Interannual Variation Characteristics of Dinoflagellates Bloom in Pengxi River in the Three Gorges Reservoir Area and Its Driving Mechanism of Multiple Environmental Factors

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Abstract

Dinoflagellate blooms are a critical focus in freshwater ecosystem health monitoring, with their outbreak mechanisms closely linked to the synergistic effects of multiple environmental parameters. This study, based on daily monitoring data during the bloom seasons of 2022–2023 in the Pengxi River of the Three Gorges Reservoir area, reveals the interannual variation mechanisms of dinoflagellate blooms. Key findings include: (1) The peak dinoflagellate density in 2023 increased by 63% compared to 2022. During peak periods, water temperature rose by 2.72 ℃ (from 20.9 ℃ in 2022 to 23.62 ℃ in 2023), pH decreased by 1.22, and conductivity increased by 43.5%. These results indicate that climate warming accelerates dinoflagellate metabolic rates, elevated conductivity reflects intensified non-point source pollution, and a weakly alkaline environment (pH 7.14–7.86) favors dinoflagellate survival. (2) In 2023, total nitrogen (TN) increased by 191% and total phosphorus (TP) by 528% compared to 2022. The N:P ratio decreased from 21.3 to 19.5, approaching the optimal range for dinoflagellates (10:1–20:1). During peak periods, NO_3^--N concentrations were significantly higher than in 2022, and the proportion of dissolved total phosphorus (DTP) increased to 42.3%. These findings suggest that suitable N:P ratios and pulse nutrient inputs create favorable conditions for dinoflagellate dominance. (3) The peak chlorophyll a in 2023 (128.34 μg/L) was significantly lower than in 2022 (115.09 μg/L), and high chlorophyll a areas were negatively correlated with dinoflagellate density. This implies that reduced cyanobacterial biomass may provide ecological niches for dinoflagellates. This study highlights the driving mechanisms of interannual dinoflagellate bloom variations in the Three Gorges Reservoir area—the combined effects of climate warming and human activities. Recommendations include optimizing agricultural non-point source pollution control, regulating N:P input ratios, and leveraging cyanobacterial community dynamics to predict dinoflagellate bloom risks, thereby enhancing the timeliness of prevention and control measures.

Keywords

Dinoflagellate Blooms, Interannual Variation, Three Gorges Reservoir, Nutrient Structure