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What causes the barren bottoms of the Baltic?

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One of the largest impacts on the Baltic Sea ecosystem health is eutrophication, which causes hypoxia (< 2mg/l dissolved oxygen). It is estimated that the hypoxic zone in the Baltic Sea has increased about four times in area since 1960 due to surplus loads of waterborne and airborne nutrients (N and P) from anthropogenic sources. Hypoxia has barren vast areas of the sea-floor, reduced the macrobenthic communities and disrupted benthic food webs in the whole Baltic basin. Hypoxia alters nutrient biogeochemical cycles; it increases the internal load of phosphorus released from sediments, which causes low nitrogen/phosphorus (N/P) ratios during summer - a factor that favors cyanobacterial blooms.

Hypoxia in the Baltic Sea is not unique to the modern era. Based on a compilation of Baltic geological records Zillén et al., (2008) showed that the deeper depressions of the Baltic Proper have experienced intermittent hypoxia during most of the Holocene. Hypoxia occurred basin-wide, at water depths varying between 73-240 m during three major periods; i.e. between c. 8000-4000, 2000-800 cal. yr BP and subsequent to AD 1800. These periods overlap the Holocene Thermal Maximum HTM (c. 9000-5000 cal. yr BP), the Medieval Warm Period MWP (c. AD 750-1200) and the modern historical period (AD 1800 to present). In contrast, oxic bottom conditions were common between c. 7000-6000, c. 4000-2000 and c. 800-200 cal. yr BP. The latter period coincides with the Little Ice Age (LIA) and its characteristic server winters.

Although we know that hypoxia has occurred in the past and probably co-varied with external forces, such as climate change and nutrient fluxes, the relative importance of these two forcing mechanisms is unresolved, which restricts predictions about the Baltic Sea ecosystem response to future climate and anthropogenic stressors. Most previous research suggests that there may be a correlation between the oxygen conditions in the Baltic Sea and climate variability in the past, primarily driven by atmospheric changes over the North Atlantic region. However, this hypothesis has not yet been tested by model simulations and the potential climate forcing mechanism(s) behind the reconstructed long-term shifts in oxygen status in the Baltic Sea are still unclear. Hypoxia during the last two millennia can also be linked to population growth, technological development and land-use expansion phases, implying that historical trends in hypoxia may not have a natural cause, but result from anthropogenic impacts.

We used a coupled physical-biogeochemical model to explore if shifts in oxygen conditions during the last two millennia in the Baltic Sea can be explained by physical forcing parameters that are known to affect bottom-water conditions in the Baltic Sea. To elucidate the driving mechanisms further, we studied the significance of changes in productivity on the size of the hypoxic area to assess the degree of human impact (eutrophication) on long time-scales. This study reveals the dominant physical forcing mechanism on hypoxia in the Baltic Sea and explains the shifts in bottom-water oxygen status during the last two millennia, especially through the MWP/LIA oscillation. We present new results on the significance of human perturbations on the marine environment and propose that cyanobacteria blooms may not be natural features of the Baltic Sea, but rather a consequence of enhanced phosphorus release that occurs together with hypoxia.