VICTORIA UNIVERSITY OF WELLINGTON
Te Whare Wānanga o te Ūpoko o te Ika a Māui

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Dear Dr Steven Lade

We received the comments from two reviewers, which we address below. We thank you and the reviewers for your time in appraising our manuscript, and apologise for the misunderstanding regarding the word count limit we thought we had set on this special issue. Both reviewers provided a positive appraisal of the manuscript but had suggestions for some revisions. We now have thoroughly revised the manuscript and below we detail the revisions that we have conducted and our responses to reviewer suggestions and questions. We detail the reviewer comments in quotations and in italics, followed by our revisions and responses in plain text after each comment. We respond to reviewer #2 in this letter.

"Reviewer #2:

This work presents a great depiction of the current state of understanding of the impact of OA on organisms and community structure. The text is generally direct and clearly written. The text generally suggests that identifying tipping points caused by OA is difficult and there are other factors to be considered. My major concern is that the paper reads more as a summary of the impact of OA rather than an assessment of how tipping point can be caused by OA.

The first parts (section 2) have some paragraphs that are a bit clearer about the difficulty of identifying tipping points from a physiological perspective only and translating this to any broader ecological processes."

Thank you for your time reviewing the manuscript and your positive appraisal.

"From my point of view, the other parts however seem mainly about changes/shifts and do not touch enough on how these changes are likely to occur; gradual (linear) vs abrupt (tipping point/bi-phasic).

Another consideration is whether tipping points are likely to be caused by CO2 alone, or influenced primarily by interactions with other parameters/stressors?

Are there shifts in community structure or simplification of food web occurring through a tipping point or are they more gradual shifts along the spatial/temporal gradient of pCO2? No doubt that a shift in community structure/habitat forming species and so on are likely, and in fact shown in some areas (e.g., CO2 seep having different communities). However, can a proper sudden change in stable state be identified at a given range of pCO2 or are these occurring mostly gradually or randomly at different sites based on the site's own characteristics? I think it is important here to clearly differentiate between gradual shift vs a sudden tipping point, or maybe the lack of appropriate data/studies to properly infer tipping points."

There are all important points that should be included in the manuscript, and we now add material in section 3 discussing these points.

"There is also a lack of more concrete direction on how to look properly into identifying actual sudden change in stable state in natural systems, for example, or thresholds in pCO2, especially in the concluding section."

We now add material in the discussion around this. Field manipulations of pCO_2 would be the only way to achieve this, though if these were fully replicated across a range of different pCO_2 values and also replicated in time and space, it would be logistically complex.

"Nonetheless, in my point of view, this can be a nice addition to the literature and provide some nice insights given it revised carefully and a little restructuring. In its current state, it feels a little as a summary to the impact of OA, to which some inferences about tipping points have been made. I hope that these comments help improve the paper.

Thank you for your positive appraisal of the manuscript.

"Specific questions (in attached file):

The title gives the impression that OA definitely causes tipping points, which from the text seems the opposite. In addition, I believe 'ecological tipping point' is a bit vague/too broad. Perhaps the title can be modified to put forward the main message of the paper a bit more clearly."

We agree, and now change the title to "Are physiological and ecosystem-level tipping points caused by ocean acidification? A critical evaluation."

"Line 25-30: Where does the 500 come from? I mean if it is table 1 then it seems only based on some physiological processes (which is stated), not 'ecological' tipping points."

This is from the field studies noted in Figure 1. We now detail these further in the discussion in section 3.

"Broadly across the text: It is not clear to me what is meant by ecological tipping point, for two reasons. Firstly, it sounds very broad, and the scope of this paper is not so broad. Secondly, because it is not clearly stated, for example in the intro. Lines 34-44: I think the introduction needs a bit more information on how OA can cause tipping points in terms of physiology, population, and community. A general introduction of the concept, so to speak. Also, there should be a clear definition of 'tipping point' against which all the studies within this paper are being judged or inferences being made. In its current state, if I were to read only the intro, I would think that this is a paper on a summary of the impact of OA on organisms. There is no information on tipping points."

We respond to the similar comment from reviewer #1, see the file in response to them for more details. Briefly, this is part of a special issue on tipping points, and thus we expect that these concepts to be properly introduced there. However, as a paper that might be read stand-alone, we now add this introduction for the reader.

"Line 60-78: This section consists of detailed information on calcification. I wonder whether such detail is needed to sway the reader towards understanding how OA links with physiological tipping points? Would some of that information be better off being used within the into and links to thresholds/tipping points be made there? Or perhaps made more concise and links to tipping points made more explicit?"

We now better link these processes to how physiological tipping points exist, and what responses we would expect to see due to changes in seawater carbonate chemistry.

"Lines 79-119: The studies from different taxa seem to suggest that a tipping point only caused by OA is rather unlikely and that there is a more linear decrease. Would that mean that a sudden shift in the measured responses would most likely be driven by cumulative effects of stressors rather than singular effect of pH? I understand that the context here is primarily on OA, but cumulative impacts also mean involvement of OA, albeit with other parameters/stressors (e,g., Russell, B. D., THOMPSON, J. A. I., Falkenberg, L. J., & Connell, S. D. (2009). Synergistic effects of climate change and local stressors: CO2 and nutrient-driven change in subtidal rocky habitats. Global Change Biology, 15(9), 2153-2162. And many other references around that topic). Therefore, would it be worth adding some information on the cumulative effects of OA and other stressors on calcification?"

We now add material that acknowledges the role OA plays in acting in tandem with other drivers. However, this is not the main aim of our manuscript, and to add this material would be complex. For example, warming can increase coral calcification rates, but only in cool seasons, whereas in warmer seasons increases in temperature will drive extensive mortality of corals.

"Lines 149-179: Same comment as the comments above about calcification (lines 60-78)."

Please see our reply above.

"Lines 250-255: No doubt that these sites provide a great opportunity to study differences in physiology, population, and communities. One of the issues is that in many instances there is a large gap between the different pCO2 levels at which parameters are being compared (that is no proper gradient), meaning that even if a very large shift in community is observed, the way that this shift has occurred is not clear. Meaning that one cannot clearly infer whether there has been a gradual shift, a sudden tipping point, or a combination of multiple factors that have changed in a stepwise manner. Similar to what the authors pinpoint in the introduction (line 45, and also line 83, for example). Perhaps this is also a gap in many natural and lab-based studies that needs to be stressed on?"

Yes, that is true for many field studies, we now add a sentence discussing this caveat. I think an issue here is also how well pCO2/pH etc is monitored at some of these locations and whether such smaller gradients in pCO2 exist consistently enough to act as natural analogues without receiving critique that they also have periods of time where pCO2 is too similar to control conditions. However, at some sites there are 100 uatm differences and also changes in coral and turf abundance already occur there (e.g., Shikine and some places in Papua New Guinea).

For laboratory work, the problems likely are in that it is difficult to control and properly manipulate seawater carbonate chemistry to precisely obtain pCO_2 levels that are between 450 and 500 µatm. For example, high profile papers discussing the need to conduct experiments at ~430 µatm do not realise that present day variability in most coastal zones far exceeds 430, and that experimental organisms would also have bene exposed to these levels on a regular basis. We now add this discussion in the text near the end of our conclusions.

"Lines 263-275: This is interesting and shows clearly that communities change in different ways, sometimes not as one would expect. Can the authors expand a bit more on the pCO2 thresholds and show the link with tipping of the communities? Or are these thresholds and links not clear enough to be called tipping points?"

We now add material full discussing this in section 3. The conceptual figure should hopefully help show that pCO_2 thresholds cannot necessarily explain the ecosystem level tipping points, but rather the physiology of the organisms present and their responses must also be known.

"Line 268-275, and lines 329-331: I am wondering whether it would help to produce a diagram that shows the trends of changing community along measured pH/pCO2 values from

these sites? I am thinking that this will more clearly show where the communities tip to a different/simplified state along the increasingpCO2 (if that is the case) and whether there are clear differences between where that happens for different sites."

This would be too difficult to include here without re-analysing all of the data from each seep site. And in some instances, there are small changes in community structure (e.g., shifts between different Cystoseira spp. in Panarea) versus larger shifts in other locations (e.g., complete removal of all coralline algae at Vulcano). Thus, it is too tricky to include. But now we include a conceptual diagram that could be useful for the readers in understanding how physiological changes add up at ecological levels.

"Line 311: remove "this" in "this ocean acidification"?"

Amended.

"Lines 286-321: This section is a nice discussion about the changes/consequences in ecological interactions driven by OA. I wonder how this links with tipping points and thresholds in pCO2/pH? I think this is the only part missing here."

We now add this into the discussion here.

"Lines 323-334: Are there a couple key gaps that can be pinpointed here regarding identifying tipping points caused by CO2 and key pathways to fill these gaps? I mean apart from better quantitative analysis/projections."

We now add further recommendations to the manuscript. A greater physiological knowledge, how this adds to ecological outcomes, and better testing/further testing of species-specific responses across gradient type approaches in larger organisms (as has been done in phytoplankton etc for instance).

"Figure 1: It is not clear whether this figure shows the actual thresholds of pCO2 that cause a tipping point or represents the general ranges of where different communities are documented in these sites. Perhaps this can be clarified in the figure and legend."

This figure shows the general ranges of pCO2 where the different community shifts were observed. We now indicate this clearly in the figure legend.

"Table 2: I feel like table 2 can be supplementary. It does not seem to add too much more info to the text except as a support to table 1, which already contains references."

We are happy to move this back to the supplementary. We will leave this to the editor to decide.