Ocean anoxia and the biological pump

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The export of organic matter from the surface ocean and its respiration at depth creates gradients in nutrient and oxygen availability that influence the structure and distribution of marine ecosystems. Today the strength of the biological pump is strongly influenced by mineral-ballasted phytoplankton. In Earth's past, however, mineralized phytoplankton were less common and, consequently, the biological pump was likely weaker. Here we use the GENIE model to quantitatively explore the impact of a changing biological pump on marine oxygen distribution and ecosystem structure. We find that under a weaker biological pump the position of the oxygen minimum zone shallows and anoxia is more prevalent near the surface, reducing oxygen availability to benthic ecosystems in shelf environments. Increasing the strength of the biological pump causes anoxia in the deep ocean but increases oxygen concentrations on the shelves where most marine animal ecosystems are found. The model results further suggest that the Phanerozoic trend toward better oxygenated oceans is a consequence of phytoplankton evolution and that it may reflect a reduction in ocean nutrient concentrations. Thus, we hypothesize that the Phanerozoic trend toward greater animal abundance and metabolic demand was driven more by increased oxygen availability than by greater food. In fact, a reduction in productivity may have been required to generate sufficient oxygen availability in the shallow oceans to make the oceans more habitable for animals.