

BGD-10-C4616-C4617 (2013) Anonymous referee #1

1. *“Significant correlations between max pH or saturation state and LAI and the range in pH or saturation state and LAI are reported. However, this is to be expected based on past work.”*

Comment: We disagree with this statement. Most of the literature on the subject has come out recently (i.e. Hoffman et al 2011, see similar discussion further below) and typically display fluctuations in pH for single sites, without attempts to test the possible driving factors accounting for differences in the strength of this effect. Whereas we concur that it makes sense to predict that LAI will be correlated to these fluctuations, as we do, this correlation does not fall from previous work. Moreover, Duarte et al. (2010) found only a weak relationship between seagrass biomass and metabolic rates. Most articles use biomass or coverage or do not report structural parameters at all when reporting pH fluctuations in the environment. For example even the recently published paper (this was published after the online publication of our paper in BGD) of Buapet et al. 2013 in *Marine and Freshwater Research* (<http://dx.doi.org/10.1071/MF12124>) looking at the effect of photosynthetic activity of seagrasses on pH uses only biomass and shoot density, not LAI. The fact that we explored several structural parameters in relationship with pH and that LAI emerged as the best predictor is important, because LAI is not routinely measured while biomass and dry weight are.

Hence the relationship with LAI is novel and represents a useful addition to the literature.

Action: The text of the revised version (Introduction) now reads “Whereas the capacity of Mediterranean *P. oceanica* meadows to affect pH is well characterised, and the relationship between pH variability, metabolic activity and water residence times in seagrass meadows have been described, not always a strong relationship is found. For instance Duarte et al. (2010) only found a weak relationship between biomass and metabolic rates, therefore detailed and simultaneous evaluation of several structural traits believed to drive these changes to assess which of those is the most important is still lacking.”

2. *The reviewer argues that the theoretical benefit to calcifiers has not been demonstrated, as average saturation state is not altered in the meadow. The reviewer agrees some benefit might be gained by alteration of minima and maxima, but feels that the existence of a sensitive response in consumers to short-term fluctuations needs to be demonstrated. The reviewer therefore suggests that our claim that seagrass production is creating refugia from the impacts of OA is too bold and suggests comparison with an appropriate reference site.*

Comment: We agree that we do not demonstrate here benefits for calcifiers, as we did not measure their performance, and have, therefore, toned down our

claims (abstract and discussion). We now pose the question of whether calcifiers would be affected by these fluctuations. Indeed, none of the 155 articles with experiments conducted to date testing responses of organisms to OA use fluctuating conditions (cf. Kroeker et al. 2013), so this cannot infer from existing experiments. We suggest that a fluctuating omega environment has implications for windows of calcification, as it may favour calcifiers relative to their performance under a comparable uniform average omega by enhancing the number of hours the organisms experience favourable conditions to calcify during the day. We conclude that future experiments should examine the behaviour of calcifiers under fluctuating omega conditions, as this study, as well as others, clearly show that organisms living in metabolic intense habitats do not experience uniform aragonite saturation states.

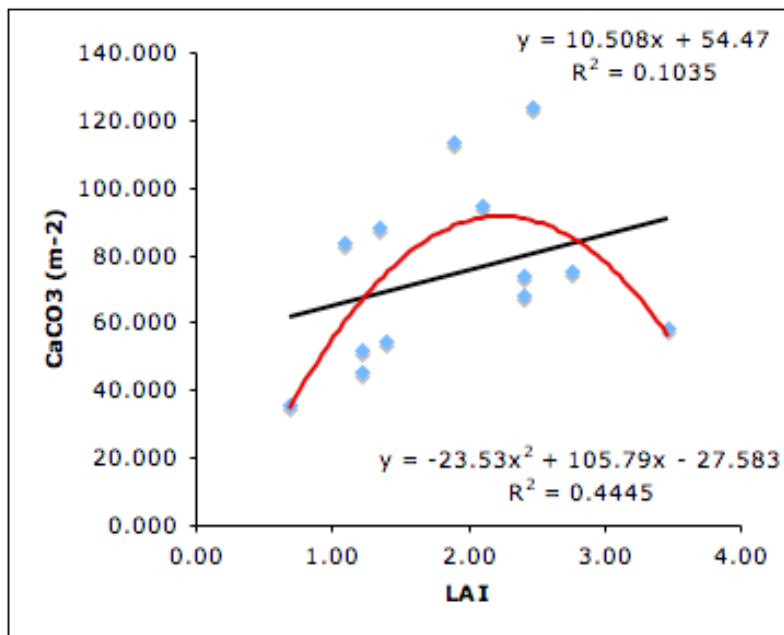
Furthermore, we consider the seagrass meadow would raise the average saturation state compared to sites without vegetation. However, it is impossible to find a proper reference site around our area as the seagrass cover is elevated and the influence of the meadow by transport of water masses, i.e. the foot print of the seagrass metabolism on the carbonate environment is enormous. For instance Gazeau et al. (2005) showed that the metabolic footprint of seagrass meadows down to 20 m depth in the Bay of Palma is translated in the $p\text{CO}_2$ signal in surface waters. The horizontal footprint is expected to be much larger than the footprint in the vertical dimension (as the horizontal component of velocity is an order of magnitude greater than the vertical component), and therefore, we would have to place sensors over 200 m away from the meadows, which would have resulted in altered conditions (e.g. depth), at the meadows studied, thereby providing a faulty control. We, therefore, believe that the best representation of the expected conditions in the absence of seagrass is provided by the intercept of the relationships between the various descriptors of the conditions and LAI (i.e. the values for LAI = 0).

Action: we now report the linear regression with intercept (LAI=0) in the Figure legends, and discuss (in the results) the amount of time the meadow elevated the pH above the mean pH for the hypothetical scenario where LAI would be 0 (i.e. without a meadow present in the bay). We added a column to Table 2 where this amount of time, as % of the total hours measured per site is added.

3. The reviewer asks to directly show a benefit to calcifiers demonstrating significant relationships between calcifier standing stock and LAI

Comment: We concur that this would indeed have been interesting, but may not have been conclusive for two reasons, first because (1) the epiphytic community is largely dependent on the surface available to colonize, and, therefore, a greater LAI is expected to lead in a greater epiphyte biomass even in the absence of effects on Omega, confounding the interpretation of relationships between calcareous biomass and LAI or Omega (correlated with LAI), and (2) the epiphytic community on *Posidonia oceanica* develops over many months (Cebrian et al. 1999), so that any effect of omega on the calcareous component of the epiphytic community operates over months, and may not be, therefore, adequately represented by omega conditions resolved over days. The relationship (Figure 6) between calcium carbonate and saturation state is weak but we chose to portray this relationship, and not LAI vs CaCO_3 as saturation

state would be the direct determinant for calcification processes, while LAI has confounding problems. For instance, as LAI increases, the effective surface for photosynthesis will not go up with the same rate as there will be increasing self-shading and exposed leaf surface would be a function of hydrodynamics (leaves laying flat under high velocities or swaying in orbital velocities with a resulting variable light environment over time), incident light and leaf surface (shading) itself. Indeed, the best fit for the relationship LAI – CaCO₃ is polynomial ($r^2=0.44$) and not linear ($r^2=0.10$), with a clear optimum; although arguably this could be caused by 1 outlier. Further, as calcareous epiphytes grow on the leaves, the light attenuation increases, so that epiphytic growth should lead to reduced metabolic rates and a reduced capacity of seagrass to affect omega beyond a particular load.



Citations used in this response

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- Duarte, C. M., N. Marbà, E. Gacia, J. W. Fourqurean, J. Beggins, C. Barrón, and E. T. Apostolaki. 2010. Seagrass community metabolism: Assessing the carbon sink capacity of seagrass meadows. *Global Biogeochem. Cycles*, 24, GB4032, <http://dx.doi:10.1029/2010GB003793>
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- Hofmann, G.E., J.E. Smith, K.S. Johnson, U. Send, L.A. Levin, F. Micheli, A. Paytan, N.N. Price, B. Peterson, Y. Takeshita, P.G. Matson, E.D. Crook, K.J. Kroeker, M.C. Gambi, E.B. Rivest, C.A. Frieder, P.C. Yu, and T.R. Martz (2011), High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison. *PLoS ONE* 6: e28983
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