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Phosphorus build-up, nitrogen loss and sulfide accumulation in response to recent deep-water deoxygenation in the Sea of Marmara

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The global trend of growing marine dead zones continues despite increased awareness and the development of relevant legislation, drastically changing the phosphorus cycle in the marine environment. Recent years have seen the development of such a system in the Sea of Marmara, a basin between the Mediterranean and the Black Sea that is unique from an oceanographic perspective. The Marmara ecosystem is rapidly deteriorating as a result of anthropogenic nutrient runoff, which results in high levels of organic carbon production and respiration and a rise in the water column's redoxcline. Deep-water oxygen levels in the Eastern Marmara (900–1250 m) have decreased over the past 30 years from roughly 80 µM to near-detection levels (5 µM). One of the largest marine mucilage outbreaks occurred in this sea in 2021, and its effects on the ecology are still being felt today. The DeepRedox and MARMOD projects, which were both nationally supported, conducted rigorous field campaigns between 2019 and 2022, which led to the discovery of the Marmara Sea's new biogeochemical regime. We found that there is a net increase in deep-water P inventory compared to 1990s, with an up to 50% increase in reactive phosphate and total phosphorus. We show evidence that microbial Fe reduction and the resulting release of mobile P surface sediments play a part in this increase, which is also attributable to increased organic matter remineralization. We also observe that water column denitrification is now dominant with fixed N-removal as a consequence. While the deep waters in the easternmost Izmit Bay have begun to become permanently sulfidic, we detected two transient occurrences of sulfide in the deep waters of the Eastern Marmara in 2016 and 2019, however in 2021 and 2022 those waters remained non-sulfidic. Overall, redox conditions have caused the deep waters of the Marmara to become more P-rich (lower N/P), with potential repercussions for the vertical delivery of nutrients and the production in the upper layer. Next research steps will include the connections between changing redox conditions, alterations in nutrient stocks, and high productivity algal blooms and mucilage events.