

Spatiotemporal Distribution Characteristics of Phytoplankton in Sizaopu River, Ningbo Qianwan New Area

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Abstract: From April to September 2025, monthly sampling was conducted in both the treated and natural sections of the Sizaopu River, Ningbo Qianwan New Area, to characterize the spatiotemporal dynamics of phytoplankton communities. In the treated section, a total of 104 species belonging to 64 genera and 6 phyla were identified, with an average density of 1.27×10^8 cells L^{-1} . Ten dominant species were recorded; notably, the dominance pattern was most simplified in August, when only *Pseudanabaena limnetica* prevailed. The average values of the Shannon–Wiener diversity index (H') and Pielou's evenness index (J') were 0.96 and 0.28, respectively. In the natural section, 111 species from 66 genera and 6 phyla were observed, with an average density of 1.79×10^8 cells L^{-1} . Seven dominant species were found, with the fewest in June, when *Microcystis aeruginosa* was the sole dominant. The average H' and J' in this section were 0.84 and 0.26, respectively. Overall, the phytoplankton community structure was similar between the two sections, with Cyanophyta being the most dominant phylum in both. However, the treated section exhibited a more stable community.

1 Introduction

Urban rivers serve multiple functions, including flood control, drainage, water supply, and ecological landscaping. However, rapid urbanization has led to the discharge of substantial amounts of untreated sewage into river channels, resulting in the continuous deterioration of aquatic ecosystems^[1, 2]. The Sizaopu River is a representative urban river located in the Ningbo Qianwan New Area. Regulated by hydraulic structures, its main channel is divided into a northern and a southern section. The water body in the northern section undergoes preliminary treatment at a wastewater treatment plant (utilizing a combined biological-chemical process), followed by advanced purification through in-stream ecological floating beds, aeration and flow propulsion systems, and other measures. In contrast, the southern section primarily receives surface runoff and effluent from the upstream Cixi urban area and industrial parks, essentially remaining in a natural state of pollutant assimilation. Phytoplankton are characterized by their small size, short life cycles, and rapid responses to changes in water quality. Their community composition and diversity characteristics have been widely employed as indicators for assessing the health of aquatic ecosystems^[3-5]. This study aims to provide a scientific basis for the ecological assessment and restoration of urban rivers by comparatively analyzing the phytoplankton community structure and dominant species succession between the treated and natural sections of the Sizaopu River.

2 Materials and Methods

2.1 Sampling Site Setup

Based on the habitat characteristics of the main channel and the distribution of sluice gates in the Sizaopu River of the Qianwan New Area, this study established a total of 16 sampling sites (Figure 1).

These include the treated river reach (Stations 1#~6#) and the natural river reach (Stations 7#~16#). Sampling was conducted from April to September 2025."

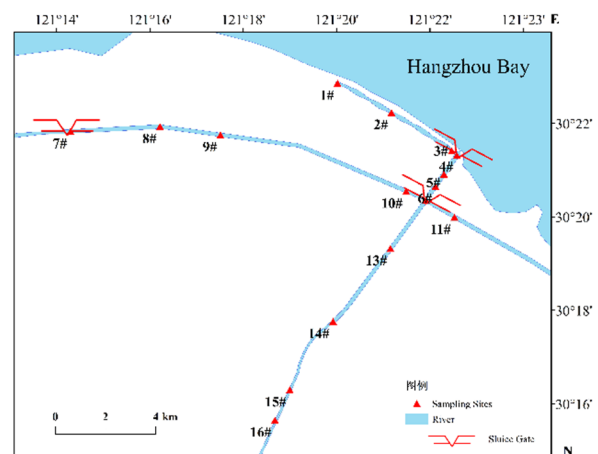


Figure 1. Distribution of sampling sites in the Sizaopu River, Ningbo Qianwan New Area.

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2.2 Sample Collection and Processing

Phytoplankton samples were collected following the guidelines specified in the National Technical Specifications for Freshwater Biological Resource Surveys, with sampling conducted at each station along the investigated section. At each sampling site, one liter of water was collected from a depth of approximately 0.5 m below the surface using a water sampler. The sample was immediately fixed with 15 mL of Lugol's iodine solution. After 48 hours of sedimentation, the supernatant was carefully siphoned off, and the concentrated residue was transferred into a 100 mL calibrated vial for storage.

For analysis, 0.1 mL of the concentrated sample was pipetted into a phytoplankton counting chamber. Species identification and cell counting were performed under a Leica DM500 upright microscope, following the taxonomic references in Freshwater Algae in China.

2.3 Data Processing and Analysis

Species with a dominance value (Y) greater than 0.02 were considered dominant in this study. Phytoplankton community structure was characterized using the Shannon-Wiener diversity index (H') and the Pielou evenness index (J'). These indices were calculated as follows:

$$Y = \frac{n_i}{N} \times f_i \quad (1)$$

$$H' = - \sum_{i=1}^S \left(\frac{n_i}{N} \right) \left(\ln \frac{n_i}{N} \right) \quad (2)$$

$$J' = \frac{H'}{\ln S} \quad (3)$$

Where S is the total number of species, n_i is the number of individuals of species i , N is the total number of individuals in the sample, and f_i is the occurrence frequency of species i .

3 Phytoplankton Community Characteristics

3.1 Species Composition and Monthly Variations

A continuous sampling survey was conducted from April to September in the treated and natural river sections of the Sizaopu River, and the results are presented in Figure 2. In the treated section of Sizaopu River, a total of 104 species of phytoplankton belonging to 64 genera and 6 phyla were identified. Among these, Chlorophyta was the most dominant group, with 48 species, accounting for 46.15% of the total; followed by Bacillariophyta, with 33 species, representing 31.73%; Cyanophyta, with 13 species, accounting for 12.50%; Euglenophyta, with 6 species, comprising 5.77%; Cryptophyta, with 3 species, accounting for 2.88%; and Pyrrophyta, with only 1 species, representing 0.96% of the total.

In the natural section of Sizaopu River, a total of 111 species of phytoplankton belonging to 66 genera and 6 phyla were identified. Among these, Chlorophyta was the most abundant group, with 56 species, accounting for 50.45% of the total; followed by Bacillariophyta, with 29

species, representing 26.13%; Cyanophyta, with 13 species, accounting for 11.71%; Euglenophyta, with 9 species, comprising 8.11%; while Cryptophyta and Pyrrophyta were the least abundant, each with only 2 species, accounting for 1.80% of the total.

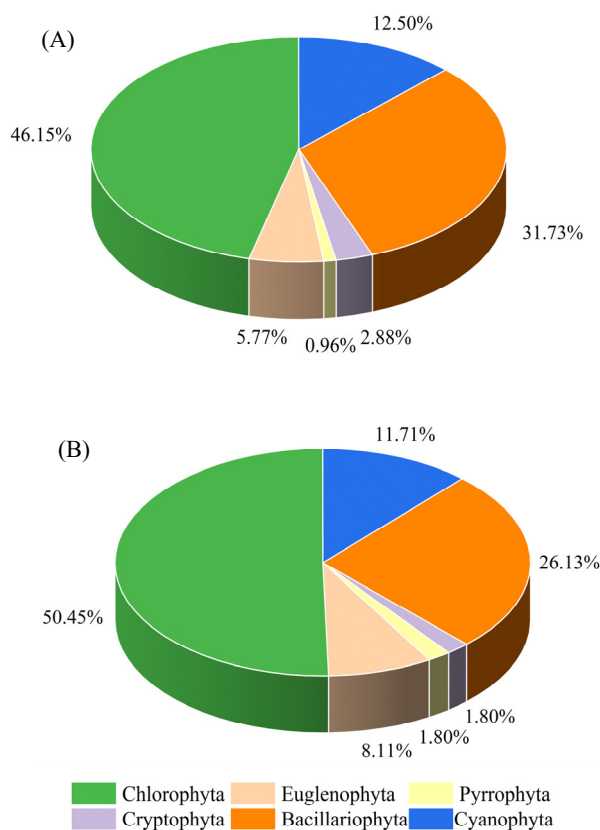


Figure 2. Species composition of phytoplankton in Sizaopu River. (A: treated section; B: natural section)

3.2 Spatiotemporal Variations of Phytoplankton Density

Spatiotemporal variations in phytoplankton density across the natural (Stations 7#~16#) and treated (Stations 1#~6#) sections of the Sizaopu River are presented in Figure 3. Phytoplankton density increased progressively in both sections from April to September, peaking in late summer and early autumn (July–September). Cyanophyta dominated the phytoplankton community throughout the study period, though their succession patterns varied spatially and temporally.

Spatially, average phytoplankton density was significantly higher in the natural section (1.79×10^8 cells·L⁻¹) than in the treated section (1.27×10^8 cells·L⁻¹). Temporally, the treated section exhibited a monotonic increase, rising from 3.23×10^7 cells·L⁻¹ in April to a peak of 2.68×10^8 cells·L⁻¹ in September—an approximately eightfold increase. In contrast, the natural section showed a fluctuating upward trend, with an explosive increase to 6.71×10^8 cells·L⁻¹ in August—substantially higher than other months.

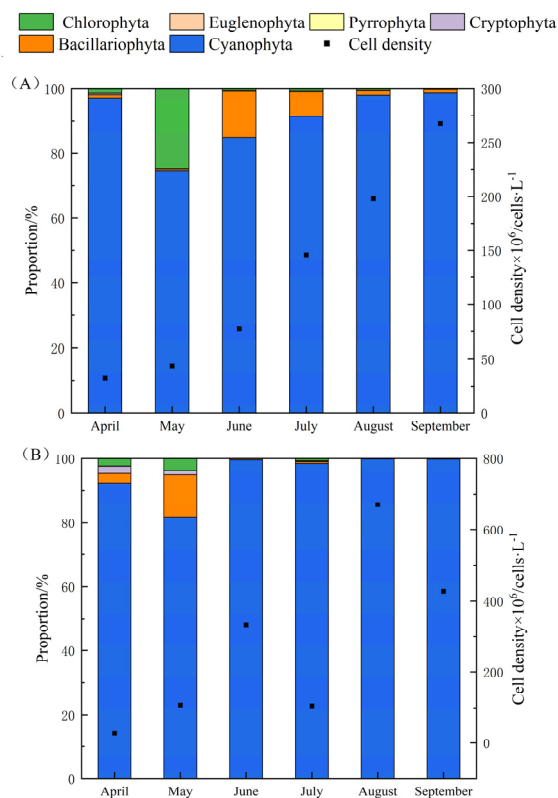


Figure 3. Spatiotemporal distribution of phytoplankton density in Sizaopu River. (A) treated section; (B) natural section

Although Cyanophyta remained the dominant phylum in the treated section, its relative abundance decreased during May~June. In May, Chlorophyta proliferated rapidly, accounting for an average of 24.80% of the community. By June, Bacillariophyta bloomed at several sites, reaching an average relative abundance of 14.45%. From July onward, Cyanophyta re-established its dominance, comprising 98.06% and 98.76% of the community in August and September, respectively—a trend toward community homogenization. Compared to the treated section, the natural section exhibited a more homogenized community structure, with higher relative abundances of Cyanophyta that persisted for longer durations. With the exception of April (92.36%) and May (81.88%), Cyanophyta consistently accounted for over 98% of the community in the remaining months, approaching nearly 100% in August and September.

3.3 Dominant Species Composition and Monthly Variations

During the survey period, distinct differences were observed in phytoplankton dominant species between the treated and natural sections of the Sizaopu River. In the treated section, a total of 10 dominant species were identified. June exhibited the highest number of dominant species (6 species), namely *Merismopedia punctata* ($Y=0.07$), *Merismopedia tenuissima* ($Y=0.03$), *Microcystis aeruginosa* ($Y=0.08$), *Pseudanabaena limnetica* ($Y=0.34$), *Oscillatoria tenuis* ($Y=0.33$), and *Navicula* sp. ($Y=0.14$). August had the fewest (1 species), with only *Pseudanabaena limnetica* ($Y=0.89$) dominating.

From April to September, Cyanophyta dominated the dominant species assemblage in the treated section, supplemented by Bacillariophyta and Chlorophyta. Notably, Bacillariophyta (*Navicula* sp.) appeared as a dominant species only in June and July, with dominance values of 0.14 and 0.07, respectively. Chlorophyta (*Chlamydomonas globosa*) emerged as a dominant species solely in May, with a dominance value of 0.23.

In the natural section, 7 dominant phytoplankton species were identified. May had the highest number of dominant species (6 species): *Microcystis aeruginosa* ($Y=0.12$), *Pseudanabaena limnetica* ($Y=0.10$), *Oscillatoria tenuis* ($Y=0.54$), *Oscillatoria boryana* ($Y=0.02$), *Aulacoseira granulata* var. *angustissima* ($Y=0.12$), and *Tetraselmis cordiformis* ($Y=0.03$). June had the fewest (1 species), with *Microcystis aeruginosa* ($Y=0.98$) as the sole dominant. The composition of dominant species in the natural section resembled that of the treated section, primarily dominated by Cyanophyta, with Bacillariophyta and Chlorophyta playing subsidiary roles. Bacillariophyta (*Aulacoseira granulata* var. *angustissima*) appeared as a dominant species only in May ($Y=0.12$), while Chlorophyta (*Tetraselmis cordiformis*) similarly emerged as a dominant species only in May ($Y=0.03$). Notably, the natural section in June exhibited a single dominant species (*Microcystis aeruginosa*) with a dominance value of 0.98—the highest recorded throughout the survey period.

3.4 Spatiotemporal Variations in Phytoplankton Diversity Indices

The monthly variations in phytoplankton diversity indices in the Sizaopu River exhibited distinct temporal patterns, with marked differences between the treated and natural sections (Figure 4). In the treated section, the Shannon-Wiener diversity index (H') ranged from 0.33 to 1.88, with an average value of 0.96, while the Pielou evenness index (J') varied between 0.09 and 0.53, averaging 0.28. Compared to the treated section, the natural section displayed broader ranges for both diversity indices. In the natural section, H' ranged from 0.05 to 2.30 (average: 0.84), and J' ranged from 0.02 to 0.70 (average: 0.26).

4 Discussion

The phytoplankton community in the Sizaopu River exhibited pronounced seasonal succession patterns, characterized by a shift from a mixed assemblage of Chlorophyta, Bacillariophyta, and Cryptophyta in spring to a Cyanophyta-dominated community in summer and autumn. This pattern aligns with the successional dynamics commonly observed in eutrophic water bodies across China.

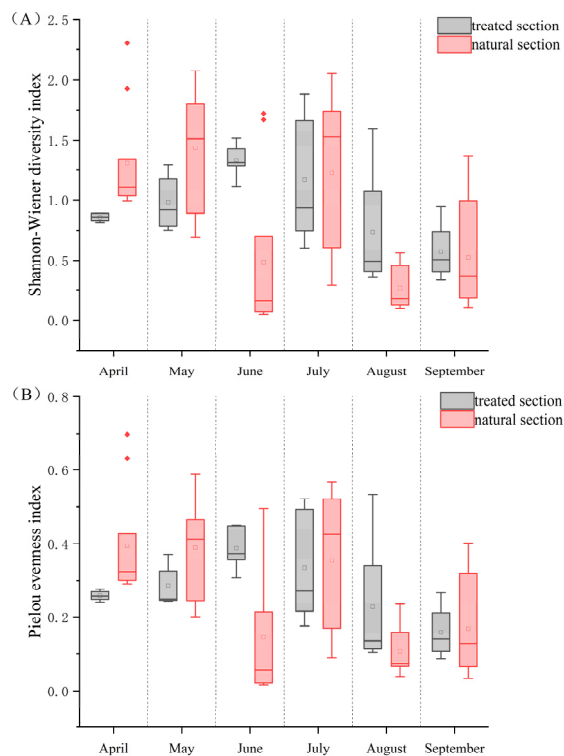


Figure 4. Monthly variations of phytoplankton (A) Shannon-Wiener diversity index and (B) Pielou evenness index in Sizaopu River

During the survey period, analysis of dominant species, Shannon-Wiener diversity index (H'), and Pielou evenness index (J') revealed relatively high ecological diversity in both sections during late spring (April–May). In May, the natural section sustained up to six coexisting dominant species, including *Aulacoseira granulata* var. *angustissima* and *Tetraselmis cordiformis*—taxa typically associated with relatively specific habitat requirements. By summer (June–August), however, the community structure in the natural section underwent drastic simplification. In June, the number of dominant species in the natural section plummeted to one—*Microcystis aeruginosa*—with a dominance value (Y) of 0.98, the highest recorded throughout the survey period. Concurrently, both H' and J' dropped to low levels. This combination of extremely high dominance and low diversity precisely characterizes the massive algal proliferation typical of stagnant, heavily eutrophic habitats.

In contrast to the rapid ecological collapse observed in the natural section during June, the treated section demonstrated considerable ecological buffering capacity and community resilience. While the natural section was overwhelmingly dominated by *Microcystis aeruginosa* in June, the treated section concurrently reached its peak in dominant species richness. This demonstrates that artificial purification measures (including wastewater plant treatment, ecological floating beds, and aeration with flow propulsion) have effectively diminished the competitive advantage of pollution-tolerant cyanobacteria in the treated reach. Consequently, this mitigates their monopoly over light and space, ultimately enhancing

phytoplankton diversity and promoting a more stable community structure.

While this study provides a detailed characterization of the phytoplankton community structure in the Sizaopu River, certain limitations should be acknowledged. A notable constraint is the lack of comprehensive, concurrent physicochemical water quality data (such as specific nutrient fractions including DIN and SRP, conductivity, and continuous flow velocity) during the sampling campaigns. Phytoplankton dynamics are fundamentally driven by these environmental variables. The absence of these parameters limits our ability to fully uncouple the specific environmental drivers behind the observed spatiotemporal patterns. Future studies in this region should couple biological monitoring with high-frequency physicochemical tracking to establish a more robust mechanistic link between water quality fluctuations and phytoplankton successions.

5 Conclusions

During this survey, a total of 104 phytoplankton species belonging to 64 genera and 6 phyla were identified in the treated section, with 10 dominant species recorded—notably, only *Pseudanabaena limnetica* dominated in August. In the natural section, 111 species from 66 genera and 6 phyla were identified, with the fewest dominant species occurring in June, when *Microcystis aeruginosa* was the sole dominant.

The mean values of the Shannon-Wiener diversity index (H') and Pielou evenness index (J') were 0.96 and 0.28, respectively, in the treated section, compared to 0.84 and 0.26 in the natural section. These results indicate that the phytoplankton community in the treated section exhibited greater stability than that in the natural section.

References

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