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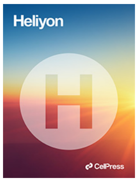

Research article

A novel indicator for defining plain urban river network cyanobacterial blooms: resource use efficiency

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ABSTRACT

Increasing eutrophication and climate change have led to heavy cyanobacterial blooms in water diversion sources (e.g., lakes, reservoirs), which can potentially cause algae-bearing water to spread to downstream to an urban river network via diversion channels. Defining the extent of cyanobacterial blooms in an urban river network has become a novel concern in urban river management. In this paper, we investigated the physicochemical and algae community characteristics of a small, closed, urban river network, JiangXinZhou (JXZ), in the Lake Taihu basin. We propose a novel indicator, resource use efficiency (RUE), for defining the extent of cyanobacterial blooms in JXZ, whose recreational drinking water comes entirely from outside diversion sources. The results show that the JXZ's aquatic habitat conditions (mean water temperature, total nitrogen concentration, total phosphorus concentration, and nitrogen to phosphorus ratio) are highly suitable for the proliferation of cyanobacterial biomass during the high-water period. The RUE was used for calculation and shows a strong relationship with algae density, which means that it can be used as an index to define the degree of urban river cyanobacterial blooms. The findings indicate that the risk of cyanobacterial bloom is absent when the RUE is less than 46.81; blooms appear in the water bodies when the RUE reaches up to 106.68. This work provides theoretical support for the sustainable use of regional water resources.

1. Introduction

A cyanobacterial bloom occurs when the abundance of cyanobacterial biomass greatly increases, tends to float under the water surface, and ultimately clusters and discolors the water (Huisman et al., 2018). Due to their toxicity, cyanobacterial blooms strongly threaten aquatic ecosystems and spoil the water quality for drinking, fishing, and recreational purposes (Huo et al., 2021; Qin et al., 2021). Cyanobacterial blooms exert diverse impacts on the environment. They reduce water transparency, weaken aquatic plant light harvesting (Reynolds, 1972; Reynolds et al., 1987). Cyanobacteria release an extreme odor upon their accumulation on lakes, reservoirs, and other water sources, thus reducing the use of fresh water resources (Izaguirre and Taylor, 2004; Juttner and Watson, 2007). Cyanobacteria also consume large amounts of oxygen and release multiple cyanotoxins in the water when they die and decompose, thus leading to the mortality of fish and benthic organisms (Rabalais et al., 2010), and also pose serious health risks to birds, humans, and other terrestrial life (Carmichael, 2001; Li et al., 2021; Merel et al., 2013).

Numerous methods (e.g., algaecides, sediment dredging, water diversion) have been applied to control cyanobacterial blooms (Qin et al., 2019; Zhong et al., 2021; Zhou et al., 2013). Water diversion projects have been proven to be an effective measure for controlling cyanobacterial blooms and have thus been widely used (Davies et al., 1992; Liu and Zheng, 2002). China has implemented an increasing number of water diversion projects in recent years, including river diversion to Lake Taihu (Li et al., 2011) which strongly reduce the nutrient level of Lake Taihu and alleviate its cyanobacterial blooms risk (Li et al., 2013). During the diversion project operation, Lake Taihu must also convey water into Wuxi, Suzhou, and other cities in the Lake Taihu basin to ensure the ecological water level. In recent years, these projects have indicated a

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tendency for Lake Taihu algae water to spill and spread downstream to the urban river network during the summer high-algae period, which may further evolve into new water ecological and environmental problems of cyanobacterial blooms in urban rivers.

An accurate and rapid determination of the extent of cyanobacterial blooms in water bodies is an important cornerstone for cyanobacterial bloom warnings, treatment, and restoration. Some studies used algae cells or the chlorophyll-*a* concentration as indicators for bloom discrimination in water (Isles and Pomati, 2021; White et al., 2014). For example, the state of Florida (USA) defined chlorophyll *a* concentrations greater than 40 μg/L in lake water to indicate algae bloom (Havens, 2003), and a chlorophyll *a* concentration of 30–40 μg/L is used as the threshold of cyanobacterial blooms in Lake Taihu (Zhang et al., 2021). However, a unified, international standard of the definition of a water bloom has not yet formed, and most current definition values (chlorophyll-a concentration) refer to lakes, without considering water blooms in urban rivers. The chlorophyll-a concentration also can't yield sufficient information on biodiversity and risk assessment (Rangel et al., 2016; Kruk et al., 2011).

Resource use efficiency (RUE) is an ecological concept that measures the ecosystem function status (Hodapp et al., 2019; Ptacnik et al., 2008; Filstrup et al., 2014; Olli et al., 2015; Tian et al., 2017; Zhao et al., 2022). The RUE has been commonly to assess biodiversity and ecosystem stability, and provides dramatic feedback to external perturbations such as anthropogenic disturbances (Hodapp et al., 2016; Steudel et al., 2012). Planktonic algae exert more sensitive RUE value changes due to their limiting characteristics (Yang et al., 2021), and specific nutrient changes are visually reflected in the algae biomass changes. There are also lower levels of aquatic biodiversity in urban river networks, thus algae can produce more biomass than fish and benthic macroinvertebrates in the same system (Yang et al., 2022). It is therefore important to explore the use of RUE to quickly and accurately define the status of cyanobacterial blooms for the ecological protection of plain urban river networks.

This study investigates the applicability of RUE for defining water blooms in urban river networks by investigating the spatial and temporal variation of nutrient and algae communities in river networks of JiangXinZhou (JXZ) during both high-algae and no-algae periods. The results are used to address the mechanism and threshold of the RUE for defining cyanobacterial blooms in urban river networks.

2. Methods and materials

2.1. Study area

JiangXinZhou was jointly built by China and Singapore in 2009 and is a world-class water science and technology application demonstration area that integrates ecological environmental protection, information technology, cultural tourism, modern urban services, and ecological housing. The area is located in the middle of the Yangtze River (Figure 1(A, B, C)), southwest of Nanjing in the Lake Taihu basin, and is a

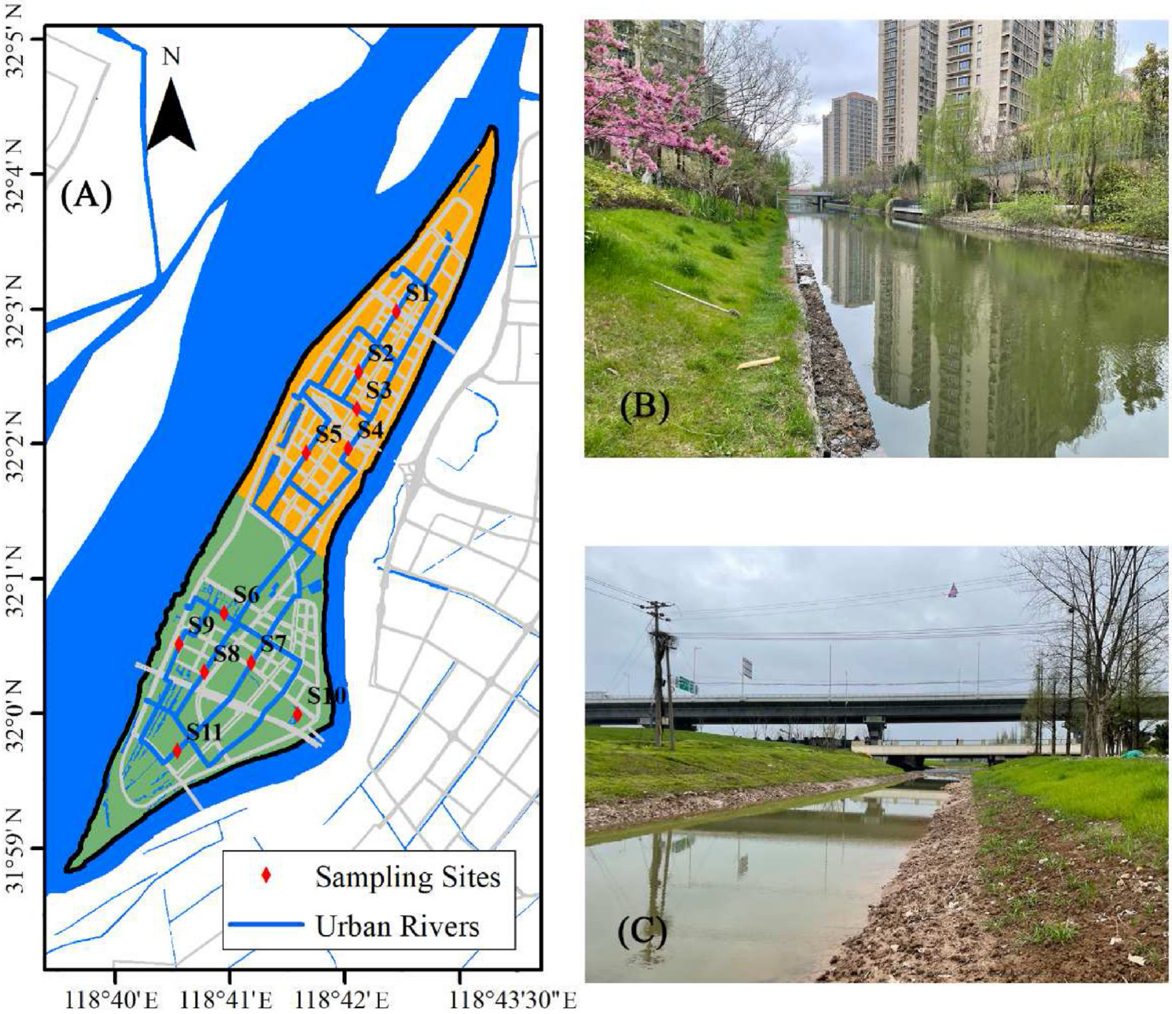

Figure 1. Location of JXZ and sampling sites. (A) yellow region means built-up area, green region means unbuilt area. (B) picture of built-up area' river channel. (C) picture of unbuilt area' river channel.

continental island in the river with a length of approximately 12 km and average width of approximately 1.2 km. The island is a place for high-tech research and senior residential development, and the scale of its urban construction land is strictly controlled. The area of built-up human activity gathering space is presently 8.46 km^2, accounting for 55.7% of the total area. The built-up area follows the standard requirements of sponge city construction and strictly controls the amount of pollutants entering the rivers. The remaining area is unbuilt with farmlands accounting for 44.3%. At present, 23 rivers with a total length of approximately 28.2 km are planned and constructed on the whole island, which have poor river circulation owing to the low level of the plain terrain.

The reason for selecting JXZ as the study area are as follows. 1) Fewer factors influence JXZ's aquatic habitat status because it is blocked by a water body. 2) The recreation and drinking water of JXZ mainly depend on external water replenishment. 3) Its unique regional characteristics, particularly the division between built-up and unbuilt areas, is conducive to comparative analysis.

2.2. Field survey

Two field surveys were conducted at JXZ: in March 2021 (low-water period) and July 2021 (high-water period) by a team of 6 persons. Each group of 3 peoples visited to the field sites of study (built-up area and unbuilt area) for 1 day every season to properly collect samples from all sites and to avoid errors caused by sampling time. A total of 11 sampling sites, including five points (S1–S5) in the built-up area and six points (S6–S11) in the unbuilt area, were studied for water quality and ecological monitoring, which contain the rivers' physicochemical characteristics, flow velocity (Vel), water temperature (WT), total nitrogen (TN), total phosphorus (TP), nitrogen to phosphorus ratio (N/P), and phytoplankton traits (community structure, biomass, and density). Water samples were randomly collected at a depth of 0.5 m in triplicate using a stainless-steel bucket, three random subsamples were collected at comparable locations given the fine-scale habitat heterogeneity. Subsamples were pooled to represent each site.. The 500-mL water samples were filled and fixed with acid and frozen in PVC bottles for nutrient analysis, and 1000-mL water samples were preserved with 1% Lugol's solution and concentrated to 30 mL after 48 h of sedimentation for phytoplankton community analysis (Chen et al., 2020).

2.3. Sample analysis

The concentrations of TN, TP, and other water quality indicators were analyzed according to the monitoring analysis method of water and wastewater. The WT was measured on site using a multiparameter water quality analyzer (Hydrolab HL4, HACH Inc., Tampa, FL, United States), Vel was measured on site using a current meter (OTT C31, HACH Inc., America). Phytoplankton were quantified using a light microscope (Olympus BX41) at 400× magnification. The units (cells, colonies, and filaments) were enumerated in random fields and $\leq$200 individuals of the most frequent species were counted (Hongjun and Yinxin, 2006).

2.4. Statistical analysis

The RUE was used to define the index of the cyanobacterial bloom status in the JXZ urban river network. Phosphorus is generally considered the limiting resource for phytoplankton growth; the concentrations of TP and phytoplankton biomass (PB) were thus used to jointly express the phytoplankton RUE. The RUE is calculated as follows (Ptacnik et al., 2008):

$$RUE = PB/TP$$

where PB is the phytoplankton biomass and TP is the concentrations of total phosphorus.

The polynomial fitting method was used to determine the RUE threshold for defining the urban river networks' cyanobacterial bloom status. The Pearson correlation was used to analyze the correlation between habitat indicators and phytoplankton growth. The Shannon-Wiener diversity indicator was used to calculate the regional algae diversity. All of the data analyses were performed in R (version 3.6.4).

3. Results

3.1. Changes of environmental variables in JXZ

The TN concentration during the high-water period was 1.22–2.79 mg/L, which falls in the IV–V water category (unhealthy) according to China's environmental quality standards for surface water, and the built-up area's condition was generally the same as that in the unbuilt area. The TN concentration during the low-water period was 1.46–4.51 mg/L and considerably higher at each monitoring site than in the high-water period. Larger TN concentration differences were obtained between the built-up (average = 2.29 mg/L) and unbuilt areas (average = 3.56 mg/L) during the low-water period, the latter of which were consistently higher (Figure 2(A)).

The TP concentration in JXZ was generally low in both the high-water (0.10–0.18 mg/L) and low-water periods (0.02–0.14 mg/L), which is classified as class II–III. Contrary to the TN concentration change, the TP was higher during the high-water period (mean = 0.12 mg/L) than in the low-water period (mean = 0.07 mg/L). The TP difference between the built-up and unbuilt areas was not significant. The entire JXZ area is generally a low-phosphorus water body (Figure 2(B)).

The N/P ratio is an indicator that has emerged in recent years to assess the cyanobacterial bloom risk. The N/P was low during the high-water period (7.3–25.4), with small differences between built-up and unbuilt areas, whereas the N/P at each monitoring site was consistently higher in the low-water period (28.0–111.0) (Figure 2(C)).

The WT of JXZ ranged from 15.5 °C to 18.0 °C (average = 16.9 °C) during the low-water period and from 24.6 °C to 31.2 °C (average = 27.8 °C) during the high-water period (Figure 3(A)). The water body in the JXZ area was basically stationary, owing to the local topography and the construction of the gates and pump stations, with a flow velocity of up to 0.016 m/s. The length of the stationary reach accounted for 34.1% of the total length, whereas the high-flow area, with a flow velocity of 0.011–0.016 m/s, accounted for only 16.6% of the total length (Figure 3(B)).

3.2. Spatial patterns of phytoplankton abundance and composition

The phytoplankton density in the low-flow period was 0.57–1.95 × 10^6 cells/L with little difference between the built-up and unbuilt areas. The phytoplankton density in the high-flow period was considerably higher (6.39–67.82 × 10^6 cells/L) with substantial differences between the unbuilt (mean = 28.95 × 10^6 cells/L) and built-up areas (mean = 9.66 × 10^6 cells/L) (Figure 4(A)). The dominant phytoplankton species in the low-flow season were mainly Cryptophyta and *Bacillariophyta*, which accounted for 5.33%–83.57% and 6.42%–46.39%, respectively (Figure 4(B)). The phytoplankton community significantly changed during the high-flow season, with Cryptophyta decreasing to 0.18%–36.69% and *Bacillariophyta* to 2.88%–27.40%, and cyanobacteria and *Chlorophyta* became the main dominant species, accounting for 11.62%–91.36% and 2.88%–58.82%, respectively (Figure 4(C)).

3.3. Spatial patterns of RUE

The RUE spatial distribution in JXZ during the high-flow period ranged from 70.05 to 197.17 (mean = 134.99) and was higher in the unbuilt area than in the built-up area. The RUE values in the low-flow period were substantially lower than those in the high-flow period, ranging from 13.41 to 69.19 (mean = 38.31). The spatial distribution

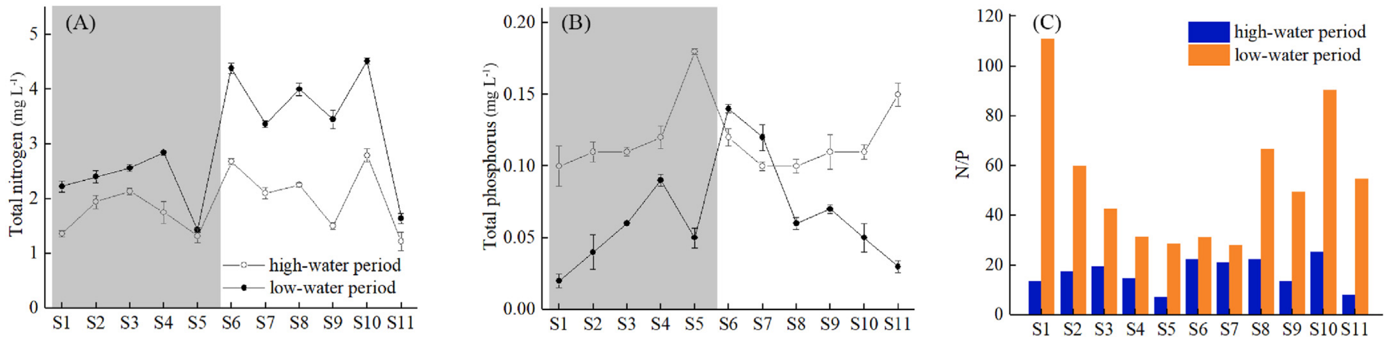

Figure 2. Changes in chemical variables at the JXZ. (A) Total nitrogen concentration in JXZ between high-water period and low-water period. (B) Total phosphorus concentration in JXZ between high-water period and low-water period. (C) Nitrogen to phosphorus ratios in JXZ between high-water period and low-water period. Error bars indicate standard deviation (n = 3).

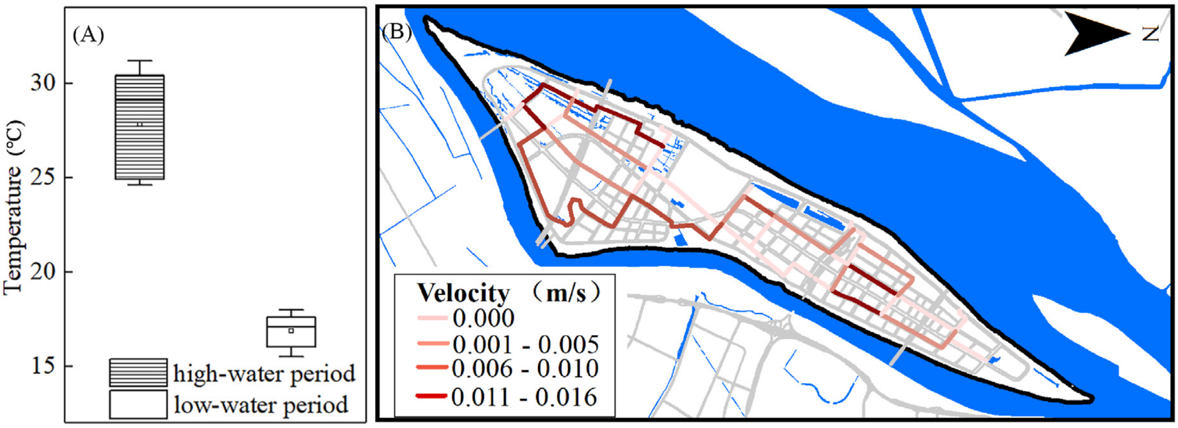

Figure 3. Changes in physical variables at the JXZ. (A) Water temperature in JXZ between high-water period and low-water period. (B) water velocity in JXZ.

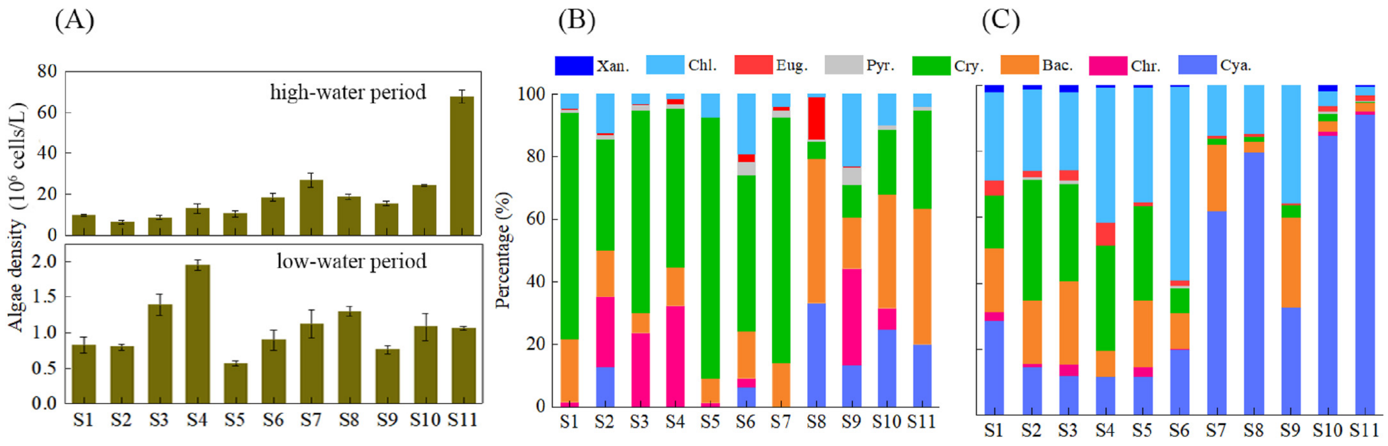

Figure 4. Changes in Phytoplankton communities at the JXZ. (A) Phytoplankton abundance. (B) Phytoplankton composition in low-water period. (C) Phytoplankton composition in high-water period. Xan., Xanthophyta; Chl., Chlorophyta; Eug., Euglenophyta; Pyr., Pyrrophyta; Cry., Cryptophyta; Bac., Bacillariophyta. Cya., Cyanobacteria. Error bars indicate standard deviation (n = 3).

was similar to that in the high-flow period, but the area of the low RUE value was larger than that in the high-flow period (Figure 5(A, B)).

4. Discussion

4.1. Plain urban river environment suitable for cyanobacterial growth

The correlation results between the phytoplankton density and WT, TN, TP, N/P, and Vel showed high parallelism (Figure 6), in which the correlation between each habitat index and phytoplankton density was greater than 0.5. These selected habitat factors were thus the main elements of phytoplankton growth in JXZ.

Water temperature is the main limiting factor of phytoplankton growth and reproduction. The activities of photosynthesis, respiration and enzyme systems involved in nutrient transport and algae conversion are all related to temperature, which is one of the main controlling factors affecting algae biomass changes and community succession (Davis et al., 2009; Visser et al., 2016). The average WT increased from 16.9 °C

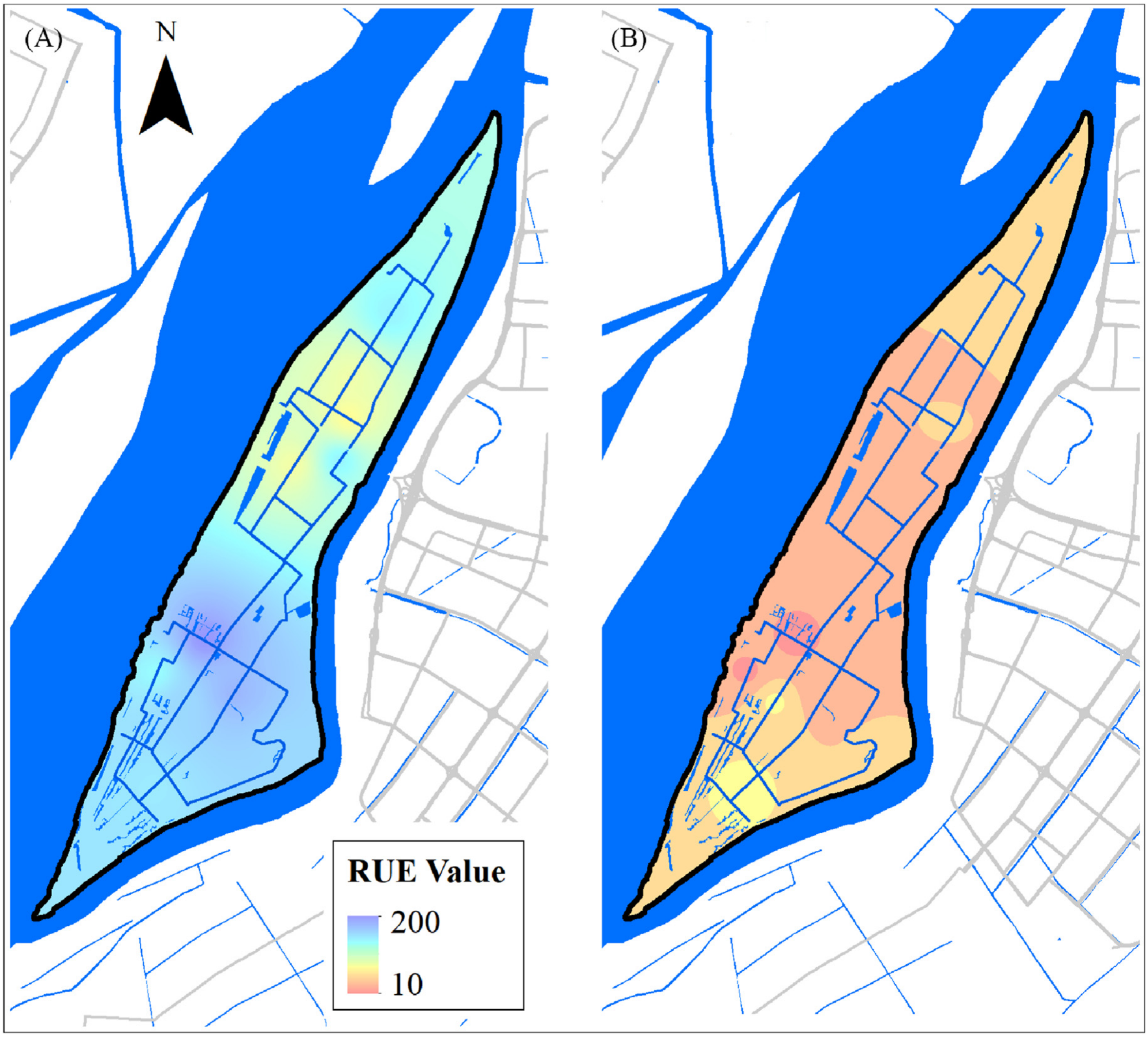

Figure 5. Changes in RUE at the JXZ. (A) RUE values in JXZ at high-water period. (B) RUE values in JXZ at low-water period.

in the dry season to 27.8 °C in the wet season, accompanied by an average algae density increase from 1.07 × 10^6 to 19.98 × 10^6 cells/L. The dominant algae species evolved from diatoms to green algae and cyanobacteria. Recent studies have shown that the most suitable temperature for diatoms is 14–18 °C, followed by green algae at 20–25 °C, and the most suitable temperature for cyanobacterial growth is mostly 25 °C (Chen and Gao, 1998). The WT in JXZ is therefore favorable for cyanobacterial growth during the high-flow period. Cyanobacteria such as Microcystis, can float up to the water surface to obtain sufficient light, thus occupying a dominant ecological position that further restricts the photosynthesis of other algae, due to their gas vacuoles, as well as the ability to synthesize mycospore-like amino acids.

Hydrodynamics is another primary factor that limits the upward flotation of cyanobacteria to the water surface and formation of water blooms (Li et al., 2014). Influenced by the topography and amount of water conservancy, the daily Vel of the JXZ area ranges from 0.000 to 0.016 m/s, and most of its rivers are in a stationary state. The growth of the river residence time reduces the mixing and dilution effect of the flow, and increases the deposition of suspended particles, leading to the accumulation of a large amount of organic matter, which offers nutrients for bottom algal growth. The low flow Vel also reduces the possibility that the cyanobacterial groups are damaged, lose buoyancy, and sink owing to turbulent kinetic and potential energy conditions of the water body, which is conductive to the formation of cyanobacterial water blooms (Wu et al., 2015, 2019).

As the material basis of algae growth, rising concentrations of nitrogen, phosphorus, and other biogenic substances are generally considered to be the root cause of cyanobacterial blooms. Internationally, it is generally considered that TN $>$ 0.2 mg/L and TP $>$ 0.02 mg/L are representative of eutrophication in a water body (Lin et al., 2008). The minimum concentration of TN in JXZ during the high-flow period is 1.22 mg/L with an average concentration of 1.91 mg/L; and the minimum concentration of TP is 0.1 mg/L, with an average concentration of 0.18 mg/L. The TN and TP concentrations in JXZ therefore exceed the eutrophication limits, which is favorable for cyanobacterial growth. Phosphorus is usually considered to be the main limiting factor for the occurrence of cyanobacterial blooms, and when the P concentration in water is close to 0.1 mg/L, the bloom outbreak risk is as high as 80% (Downing et al., 2001). The P concentration in JXZ during the high-water period was favorable for cyanobacterial blooms. In addition to the single-factor assessment method of N and P concentrations, the “N/P hypothesis” is also a common way to discriminate the formation of water blooms. Cyanobacterial blooms tend to be dominant in water with N/P $<$ 29 (Lin et al., 2008). The N/P in JXZ was 7.3–25.4 in the high-water season, thus indicating a tendency for blooms.

4.2. RUE for defining urban river network water blooms

The correlation between the RUE and algae density is significant ($R^2 = 0.86$, $P < 0.01$), which indicates that the RUE can be used to define

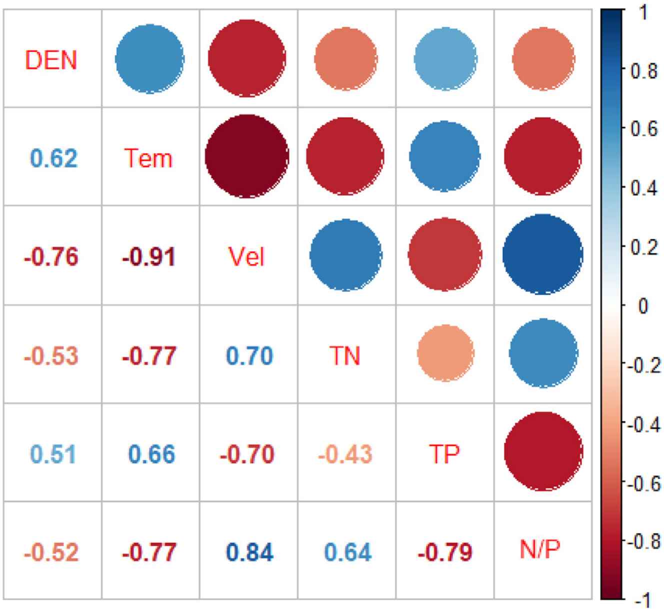

Figure 6. Relationships between environmental variables and phytoplankton community structure. DEN., Algae density; Tem., Water temperature; Vel., Flow velocity; TN., Total nitrogen; TP., Total phosphorus; N/P, Nitrogen to phosphorus ratios.

Table 1. Classification standard of cyanobacterial bloom degree based on algal density and RUE.

Degree of cyanobacterial bloom	Algae density (cells/L)	RUE	Features of cyanobacterial bloom	Water phenomenon
I	$0 \le D < 2.0 \times 10^6$	$0 \le$ RUE ≤ 46.81	No cyanobacterial bloom	There is no algae aggregation in water, and algae particles can generally not be recognized in water
II	$2.0 \times 10^6 \le D < 1.0 \times 10^7$	$46.81 <$ RUE ≤ 106.68	No obvious cyanobacterial bloom	A small concentration of algae on the surface, or a small number of algae particles can be identified in the water
III	$1.0 \times 10^7 \le D < 5.0 \times 10^7$	RUE >106.68	Present cyanobacterial bloom	Suspended algae particles can be seen in the water or algae gather into patches in the water

urban river water blooms (Figure 7). Urban rivers are closely related to human life. When cyanobacterial blooms form on the surface of an urban river, they are easily detected by humans and can lead to panic. This paper therefore adopts the provisions in Chinese HJ 1098–2020 "Technical specifications for monitoring and evaluating algae bloom based on remote sensing and field monitoring" (Ministry of Environment Protection of the People's Republic of China, 2020), and investigates if remote sensing images can identify floating water blooms on the water surface as a discriminating criterion. The discriminating limit of algal density in the RUE is determined by fitting the curve to accurately define the water blooms of urban rivers. The results show that there were no water blooms when $0 \le$ RUE ≤ 46.81, no notable water blooms when $46.81 <$ RUE ≤ 106.68, and that water blooms formed in rivers when RUE >106.68 (Table 1). The fitting results show that the RUE followed a decreasing trend when algal density exceeded 50×10^6 cells/L, because there were no water blooms in JXZ when the field surveys were conducted. Cao et al. (2022) calculated the threshold value for bloom outbreak in the world and stipulated that chlorophyll-a concentration of (10,26] would lead to bloom, at which time the total phosphorus concentration was 0.06 and RUE was equal to 45, which was basically consistent with our result (RUE = 46.81).

At the sites with high RUE values, cyanobacterial biomass in the water greatly exceeded that of other algae species and became the dominant species (Figure 4). According to the Chinese GB 3838-2002 "Environmental quality standards of surface water" (Ministry of Environment Protection of the People's Republic of China, 2002), the TP in JXZ is class III (TP < 0.2 mg/L), which reflects a low-P habitat. In this habitat, cyanobacteria achieve phosphate hyper-accumulation by forming polyphosphate particles for continuous population growth. Decaying cyanobacterial release large amounts of particulate nitrogen and phosphorus, which can be absorbed by other cyanobacteria (Chuai et al., 2011; Shi et al., 2003). Those two processes achieve phosphorus cycling between cyanobacteria and facilitates continuous cyanobacterial proliferation. Cyanobacteria can also grow to form agglomerates, providing more space for epiphytic bacteria who absorb nitrogen and phosphorus from decaying cyanobacteria as a kind of temporary reservoir, which can be reused by cyanobacteria (Jiang et al., 2007; Yuan et al., 2009). This dual P-cycle mechanism of the cyanobacterial phosphorus cycle and cyanobacteria–epiphytic bacteria phosphorus cycle causes cyanobacteria to proliferate and form dominant species. Low-P concentrations (denominator) and higher cyanobacterial biomass abundances (numerator) together form high RUE values.

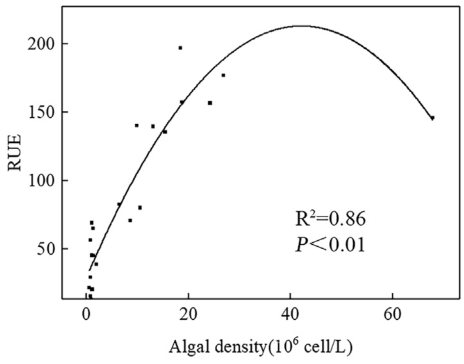

Figure 7. Relationships between RUE and algae density.

The RUE is also an important indicator of biodiversity (Yang et al., 2022). In this paper, three distinct characteristics were comparatively analyzed at each sampling site in JXZ during the high-water period. First, the algal density demonstrates that when algal diversity is high, the cyanobacterial percentage decreases due to the competition of nutrients and ecological niches. For example, the cyanobacteria percentage was 28.57% at S1 with a diversity of 1.63, while the cyanobacteria

Table 2. Algal density, cyanobacteria percentage, and cyanobacterial RUE in each sampling site in the high-water period.

Sampling sites	Algal density	Cyanobacteria percentage	Cyanobacterial RUE
S1	1.63	28.57%	38.95
S2	1.51	14.68%	24.46
S3	1.64	11.86%	16.99
S4	1.39	11.72%	6.65
S5	1.48	11.62%	8.16
S6	1.20	19.83%	13.14
S7	1.02	61.99%	53.19
S8	0.68	79.83%	87.20
S9	1.24	32.69%	5.12
S10	0.70	84.78%	56.23
S11	0.42	91.36%	423.19

percentage was 91.36% at S11 with a diversity of 0.42. The high diversity of algal organisms therefore weakened the RUE of the cyanobacteria, with a cyanobacterial RUE at S1 of 38.95 and S11 reaching 423.19 (Table 2). The use of RUE for the definition of cyanobacterial blooms allows for a deeper analysis of the role of diversity in enhancing ecosystem stability and provides theoretical support for cyanobacterial bloom control strategies.

5. Conclusion

The trend of cyanobacteria spreading to downstream rivers of lake reservoirs and other water diversions is gradually emerging. An appropriate approach to accurately define the degree of water blooms in rivers, especially urban rivers, is an important task to ensure the health of drinking water, fishing, and recreation. Our results show there are two reasons that cyanobacterial blooms form easily in plain urban river networks: 1) exogenous water inputs contain a high concentration of cyanobacteria, 2) suitable habitat conditions for cyanobacterial growth and reproduction due to the characteristic of slow flow velocity and high nutrient concentration. The RUE correlates significantly with algal density and can be used as an indicator to define the degree of urban river water blooms. The RUE was found to positively correlate with cyanobacterial blooms, and higher RUE values were associated with higher risks of cyanobacterial blooms. Cyanobacterial biomass in urban rivers, which are low-phosphorus concentration habitats, also grow heavily during high-water periods, thus producing a high RUE value. The dual P-cycle mechanism of the cyanobacteria–cyanobacteria phosphorus cycle and cyanobacteria–epiphytic bacteria phosphorus cycle create cyanobacterial biomass in urban rivers, which is a low-phosphorus concentration habitat that grows strongly during the high-water period and yields a high RUE value. The cyanobacterial RUE is limited by the high diversity of algae, which preempts the growth of cyanobacteria and lowers the risk of cyanobacterial blooms.

Our study provides a new method to define the extent of cyanobacterial blooms in urban rivers and theoretical support to achieve sustainable regional water resource use. However, this paper is only an example analysis with a field survey, in which the RUE factor was developed using JXZ as a target niche to obtain partial results. Thus, it is recommended that future studies should include follow-up work designed, 1) using synthetic media or mimicking niche water as controls, 2) using simulation studies as validations; 3) using more plant urban river networks that aim to confront cyanobacterial blooms as target niches, to evaluate whether the RUE is effective in the long term.

Declarations

Author contribution statement

Yifan Su: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Yun Li; Ziwu Fan: Conceived and designed the experiments.

Lin Gan: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Chen Xie; Rui Ding; Guoqin Liu: Analyzed and interpreted the data.

Yang Liu: Performed the experiments; Analyzed and interpreted the data.

Yipeng Liao: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Jingxiu Wu; Jianhao Sun: Contributed reagents, materials, analysis tools or data.

Guangyu Chen; Wenhan Zhu; Jingtian Ma: Performed the experiments.

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Data availability statement

The authors do not have permission to share data.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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