Hypoxia in the Stockholm Archipelago over the past 3 ka: A natural phenomenon or human-induced?

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Excessive anthropogenic nutrient input and global warming have led to a rapid expansion of hypoxia in the Baltic Sea over the past century. Two earlier phases of widespread hypoxia, coinciding with the Holocene Thermal Maximum (HTM, ~8-4 ka before present; BP) and the Medieval Climate Anomaly (MCA, ~1.2-0.8 ka BP), have previously been identified in deeper parts of the Baltic Sea. While the warm climate is thought to be a key driver of the hypoxia during the HTM and MCA, anthropogenic nutrient input also may have played a role. Relatively little is known about the bottom water redox conditions in the coastal zone of the Baltic Sea during the Holocene.

Here, we reconstruct Holocene bottom water redox conditions and identify the key drivers of deoxygenation at three sites in the coastal zone near Stockholm (Stockholm Archipelago) based on sediment records. Sediment concentrations of organic carbon and redox sensitive elements (e.g. molybdenum) show that bottom waters in our study area were hypoxic until ~1 ka BP, followed by a period of oxygenation which lasted until the development of modern-day hypoxia at the beginning of the 20th century. TEX_{86}-based sea surface temperature reconstructions highlight that periods of deoxygenation and warming coincide, suggesting a mechanistic link. Increased anthropogenic input of Pb and Zn to the sediment is first observed at ~1 ka during the period of oxygenation. We conclude that, before the modern period, hypoxia was not human-driven and that changes in temperature, combined with isostatic rebound, were critical in determining trends in bottom water oxygen.