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Interactive comment on "Technical Note: Artificial coral reef mesocosms for ocean acidification investigations" *by* J. Leblud et al.

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Interactive comment on "Technical Note: Artificial coral reef mesocosms for ocean acidification investigations" by J. Leblud et al.

Anonymous Referee 2 Received and published: 10 December 2014

–General comments– **This technical note describes methods used to set up and maintain simplified reconstructed coral reef communities, in closed-circuit aquariums (i.e., with reduced water changes), during several years, under conditions that mimic those, which prevail in a natural reef. Part of the control of the chemistry is biologically mediated. The manuscript is interesting because it shows that a technique of reef tank husbandry can be used to investigate the im-**

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pact of OA on a coral reef. Nevertheless, the method is not highly novel. Indeed, the experimental set up combines a series of well-known processes and systems such as interconnected tanks that reef hobbyists and aquarists have been using for many years to replicate and keep coral reefs away from the ocean. And the authors' statement that their mesocosm is an established ecosystem may be erroneous.

Thanks for your review. To make it clear about novelty of the method, we do not claim originality in the separate techniques and devices used to build the mesocosms, nor on the potentials to grow corals or keep a simplified coral reef community in a closed-circuit system. All those are well know to reef hobbyists and public aquaria maintainers. Yet, the use of such a system to study the effect of OA (or other physico-chemical changes in the environment) while maintaining realistic levels and daily fluctuations of main parameters like pO2, pCO2, pH, NH3, NO3-, PO4—, and to a certain extend, alkalinity Ca++, Mg++ in a closed-circuit system, is original. These challenges was clearly explained at the beginning of the Design part, p5:l-122-127. Concerning the question wether the ecosystem is established or not, we also give the definition of an established minicosm, which is related to recycling and stabilization of macronutrients in the system. This is explained at p14:l433 – 443 p15:l444 – 445 in the new version of the manuscript. Specific comments

Please see the text updates in the attached pdf file.

–P 15464: l 4-5: Why "water changes from the reef"? Water changes can be made using artificial seawater or natural water taken in a sea devoid of coral reefs.

Indeed, the sentence was changed accordingly at p1:l-6.

–P 15464: l 5-6: At this stage, without definitions of mesocosms and microcosms it's difficult if not impossible to understand the meaning of the sentence "with a more realistic physico-chemical environment than microcosms".

BGD

11, C8852–C8859, 2015

Sentence was changed according to this remark p1:l-5-9 :“Minicosms are defined here as artificial communities maintained in (semi)-closed systems, i.e. with limited and controlled exchanges with the external environment. They are run in the laboratory, or on site, with realistic levels, and field-like daily fluctuations, of the main physico-chemical parameters. Physico-chemistry is controlled thanks to a combination of biological controls and self- regulations and, where this is not possible, technical means.

–P 15465: l 1-2: To make things more understandable the authors should explain what they have in mind when they use the word “aquarium” and place here the definitions of microcosm and mesocosm they give later in the text.

The introduction was intensively reworked to clearly define aquaria, microcosms and mecocosms.

–P 15465: l 14: This sentence deserves explanations.

The sentence was reworked at p2:l-21-31

–P 15465: l 24-29 and P 15466: l 1-4: These considerations are relevant. However they might be too long and the authors’ arguments perhaps not at the right time and in the right place in the text so that one tends to lose the sense of the reasoning.

Introduction was reworked, and these information were added to the discussion at p14:l-430-436.

–P 15466: l 22: At this stage one doesn’t understand why the authors introduce a space- time scale in their definition of a mesocosm.

This information is indeed not necessary here and is thus removed.

–P 15466: l 24-25: The experimental set up described in this paper doesn’t correspond to the Odum’s (1984) definition of mesocosm: "bounded and partially enclosed outdoor experimental setups".

BGD

11, C8852–C8859, 2015

You are right, this precision was added.

–P 15467: l 3-4: All of the lab experimental set ups of this kind are artificial by essence but there are devices, which are less artificial than others. See for example Hazan Y.,WangensteenO.S.,FineM.,2014.ToughasarockâA ÌĘS ÌĄboringurchin:adult Echinometra sp. EE from the Red Sea show high resistance to ocean acidification over longâA ÌĘS ÌĄtermexposures.MarineBiology.61(11):2531-2545.

"Artificial" seems not to be the best term to use for our experimental design. "Artificial mesocosm" was thus changed into "minicosm".

–P 15467: l 7-26: These considerations are relevant. However they might be too long and the authors' arguments perhaps not at the right time and in the right place in the text so that one tends to lose the sense of the reasoning. This comment applies to the whole introduction.

The introduction was reworked and only presents the different studies from the literature. Comparison of the system was moved to the discussion where it is more appropriate, indeed.

–P 15471: l 19-25: The technique, which consists in connecting a tank to one or several sumps or refugia harboring photosynthetic organisms kept under reverse photoperiod, is well known. Reef hobbyists have been using it for many years to minimize the daily variations of pH and pO2. One can find on the market es- pecially designed timers (http://reefbuilders.com/2010/11/16/nature-aquarium-control- timer-compact-package-features) and aquariums equipped with refugia illuminated with a system called Reverse Daylight Photosynthesis (RDPTM).

We agree that it is a well-known method. The material and method was modified at p:8 l 228 – 237 to clarify this point, and the explanations about our refugia were synthesized.

–P 15472: l 6-8: One might wish to understand how "enough anaerobic zones" could lead to stabilized concentrations of orthophosphates. References?

The anaerobic zones have nothing to do with orthophosphates concentrations. Sentence was changed in order to avoid this misinterpretation at p 8:l-241-243. "A good balance between photoautotrophs, grazers and possibly some predators, together with efficient recycling of the organic matter is required. Moreover, anaerobic zones in the substrate promote denitrification."

–P 15472: l 18-19: The two years of tuning by trial and error needed to obtain the requested experimental conditions is the major inconvenience of this method.

The first setup of the system took quite a long time due to the different trials, but future experiments can be performed faster given these first data.

–P 15474: l 4-5: The authors forget to mention that, in a mesocosm: -Nitrification, which releases protons, is a major cause of alkalinity consumption, and -Bioerosion (bacteria, cyanobacteria, boring sponges etc.), which dissolves CaCO3, is a major source of alkalinity. These processes deserve better developments.

We agree with your comment, nitrification also decreases alkalinity while bioerosion increases it. It was added in the explanations at p8l:-215. Nevertheless in a coral reef minicosm with fast growing hermatypic corals, calcification is by far the highest factor of the alkalinity change. Almost 2 kg of hermatypic scleractinians were placed in the experimental aquaria at the beginning of the experiment. The average skeletal growth of these organisms was around 1Regarding bioerosion, it was estimated in the present experiment and was equal to 0.02 mol.day-1 in each mesocosm: it has thus 10 times less impact on alkalinity than calcification.

–15481: l 14-15: One wonders why the pO2 was monitored only during 5 days at the end of the experiment. pO2 was measured every two months in each experi-

BGD

11, C8852–C8859, 2015

mental aquarium during all the experiment. Nevertheless oxygen exchange modeling was only performed during five days at the end, due to limited availability of the O2 probes (they were also used for measurements in respirometers). It was added at p11:l-324-327.

–15482: l 1-6: The differences between laboratory based artificial mesocosms and microcosms are not enough clear.

The difference resides in the way daily fluctuations of main physico-chemical parameters are controlled: no particular control for microcosms, and control down to realistic fluctuations as much as possible according to a reference site in the field for, now called, minicosms. However, the distinction is critical because for the same average value of a parameter under control (the value that is usually provided in publications), variations may be more of less important and more or less realistic between the day and the night. This impacts, of course, living organisms in the micro/mesocosms. The minicosm's definition was emphasized in the beginning of the discussion p14:l-430-436.

–15482: l 9-15: The authors utilize many artificial means to control the chemistry of their experimental tanks. Hence, one can think that an ecosystem, which is so much artificially constrained, might not behave similarly to a natural one.

We completely agree. As explained at p17:l-536-538,"Minicosms will always remain complementary tools, because, being artificial, results cannot be extrapolated carelessly to natural ecosystems."

–15482: l 22-23: "small technical input". The technical input is artificial and big, not small! We agree, the term 'small' was pointless. The discussion was reworked and this sentence was removed.

–15483: l 11: "dead fishes". It would be interesting to know what was the biomass and composition of the fish populations. Yes, we now give details about

BGD
11, C8852–C8859, 2015

the fish introduced in our minicosms in the material and methods at p10:l 278-281.

–15483: l 23: The experimental set up includes a mechanical perlon filter and a protein skimmer, which removes particulate and dissolved matters. In this respect, the claim that artificial filtration is limited to a strict minimum is questionable.

Natural reef ecosystems are open systems connected both with open ocean and with adjacent ecosystems. In this regards, they exchange matters with other systems. In closed systems such as laboratory controlled minicosms, these exchanges have to be simulated mechanically. Perlon filter allows to catch particles which otherwise would sediment on coral colonies: sedimentation can cause several damages (see Sheridan et al 2014). Skimmer, which catch organic matters, is essential in such closed systems to remain in oligotrophic conditions (Delbeek and Sprung, 2007). It is thus required to simulate the exports in such a closed system. The Figure 4 now explains these concepts. Without such a filters, the closed system would appear more artificial, due to the inexistence of outputs from the ecosystem.

–15485: l 10-12: "the simplified ecosystems (...) had the opportunity to follow their own "evolution". Reef hobbyists know very well this phenomenon, which (I think) casts doubt over the ability of the experimental set up to reproduce the long-term evolution of a natural ecosystem. Yes, it is hard to consider that both mesocosms are true replicates at the end of the experiment.

The same remark can be made about natural ecosystems: they are all unique and have their own histories. This is, indeed, a major characteristic of a complex system with many degrees of freedom. We observe, here, that a minicosm that is more complex than an aquarium experiment as we defined in the paper, shares the same property. Each minicosm is unique and tends to follow its own path after a certain time. Thus, on the contrary, a minicosm is more similar to a natural ecosystem in this aspect... but that prevents somehow easy interpretation of replicated systems.

BGD

11, C8852–C8859, 2015

–15487: l 1-8: These considerations give the feeling that the method includes a large part of empiricism, which cast doubt over its interest as a scientific tool.

Everybody studying complex systems knows that there is a part of its behavior that is unpredictable. Nevertheless, there is an abundant literature about the study and modeling of such systems. All these models are, by nature, a simplified view and they often if not always, contain adjustment parameters. Still, these remain serious, scientific and well-documented studies. Here we deal with experiments with one such complex system (our artificial reef ecosystem). So, yes, it was not possible to predict in advance how all aspects of the minicosm change with time and we noted a difficulty with the separate refugia in the particular case of different pH conditions. This is certainly a starting point for further investigations and enhancements... yes, but to state that the whole system looses interest as a scientific tool seems a little bit exaggerated.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/11/C8852/2015/bgd-11-C8852-2015-supplement.pdf

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