Biogeosciences Discuss., 10, C7459–C7464, 2013
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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "Exploring local adaptation and the ocean acidification seascape – studies in the California Current Large Marine Ecosystem" *by* G. E. Hofmann et al.

G. E. Hofmann et al.

hofmann@lifesci.ucsb.edu

Received and published: 18 December 2013

Below we outline the changes that we have made to the comments from Reviewer #4. In each case the comment from the reviewer appears first and is followed by our response.

Major Comments:

1) The concept of a broad mosaic of pH is introduced in the abstract and the introduction on page 11829 but is not defined. Most of the studies reviewed in this manuscript characterize the potential response of calcifying organisms to the large spatial variability of pH in the CCLME, so does the broad mosaic refer to this spatial variability? It

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would be valuable to explain what pH mosaic is in the introduction. If the pH mosaic as currently addressed in this manuscript is only referring to spatial variability, what about temporal variability, which is also large in the CCLME? One of the more powerful applications of high-resolution autonomous sensors is in describing the temporal variability of the environment. Does the OMEGAS group plan to address how calcifying organisms respond to natural gradients in temporal variability across the CCLME or may respond to changes in temporal exposure to low pH waters in the future? If so, it would be useful to address these future directions in the summary section.

We have clarified by noting that this is a spatial mosaic in the abstract and introduction. We agree that one of the value of high-resolution in-situ sensors is the ability to describe the nature of temporal variability at high frequency scales. We note however, that a first step is to test whether sites in fact differ from one another. This is particularly important in coastal environments where temporal variability have typically swamped our ability to uncover spatial patterns through discrete sampling. We certainly agree that the temporal attributes of pH variability (in addition to covariation between OA and other environmental stressors) can be important, and we have added a discussion in the Future Directions section to convey those key points per suggestion by Reviewer 3. Our primary interest here is in reporting the progression of research from first identifying site differences in pH and secondly by examining organismal responses across the range of observed in-situ exposures as a function of their origin. The coupling between the frequency content of pH temporal variability and the responses of organisms are important next generation research questions for our field, but are not questions that we have addressed in our current research. We can certainly speculate on these questions but feel that our present presentation of the alignment between spatial differences and mean state exposure studies are the best supported information to be conveyed.

2) Because the Chan et al. 2013 manuscript is in preparation, Section 2 starting on page 11831 requires a more detailed description of the methods and results of the chemical observations. While the Hofmann et al. manuscript is a review, it precedes

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published results of the OMEGAS project's chemical observations and should not refer the reader to research results in preparation. Section 2 should include a brief description of the methods, including how, where, and at what frequency pH, temperature, salinity, pCO2, alkalinity, and current magnitude and direction (i.e., the parameters mentioned in the introduction) were measured.

We now refer the readers to two papers that have been published since submission where description of pH methods and summary statistics for site differences can be found; these are Evans et al. 2013 and Pespeni et al. 2013). In addition, we have added descriptions of the data sources in Figure 2 including frequency for pH sensors and discrete pCO2 and total alkalinity samples for clarity. We have referred the readers to references for descriptions of mooring-based currents, temperature and salinity but have not expanded text as those results are not reported here and are mentioned of those parameters only serve to provide a more complete picture of the scope of the oceanographic observations that we are undertaking.

Figure 2 captures the overall exposure to low pH conditions over the entire summer of 2010, but what was the range of pH values measured, the average length of time that these low pH conditions persisted and how did these observations vary across the study sites ? Similarly, what were the patterns in pCO2 observations? The authors may want to consider adding a figure that illustrates these patterns.

As we note in our comment above, our preference is to focus on attributes of the pH environment that aligns with the biological studies that we performed and reviewed here. With respect to pCO2, we address this point below.

3) The manuscript mentions patterns of carbonate chemistry and present day pCO2 levels documented by OMEGAS, but the only observations of the carbonate system presented in the current version of this manuscript are pH observations. The authors need to be more explicit on how pH observations inform patterns in the other carbonate parameters. For example: a. Page 11834 lines 13-29: This paragraph begins by stat-

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ing experiments were conducted to test the response of organisms to variation in pH that was demonstrated by the OMEGAS observations, but the rest of the experiments reviewed in Sections 3 and 4 use variations in pCO2 levels to test organism response. In its current form, the manuscript does not describe the connection between pH observations and the pCO2 levels used in the experiments. Were pCO2 levels in the CCLME measured directly or calculated? If calculated, how? If measured, one way to make the connection between the chemical observations and biological experiments would be to add pCO2 obs to Fig. 2. Cumulative frequency of pCO2 _600 μatm or higher could be added as a secondary y axis. Or the authors could provide a brief summary of pCO2 variability documented by the OMEGAS observations as proposed in #2 above. In addition, authors should state the pCO2 levels used in the experiments. For example, what are the levels "representative of present-day pCO2 levels documented by OMEGAS field sensors"?

We now note in the text that for the intertidal environment, pCO2, along with alkalinity, were measured from discrete bottle samples. This information was used to constrain the possible range of pCO2. We further note that because pH and pCO2 are well recognized to covary tightly, this relationship and knowledge of the observed range in alkalinity provided constrained estimates of pCO2 levels for laboratory experiments. We have also added an estimate of pCO2 for pH of 7.7 as it relates to experimental treatments reported in Fig 3. Finally, we can frame the pCO2 choices used in experiments with data recorded by the OMEGAS sensors and have included those adjustments in the revised version of the text.

b. Page 11833 last line: In the current manuscript, only pH is presented, so this line should read "to this pattern of pH levels". c. Page 11832 line 5: In the current manuscript, only pH is presented, so this line should read "to describe shifts in ocean pH".

These suggested changes to the text have been made.

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4) Page 11829 lines 19-23: This sentence is confusing and needs to be modified. Changes in pH and saturation state in the ocean are driven by a variety of natural processes in addition to anthropogenic CO2. If the focus of this statement is the anthropogenic impact, it should read "Ocean acidification is driven by absorption of . . ."

We have made this change in the text.

5) Page 11831 lines 10-11: Bates et al. (2012) and Dore et al. (2009) report declines in pH of -0.0017 to -0.0019 yr-1, which equates to a 20 year change of -0.03 to -0.04. Please double check the decline in pH values presented here. The authors should also reference Santana-Casiano et al. 2007 (GBC, VOL. 21, GB1015, doi:10.1029/2006GB002788) for the ESTOC time series.

We have added Santana-Casiano et al. 2007 to reference.

We appreciate the reviewer's careful attention here. As we noted in the manuscript, the long-term trend is superimposed on a seasonal range of similar amplitude. In addition, rate estimates from the ocean time-series stations are sensitive to time windows and methods of pH calculations. We base our description of the lower end of the rate of change on Dore et al. (2009). In the supplementary material, pH-calc holds a 95% confidence interval of 0.0015 to 0.0022 for pH change per year, for pH-measured, a 95% confidence interval of 0.0018 to 0.0009. The latter yields our lower bounds estimate of -.02 unit change per 20 yr from the time-series stations.

6) Page 11839 line 26: Not until the summary is oxygen mentioned as another environmental factor in the CCLME. Considering low oxygen conditions occur with low pH and saturation state conditions in the CCLME, it would be beneficial to the broad audience of Biogeosciences to introduce this concept in the introduction.

We very much agree that considering low oxygen (in addition to other global change stressors) is essential. We have highlighted this importance in our summary section.

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Because understanding the interactions between low oxygen and OA were beyond the scope of our studies, we have opted to not emphasize this issue in the introduction.

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