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Phosphorus dynamics and productivity during modern and past intervals of coastal hypoxia

T. Jilbert (1), C. P. Slomp (1), and D. J. Conley (2)

(1) Dept. of Earth Sciences - Geochemistry, Utrecht University, Utrecht, Netherlands (T.S.Jilbert@uu.nl, C.P.Slomp@uu.nl), (2) GeoBiosphere Science Centre, Lund University, Sweden (daniel.conley@geol.lu.se)

Numerous coastal environments worldwide are suffering from the expansion of ‘dead zones’ associated with eutrophication and hypoxia. The nutrient element phosphorus (P) plays a key role in sustaining low-oxygen conditions in these environments. While anthropogenic loading of P and nitrogen (N) often provides the initial trigger to hypoxia, enhanced P regeneration from sediments under low-oxygen conditions can resupply P and sustain high productivity. The dead zone of the modern Baltic Sea is a classic example of a system where enhanced P recycling drives the expansion of hypoxia, and much research focuses on possible remediation strategies. The Baltic is also naturally vulnerable to hypoxia due to the stratification of its water column, and has flipped in and out of basin-wide hypoxic states several times during its 8000-year existence.

In this study, we use sedimentary records from the Baltic Sea to investigate the phosphorus, carbon and oxygen dynamics in the modern, Medieval and early Holocene hypoxic intervals. Trace metal profiles suggest that euxinic (i.e. sulfidic) deep water conditions developed during all three periods. Elevated sedimentary C/P ratios support the theory that accelerated regeneration of P relative to carbon helped sustain the high productivity/low oxygen regime. The termination of euxinic conditions in the early Holocene and Medieval intervals appears to have occurred relatively rapidly (on a timescale of decades). However, we show that the modern organic matter flux to the seafloor far exceeds that during the previous euxinic intervals. These results suggest that the recovery from the modern hypoxic interval may be slower than previous terminations, due to the extreme build-up of P in the water column and sediment. Moreover, the projected warming of the Baltic may further elevate productivity and sustain basin-wide hypoxia in the medium-term future. This work suggests that only continued long-term reductions of P loading can drive the system back to oxic conditions.