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Biogeosciences Discussions

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

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Gooday et al.

This is a very thorough review of estuarine, coastal and marine paleoenvironmental studies of sediment cores aimed at reconstructing eutrophication and dissolved oxygen (DO) depletion. The paper's large scope reflects the growing acceptance – in fact, necessity - of paleoenvironmental reconstruction to extend much-too-short instrumental records for decision support in coastal restoration. Although the authors did not stress direct application of paleo-studies, their excellent review should serve as a reminder of what is at stake. Estimated costs for coastal ecosystem restoration projects can reach into the billions of dollars to pay for remedial actions to restore ecosystem functioning. Decision makers require accurate information on the range of natural con-



ditions prior to human disturbance to set restoration targets and timetables. Given the uncertainties about future climate change, it also is critical to understand ecosystem functioning over longer timescales spanning intervals of high-amplitude climate variability. 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.

A key take-away point of this paper is the view that paleo-eutrophication/DO studies are a subfield of paleoceanography. Certainly this makes sense, but papers on coastal sediment records rarely are published in leading paleoceanography journals, whose climate-oriented readership overlaps only minimally with the largely biological readership for leading estuarine coastal journals. Another important point was the authors' distinction between proxies for organic enrichment (eutrophication) and those for oxygen levels, which they considered a major challenge in the study of hypoxia.

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.

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, bioturbation 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. 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.

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