

## ***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.***

### **Anonymous Referee #4**

Received and published: 5 November 2013

In this manuscript, Hofmann et al. review a novel project that is, to my knowledge, the first to combine chemical, biological, and ecological observations to address potential OA impacts over a broad geographic range. These types of observations will be critical to establishing a baseline of pH variability in the nearshore environment, quantifying responses of calcifying species and populations of calcifiers to natural variability and long-term change, and forecasting potential impacts of OA in the CCLME. This review provides a thorough account of recent results from the biological studies led by OMEGAS investigators and the future directions of the consortium. However, some revisions will be necessary in order to provide a more robust overview of the “pH mosaic” observed at the nearshore study sites (see comments 1 and 2 below).

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These nearshore pH observations are a key component to the OMEGAS goal of linking present-day environmental conditions to the physiological plasticity and potential adaptive capacity of organisms in the CCLME.

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 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.

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 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, pCO<sub>2</sub>, alkalinity, and current magnitude and direction (i.e., the parameters mentioned in the introduction) were measured. 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 pCO<sub>2</sub> observations? The authors may want to consider adding a figure that

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illustrates these patterns.

3) The manuscript mentions patterns of carbonate chemistry and present day pCO<sub>2</sub> 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 stating 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 pCO<sub>2</sub> levels to test organism response. In its current form, the manuscript does not describe the connection between pH observations and the pCO<sub>2</sub> levels used in the experiments. Were pCO<sub>2</sub> 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 pCO<sub>2</sub> obs to Fig. 2. Cumulative frequency of pCO<sub>2</sub> ~600 μatm or higher could be added as a secondary y axis. Or the authors could provide a brief summary of pCO<sub>2</sub> variability documented by the OMEGAS observations as proposed in #2 above. In addition, authors should state the pCO<sub>2</sub> levels used in the experiments. For example, what are the levels “representative of present-day pCO<sub>2</sub> levels documented by OMEGAS field sensors”?

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”.

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 CO<sub>2</sub>. If the focus of this statement is the an-

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thropogenic impact, it should read “Ocean acidification is driven by absorption of . . .”

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<sup>-1</sup>, 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.

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.

7) In its current form, the abstract does not provide a complete summary of the manuscript; it only describes the problem, introduces the OMEGAS project, and mentions the broad topics that will be discussed. The abstract is missing a couple sentences on the key findings and conclusions of the studies reviewed in this manuscript, such as the geographical difference in frequency of low pH waters and the patterns (or lack of patterns) in acclimatization and adaptation of calcifying organisms.

Minor edits:

- Page 11834 lines 1-3: “increasingly” used twice in this sentence.
- Page 11834 line 27: pCO<sub>2</sub> “values” or “levels” instead of “pCO<sub>2</sub>s”.
- Page 11834 line 28: delete pCO<sub>2</sub>.
- Page 11838 line 27: How is photosynthesis dependent on availability of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup>? Please explain or modify or add CO<sub>2</sub> to that sentence.
- Page 11839 lines 16-17: Should this sentence read: “Since it is the physical environment that makes a large contribution to . . .” not “. . .to make a large contribution to . . .”?

**BGD**

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C6388



- Figure 2: In caption, (A) should be 7.7 and (B) should be 7.8.
- Figures 4 and 5: What site is “Santa Barbara” and “SB” in Fig 4a and Fig 5b? Should these be Lompoc or LOL? Keep site names consistent with those presented in Fig. 1.
- Figure 4: Please fix this statement “from the Santa Barbara are and Van Damme were”.

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Discussion Paper

C6389

