Comments to the Author(s)

This manuscript is ambitious and seeks to connect "Physiological and ecological tipping points caused by ocean acidification," as its title indicates. To my knowledge, this question has never been explored in ocean acidification research field and is of crucial importance for understanding the occurrence of tipping points and their consequences for ecosystem and global earth system functioning. This review addresses research requirements highlighted in the latest International Pannel on Climate Change's reports and is of major interest for the scientific community. By connecting tipping points in the biosphere to those occurring in the ecosphere, this study is perfectly in the scope of the journal "Earth System Dynamics".

However, despite the critical interest of its research question, this article requires major revisions before being considered for publication. First, despite its title, the article fails to discuss the link between physiological tipping points and their ecological counterpart. To address this problem, efforts must be made to connect the second part, "direct impact on key physiological processes", and the third part, "changes at naturally high CO_2 locations". Key concepts discussed in the article (physiological tipping point, ecological tipping point, reaction norms) are not defined in the introduction, which threatens the understanding of the entire article. There is a lack of a whole body of literature (see references below) on physiological tipping points to ocean acidification, particularly for molluscs, echinoderms, and pteropods. Discussion of tipping points is almost absent in parts 2.2 and 2.3, which contrasts with the title of the manuscript. Part 3 on "Ecological Tipping Points" lacks important concepts such as "engineer species" to effectively link with Part 2 on "Physiological Tipping Points". A figure is missing to help readers understand the ecological concepts described in Part 3. Finally, despite its crucial interest for the study, Table 1 is not really discussed even if it could help to resolve some of the problems mentioned above.

If significant revision work is done, I believe this review could be of great interest to readers of "Earth System Dynamics" and to the scientific community working on climate change in general.

General comments

The term "photo-physiology" has an elusive and very broad meaning. Here, the use of the term "photosynthesis" would be more relevant and would unambiguously qualify the physiological phenomenon mentioned in this article.

Introduction

Lines 44-46: "*However, these analyses rarely assess changes in processes at specific time points or at pCO2 values corresponding to such time points. Instead, they usually determine whether standardised responses are different from zero.*" Why is it a problem not to analyse changes in processes at specific times or pCO2 values? I think it lacks a bit of context for the reader to understand the importance of studying changes in processes over a wide range of acidified conditions (pCO2, pH, Ω), i.e. reaction norms, in order to identify tipping points.

Key concepts for the understanding of the article and its relevance should be defined in the introduction: "physiological tipping point" and "ecological tipping point". What is the definition of a tipping point for a living organism? What is the definition of a tipping point for an ecosystem? What is their relevance for the acclimation/adaptation of species to climate change, the functioning of the Earth system and conservation/mitigation policies? Why is it so important to identify them? These concepts are never clearly defined in the article threatening the global understanding. This reference can help: *Carrier-Belleau et al., 2022. "Tipping Points and Multiple Drivers in Changing Aquatic Ecosystems: A Review of Experimental Studies." Limnology and Oceanography 67, no. S1: S312–30.*

Moreover, I think the article would benefit from defining the concept of "reaction norms" in the introduction. Indeed, establishing reaction norms (modelling physiological processes over a wide acidification range) is essential to identify tipping points. Reaction norms can take many different forms and can for example be non-linear, e.g. showing tipping points, or linear. This explains the different reaction norms observed in corals mentioned by the authors in lines 79-83. Therefore, defining the concept of "reaction norms" would greatly improve clarity for the reader. This should be done in the introduction when the authors discuss the different methodologies used in ocean acidification research.

Part 2. Direct impact on key physiological processes

Lines 56-57. "*However, there are also instances of resistant species or entire taxa (Kroeker et al., 2013b; Leung et al., 2022).*" Please specify the names of these taxa.

Lines 77-78. "*These three taxa are also identified as the most at risk from the effects of ocean acidification.*" Please add a reference.

Line 80. "*relationship.*" Replace with "reaction norm". Same comment for the rest of the article.

The paragraph, lines 94-105, on tipping points in mollusc calcification, omits references available in the literature referring to this issue. The following references must be included:

Bednaršek et al., 2019*. "Systematic Review and Meta-Analysis Toward Synthesis of Thresholds of Ocean Acidification Impacts on Calcifying Pteropods and Interactions With Warming." Frontiers in Marine Science 6.* This meta-analysis identify tipping points for the whole taxon of pteropods including for calcification and shell structure.

Lutier et al., 2022. *"Revisiting Tolerance to Ocean Acidification: Insights from a New Framework Combining Physiological and Molecular Tipping Points of Pacific Oyster." Global Change Biology 28, no. 10.* This study describes tipping points in the calcification and shell parameters of the pearl oyster.

Lines 120-135. This paragraph regrets the lack of studies determining the physiological tipping point in the response of species/taxa to ocean acidification, and in particular the lack of meta-analyses. Although rare, such studies does exist. There is, for example, two meta-analyses (Bednaršek et al., 2021, 2019). It is therefore necessary to cite more references so as not to give a false impression to the reader, for example (this list is non-exhaustive):

Bednaršek et al., 2021*. "Synthesis of Thresholds of Ocean Acidification Impacts on Echinoderms." Frontiers in Marine Science 8.*

Dorey et al., 2013 *"Assessing Physiological Tipping Point of Sea Urchin Larvae Exposed to a Broad Range of pH." Global Change Biology 19, no. 11.*

Lee et al., 2019. *"Tipping Points of Gastric pH Regulation and Energetics in the Sea Urchin Larva Exposed to CO2 -Induced Seawater Acidification." Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 234 (August 1, 2019): 87–97.*

Lutier et al., 2023. "Pacific Oysters Do Not Compensate Growth Retardation Following Extreme Acidification Events." Biology Letters 19, no. 8

Ventura et al., 2016. *"Maintained Larval Growth in Mussel Larvae Exposed to Acidified Under-Saturated Seawater." Scientific Reports 6, no. 1.*

Bamber, 1990. *"The Effects of Acidic Seawater on Three Species of Lamellibranch Mollusc." Journal of Experimental Marine Biology and Ecology 143*

Bamber, 1987. *"The Effects of Acidic Sea Water on Young Carpet-Shell Clams Venerupis Decussata (L.) (Mollusca: Veneracea)." Journal of Experimental Marine Biology and Ecology 108, no. 3*

There is almost no discussion of "tipping points" in subsections 2.2 and 2.3 on "photophysiology" and "internal pH regulation" even though this concept is emphasized in the title of the article. I understand that this is due to a lack of literature on the subject. However, I think it is possible to make assumptions about the existence of potential tipping points in these key physiological processes based on all the information presents in literature. For example, some thresholds seems to exist in the functioning of photosynthesis in organisms exposed to ocean acidification (Chen et al., 2014. *"A Red Tide Alga Grown under Ocean Acidification Upregulates Its Tolerance to Lower pH by Increasing Its Photophysiological Functions."*). For tipping points in "internal pH regulation", data are presents in Bednaršek et al. (2021) and Lee et al. (2019).

Part 3. Changes at naturally high CO_2 locations

I think the title of this part should be changed to "ecological tipping points" for clarity. Indeed, the study of changes in an ecosystem naturally rich in CO_2 is only one of the methodologies for determining tipping points, another being modelling. Further efforts should be made to define what ecosystem tipping points are, i.e. the transition from a stable to an unstable state, and why it is important to identify them (conservation policies, etc.). A conceptual figure would benefit the reader and greatly improve clarity.

Additional efforts should also be made to connect physiological tipping points with ecosystem tipping points. Indeed, for the moment part 3 is not really linked to part 2. The questions are: "What happens to a species when ocean acidification reaches its physiological tipping point?" "How does this translate into tipping points for the ecosystem? ». The authors are already exploring the modification of competition between species by ocean acidification in an attempt to link the physiology of species to ecology. However, this needs to be explored further, for example by discussing the key concepts of "engineer species", "trophic food webs" and "cascade effect". Some mesocosm experiments could also provide clues to the existence of ecological tipping points, for example:

> Legrand et al., 2017. *"Species Interactions Can Shift the Response of a Maerl Bed Community to Ocean Acidification and Warming." Biogeosciences 14, no. 23*
>
> Wright et al., 2018. *"Ocean Acidification Affects Both the Predator and Prey to Alter Interactions between the Oyster Crassostrea Gigas (Thunberg, 1793) and the Whelk Tenguella Marginalba (Blainville, 1832)." Marine Biology 165, no. 3*

This reference could also help:

> Monaco & Helmuth, 2011. *"Chapter Three - Tipping Points, Thresholds and the Keystone Role of Physiology in Marine Climate Change Research." In Advances in Marine Biology, Academic Press, 2011.*

Conclusion

Lines 326-328. "*Quantitative projections of the tipping points at which CO2 will have negative (or positive) impacts is also required for most taxa, where here we generally rely on semi qualitative assessments for all taxa except corals and coralline algae."* Incorrect, see reference list for echinoderms and molluscs above.