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Seasonal oxygen deficiency over the western continental shelf of India

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The North Indian Ocean contains about two-third of the global continental-margin area affected by natural oxygen deficiency ($O_2 < 0.2$ mL L^{-1}) in the water column. Also, the littoral countries of this semi-enclosed basin account for a quarter of the world's population, making the sensitive O_2-depleted environment especially vulnerable to anthropogenic perturbations. We describe here factors responsible for the occurrence of O_2 deficient conditions, their evolution over the annual cycle, and their impact on biology and chemistry off the west coast of India. The O_2 deficiency in this region, associated with the seasonal (southwest monsoon) upwelling, seems to have intensified in recent years, presumably in response to enhanced nitrogen loading from land. The O_2 deficiency affects patterns of organic production and distribution of organisms including commercially important fishes, and modifies chemical fluxes through microbial reduction of polyvalent elements especially nitrogen (denitrification). While the extent of water-column denitrification over the shelf is modest (1.3-3.8 Tg N y^{-1}), a very substantial fraction of the nitrate undergoing reduction appears to end up as nitrous oxide, which accumulates to levels rarely seen elsewhere in the ocean. Relative changes in dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) closely conform to those predicted by the Redfield-Ketchum-Richards stoichiometry in the oxic and suboxic waters. However, a higher-than-expected buildup of DIP occurs in anoxic waters, probably due to dissolution of the iron-oxyhydroxo-phosphate complex from sediments. This DIP may support nitrogen fixation after the cessation of upwelling.