Nutrients, ecosystems, and the expansion of eukaryotic life

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Surface ocean ecosystems have evolved considerably over time. In particular, the autotrophic marine biosphere has been dominated by anoxygenic and oxygenic photosynthetic bacteria for the vast majority of Earth's history. There is little evidence for an important role for eukaryotes in marine ecosystems prior to the late Proterozoic, despite the appearance of crown group eukaryotes in the fossil record nearly 1 billion years earlier. Though critically important for understanding the oxygenation of Earth's ocean-atmosphere system, the evolution of the biological pump, and the emergence of animal life, the mechanisms driving this macroecological lag remain poorly understood.

Here, we use an Earth system model of intermediate complexity (cGENIE), equipped with a size-structured marine ecosystem model[1], to explore the impact of varying marine nutrient inventory on the structure of planktonic communities in the surface ocean. We find a strong dependence of planktonic ecosystem structure on nutrient levels in the ocean interior, with higher [PO_4^{3-}] levels leading to greater overall biomass, broader size spectra, and increasing abundance of large zooplankton grazers. We integrate these patterns with microfossil, organic biomarker, and inorganic geochemical data for contemporaneous time-dependent changes to the late Proterozoic phosphorus cycle and shallow marine ecosystems, and suggest that the impact of nutrient availability on ecosystem structure represents a critical factor linking ocean chemistry and biological innovation during late Proterozoic time.

[1] Ward, B.A. *et al*. (*In review*) EcoGEnIE 0.1: Plankton Ecology in the cGENIE Earth system model. *Geoscientific Model Development*.