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Interactive comment on "The effects of intermittent exposure to low pH and oxygen conditions on survival and growth of juvenile red abalone" *by* T. W. Kim et al.

T. W. Kim et al.

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Dear Referee #2,

We appreciate the valuable comments on our manuscript. We have analyzed the data and presented the results again considering your comments. We hope that our revision and responses below would satisfy your remaining concerns.

Anonymous Referee #2 Received and published: 23 April 2013

The paper by Kim et al. investigated the impact of simulated upwelling conditions on the mortality and growth of juvenile red abalone. This is an very important topic in the

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context of climate change in coastal areas. Upwelling conditions with low pH and oxygen concentrations will increase in frequency and time at the western California coast in the near future. The authors mimicked upwelling conditions in the laboratory for 6 hours (short-term) and 24 hours (long-term), for a comparison to present upwelling conditions and exposures as expected in the near future. Mortality and growth rates were determined during recovery in the following days. This is one of the first studies investigating the effects of upwelling conditions i.e. the combination of reduced pH and low oxygen on a commercially important intertidal snail. Short-term effects had almost no effect on abalone indicating its capability to cope with these conditions already. The authors explained this with an adaptation of the animals to present upwelling conditions. In contrast, so-called long-term upwelling conditions drastically decreased survival and growth. The authors suggested that low oxygen content is the main stressor for juvenile red abalone, because of its biggest impact on mortality. Interestingly, individual variability was highest under low pH and low oxygen conditions, indicating that some animals have already the capability to withstand even longer impacts for some reason. The paper is well written and gives an adequate introduction into the topic. However, for a better understanding of the experiment, some parts of the material and methods section should be improved, e.g. a scheme of the experimental set-up would be helpful in addition to the figure of the experimental treatment.

Responses: We now substituted the supplementary figure with a new figure to show the evolution of pH throughout the experiment to provide the better explanation how we have scheduled our experiment by answering the reviewer #1's comments.

Specific comments: An additional comment on the water-mixing properties of the set-up and the sea water chemistry within the jars would be helpful. The terms short- and long-term exposure may be misleading. So far as I understood, are upwelling conditions for 6 hours typical for this region? Isn't it therefore better to call the exposure times as "typical or normal" in comparison to "extended" exposures, for instance?

It is not clear, how animals, which died during the experiment, contributed to the analy-

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sis of growth rates. If possible the authors should separate the data between survivors and non-survivors. The authors presented growth and mortality rates only, which leads to a discussion with a lot of open questions. If the authors can provide additional parameters like sex, condition factor and other appropriate indices, it might be possible to get evidence, why some animals survived the experiments and some not. The authors should give some possible explanations together with a deeper discussion on the potentially involved physiological mechanisms behind the observed individual differences. For instance, literature on physiological responses of intertidal snails under hypoxia or hypercapnia is missing completely.

Response: We didn't have the facility to gradually change pH and oxygen value of the treatment seawater at the same time. So we just delivered the treatment water to the jar from seawater in normal condition through the 10 mm diameter hose at the 30 ml/min rate. It took about 15-20 min for water in the jar to be completely replenished with treatment water. We added the further details of the water chemistry in the Table 2. As the reviewer suggested, we substituted the "short-term" and "long-term" exposure with "typical" or "extended" exposure. We separated the data into dead and alive abalones and did analysis again. However, we didn't find any significant difference on the effect of "dead" or "alive" status of abalone or their interaction with treatment. We added this information in Lines 229-232. Other than growth and mortality, we currently don't have data of the other measurements. We are developing the idea for the next-step experiment and we added this issue in the Discussion. We also deeply discuss the issue of individual variation in the Discussion. Please see Lines 282-299.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/10/C2026/2013/bgd-10-C2026-2013-supplement.pdf

Interactive comment on Biogeosciences Discuss., 10, 3559, 2013.