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Interactive comment on "Historical records of coastal eutrophication-induced hypoxia" *by* A. J. Gooday et al.

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1) Hypoxia vs. anoxia. Moderately hypoxic waters, with oxygen just below 2mL/L, are far from being anoxic. Thus, seafloor faunal or geochemical changes observed at or close to anoxia (lower end of dysoxia), are not necessarily attained at hypoxia. A considerable part of the manuscript ("Chemical and Mineralogical Indicators") justifiably relates to "absence of oxygen," but it should be stated unequivocally that hypoxia could exist without in-situ production of pyrite or anomalous concentration of certain trace metals, and that biomarkers of severe hypoxia at OMZs may not to be found in coastal hypoxia.

Response. The following sentences added at the end of section 2 (lines 166-171) - 'Whereas bathyal oxygen minimum zones are conventionally defined by oxygen con-

centrations of <0.5 ml L-1, the upper limit of coastal hypoxia placed much higher, at 1.47 ml L-1 (= 2mg L-1). Although some animals may exhibit avoidance reactions, or even die, at these DO concentrations (Levin et al., 2009), most of the geochemical and faunal indicators of hypoxia only become apparent at much lower values.'

2) Foraminifera. Forams have been emphasized in the review because there is substantial data on them from hypoxic area sediments. We must remember, however, that forams are useful in paleohypoxia studies simply because their shells are abundant in sediment cores (and counting them makes sense); in general, they are less sensitive than metazoans to the effects of oxygen depletion. To my knowledge, there is no coastal foram species whose mere presence/absence would indicate hypoxia. Also, some foram indices of hypoxia have been based only on observed stratigraphic trends, without corroborative correlations with values of bottom-water oxygen or those of putative oxygen stand-ins such as sedimentary TOC. In addition, there are no dependable laboratory experiments on the effect of oxygen depletion on populations of foram species. Microhabitats of many species are variable, and species considered as "typical of oxygenated habitats" do occur in waters that are definitely hypoxic for larger metazoa. It would improve matters if, in future studies, reasons (including microhabitat considerations) are given why particular species or species groups were chosen to formulate a foram index. Use of geographically restricted species is necessarily limited. Eubuliminella morgani is endemic to the Gulf of Mexico, and is abundant in its present hypoxic belt. Even if the stratigraphic trends of the species provide us with clues on temporal variations of bottom-water oxygen, the findings would be inapplicable elsewhere.

Response. A) lines 217-222. '(Foraminifera) have an outstanding fossil record and are sensitive indicators of environmental conditions including hypoxia. However, they are more tolerant of hypoxia than most metazoan taxa, and with the likely exception of Virgulinella fragilis, which is found in oxygen-deficient, sulphidic habitats in coastal and deeper water settings worldwide (Tsuchiya et al., 2009), no species is confined

to hypoxic environments.' B) lines 345-348. 'This index is probably only applicable locally; not all of the species concerned are widely distributed in hypoxic environments (B. morgani is apparently endemic to the Gulf of Mexico). . ..'

3) Other benthic organisms. The only other group of well-preserved, shelled meiobenthos is the Ostracoda. As the review shows, some tolerant species seem to be good indicators of worsening hypoxia. However, unlike forams, if most ostracods "usually are intolerant of hypoxia," their changing abundances hold real promise as markers of hypoxia trends; their historical distribution in undisturbed, rapidly deposited, coastal sediments needs to be studied more thoroughly.

Response. Lines 410-414. 'Ostracods are much less common than foraminiferans in sediment cores, and usually play a supporting role in historical reconstructions (e.g. Alve, 1991). However, although only a few studies focus specifically on ostracods as tracers of anthropogenic environmental change in coastal environments, these crustaceans hold considerable promise as indicators of trends in hypoxia.'

4) Sediment laminations. Since we are talking about coastal hypoxia, it would help if water depths were given for cores that show such laminations.

Response. Lines 495-518. Depths added

5) Eutrophication vs. hypoxia. If coastal hypoxia is "eutrophication-induced" (as in the title of the manuscript), the best way to separate the influence of oxygen depletion from that of organic enrichment would be through controlled laboratory experiments; this has not been done. Population statistics on abundant species (forams, e.g.,) obtained from localities affected by eutrophication but not by hypoxia may help, but still may not provide unequivocal answers, because species living in organic-rich substrates may also be hypoxia-tolerant. (Are there foram species that thrive well in organic enriched substrates but are intolerant of hypoxia, or vice versa?) The subjectivity in the interpretation of faunal data in cores (re. eutrophication vs. hypoxia) is almost unavoidable.

Response. Infact, there have been some good laboratory experiments addressing the effects of hypoxia and oxygen deficiency. We briefly describe these in lines 1190-1198 (section 5.2). We have also added some lines (1190-1198) about the rare cases of oxic/eutrophic and hypoxic/oligotrophic settings.

5) Corrections. p. 2575, line 8. Change rotaliids to Rotaliida (to avoid confusion with Rotaliidae). p. 2582, line 6. Change Pautuxet to Patuxent. p. 2589, line 4. Change hematite to maghemite. p. 2389, lines 5-6. Change ferromagnetic to ferrimagnetic. p. 2389, lines 21 & 22. Change remnant to remanent. p. 2389, line 24. Change elements to compounds. p. 2611, line 8. Change Navqui to Naqvi. p. 2643, figure caption. Change "tolerant or intolerant of" to "with different tolerances to."

Response. All corrections done, except for p. 2589, line 24 where the word 'elements' refers to trace metals, not compounds.

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