

Interactive comment on “I / Ca ratios in benthic foraminifera from the Peruvian oxygen minimum zone: analytical methodology and evaluation as proxy for redox conditions” by N. Glock et al.

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We thank the reviewer for his constructive comments and positive feedback. Below we comment in detail the points of revision.

JB: I have received this manuscript before for a so called “quick review” and provided some comments. Many of those comments have already been taken care off in the present manuscript but some issues remain. First of all, this paper is a valuable contribution for BG(D). The msc is well written but some formulations should be checked by a native English speaker. For instance, introduction, line 14, p. 11639: “foramnifera” should be “foraminifera”. Introduction, line 23: “oceanic warming” should be “ocean

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warming”. Line 25, p. 11647: “Due to the TROX model the living depth ...” should be “According to the TROX model, the living depth ...”. Line 29, p. 11647: “... to migrate in the pore waters. . .” should be “. . . to migrate into the pore waters . . .”. These are just a few examples. Also, please spend some “;”.

Reply: The suggested changes have been done. The paper has been native checked.

JB: Below are a few minor remarks. The text can also be more concise, for instance: Abstract, line 5-7: “We test cleaning and measurement methods to determine I / Ca ratios in benthic foraminifera from the Peruvian oxygen minimum zone.” Leave out the last part because you have already mentioned that. Just write: “We test cleaning and measurement methods to determine I / Ca.”

Reply: As the reviewer suggested we changed this sentence in the revised version of the manuscript:

Cleaning and measurement methods for the determination of I/Ca ratios are tested.

JB: Also: Abstract, line 12-14: “Although I / Ca ratios in benthic foraminifera might prove to be a valuable proxy for changing redox-conditions the iodine volatility in acidic solutions, ::: ”. Leave out the first part to be more concise: “The iodine volatility in acidic solutions, ::: ”. Abstract, line 15-16: “severely interfere with ::: ” change to “need to be accounted for when applying the :::”

Reply: As the reviewer suggested we changed this sentence in the revised version of the manuscript:

The iodine volatility in acidic solutions, the species dependency of I/Ca-[O₂]BW correlations, and the individual variability of single tests need to be accounted for when applying the I/Ca ratio as a proxy for redox conditions.

JB: The authors picked two infaunal species and two epifaunal species: Is there any proof that “In an eutrophic environment like the Peruvian OMZ where organic matter at the seafloor is available in excess (Mallon et al., 2012) an overprint by the organic flux

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is not to be expected.” (line 15-17, p. 11639)? I doubt that and would still expect to see a difference between bottom and pore water. . .

Reply: Actually this was a misunderstanding from our side regarding the initial “quick review”. Of course oxygen is consumed within the pore waters by the degradation of organic matter and later in the paper we also commented on oxygen profiles within the pore water. This sentence has now been removed from the introduction since it was intended to comment on the influence of organic matter on the living depth of infaunal foraminifera according to the TROX model and not on the diagenesis of organic matter. Furthermore we changed this part of the introduction slightly to avoid further misunderstandings:

Infaunal foraminiferal species are able to migrate into the pore waters. Oxygen in the pore waters is consumed by the diagenesis of organic matter (Froelich et al. 1979), which might complicate quantitative O₂ reconstruction through infaunal species. Nevertheless, bottom water oxygenation usually has a strong influence on the oxygen gradient and penetration depth into the pore waters (Morford et al. 2005), which justifies to use also infaunal foraminiferal species for this study.

JB: . . .and in line 11, p. 11647 you write: “. . .since the oxygen gradients in the pore waters are quite steep.” Any data available?

Reply: Actually there is no published data available from the Peruvian oxygen minimum zone regarding this topic. Nevertheless, unpublished data (Sommer et al., pers. comm.) is showing, that at 1000 m water depth where fluctuations of bottom water O₂ in the range of 30 to 44 μ M were recorded (Sommer et al., unpublished data) in situ micro-profiling revealed that O₂ penetration depth into the sediments only reached a maximum of 5 mm. The boundary to the permanent anoxic center of the Peruvian OMZ is located at around 500 m depth and closer to that boundary oxygen in the pore waters was not even measurable at all. Since this data is not published and cannot be cited in our manuscript we changed this part and added the following citation regarding

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oxygen pore water profiles from the OMZ off Pakistan:

This difference might either be related to a strong vital effect or to a species dependant difference in calcification depths. Oxygen gradients in the pore waters of a comparable OMZ off Pakistan are quite steep under suboxic conditions (Bogus et al., 2012) and IO₃- probably follows this gradient. Thus, a difference in calcification depth might have a severe influence on the I/Ca ratio.

JB: Although this msc focusses mostly on “analytical methodology and evaluation as a proxy for redox conditions”, it would be good to expand a bit more on some of the other aspects, that are just as important if applying proxie relationships. The authors already did quite a good job in section 4.2 but could, if data allow, be more specific. For instance, if you look at the variability of I/Ca (see 4.2, p.11646, line 17-20: “Furthermore, the variability of foraminiferal I/Ca ratios by location (e.g. [O₂]BW) or species is much higher than the uncertainties discussed in Sect. 4.1, which indicates that the trends in the I / Ca-[O₂]BW relationships are robust in respect to the technical issues.”), it seems that, at this stage, it is more of a qualitative proxy (more or less oxygenation) than a quantitative one. They should comment along those lines or add some additional information. . . .

Reply: We added the following sentence into the discussion regarding this topic (Page 11 line 18-20):

Regarding these issues, samples have to be carefully prepared and measured or foraminiferal I/Ca ratios might be considered more a qualitative to semiquantitative proxy at this stage.

JB: . . . For instance, line 2-3, p 11647: “Consequently, some samples are limited to one analysis.”. If data are available, I suggest to add a discussion on “patchiness” (how much of the signal is local variability) and to add a statistical discussion on how large the sample size should be to get robust numbers (e.g. use a “Jack-knife” technique).

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Reply: Unfortunately there is no data available about the foraminiferal patchiness off Peru nor on the influence of patchiness on I/Ca. All sample duplicates we measured are from the same cores and not from other cores close to the first core. The statistical discussion on how large the sample size should be using the “Jack-Knife” technique is completely out of focus of this initial study on foraminiferal I/Ca ratios. “Jack-Knifing” makes sense if a high amount of replicate measurements on different specimens from the same location is available like in the study of Schiffelbein and Hills (1984): We got a maximum of 5 replicate measurements on different specimens from the same location (not ~30 like Schiffelbein and Hills).

JB: Last but not least, the last sentence in the conclusion reads: “When samples are carefully prepared and measured, accounting for the pitfalls outlined here, the resulting I/Ca ratios from benthic foraminifera analysis may be considered a robust proxy for redox conditions in the ambient water mass.” In the light of the discussion, I suggest to tone down this conclusion.

Reply: We toned this sentence a bit down in the conclusions of the revised manuscript: When samples are carefully prepared and measured, accounting for the pitfalls outlined here, the resulting I/Ca ratios from benthic foraminifera are considered to be a promising proxy for redox conditions in the ambient water mass.

Reference: Schiffelbein, P. And Hills, S.: Direct assesement of stable isotope variability in planktic foraminifera populations, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 48, 197-213, 1984, DOI: 10.1016/0031-0182(84)90044-0.

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