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Biogeosciences Discussions

Interactive comment on "Effects of natural and human-induced hypoxia on coastal benthos" *by* L. A. Levin et al.

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Summary: This is a comprehensive review of how natural and human-induced low dissolved oxygen (hypoxia and anoxia) effect benthic organisms. By benthic the authors included diverse taxonomic groups from bacteria to fishes. The introductory material explains the connection between physical and biological factors in the development of low dissolved oxygen, and the varied but general nature of organism responses. The similarities and differences in organism responses to natural and human-induced low dissolved oxygen are well presented with a good cross-section of regional examples. The interplay and synergy of multiple stressors in shaping a ecosystem's response are an important element of this review.

Comments: While there are similarities and differences in the benthic response to

both natural and human-induced hypoxia, the key difference between them is the time-scales of their appeared. Oxygen minimum zone (OMZ) and upwelling related hypoxia have been features of our global oceans for centuries (Helly and Levin 2004). Historically, human-induced hypoxia appears to have been confined to highly modified watersheds or harbors and not a global phenomenon (for the contrast in time see; Brongersma-Sanders 1957, Diaz and Rosenberg 2008). In the relatively short period from about 1950 to today, in response to increasing reliance of industrial fertilizers to feed an ever expanding population, humans have drastically altered global Nitrogen cycling and coastal primary production to the point that now human-induced hypoxia has become a principle stressor of coastal systems on a global scale (Galloway et al. 2004, 2008). The relationship between increased fertilizer use and increased number of human-induced hypoxic systems lagged about 10 years (Figure 1). The time it took for excess organic matter from primary production to buildup and overwhelm an ecosystem's assimilative capacity to the detriment of higher trophic level and the benefit of microbes (Diaz and Rosenberg 2008, Turner et al. 2008).

One form of human-induced hypoxia not mentioned in the review, likely because it is a feature of small and shallow tributary systems, and only recently studies, is diel cycling hypoxia. In small eutrophic systems dissolved oxygen can range from super-saturated during daylight hours from enhanced primary production to near anoxic at night from enhanced heterotrophic respiration. This form of hypoxia can occur even in the absence of water column stratification with many cycles during the warm summer season (see recent studies by; Verity et al. 2004, Tyler and Targett 2007, Tyler et al. 2009). Part of the benthic response to diel hypoxia mirrors that of larger coastal systems to seasonal hypoxia with lower diversity and dominance by tolerant species (Tuzzolino 2008). These small systems appear to be preconditioned to organic enrichment stress, so mortality is not a typical response. Physiological and behavioral adaptations appear to be sufficient to allow for survival during the nighttime hypoxic period. Mobile fishes migrate out and in of these systems as dissolved oxygen declines and rises again.

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Unfortunately, the authors present convincing evidence that the future for both natural OMZs and upwelling related hypoxia, and human-induced hypoxia in a warmer world with an increasing population is expansion, with very serious consequences for benthic and fisheries resources.

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Text edits: Page 3571, line 13 and page 3572, line 3: change Vaquer to Vaquer-Sonyer

Page 3585, line 24: is CalCOFI an abbreviation? It should be spelled.

Page 3615, line 23: should be Baltic Sea not Black Sea. I suspect a typo.

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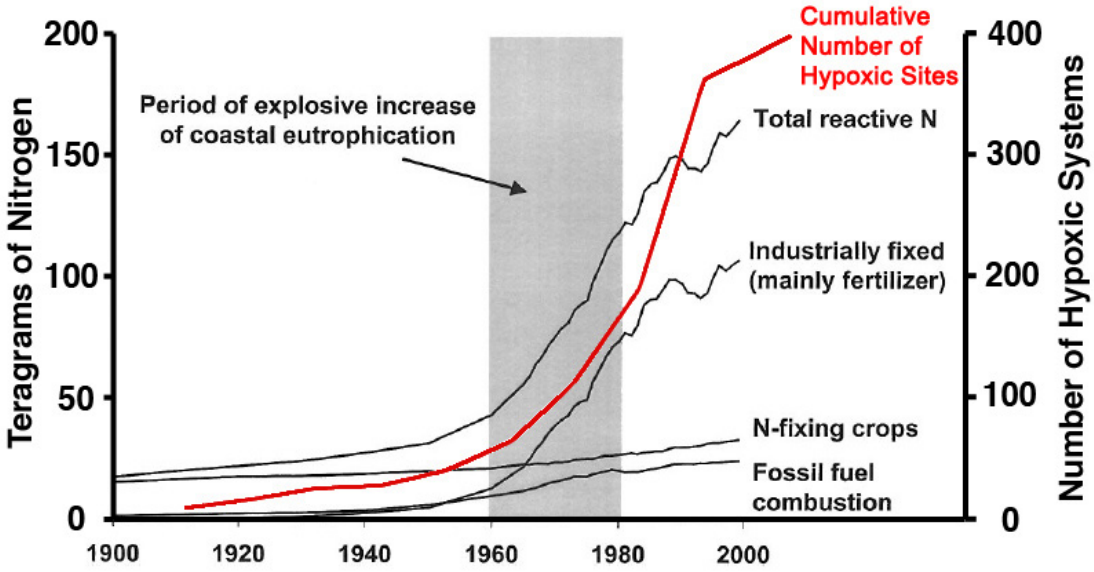

Fig. 1. Figure 1. Temporal relationship between industrial fertilizer use and the number of human-induced hypoxic areas (modified from Boesch 2002 and Diaz and Rosenberg 2008).

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