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

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I thank Dr Cronin for his encouraging and helpful comments. I have responded to specific points as follows.

Point 1) Regrettably, despite the enormous literature on coastal hypoxia cited here, most studies represent relatively small-scale, often one-time research projects. Compared to well-funded monitoring programs that generate environmental data in already impaired ecosystems, funding for paleo-studies of the natural system is hard to come by and scattered, such that additional proxy development and application to restoration questions remains sorely needed.

Response. I agree and have incorporated this important point in section 6 (lines 1341-

1342)

Point 2) The authors suggest that all proxies of eutrophication and DO are qualitative. I wouldn't go this far. In any paleo-field, many factors can influence physical, chemical biological proxies, including post-depositional changes. Still, calibration and verification of proxy methods through field, lab, and models methods are used to put numbers on past environmental conditions, even if error bars remain large. Adopting the calibration/verification approach of many tree-ring studies might be considered in proxy development. In addition, multi-proxy reconstructions have proven to be of greatest validity in paleoclimatology and the authors stress this need for paleo-DO studies.

Response. I agree. Quantitative proxies have been developed based on large datasets for several faunal groups. The following passage is added to the section 6 (Future Directions, lines 1369-1377) – 'Clearly, quantifying proxies for hypoxia involves considerable challenges. Nevertheless, quantitative estimates of past climatic parameters, notably temperature, have been developed based on tree rings (Briffa et al., 2004, 2008; Yadav and Singh, 2001) and fossil beetles (Huppert and Solow, 2004). Similarly, transfer functions based on planktonic foraminifera and dinocysts have been used to estimate sea-surface temperatures during the last glacial maximum (CLIMAP Project Members, 1976) and modern primary productivity, temperature and salinity (Radi et al., 2007, 2008), respectively. Given a large enough dataset, it may be possible to develop similar approaches to the quantification of past hypoxia.'

Point 3) One point deserving note is the distinction between bioturbation and burrowing. To a geologist/sedimentologist [at least this one], the former is always an issue in an oxic benthic environment because mixing by small organisms [e.g., meiofauna] influences temporal resolution, depending on sediment accumulation rate and how deep and fast organisms are mixing the sediment. In fact, recent studies suggest that bioturbation is not necessarily destructive and bioturbated sediment can retain much of the original bedding. Moreover, to sedimentologists and paleobiologists, analysis of bioturbation in ancient sediments is a tool in the study of sedimentary facies. Thus, bioturba-

tion does not necessarily prevent detailed paleoenvironmental reconstruction. In contrast, deep burrowing by individual molluscs or other infaunal benthos can wreak havoc on a sediment core chronology, and heavily burrowed sediment sequences should be avoided.

Response. I have made the following modifications. A) The opening sentence of section 3.2 now reads - 'A variety of mechanisms can generate laminations (varves) but all require that the laminated sediment fabric is not totally disrupted by bioturbation (Kemp et al., 1996), physical disturbance, or the burrowing activities of larger animals such as echinoderms and molluscs.' B) The following sentence is added in lines 485-486 – 'Although bioturbation disrupts sediments, it also provides important environmental information (Savrda and Bottjer, 1991; Levin et al., 2000).'

Point 4) CHIRP and other geophysical surveys to select core sites and X-radiographs of cores to look for burrows help mitigate these and other problems and they add immensely to the value of paleo-reconstructions.

Response. I have consulted colleagues who are familiar with CHIRP and have been told that it would not be possible to image burrows with this system, which has a decimetre-scale resolution.

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