Interactive comment on "Environmental variations in a semi-enclosed embayment (Amvrakikos Gulf, Greece) – reconstructions based on benthic foraminifera abundance and lipid biomarker pattern" *by* S. Naeher et al.

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At first, we would like to thank Prof. Filipsson for the critical review and the numerous comments, which improved the quality of our manuscript. Please find below our answers to each comment. The page and line numbers correspond to the manuscript published in Biogeosciences Discussions.

Main critics/comments:

Prof. Filipsson: The aim of the study. The authors seem to be very fixed on the

on the eutrophication idea and it seems to be common knowledge that the area is eutrophic, then why did the authors perform the study? What new knowledge did this study contribute with?

> Answer: Yes, we agree that eutrophication of Amvrakikos Gulf has been reported previously. But we wanted to study how eutrophication changed this ecosystem within the last decades and which role the ocean played regarding water exchange and oxygen supply. Another goal of the study was to reveal the effects of low oxygen concentrations on microbial communities (as traced by lipid biomarkers) and foraminifera assemblages, such as for instance adaptation, community shifts or species extinction. Furthermore, the applicability and robustness of biotic and geochemical proxies for reconstructions of such environmental alterations was tested in the sediment of a fjord-type estuarine setting. Because these reasons are not clear in the manuscript, we added these explanations to the last paragraph of the introduction. These changes were added to the new paragraph instead the paragraph: Page 7409, lines 6-8.

Prof. Filipsson: The manuscript must be structured in a more orderly fashion. As it is now, it is a mix between results and discussion in the result sections. The two cores are compared and discussed in the result section, something which clearly belongs to the discussion.

> Answer: We improved the structure of the manuscript. We removed all aspects that contain interpretations in the result section and included those into the discussion. In the following we summarise all changes made:

Page 7410, lines 12-16: Now, the core description is part of the results section, but the colour interpretation was moved to chapter 4.1.

Chapter 4.2: Part of this chapter was included into the new chapter 5.1 ("Benthic foraminifera abundance"), separating better between the results and the discussion sections.

Chapter 4.3: This part was condensed because a large part was moved to the discussion chapters. Some repetition like for instance the origin of the biomarkers were included into chapters 5.3-5.5. In chapter 4.3 we also separated the descriptions of both cores without comparing them anymore in the results chapters. The comparison of the cores were included into the discussion chapters.

Prof. Filipsson: I would like to see the age model presented and discussed since it is of vital importance to understand and detail when the environmental changes occurred and to determine how reliable the chronology is.

> Answer: The age models based on sedimentary 210Pb profiles were added as figure 2 and described in chapter 4.1 (see attached files).

Prof. Filipsson: The authors would be helped by a professional English grammar and spelling check. I have changed some but I'm not a native speaker.

> Answer: The manuscript was checked for English grammar and spelling errors. We made the following corrections in the manuscript:

Page 7407, lines 11-14: Sentence changed as follows: "The occurrence of isorenieratane, chlorobactane and lycopane supported oxygen monitoring data indicating that anoxic (and partly euxinic) conditions prevailed seasonally throughout the western part of the gulf with more severe oxygen depletion towards the east."

Page 7407, lines 16-17: Sentence corrected as follows: "Altogether, these developments led to mass mortality events and ecosystem decline in Amvrakikos Gulf."

Page 7408, lines 13-14: The end of the sentence corrected: "...last 50 years by means of sedimentary proxies"

Page 7409, lines 4-5: Corrected as follows: "...whereas long-chain alkenones have been proven useful..."

Page 7409, lines 6-8: The whole paragraph was changed. It also contains the aims of

our study.

Page 7409, lines 22-23: Sentence changed to: "A brackish surface layer flows out, whereas saline water enters the Gulf with the bottom layer."

Page 7414, line 9: Changed to: "...TOC increased from 1.4 in the lowermost part to 6.1 wt%..."

Page 7416, line 24: Sentence corrected as follows: "...OM content in areas influenced by Po River..."

Page 7416, line 26: Sentence corrected as follows: "...known to occur in benthic assemblages of oxygen..."

Page 7417, lines 23-24: Changed to: "The downcore fluctuations in the abundance of the benthic species of Cluster I compared to the upper core could be used to trace high OM supply and oxygen depletion."

Page 7420, line 11: "by" instead of "in"

Page 7416, line 26: Sentence changed to: "The increase in population of benthic foraminiferal assemblages was associated..."

Page 7425, line 7: "however" instead of "but"

Other changes (based on comments of Prof. Filipsson in the attached manuscript):

Page 7407, line 4: "and species distribution" was added

Page 7407, line 5: "markedly" instead of "dramatically"

Page 7407, line 7: Full names added to the abstract: Bulimina elongata, Nonionella turgida, Textularia agglutinans, Ammonia tepida

Page 7407, line 9: "were" instead of appeared

Page 7407, line 14: "oxygen depletion" instead of "hypoxia"

Page 7407, line 26: For this reason we cited the paper of Ferentinos et al. (2010), where the oceanographic regime of Amvrakikos Gulf is further discussed. We added to the whole sentence as follows: "Amvrakikos Gulf, located in north-western Greece, is a semi-enclosed embayment characterized by a complex lagoonal system and an extensive delta (Kapsimalis et al., 2005). It has a fjord-like oceanographic regime due to a shallow sill, which reduces deep-water exchange with the ocean (Ferentinos et al., 2010)."

Page 7408, line 4: We added oxygen concentrations, which were defined to represent hypoxic and anoxic conditions. We removed the word "dysoxic" throughout the text to get a consistent terminology. Therefore, the sentence was changed to: "Despite the efforts, which have been made for the protection and conservation of this unique area, the western part of the gulf is suffering from seasonal hypoxia (oxygen concentrations <2 mg l-1), whereas the eastern part is also affected by seasonally anoxic conditions (oxygen concentrations <0.5 mg l-1) (Kountoura and Zacharias, 2011)."

Page 7408, line 8: "reached a peak" was changed to "...stress in the gulf resulted in a sudden massive mortality..."

Page 7408, line 12: "over historic timescales" removed

Page 7408, line 15: "nutrient content" instead of "eutrophication"

Page 7408, line 22: sentence changed to: "...benthic foraminifera populations and their diversity are usually reduced and the assemblages are dominated by relatively tolerant species."

Page 7408, line 25: We changed the errors in the references according to the guidelines of Biogeosciences throughout the text.

Page 7409, lines 6-8: For clarification of the determination of forams and biomarkers, we changed the sentence as follows: "In this study the combination of benthic foraminifera and sedimentary lipid biomarker proxies in two sediment cores was used

to characterise environmental changes and the implications for the living biomass during the recent history in Amvrakikos Gulf."

Page 7409, line 18: The halocline is between 8 and 12 m according to Ferentinos et al. (2010).

Page 7410, line 1: "documented" instead of "established"

Page 7410, lines 3-7: We separated both sentences as follows: "Since the 1970s the gulf has been altered, mostly due to extensive agriculture, aquaculture and urban development, and the establishment of oil stations along the southern border of the gulf. Furthermore, since the construction of two dams the run-off of the Arachthos River has been controlled."

Page 7410, lines 7-8: Sentence corrected as follows: "In 2008, water with a higher density filled the deeper parts of the basin and lifted the anoxic layer, which led to a massive fish mortality event (Ferentinos et al., 2010)."

Page 7410, lines 10: "have" instead of "had"

Page 7410, lines 12-16: We removed the whole passage and included it into the results section by combining it with the chapter about the age model. This means we created a new chapter called "4.1 Sediment cores and age model".

Page 7411, line 3: The sampling interval ranges between 0.5 and 2 cm.

Page 7411, line 5: "The" included before the word "samples".

Page 7411, lines 6: The sentence was changed to: "At least 200 specimens of benthic foraminifera were picked and identified from each sample"; The majority of the samples analysed contained more than 280 foraminiferal tests. Only few samples mostly from core Amvr15 contained about 200 specimens. The number 200 specimen per sample was set to include these samples in the data set. However, in some studies, such as for instance Cearreta, et al. (2007) and Carboni, et al. (2009), the number of benthic

foraminiferal specimen is also less than 300 per sample.

Page 7411, line 12: The authors avoid using the BFAR index (no. benthic foraminifera g of dry sediment-1) x (sed. rate in cm yr -1) x (dry bulk density in g cm-3) since it has been proposed by Herguera and Berger (1991) for tests larger than 150μm. Although this method has been applied as palaeoproductivity proxy and for specimen <150μm there is still doubt for the reliability of the method (Gooday, 2003, Jorissen, et al., 2007)

Page 7412, line 18: The age models for both cores based on the sedimentary 210Pb profiles. These models were described in this subchapter and added as figure 2.

Page 7412, line 22: changed to "specimen per g of sediment"

Page 7413, line 9: This sentence has been changed.

Page 7413, line 6: new paragraph

Page 7413, lines 12-21: these sentences have been removed and/or added into chapter 5.1 in the Discussion

Page 7414, lines 1-3: this sentence has been removed and added into chapter 5.1 in the Discussion

Page 7414, lines 8-10: The values were included into the sentence. Now, it should be clear that an increase towards the top of the core is described.

Page 7414, lines 18-24: The whole passage was reorganised/structured as follows: "The atomic C/N ratio was lower in core Amvr13 than in core Amvr15 with values slightly below 10 and 13-16, respectively. In the lower part of core Amvr15 (below 20 cm, before 1977), C/N values ranged between 7 and 27 (Fig. 2). In core Amvr13, total nitrogen contents were below the detection limit in 2-3 cm and 18-20 cm, which hindered the calculation of the C/N ratios. While the δ13CTOC remained almost constant throughout both cores with on average about 3-4‰ higher values in core Amvr15."

Page 7414, line 24: We also included the ages in addition to all depth units throughout

the text to be consistent.

Page 7414, line 25 until page 7415, line 2: The whole passage was reorganised/structured as follows: "The profiles of branched alkanes and isoprenoids were very similar to hopanoids in both cores (Fig. 5). These compounds can be used as bacterial biomarkers (Rohmer et al., 1984;Summons et al., 2007). These lipids were relatively constant throughout core Amvr15. In core Amvr13, the concentrations were highest in 28-29 cm (1974-1975) and in the upper 10 cm (since about 1998). In contrast, they were lowest in 12-14 cm (1993-1995) (Fig. 5)."

Page 7415, lines 14-16 (also until end of this subchapter): We believe that we cannot list all the different biomarkers in the introduction. It is an observation that we found certain markers, also with different concentrations throughout the sediment. Therefore, the observations of these lipids are results. Of course, we already interpret the origin of the biomarkers in the results section, but we need that as a basis for our environmental reconstructions, which are part of the discussion section.

Page 7416, line 12: "appears" instead of "appeared"

Page 7417, line 17: The sentence has been slightly modified. The following citations discuss the habitats of Ammonia beccarii and Bulimina aculeata as follows: Goineau et al., 2011: "Bulimina aculeata is commonly reported in ïňĄne-grained sediment from the continental shelf and the open slope (Jorissen et al., 1998; Mendes et al., 2004; Murray, 1991b). This species can feed on phytodetritus, and is probably able to quickly ingest fresh OM derived from marine primary production (Eberwein and Mackensen, 2006; Kitazato et al., 2003; Nomaki et al., 2005a, 2005b, 2006; Duchemin et al., 2008)." Debenay et al., 2005: "The high relative abundance of the marine species Ammonia beccarii along the southern coast suggests stronger marine influence in this area."

Page 7417, line 28: "most likely" instead of "probably"

Page 7418, line 2-4: We also added this comment to the text as an alternative expla-

nation. Of course, also remineralisation can cause such a decrease of TN and TOC values within the sediment. But the agreement with other lipids, which are related to a higher productivity and the shift towards foraminifera, which are indicators for higher OM supply/sedimentation to the sediment surface suggest an increased productivity due to eutrophication.

Page 7418, line 5: "foraminiferal" was included

Page 7418, line 15: "is" instead of "was"

Page 7418, line 21: We replaced the atomic with the elemental C/N ratio in the text and figure 4.

Page 7419, line 8: Yes, the Suess effect usually needs to be considered. It can influence the measured d13C values, which can lead to wrong explanations, at least in systems which are in equilibrium with the atmosphere (as discussed in the cited paper). But in eutrophic systems (such as Amvrakikos Gulf), the Suess effect can be considered to be of only minor influence, as further discussed in the text.

Page 7420, lines 1-2: The sentence in which we compare the chlorin index values with a Swiss lake were removed. We agree that it is not a necessary addition to this manuscript. We also removed these values from figure 4.

Page 7420, line 14: "foraminiferal" added as suggested

Page 7424, lines 10-12: The temperature data in the introduction were from the publication of Kountoura and Zacharias (2011), which comprise data obtained during field campaigns between April 2009 and March 2010. These data are not continuous, neither throughout the year nor over many years. Similarly, Ferentinos et al. (2010) discuss data, which comprise June and August 2009. We also checked the ICES for time series, but there were no water temperatures available for Amvrakikos Gulf. Therefore, we could compare our proxy based temperature estimates only with air temperature data. Reference for these data was added to the figure caption and in the text.

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Page 7420, line 16. In addition to the Pearson correlation coefficient, the confidence level (p values) was added throughout the text.

Page 7421, line 19. The sentence has been changed and the correct reference was added: "Furthermore, mass mortality events of fish and reduction of fish populations in aquaculture rafts were observed between 1988 and 1997 (Ferentinos et al., 2010)."
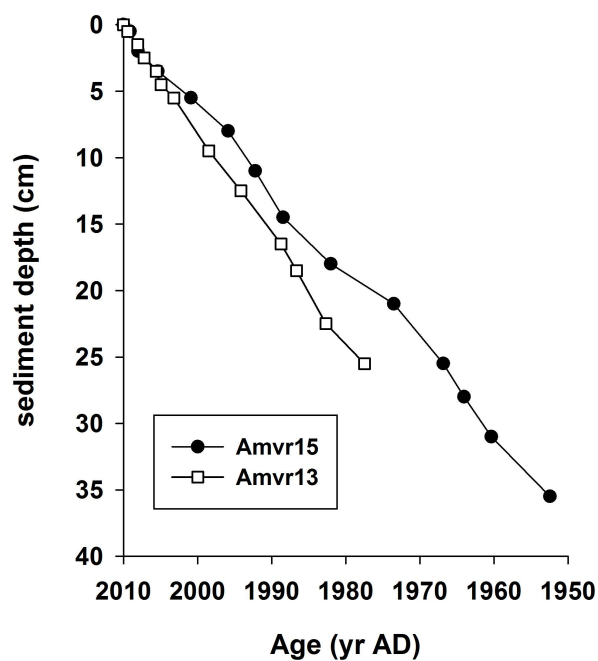
Interactive comment on Biogeosciences Discuss., 9, 7405, 2012.
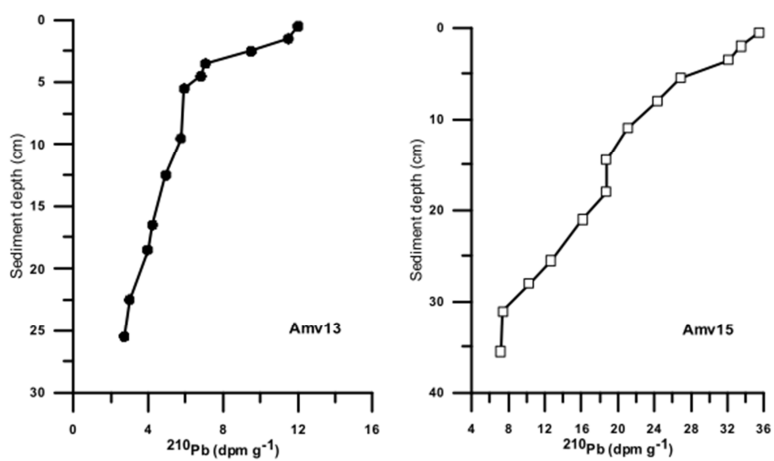
Fig. 2:

Fig. 1.

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Fig. 2.

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