EGU23-7565, updated on 24 Apr 2024
https://doi.org/10.5194/egusphere-egu23-7565
EGU General Assembly 2023

Recent advancement in water quality indicators for eutrophication in global freshwater lakes

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Excessive nutrient (nitrogen and phosphorus) loadings to freshwater lakes cause eutrophication, which is a global water quality issue. Anthropogenic activities in lake basins emit nutrients, either as point- (e.g., sewage) or diffuse sources (e.g., agricultural runoff). Their typical impacts on lake water quality include the occurrence of harmful algal blooms, hypoxia and fish kills. These impacts are likely to worsen due to climate change, population growth and economic development. The response of lakes to a change in nutrient inputs depends on their interactions with the climate, land-use, hydrology and socio-economic conditions of a lake basin. These feedback mechanisms, however, are not often included in the eutrophication assessments for lakes. In this study, we present a new causal network of the drivers-pressure-state-impact-response (DPSIR) framework using a total of 58 sub-indicators to characterize all the DPSIR elements and systematically conceptualize the complex interactions of nutrients in freshwater lake basins. The network provides a holistic perspective on nutrient dynamics of multiple indicators and their interactive effects on water quality in lake basins, which is key to improving water quality management. Furthermore, we disentangle the complex eutrophication mechanisms using drivers and pressures, that represent different sources and nutrient pathways. The study highlights coupling of lake systems in water quality modeling frameworks and assessments which is required to understand its impact on water quality from human activities in the basin. The drivers and pressures can be used as proxies to provide meaningful information on nutrient emissions and biogeochemical pathways, that can fill the gap in water quality monitoring data, especially in data scarce regions such as Asia and Africa. These indicators can be used to set realistic water quality targets, and are, therefore, beneficial in long-term policy making and sustainable water quality management.