Spatiotemporal variations in the degree and frequency of Baltic Sea Holocene anoxia

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The modern Baltic Sea is the world's largest anthropogenically forced anoxic basin, with sub-basins displaying increases in the degree (oxygenated < manganeous < euxinic) and frequency (seasonal < oscillatory < permanent) of anoxia with increasing distance from the sill at the Danish Straits[1]. Despite the large spatiotemporal range of water column redox conditions observed today[1] and the known occurences of natural Baltic anoxia throughout the Holocene[2], no study has examined the spatial distribution of varying anoxic regimes in the Baltic's past. Here, using records from three Baltic sub-basins with increasing distance from the sill (Little Belt < Bornholm Basin < Landsort Deep), captured during IODP Expedition 347, and a combined Fe-Mn-Mo-S approach, we specifically define the degree of past spatiotemporal anoxia through the Baltic Holocene. Similar to previous studies, we observe two prominent and contemporaneous sapropel units with evidence for anoxic conditions at each sub-basin, roughly overlapping with the Holocene Thermal Maximum and Medieval Warm Periods[2]. Our data from Mo and Fe geochemistry indicate that each past anoxic event, similar to today, is characterized by redox conditions progressively more reducing with increasing distance from the sill. Preliminary Mo isotope results provide evidence that the earliest anoxic period was the most widespread and most reducing—characterized by water column sulfide accumulation (euxinia) at all three sub-basins. However, the concentrations and frequency of euxinia amplified with increasing distance from the sill. The more recent anoxic sapropel unit displays the same general relationship, but the redox transect is characterized by relatively less reducing conditions ranging from euxinic to seasonally anoxic. Ultimately, our results indicate that periods more reducing than or similar to the modern Baltic have occurred naturally over the Holocene. However, extreme euxinic conditions approaching that of the Black Sea are not recorded in the past and are unlikely to occur in the future.

[1]Carstensen et al., (2014) *PNAS* 111, 5628-5633.
[2]Zillén et al., (2008) *Earth-Science Reviews 91*, 77-92.