

Interactive comment on “Response of the temperate coral *Cladocora caespitosa* to mid- and long-term exposure to $p\text{CO}_2$ and temperature levels projected in 2100” by R. Rodolfo-Metalpa et al.

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We appreciate the thorough reports of those reviewers #1 and 2. Their comments have significantly clarified and improved the revised version of the manuscript.

Both referees recommended publication of our ms in Biogeosciences, suggesting changes and several revisions to the text. Their comments are addressed below.

Referee 1

We made most of changes suggested by the referee. In particular, we use standard
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error throughout the ms; we deleted the sentence “In the light of this evidence, more experiments are necessary at lower pH levels, in order to discriminate between the two processes by using methods such as the ^{45}Ca uptake (Tambutté et al. 1995).” because incorrect as suggested by the referee.

Referee 2

"A more detailed mechanistic explanation is needed. It would be good if the authors embed their hypothesis in a general model for calcification, that explains why a slower calcification due to energy or saturation conditions is more resistant against decreased calcite/aragonite saturation." We would like to do that! A mechanistic understanding of the coral calcification mechanism, and therefore its response to ocean acidification, is critical. However, the calcification mechanism is still debated. The referee cited one of the theories formulated to explain the calcification mechanism, the Ca^{2+} ATPases. "By Ca^{2+} -H⁺-ATPases the pH is locally increased, leading to a shift in the carbonate system and thus enhanced carbonate". It is thought that carbonate is generated in or near the calcification sites, at the skeleton. This is generally accepted, and some studies have shown that coral calcification rates are directly related to seawater Omega aragonite, hence to the carbonate ions concentration. However, recent findings suggest that bicarbonate might play an important role in the calcification process (Herfort et al 2008, J Phycol 44, 91-98 and Jury et al 2009 Global Change Biology accepted article). In the light of this new point of view, we revised our manuscript adding to the discussion the following paragraph: "Many studies have shown a negative relationship between $[\text{CO}_3^{2-}]$ in the external seawater and calcification rates (e.g. Langdon and Atkinson 2005), making the carbonate ion the principal actor controlling coral calcification. Although ocean acidification also increases the concentration of bicarbonate, its role on calcification has generally not been considered. Jury et al. (2009) recently tested the separate effect of various parameters of the carbonate on the calcification of the Caribbean coral *Madracis mirabilis*. They suggest that the concentration of bicarbonate better explains changes in the rate of calcification than the concentration of

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carbonate.”

"Also the authors should design tests for their hypothesis. As it is now, we seem to have a circular reasoning: the low temperatures lead to lower oversaturation (lower carbonate concentrations), thus to lower calcification rates, and when we have lower calcification rates the carbonate supply is less critical. But exactly the carbonate concentration limits the calcification at low pH, so further decrease of carbonate by low pH should further limit the calcification rate." Assuming carbonate as the predominant actor in controlling the calcification rate of corals (see previous comments), Referee comment should be right: corals calcification rate is both indirectly affected by a decrease in temperature (see table 1: winter vs. summer), because the decrease in carbonate ions concentration, as well as directly effected by a decrease in carbonate ions (400 vs. 700). However, this mechanistic explanation does not consider that seawater temperature has a great effect on coral metabolism, controlling also the calcification rate. Indeed, the mechanism means that a decrease in carbonate ions concentration should affect more corals calcification at lower temperatures than at higher temperatures. This is in disagreement with our findings. *C. caespitosa* calcification in winter (13°C) was much lower than in summer (24 °C) both under acidified than normal pCO₂ conditions. We believe that either the slight decrease in carbonate ions concentration (16-25%) induced by the low temperatures (winter vs. summer, T vs T+3; Table 1), or the greater decrease projected for the year 2100, do not lead to a decrease in calcification rate of *C. caespitosa*. Calcification was controlled by only a change in temperature, not carbonate ions concentration.

"p7118 It would be good to explicitly state why the different methods to manipulate the aragonite saturation state lead to different conclusions." The following paragraph was added to address this suggestion: "The first explanation lies in the very different methods used to manipulate Ω aragonite in experimental studies, mostly by bubbling with CO₂-enriched air and addition of acid. These two approaches result in different outcomes (Gattuso and Lavigne, 2009). The former approach increases the concentra-

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tion of dissolved inorganic carbon (DIC) at constant total alkalinity and therefore mimics well the changes generated by ocean acidification. The latter approach decreases total alkalinity at constant DIC, which does not mimic well future changes in the carbonate chemistry. Methodological differences were suggested to explain for the various responses to ocean acidification reported in coccolithophores (Iglesias-Rodriguez et al. 2008) but this suggestion was subsequently discounted (Shi et al., 2009).”

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