M part in the abstract stated only: "Specimens of the dominant coral and algal taxa were collected from the reef platform of Browse Island located on the mid-shelf just inside the 200 m isobath off the Kimberley coast. During experimental light/dark incubations, ..." And then, you are already talking about results. How many species? Light/dark incubations in situ, ex-situ? How many incubations, and how long? What about calcification?

We have restructured the abstract so that it now includes more information about the methods we used.

- L22-23: Try to be consistent. One time you do a range of values X - X; another time, you do X to X. stick to one (I prefer the second one)

We have changed the text in the abstract so it now reads "all algae were net autotrophic producing 6 to 111 mmol O₂ m⁻² day⁻¹."

This comment is valid for the whole manuscript!

We have changed the values ranges within the text of the manuscript from "X - X" to "X to X" throughout to ensure consistency.

Introduction.

I had some trouble with the introduction. The ideas are there, but maybe not well arranged. If I followed you correctly, here is your plan: CO₂ rising > Functioning and Reef Health > OA and calcification > Algae and calcification > Community metabolism (Calcification and photosynthesis) >

Change in pH > Question. You will see it in my comments below, but I won't just focus on CO2 since you're not looking at it specifically in this study. I will talk about threats more in general. The paragraph on community metabolism and functioning reef health could also be coupled, but I understand your strategy. I might have appreciated a more fluid introduction, but it is still functional. See my comments below.

We thank the reviewer for the constructive criticisms of our introduction and especially for supplying a number of more recent references. We have re-written the introduction to emphasize the calcification rates, productivity and reef functioning more in the context of general pressures that can act to constrain these processes. As the reviewer so rightly points out our study is not specific to ocean acidification, and we have adjusted accordingly.

- L41-43, the way to write it is clumsy. Please rephrase.

I'm a little confused here because you're right to talk about the threats of climate change. But I don't understand why you focus on the OA only when you have the chance to study a remote island: I mean, there is a lower / even zero anthropic pressure (nutrient run-off, sedimentation...). I will expand it in this paragraph.

We have re-written the introduction to emphasize the calcification rates, productivity and reef functioning as the focus instead of ocean acidification.

REF :

1) Hughes, Terry P., et al. "Coral reefs in the Anthropocene." *Nature* 546.7656 (2017): 82-90.

2) Hughes, Terry P., et al. "Global warming and recurrent mass bleaching of corals." *Nature* 543.7645 (2017): 373-377.

- L57: Pretty close to what you are doing. I think a similar study to cite would be, especially if you refer to health by looking at metabolism:

1) Carlot, Jeremy, et al. "Scaling up calcification, respiration, and photosynthesis rates of six prominent coral taxa." *Ecology and Evolution* 12.3 (2022): e8613.

We have moved this text in the re-written introduction to the last paragraph with updated citations and it now reads "Metabolic measurements of reef organisms are necessary to characterize reef health in terms of fundamental processes such as photosynthesis, respiration and calcification (Madin et al., 2016; Carlot et al., 2022)."

- L60: when you talk about Respiration, please use the standard terminology: "Dark Respiration".

We have changed the text to now read "i.e., the difference between gross primary production and dark respiration,..."

We have changed "respiration" to "dark respiration" where suitable throughout.

- L65: There are lots of references here. Notably, all the works from Perry et al. (2008, 2012); an older reference would also be Vecsei et al. (2004).

We have included references to Vecsei, 2004; Perry et al., 2008; and Perry et al., 2012 to the corresponding text.

<https://scholar.google.com/citations?user=7v8IXzYAAAAJ&hl=en&oi=sra>

- L67: If I advocate for the devil, some encrusting corals bring nothing strictly in terms of 3D. I am not sure it is relevant to mention 3D here, especially in this study.

Reference to 3 dimension of reef structure has been removed. The text now reads "Scleractinian corals are primary reef builders in tropical environments producing CaCO₃ through skeletal deposition."

- L69: REF

We have added reference to Kleypas and Yates, 2009.

- L75: A more recent study would be welcome to discuss future projections...

1) Cornwall, Christopher E., et al. "Global declines in coral reef calcium carbonate production under ocean acidification and warming." *Proceedings of the National Academy of Sciences* 118.21 (2021): e2015265118.

We have added reference to Cornwall et al., 2021. The text now reads "... with the majority of coral reefs unable to maintain positive net carbonate production globally by 2100 (Cornwall et al., 2021)."

- L80: This statement is critical, given your discussion, and you do not mention the work of Houlbreque et al., in the discussion. Too bad...

Reference to relevant works by Houlbreque et al. has been added to parts of the discussion.

- L82: I'm a bit confused about this formulation. Although mass bleaching events are due to thermal stress, bleaching can occur from another cause (i.e., oxidic stress due to pollution or disease...). I will remove "during bleaching event" or rephrase it.

Reference to bleaching events has been removed. The text now reads "Rates of primary production and dark respiration increase but community excess organic production decreases dramatically in reefs under thermal stress (Kayanne et al., 2005)."

- L91: Turf can enhance the productivity of the general system by feeding fish, but not in the way you mean here, in terms of benthic productivity. Am I wrong?

You are correct. We've changed the text so it now reads "... but inconspicuous turfs and encrusting coralline algae contribute substantially to reef benthic primary resources in these areas..." to clear up the ambiguity around the term "primary production" which generally means the sequestration of carbon.

- L95: REF

We have added reference to Purcell and Bellwood, 2001

Remove "like corals" or write "like coral reefs", but it is not necessary; it just bloats the sentence to lose the reader.

We have changed the text so it now reads "Calcified macroalgae can also contribute significantly to the deposition of carbonates."

- L96, 99: REFS

We have added reference to Vroom et al., 2003, Smith et al., 2004, Nelson, 2009.

- L100: What is the ref of the Caribbean?

We have added reference to Blair and Norris, 1988, and Nelson, 2009.

- L102: It's a little bit fair to extrapolate to the globe with a single reference from 1988 in Tahiti (French Polynesia).

We've changed the text to now read "In certain locations precipitation of Calcium carbonate can approach 2.9 kg CaCO₃ m⁻² yr⁻¹, positioning Halimeda as a major contributor to carbonate budgets within shallow waters around the globe." With a reference to Price et al., 2011 which contains estimates of Halimeda contribution to reef calcification from around the globe.

- L123: It's not so difficult to define it, actually. But it becomes very challenging "in situ". Add it.

We have changed the text so it now reads "How calcifying primary producers such as corals with zooxanthellae and calcifying algae affect water column chemistry becomes very challenging to measure in situ."

- L139: This is an excellent paper, but he has updated his results since. It would be nice to see if you are still in the same category.

1) Halpern, Benjamin S., et al. "Recent pace of change in human impact on the world's ocean." Scientific Reports 9.1 (2019): 1-8.

We have included reference to Halpern et al., 2019 in addition to his 2008 paper.

M&M.

Overall, it was pretty good. There is some information missing, but I was able to follow everything. I would have appreciated a figure showing the experimental protocol. That would have helped a lot. I'm not sure I understood why there were three dates, maybe I lost the info, or it's not explained. I'm a bit more concerned about the seasonal effect, especially with algae, but I'll come back to that in the discussion.

Photographs of experimental setup added as Figure 2, all subsequent figure captions changed to reflect this addition.

What were the units obtained for Respiration and calcification? Did you do any conversions?

Respiration rates were calculated as the O₂ produced (measured in micromol per L per unit time and converted in mmol per day per incubation core) divided by the surface area of the algal or coral specimen (in m²) for units in mmol per day per m².

Calcification rates were calculated as the CaCO₃ produced (in g per day) per surface area of the algal or coral specimen (in m²). These units are converted from pH and alkalinity using the 'seacarb' package in R as stated

- L158-160: I'm not familiar. Is that a lot for this system? It seems relatively low to me, especially for a remote system

This is quite low, but not atypical for the region.

- L174: I'm not sure that estimating the age is relevant. What does it bring to you?

The age is important as a point of reference for the reader as calcification and respiration rates are likely to differ between juvenile and adult specimens.

- L185: There is some information missing here. Volume?

Text moved to L202. Sampling volume is stated in the preceding sentence at L200.

- L189: Why 12 for Sargassum and 6 for the others?

Text changed to address ambiguity and now reads "Depending upon abundance, individual specimens of algae and coral were placed in 6– to 12 replicate incubation cores per taxa except where not enough individuals could be found."

Essentially, Sargassum was found in greater quantities in April 2016 than other taxa so that is why we incubated 12 plants as opposed to 6.

- L199: Why 24 cores? I do not understand. Where does 24 come from?

6 cores fit evenly spaced in each of the 60 L tubs where self-shading is minimised. We used 24 cores because that is the total number we could fit into the 4 tubs.

Text at L184 changed to "Six 1.56 L clear Perspex incubation cores (24 total per incubation) fitted with stirring caps, were placed in each holding tank and spaced evenly apart to minimise shading (Fig. 2).

- L210: It's great to have defined the surface, but for the turf, you have mainly defined the surface you extracted.

Did you make sure to select the strict minimum? How? There are a lot of limits on this turf component. How did you do in 2017 to have the turf without the substrate (Fig 2)?

Turf without a substrate were flat two-dimensional pieces of turf (not attached to pieces of rock), hence we were able to measure the surface from a simple photograph. For turf with substrate, the pieces were three-dimensional, hence why we had to use a wax dipping method to estimate the surface area. The turf 'fronds' are so small that there is no way to measure the actual combined surface area of them.

- L231: How many replicates triplicates for alkalinity? I am surprised not to see the Dickson et al. (2007) reference in this section.

The methodology from SOP3b in Dickson et al., 2007 was used to determine the alkalinity for single replicates due to sample volume constraints. The text has been changed to From SOP3b in Dickson et al. 2007, total alkalinity was determined for single replicates to the nearest...

Dickson et al. 2007 has been added to the list of references.

- L241: Referencing problem with R

Citation corrected. Now reads (R Core Team, 2018).

- L244: What about the flow? Which pump? What about the light intensity? What about bacterial Respiration?

Relevant information on the pump used is now provided at L179 "... filled with seawater and connected to a flow-through seawater system driven by an Ozito PSDW-350 watt Dirty Water Submersible Water Pump with a maximum flow rate of 7,000 litres/hour..."

L183 includes information on instrumentation used to measure light intensity “The intensity of photosynthetically active radiation (PAR) was recorded for each set of incubations with a HOBO Micro Station logger (H21-002, Onset) placed inside one of the tanks.”

Bacterial respiration was not specifically determined for this set of experiments however in the seawater controls O₂ changed by < 0.01 mmol h⁻¹ in both light and dark incubations, showing that the contribution of any organisms (i.e. bacteria, phytoplankton, etc.) in the seawater itself to either light driven productivity or dark respiration was minimal.

Results.

This part was the weakest. There are some discussion parts in it. See specific comments.

- L273-275: Mix of Discussion / Results, a useless first sentence. Rephrase.

Suggestion: "Nutrient concentrations were low and similar among sampling trips (Table 2)."

Text changed to “Nutrient concentrations were low and similar among sampling trips (Table 2), as is characteristic of tropical Eastern Indian Ocean offshore waters (McLaughlin et al., 2019).”

- L275-277: Why are you only talking about 2017 values?

We have changed the text so it now presents the lower and upper ranges of the nutrient concentrations measured.

- L279-280: Compare what is comparable. First light and then temperature but not light with temperature.

Sentence split to alleviate ambiguity of comparisons and now reads as “PAR levels were 1500 to – 1587 μE m⁻² s⁻¹ and slightly higher in October. Temperatures were 28.3 to 32.8°C and highest in April.”

- L281: Which differences?

Text has been changed and now reads “Carbonate system parameters were not obtained for April 2016, and some minor differences in pCO₂, HCO₃⁻, CO₃²⁻, DIC and Ω Aragonite were noted between October 2016 and 2017 (Table 2).” to highlight the parameters measured in 2016 and 2017.

- L288: Sometimes, a comma would be really useful to understand the flow of your sentence. This is more of a general comment.

Text changed and now reads “Changes in dissolved O₂ differed among taxa, and between light and dark incubations.” Comment about commas understood.

- L289-290: Are you talking about bacterial Respiration? If so, please be explicit. This is too bad that you did not apply a correction, even a small one. It would have shown the accuracy of your results.

Yes, bacterial and plankton respiration. As stated in the text, the controls displayed values that were so small compared to the production and consumption of oxygen in the algal and coral incubations that no correction was deemed necessary.

- L300-302: This part goes into the discussion.

We have moved this text into the discussion section.

Also, OK, it's a good point, but not necessarily; it can be a response to oxygen stress due to the chamber (according to the EPA, your organisms should not have an oxygen concentration lower than 80%, did you look at it?).

We thank the reviewer for highlighting this. We were unaware of this threshold and will consider investigating in future studies.

Also, the 9cm diameter for corals is not that small. Especially when you estimated that your corals were up to 7 years old at the beginning!

We appreciate the reviewer clarifying size age relationships for coral colonies and have amended the text.

- L304-306: I think it is better to talk about significance. Indeed, it seems non-significant. I'd prefer to see what's significant or not; mentioning the range of change is great but not enough (you need both). Add this information.

We are not sure what the reviewer is referring to here as being non-significant? A change in pH of 0.03-0.25 is large. The choice of word (minor) is deliberate so as not to confuse this with statistical significance.

- L315: Once again, minor = non-significant

The choice of word (minor) is deliberate so as not to confuse this with statistical significance.

- L317: The adjusted R² is not small for ecological models. Would it be better to look only at species? The fact here is that you do not have a lot of samples, and this is why you got lower R² than your expectations

It was not really possible or practical to look at individual species due to low sample numbers. This analysis supports the observation that changes in pH were driven by metabolic uptake and release of CO₂ even with the low r² values, which can be explained by the fact that there is variability among individual specimens and species.

- L322: That is surprising. Even at night, calcification activity should be less but not negative. Check with other papers for a response to the review.

We agree that this was surprising and may be an artefact of the experimental conditions. This has been added to the results section and the language of what caused the change has been toned down.

- L324: Is the ratio Daylight/Night equal to 1 in your location? It would be more accurate to check it instead of assuming it

Text changed to "The resulting net calcification rates (based on equal periods of light and dark - monthly average sunrise and sunset at Browse Island of 0552 and 1739 for April, and 0519 and 1754 for October; WillyWeather, 2022)"

WillyWeather, 2022 website citation has been added to the reference list.

- L326: Strongly correlated: Prove it (Hint: R²)

We have provided the results of an ANOVA with a p-value in the figure legend which we believe provides a more robust analysis.

- L330: Intertidal, which categories in Fig 7? The high reef platform, I assume. Say it.

Text changed to "In intertidal habitats (lagoon and high reef platform) around Browse Island, the estimated relative contributions..."

Add also error bars. It might be significantly different

Figure 7 represents a conceptual diagram of the reef metabolic processes, hence, error bars are not included.

- L333: It would be good to recall the cover in Halimeda to get an idea of the contributions

Text changed to include % cover now reads "In intertidal habitats around Browse Island, the estimated relative contributions of coral (8% cover) and Halimeda (7% cover)..."

- L338: It would be nice to have a value or a percentage to judge the negligible.

Text now reads "Galaxaura, which had high measured rates of productivity and calcification, was extremely rare (0.02 % total cover found only in October 2017; Olsen et al., 2017) and thus its contribution to community calcification and productivity were negligible."

Discussion.

Overall it's good. I wish you would have talked about seasonality, which is totally ignored. It would be nice to compare your values obtained with different methods to support the robustness of your results. Also, it would be interesting to discuss them in the face of climate change since you went in that direction in the introduction. The last paragraph of the discussion before the conclusion is excellent.

Unfortunately, we were not successful in collecting carbonate system parameters in April of 2016 so were unable to compare Austral autumn with Austral spring in October 2016. While we could discuss inter-annual variability, we felt that our sample size was insufficient to confidently elucidate any trends.

- L344: at line 155, only 5m, now more than the double!

Text clarified at L355. Now reads "Browse Island has the only emergent mid-shelf reef in the Kimberley bioregion with semidiurnal tides reaching a maximum range of < 5 m, half of those tides experienced by reefs closer to the coast."

- L346: I prefer the word "composed" rather than "inhabited" – the second one being more used in the scientific literature for humans.

Text changed and now reads "The region contains thousands of islands with a total reef area estimated to be ~2000 km² (Kordi and O'Leary, 2016), composed of inhabited by diverse coral reef and seagrass communities..."

- L352-353: Do not get the sentence. Rephrase.

The text has been changed to "The region-wide averages of coral cover and macroalgal cover are 23.8% and 7.1% (Richards et al., 2018) respectively. However, the relationship at Browse Island is reversed with macroalgae more dominant at 28% total cover to that of coral at 9% total cover."

- L369: OK, this is fair, but were results for Halimeda or coral different in other studies?

We've added an additional reference to Houlbreque et al., 2009.

- L376: I wouldn't necessarily use the terms "Functional groups" since you are always looking at the same functions with different species. I would say species or taxonomic groups.

Text changed and now reads "... but the metabolic measurements showed clear differences among taxonomic groups."

- L382: Yes and no. They remain autotrophic but get heterotrophic supplies. There is probably a mountain of Houlbreque refs to quote here.

Text changed to "Although autotrophic, our data indicates that the majority of the corals we studied utilise heterotrophic supply through feeding to help sustain growth in addition to photosynthesis by zooxanthellae."

We have added some relevant references to work done by Houlbreque et al. in parts of the discussion.

<https://scholar.google.com/citations?user=gbjGctUAAAAJ&hl=en&oi=sra>

- L386, 414, 422: Only one / add Refs!

- L422: Here, it's good to know what base units you had.

As written in the following text we used $g\ m^{-2}\ year^{-1}$

- L463: Excellent paragraph!

- L472: I'm not sure I understood? How do you estimate metabolism aerially? On the other hand, relief is possible with photogrammetric methods.

We used photogrammetric quadrats collected on the trips to estimate the cover of coral and macroalgal species. From this cover data we scaled up our metabolic rates to estimate the community metabolism for the reef habitats around the island. We've clarified this in the redrafted discussion of the paper.

Figures and Tables.

Photographs of experimental setup added as Figure 2, all subsequent figure captions changed to reflect this addition.

You have not discussed the nutrients in slide 2. You can refer to the work of Jacob Allgeier to help you.

<https://scholar.google.com/citations?user=1Ug8lwAAAAJ&hl=en&oi=sra>

We have added a paragraph in the discussion section to address the nutrient data found in Table 2 and provide some commentary and wider context for our results.