Biogeosciences Discuss., 8, C5120–C5125, 2011
www.biogeosciences-discuss.net/8/C5120/2011/

Biogeosciences Discussions

Interactive comment on "The metabolic response of pteropods to ocean acidification reflects natural CO_2-exposure in oxygen minimum zones" *by* A. E. Maas et al.

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Received and published: 30 December 2011

We thank the reviewer for her/his constructive suggestions for our paper. Below, we respond to each of the reviewer's comments on a point by point basis. Reviewer comments are in plain text and author response is in bold. In general we have attempted to better estimate the carbonate chemistry of our system and to explicitly express differences between surveys and collection methods and the potential impact on our results.

l-18-p 10296: Feely et al., 2004 is not a good reference for the increase of CO2 from 280 ppm to 390 ppm.

Replaced with IPCC, 2007

-l-20-p 10296: Maybe you should include a reference here.

Added reference for Sabine et al., 2004

-l-16-p 10298: Is 400 ppm significantly different from the "normal" CO2 concentration?

400 ppm was included as the theoretical CO2 concentration at 30° N in the open ocean as per Fabry et al., 2008. The oxygen minimum zone in the Gulf of California does not follow the pattern of the open ocean at this latitude, but instead has an O2 minimum and CO2 maximum similar to the ETP. The sentence has been revised to reflect this fact: "Specifically, in the ETP and Gulf of California around depths of 200 m, CO2 levels reach higher than 1000 ppm (Fabry et al., 2008; Paulmier et al., 2011)."

-l-18-p 10298: The fact that a $<$ 1 at 1000 ppm is highly dependent on TA and temperature. Are you sure that it is true at 10 °N? This statement need more details or it should be removed.

Fabry et al. 2008 published data supporting the claim that aragonite is undersaturated at 10 ° N. We have added calculations based on our pH, salinity, temperature profiles and applying WOCE data on alkalinity to support this statement: "Carbonate chemistry of the region was estimated using WOCE alkalinity values (P-18 1994 and 2008), pH and CTD profiles of salinity and temperature using the CO2sys developed by Lewis and Wallace (1998). WOCE alkalinity data from 200 m was relatively consistent at nearby latitudes between 1994 (2298 $\pm$ 9.2) and 2008 (2300.5 $\pm$ 4.5), suggesting that these values are reasonable estimates of OMZ alkalinity." "...these animals are surrounded by low pH water (7.4 – 7.5) and, based on the alkalinity of the region at 200 m (2300 μmol kg-1, WOCE data P-18 2007), are likely experiencing levels of CO2 1000 ppm by a depth of 200 m (Feely et al., 2004; Fabry et al., 2008; Byrne and Elliott, unpublished data). As-

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suming an average salinity of 34.7, a temperature of 10° C, a depth of 200 m (CTD data) and incorporating the measured pH with the known alkalinity of the region, aragonite is undersaturated in the OMZ (CO2sys; ΩAr = 0.65).”

-l-10-p 10299: More details on the collection of the organisms will be welcome. What was the depth of collection of the organisms? Which species were collected by scuba, which one by trawling?

Table 1 now contains information about the species collected during the discrete expeditions. Details of collection have also been added to the methods section: “We retrieved animals from a 61 cm-diameter 335 μm-mesh bongo net trawl, a 10 m2 Tucker trawl with a thermally protected cod end (Childress et al., 1978), or using SCUBA down to 30 m (Haddock and Heine, 2005). Individuals of each species were collected using all three methods.”

-l-13-p 10299: Why did you work at 20°C? I am a bit concerned by the temperature choice since you worked on species that can leave at much cooler temperature. For example if your organisms were collected at 50- 100 m deep, the temperature at the collection depth was $\sim$ 15 °C. Temperature could have a strong impact on your results, since the non-migrating species is the only one that is living at 20 °C.

Individuals of each species were consistently collected above 20 m where waters were above 20° C. Text has been added explaining the choice of experimental temperature: “This temperature was chosen to replicate the average temperature above the thermocline among the three stations. All species of pteropod in this study appear to regularly spend a portion of their day in the mixed layer, and it is here that the effects of ocean acidification will have an impact their physiology.”

-l-21-p 10299: Complementary information on the carbonate chemistry are critical to better assess the impact of reduced pH on pteropods. Please specify the pH scale use, the calibration method used, : : : Did you measure another parameter of the carbonate chemistry (DIC, TA,..)? Without these information it is difficult to place this study in the

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context of ocean acidification.

DIC and alkalinity of the system were not properly measured. Our estimates of the carbonate system are based on the known alkalinity of the region, and upon temperature, salinity and the pH calculations as described in response to Reviewer 1. Details about pH calculations have been added to the manuscript: "Profiles of pH in the ETP in 2008 were measured using the standard SOP for pH analysis with m-cresol purple (Byrne and Elliott, unpublished data)."

- The small dataset might have a huge impact on your results. Can you specify the power of your statistical test?

The low sample size has been explicitly acknowledged in the results section: "This low sample size and the large variability in oxygen consumption and ammonia excretion rates suggest that comparison between high and low CO2 treatments should be treated with caution for C. virgula."

-l-10-p 10301: The figure 5 do not show the differences in vertical distribution between species since the species are not specified on the figure.

The species labels were lost in revision and have been replaced.

-l-22-p 10301: Could you specify the pH scale of these measurements?

Text has been added to the methods to provide more explicit methods for the pH measurements: "Profiles of pH in the ETP in 2008 were measured using the standard SOP for pH analysis with m-cresol purple (Byrne and Elliott, unpublished data)."

- Discussion on the effects of the sampling (difference scuba / plankton net), temperature, small dataset should be included.

Results have been added to elaborate on the effects of sampling and the small dataset: "Species collected at multiple sites had no significant difference in

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metabolic rate (H. striata p = 0.66, C. virgula p = 0.27, C. pyramidata p = 0.17). Collection methods had no significant impact on metabolic rate (one-way ANOVA, F(2,66) = 0.215, p = 0.81). The number of individuals captured in good condition and usable for respiration experiments varied among species, with significantly lower abundances of C. pyramidata and C. virgula. This low sample size and the large variability in oxygen consumption and ammonia excretion rates suggest that comparison between high and low CO2 treatments should be treated with caution for C. virgula."

-l-22-p 10301: More details in the results would be necessary to do this statement.

The species labels that are now included in Fig 5 provide the data necessary to support this statement.

-l-08-p 10302: Since Diacria quadridentata was collected close to the surface, this species was probably less stressed by the sampling than the species collected deeper. Furthermore it is the only species living continuously at $\sim$ 20 °C, the incubation temperature. Could you discuss this issue?

Many of the organisms were captured at the surface as well as at depth. Post-capture treatment was designed to minimize differences in physiology as a result of thermal shock. The methods have been clarified to emphasize this point: "After capture, organisms were put into 0.2 micron-filtered water at densities $<$ 10 individuals l-1 and left to acclimate at 20°C for at least eight hours. This temperature was chosen to replicate the average temperature above the thermocline among the three stations. All species of pteropod in this study appear to regularly spend a portion of their day in the mixed layer, and it is here that the effects of ocean acidification will have an impact on their physiology. Acclimation was intended to allow all species to recover from thermal shock associated with different collection methods and to provide time for gut clearance."

Discussion was also added to remark on the physiological stress of continuous

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maintenance at 20° C: "Furthermore, this study was done exclusively at 20 °C, so animals which regularly migrate to depth may have been experiencing temperature stress from continual maintenance in mixed layer conditions. Since D. quadridentata appears to only be found above the thermocline, it would not be similarly impacted, potentially confounding interspecific comparisons of sensitivity to CO2."

Interactive comment on Biogeosciences Discuss., 8, 10295, 2011.