

***Interactive comment on* “The benthic foraminiferal community in a naturally CO₂-rich coastal habitat in the southwestern Baltic Sea” by K. Haynert et al.**

K. Haynert et al.

khaynert@geomar.de

Received and published: 19 September 2012

REPLY TO REVIEWER'S COMMENTS:

We thank both reviewers for taking the time to scrutinize our manuscript. The comments were thoughtful and constructive helped to improve the manuscript. We addressed the questions and amended the parts of the manuscript which were criticized. Please find our replies to the reviewer's' comments in the following.

REVIEWER 1

SPECIFIC COMMENTS

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REVIEWER 1: Two different diversity indexes were calculated for the foraminiferal community and shown in Table 5, but I miss any interpretation of these data.

REPLY: Calculations of both diversity indices exhibited too low values at all stations during the one year cycle. These implied a low diversity of living and dead assemblages. There is a maximum of 8 species constituting the community. Hence, any changes in assemblages composition will induce only low differences in the diversity. Therefore, we have decided to omit the diversity indices in the respective chapters.

REVIEWER 1: Results, living assemblage: a) Maximum numbers at station FF1 in October indicate numbers around 50 ind. 10 cm⁻³ in Fig. 4, but the authors mention 101 ind. 10 cm⁻³ in the text and in Table 5. Figure 4 has to be checked.

REPLY: We checked the Fig. 4 again, changed the y-scale which was wrong.

REVIEWER 1: Results, living assemblage: b) Pie charts are one way to show foraminiferal communities, but they base on percentages, and this can sometimes be problematic. For example, at station FF1 *Ammonia aomoriensis* makes 61% of the fauna in April, but the total density of foraminifera is very low in April. Actually, counts of *A. aomoriensis* are low and living conditions for this species at this station are not good in April. Table 5 gives no information about bi-monthly counts per 10 cm⁻³ on species level, but I think this will be interesting (as an additional table or figure for the three main species) because the response to carbonate chemistry changes seems to be species depending, as the authors show later in the manuscript.

REPLY: We prepared a new table with population densities and abundance of the three dominant species. Table 7 was included in supplements.

REVIEWER 1: Results, living assemblage: c) The last part of this chapter (p. 7794, line 9-12) is an interpretation and does not belong to the results. Additionally, I cannot follow the explanation here, why should *A. cassis* immigrated into the community, it was always found living at this station, even in August 09 (at least one living individual in a

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low split was mentioned in Table 5) and therefore reproduction instead of immigration would also be possible, maybe both.

REPLY: We changed the last part of the chapter. We agree that reproduction events are the main reason for high population densities of *A. cassis* in October and December at station FF4. The parameter which influences the frequency of *A. cassis* is described in the discussion chapter 5.2.

REVIEWER 1: Results, dead assemblage + Discussion, Foraminiferal community: I am surprised about the bi-monthly high variations in the abundance of dead foraminifera at the stations. I think this cannot be explained with living assemblages alone, because living assemblages often do not show these high variations here (e.g., FF1, June to October). Other factors should be discussed (what about transport processes in this area?).

REPLY: We think transport processes do not play an important role in this case. During the one year sampling, the corer station was exactly defined, however, due to an unpreventable drift of the vessel, the sampling on the repeated cruises did not take place at exactly the same position. Foraminiferal assemblages are most probably not evenly distributed. It is well known, that patches of 1-3 m in diameter prevail on sand bottoms with high variations in population density of dominant species. It is therefore considerable, that such patch of high diversities of living species also produces a higher number of empty tests to the dead assemblages at this place. We assume that the sediments could mirror the high degree of patchiness. Therefore already a small deviation of the sampling point may cause some degree of variation, in the dead assemblages.

REVIEWER 1: Results, co-variance of population density: Did the authors test co-variance between *Ammotium cassis* and saturation state, too? Although this is an agglutinated species, it may response indirectly to changing carbonate chemistry in the habitat because it shows advantages under undersaturated conditions.

REPLY: We tested the co-variance of *Ammotium cassis* and saturation state, but no

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correlation was recognized. The data provide no evidence that *Ammotium cassis* could be affected by changing carbonate chemistry. In the current study, we will focus only on the calcareous specimens, because they directly respond to changing carbonate chemistry.

REVIEWER 1: Results, tests of living calcareous foraminifera: the whole chapter needs modification and better explanations. a) 64% of the tests of living *A. aomoriensis* were intact, the remaining 36% showed different stages of tests, classified as (1) intact tests, (2) + (3) loss of chambers. When reading this text, it is not clear for me how to distinguish intact tests from the first 64% and intact tests of the rest.

REPLY: We revised the chapter as specified below.

REVIEWER 1: Results, tests of living calcareous foraminifera: b) In the first part of this chapter, authors mention the observation of chamber loss. In line 26 on page 7797, they suddenly start to speak about dissolved chamber walls that were heavily decalcified. For me, the loss of chambers means that they are gone and there is no wall left. Otherwise, chambers show holes, as indicated in Fig. 6:4.

REPLY: By the term 'loss of chambers' we wanted to describe the observed dissolution/decalcification on the tests of *A. aomoriensis*. As this term is misleading we changed it 'dissolution stages'.

REVIEWER 1: Results, tests of living calcareous foraminifera: c) The authors mention Fig.6:1-3 as examples for irregular shape and interruption, but in the legend they describe it as "recalcifying". The authors mention Fig.6:5 as an example for the loss of two chambers, but I cannot see two chambers missing.

REPLY: We revised the legend of Fig. 6 and added "irregular test shape". In this figure we refer to dissolution/decalcification of the last chamber or more than two chambers not to a complete loss. Fig. 6: 5 exhibited clearly dissolution features on the whole test.

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REVIEWER 1: Results, tests of living calcareous foraminifera: d) It would be interesting to see pictures of the individuals from station FF4 that have left only the inner organic lining.

REPLY: Our statement was based only on few observations during picking under the microscope. As we did not quantify this feature or took pictures. The observation was confirmed by another colleague. However, we keep with mentioning this observation but will not put deciding emphasis to it.

REVIEWER 1: Results, tests of living calcareous foraminifera: e) Maybe the number of observations is too low, but is it possible to observe any correlation between recalcification processes and changes in the saturation state?

REPLY: That's a really important point for further studies. Unfortunately, the data set of recalcification based on few observations of some specimens, therefore it is not possible for us to correlate these observations quantitatively with changes in the saturation state.

REVIEWER 1: Discussion, Foraminiferal community: Page 7798, line 4-5. Why do the authors think that oxygen conditions were favourable in October 2009 at this station?

REPLY: We speculated that oxygen could have been favorable and may have played an important role of population densities, but we did not measure it. Consequently we revised the sentence.

REVIEWER 1: Discussion, Comparison with earlier finding: Faunal differences between FF4 and FF5 in 2009 and between 2006 and 2009 are very strong. Are there any additional environmental data available in the area that may help to understand this change? Do other groups of organisms show similar variations here?

REPLY: To date, we have no further environmental data available, which would help to understand this change in the living assemblages between the stations and the years. We therefore suggest, that the sediments could be characterized by a high degree of

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patchiness.

REVIEWER 1: Discussion, Impact of rising atmospheric CO₂: Page 7804, line 19 ff: For me, the last paragraph about planktonic foraminifera is not directly connected to the topic of the manuscript and therefore redundant.

REPLY: We concede, planktonic foraminifera are not directly connected to the topic of our manuscript. However, and in order to highlight the profound differences between the carbonate chemistry in pelagic and benthic environments and also their changes by ocean acidification, we would like to keep the paragraph. See also comment by reviewer 2.

REVIEWER 1: Conclusions: Page 7805, line 5-7: Sediment pore water is often, but not always, supersaturated, as the authors showed before. The text should be adapted here.

REPLY: The text was adapted in the conclusion chapter.

REVIEWER 1: Figure 4: For me, increasing and decreasing population densities in the living fauna seem to follow the trends of increasing and decreasing pCO₂ in the pore water, which has probably something to do with food supply and degradation processes in the sediment. It would also be interesting to see the undersaturated and supersaturated situations at the different time intervals in this figure (maybe with different background colours, or horizontal bars?).

REPLY: In fact, the patterns suggest a certain co-variance. However, food supply and degradation of organic matter certainly influences the carbonate chemistry of the sediment and could explain the fluctuations in the living assemblage (see discussion, chapter 5.2). But the dead and living assemblages were not directly affected by changing pore water pCO₂, respectively $\delta^{13}C_{org}$. A further parameter in figure 4 would make it difficult to understand the figure. Therefore, we added new figure 9 in the supplements which includes the relation to $\delta^{13}C_{org}$.

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TECHNICAL CORRECTIONS AND MINOR COMMENTS

REVIEWER 1: Page 7786, line 8: Maybe better start the sentence with “Calcareous benthic foraminifera are common. . .”

REPLY: We changed the beginning of the sentence to “Calcareous . . .”.

REVIEWER 1: Page 7791, line 11: " from -0.9 to 1.1. . . .

REPLY: The mistake was corrected.

REVIEWER 1: Page 7793, line 18, Fig. 9: It is very irritating for the reader that Fig.9 will be mentioned in the text very early, between mentioning of Fig. 3 and Fig.4, and I suggest converting Figure 9 in Plate I.

REPLY: We changed Fig. 9 to Plate 1.

REVIEWER 1: Page 7794, line 14: “During the whole investigation period (except of June at FF4 and FF5),”

REPLY: We included “(except of June at FF4 and FF5)”.

REVIEWER 1: Page 7794, line 23: something is missing in this title, maybe: “Co-variance of population densities of living specimens with saturation state”

REPLY: We changed the title to “Co-variance of population densities with respect to carbonate chemistry”.

REVIEWER 1: Page 7795, line 2, line 12 + line 13: I guess that 5, 15 and 53 ind. 10cm⁻³ are average values, but it is not really clear in the text.

REPLY: The values of population density are mean values, this has been clarified in the text.

REVIEWER 1: Page 7796, line 2: “...left in October and December.”; not February?

REPLY: We corrected the mistake and included February.

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REVIEWER 1: Page 7800, line 18: "...that foraminifera respond..."

REPLY: Corrected.

REVIEWER 1: Figure 6: I suggest dividing this figure in a) upper part, graphs, and b) lower part, pictures

REPLY: We separated figure 6 in two parts.

REVIEWER 1: Figure 9, 2: Probably *Ammonia aomoriensis* instead *A. beccarii*, I guess?

REPLY: *Ammonia beccarii* was the wrong taxon, we changed it to *Ammonia aomoriensis*.

REVIEWER 1: I miss some hints in the manuscript concerning the content of the supplementary material.

REPLY: We included the missing hints of the supplementary material in the text.

REVIEWER 2

SPECIFIC COMMENTS

REVIEWER 2: Diversity indexes, Shannon H and Fishers alpha, were calculated, but not shown in the text. Results should be stated, or the respective chapters can be deleted.

REPLY: See reply to the first comment of Reviewer 1.

REVIEWER 2: Reviewer 2 questioned that foraminifera globally precipitate 0.2 Gt CaCO₃ per year of which one-third is produced by planktonic foraminifers and demonstrated that our values were not in agreement with the cited literature. Furthermore was noted, that the magnitudes and conversions were not enough explained for most of the readers.

REPLY: This is a very important comment, we re-investigated the information sources,

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corrected the mistake and explained the subject in more detail (see text and supplements, table 9). Indeed, we had largely misunderstood the figures provided by Langer (2008). Following Catubig et al.(1998) and Schiebel (2002), planktonic foraminifers precipitate on average 3.24 and export 2.9 Gt CaCO₃ from the photic zone per year on a global scale, of which about 0.9 Gt accumulate on the sea floor in pelagic environments. From data presented by Hallock (1981), Langer et al. (1997) and Wefer and Lutze (1978), we reckon a benthic foraminiferal carbonate production of 0.04 Gt yr⁻¹ in coral reef and shallow water carbonate environments, and 0.03 Gt yr⁻¹ on non-carbonate shelves. For other neritic environments, we assume a benthic foraminiferal carbonate production of another 0.03 Gt yr⁻¹ with reference to the data provided by Milliman and Droxler (1996). In total, we therefore estimate a neritic foraminiferal carbonate production of 0.1 Gt yr⁻¹. Loss due to erosion, dissolution or export from the shelves may vary between 13 % in reef environments and 95 % or even more on non-carbonate shelves (Langer et al., 1997; Wefer and Lutze, 1978; Milliman, 1993). The neritic benthic foraminiferal carbonate accumulation is therefore estimated to 0.045 Gt yr⁻¹. If we take the global benthic foraminiferal carbonate burial rate of 0.2 Gt yr⁻¹ at face value (Langer, 2008), calcareous benthic foraminifera from the continental slopes and deep sea basins contribute 1.5 Gt carbonate per year to surface sediments. Considering an average preservation of about 45 % of deposited carbonate particles when they are incorporated in the sedimentary record, a global carbonate production of pelagic benthic foraminifera would be in the order of 0.32 Gt yr⁻¹, supplementing the global benthic foraminiferal carbonate production rate to 0.4 Gt yr⁻¹, which is not less than a seventh the export production of planktonic foraminifera at 100 m water depth (Schiebel, 2002). The growth and dissolution of planktonic foraminiferal tests is of great importance to sustain the global alkalinity flux (Milliman et al., 1999). Once their carbonate export to deeper waters is diminished at rising pCO₂, shallow marine benthic foraminifers will either sustain their carbonate production (e.g. McIntyre-Wressnig et al., 2011, this study) or even increase as with some symbiont-bearing reef foraminifera (Fujita et al. (2011)). We therefore argue that a shift in foraminiferal carbonate produc-

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tion from pelagic to neritic environments is to be expected.

TECHNICAL CORRECTIONS

REVIEWER 2: page 7791, line 11: I guess you mean -0.9, but not 0.9, because -0.9 was given as the minimum temperature in line 5, same page.

REPLY: Corrected.

REVIEWER 2: page 7800, line 1-2: What dominance do you refer to, living, or dead, or total assemblages?

REPLY: We refer to living assemblages of *A. aomoriensis*, corrected.

REVIEWER 2: line 10: You quote Ellison 1986, but this is not referenced; I guess you mean Ellison et al. 1986 (as given under References)?

REPLY: We corrected the reference.

REVIEWER 2: line 21: same with Allison 2010 (not referenced), but Allison et al. 2010 (see References)?

REPLY: Corrected.

REVIEWER 2: page 7802, line 24: Stouff et al. 1999b cited (and found as such under References), but only one reference given, thus delete 'b'.

REPLY: The "b" in Stouff et al. 1999 has been deleted.

REVIEWER 2: References: Alphabetic order of single, double and multiple authorships must be checked, see for example Dickson, A. G., or Langer M. R..

REPLY: References were revised and reordered according to the journal instructions.

REVIEWER 2: Figure 9: modify the 'formerly considered taxon *A. beccarii*.

REPLY: We corrected the mistake and changed the taxon to *A. aomoriensis*.

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GRAMMATICAL AND TYPOS CORRECTIONS

REVIEWER 2: page 7783: of the SW Baltic Sea

REPLY: Changed “in” to “of”.

REVIEWER 2: page 7794, line 13: delete ‘the’

REPLY: We deleted “the”.

REVIEWER 2: page 7785, line 4: remember coal and peat. Deforestation nowadays is estimated to account for 20-25% of anthropogenic CO₂ release!

REPLY: We agree and added deforestation into the text. In our opinion, combustion of fossil fuels includes coal and peat.

REVIEWER 2: page 7786, line 26: examples

REPLY: Corrected.

REVIEWER 2: page 7788, line 16: The fractions 63-2000 μm and $> 2000 \mu\text{m}$

REPLY: We changed the beginning of the sentences.

REVIEWER 2: line 17: The fraction 63-2000.

REPLY: Changed.

REVIEWER 2: line 20: whereas unstained tests

REPLY: Changed.

REVIEWER 2: page 7789, line 1: and an Electron Probe

REPLY: We added “an”.

REVIEWER 2: line 26: directly into

REPLY: Changed.

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REVIEWER 2: page 7791, line 15: pycnocline

REPLY: Corrected.

REVIEWER 2: page 7792, line 26: from the depth-interval 0 to 1 cm

REPLY: Changed.

REVIEWER 2: page 7794, line 10: no colon before that

REPLY: Deleted.

REVIEWER 2: page 7795, line 2: no colon after)

REPLY: Deleted.

REVIEWER 2: line 9:, respectively (Fig. 5)

REPLY: We added “,respectively”

REVIEWER 2: line 21: stages of test dissolution

REPLY: Corrected.

REVIEWER 2: page 7796, line 1: were destroyed, and only the inner organic lining was left in nearly all individuals during October and February

REPLY: Changed.

REVIEWER 2: line 16: these natural fluctuations are common in eutrophi . . .

REPLY: Changed.

REVIEWER 2: line 26: no colon

REPLY: Deleted.

REVIEWER 2: page 7797, line 3: remove thereby with thus

REPLY: Changed.

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REVIEWER 2: line 27: remove fauna by population

REPLY: Changed.

REVIEWER 2: page 7798, line 20: moved into

REPLY: Corrected.

REVIEWER 2: page 7799, line 22: remove 'They' by 'Both stations'

REPLY: Changed.

REVIEWER 2: page 7800, line 18: foraminifera will respond

REPLY: Corrected.

REVIEWER 2: line 19: remove lowered by hampered

REPLY: Changed.

REVIEWER 2: page 7801, line 14: adapted to high

REPLY: Corrected.

REVIEWER 2: line 21: remove 'and' by 'but'

REPLY: Changed.

REVIEWER 2: line 23: remove in by within

REPLY: Changed.

REVIEWER 2: line 27: Biogenic calcification is expected to

REPLY: Changed.

REVIEWER 2: page 7802, line 2: remove colon after water, place colon after observed,
remove highly by significantly

REPLY: Changed.

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REVIEWER 2: line 11: remove colon after forces

REPLY: Changed.

REVIEWER 2: page 7803, line 1: ranged in average from 306 μm in minimum up to a maximum of 461 μm . (same for next line)

REPLY: Changed.

REVIEWER 2: page 7803, line 9: Thus infers = ? This infers ?

REPLY: This infers.

REVIEWER 2: line 6 to 8: statement absolutely unclear, use two sentences

REPLY: We revised the statement and added two understandable sentences.

REVIEWER 2: line 9: remove Thus by This

REPLY: Changed.

REVIEWER 2: line 11: factors prevailing at

REPLY: Corrected.

REVIEWER 2: line 13: than others which may lead to future shifts in community structure.

REPLY: Changed.

REVIEWER 2: line 22: as well as dissolution features, might be

REPLY: Changed.

REVIEWER 2: page 7804, line 2: remove additional by 'increasing CO2 levels'

REPLY: Changed.

REVIEWER 2: line 8: Fjord, in comparison to open ocean environments.

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REPLY: Changed.

REVIEWER 2: line 10: colon after However,

REPLY: We added colon after “However”.

REVIEWER 2: line 11: colon after *A. aomoriensis*,

REPLY: We added colon after “*A. aomoriensis*”.

REVIEWER 2: line 14: species, such as *E. incertum*, (two colons)

REPLY: Corrected.

REVIEWER 2: line 19: delete ‘in the water column’ (where else ?)

REPLY: We did not delete “in the water column” from the text. We think it is an important point to point out the strong differences of the carbonate chemistry between the water column and the sediment pore water.

REVIEWER 2: line 25: precipitates

REPLY: Corrected.

REVIEWER 2: page 7805, line 2 remove ‘In this habitat, bottom’ by ‘Bottom’

REPLY: Changed.

REVIEWER 2: line 6: in consequence of

REPLY: Corrected.

REVIEWER 2: line 15: The dissolution response also differs

REPLY: Corrected.

REVIEWER 2: line 19: remove ‘could be’ by ‘offer’, and remove ‘in’ by ‘for’

REPLY: Changed.

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REVIEWER 2: line 22: delete 'it is'

REPLY: We deleted "it is".

REVIEWER 2: line 25: modeled; remove to by towards

REPLY: Changed.

REVIEWER 2: line 28 remove 'in' by 'for'

REPLY: Changed.

Interactive comment on Biogeosciences Discuss., 9, 7783, 2012.

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