

Article

Study on the Distribution Characteristics and Influencing Factors of Phytoplankton Communities in Poyang Lake, China, Under Summer High-Temperature and Drought Conditions

Yu Chu ^{2,†}, Kexin Miao ^{1,†} , Lingquan Zeng ^{1,3}, Zishu Ye ¹ , Qi Zhu ^{1,*}, Chunhua Li ¹ and Chun Ye ^{1,*}

¹ Laboratory for Lake Pollution Control of the Ministry of Ecology and Environment, Chinese Research Academy of Environmental Sciences, Beijing 100012, China; miaokx@craes.org.cn (K.M.); cenglingquan22@mails.ucas.ac.cn (L.Z.); 15990089252@163.com (Z.Y.); lich@craes.org.cn (C.L.)

² Faculty of Science, University of Queensland, Brisbane, QLD 4101, Australia; chuyu0910@163.com

³ Key Laboratory of Marine Ecological Conservation and Restoration, Ministry of Natural Resources, Xiamen 361005, China

* Correspondence: zhu.qi@craes.org.cn (Q.Z.); yechun@craes.org.cn (C.Y.)

† These authors contributed equally to this work.

Abstract

Extreme heat and drought in Poyang Lake may contribute to pollutant accumulation and phytoplankton blooms. In order to understand these dynamics, phytoplankton assemblages and physicochemical parameters were compared between a high-temperature drought year (2022) and a reference year (2023). Population statistics, physicochemical parameter measurements, correlation analysis, and redundancy analysis (RDA) were used in the study to investigate phytoplankton communities and environmental factor impacts under high-temperature droughts. The results indicate the following: (1) There were 97 species of phytoplankton belonging to 7 divisions, primarily Chlorophyta, Bacillariophyta, and Cyanobacteria. The average phytoplankton density was 14.31×10^6 cells/L, and the biomass was 7.72 mg/L. Cyanobacteria accounted for 83.90% of the total phytoplankton abundance; *Microcystis flos-aquae* was the dominant species throughout the lake. (2) Habitat conditions vary significantly from region to region ($p < 0.05$). Transparency (SD), total nitrogen (TN), total phosphorus (TP), and nitrate nitrogen ($\text{NO}_3\text{-N}$) are key environmental factors affecting the structure of phytoplankton communities in the lake. Notably, the low SD likely resulted from both high turbidity and phytoplankton abundance, particularly cyanobacterial blooms. (3) The comparison between 2022 and 2023 suggests that the high-temperature and drought conditions in 2022 may have contributed to a substantial decline in lake water level and to the accumulation of nitrogen and phosphorus. These changes could, in turn, have favored phytoplankton aggregation and growth. However, because the comparison covers only two years and lacks continuous water temperature observations, these associations should be considered preliminary.



Academic Editor: Simon Blanchet

Received: 8 May 2026

Revised: 23 June 2026

Accepted: 25 June 2026

Published: 30 June 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

Keywords: Poyang Lake; phytoplankton; community structure; environmental factors; spatial heterogeneity

1. Introduction

Phytoplankton, as the primary producers in freshwater ecosystems, play a crucial role in energy conversion, material cycling, and information transfer [1,2]. The distribution of species is closely related to environmental factors, and suitable climatic conditions and good water quality are prerequisites for their healthy growth. Among these factors, water

temperature and nutrient salts are important determinants of phytoplankton community succession [3,4]. Research shows that high temperatures and low transparency in bodies of water are conducive to the growth of Cyanobacteria [5]. Increased concentrations of nutrients, such as nitrogen and phosphorus, also stimulate algae growth [6]. Wu Yusheng et al. conducted a survey of the phytoplankton community in Luoma Lake. They found that WT, TP, and the N-P ratio significantly affected the community structure [7]. Yang Yalan et al. proposed that WT, pH, and soluble phosphorus are key environmental factors promoting the succession of phytoplankton communities in Erhai Lake, Dali [8]. In recent years, extreme weather events, such as high temperatures and droughts, have significantly impacted the hydrological conditions of lakes and altered phytoplankton communities [9,10].

Poyang Lake, China's largest freshwater lake, is an important regulating lake in the middle and lower reaches of the Yangtze River [11]. Due to human activities and climate change, the phytoplankton community in Poyang Lake has shown a continuous degradation trend. Cyanobacteria have gradually become dominant in the lake, leading to the simplification of the phytoplankton community structure. In the 2009–2012 survey, Bacillariophyta was the dominant phylum in Poyang Lake's phytoplankton community, while Cyanobacteria accounted for only 4.0% [12]. Data from 2018 to 2019 shows that Cyanobacteria, Bacillariophyta, and Chlorophyta have become dominant populations [6]. The number of phytoplankton species in Poyang Lake is decreasing, while density and biomass are increasing. This greatly increases the risk of algal blooms [13].

Additionally, temperatures in the Poyang Lake basin have been rising, with extreme temperatures exhibiting significant variability from year to year and an increase in the number of days with extremely high temperatures. In the summer of 2022, the basin experienced an extreme drought, accompanied by far-below-average rainfall and unusually high temperatures [14,15]. This led to a rapid decline in water levels and the phenomenon of "flood season drought." Such extreme droughts can cause significant changes in hydrological conditions, alter the lake's physical and chemical properties, affect algal growth, and even threaten the survival of aquatic organisms [16,17]. Li Wenxuan et al. conducted a continuous survey of the phytoplankton community in Poyang Lake and found that rapid evaporation of lake water under drought conditions leads to a significant increase in phytoplankton density and biomass, but the mechanism underlying these effects remains unclear [18]. Therefore, it is necessary to further investigate how temperatures and drought conditions affect the phytoplankton community and its habitat in Poyang Lake, as well as the mechanisms underlying these effects.

This study focuses on the Nanchang Lake District of Poyang Lake from 2022 to 2023. By analyzing the lake's spatial heterogeneity and the influence of environmental factors on the spatiotemporal distribution of phytoplankton communities, as well as combining data from previous years' surveys, the study explores how phytoplankton communities respond to high temperatures and drought events. The findings will establish a theoretical basis for protecting and restoring the ecology of Poyang Lake under extreme climate conditions. Additionally, the data will support maintaining water quality and ecological security in the Poyang Lake basin.

2. Materials and Methods

2.1. Site Description

Poyang Lake (28°22'–29°45' N, 115°47'–116°45' E) is located in northern Jiangxi Province, northeast of Nanchang City, on the south bank of the middle and lower reaches of the Yangtze River. Poyang Lake is the largest freshwater lake in China. Its drainage basin covers 161,220 km², and the lake plays an important role in water regulation and maintaining regional ecological landscape. Monthly air temperature and precipitation

in the Poyang Lake basin for selected years are shown in Figures 1 and 2, respectively. Compared with 2023, which was selected as a representative reference year, the summer of 2022 was characterized by relatively high air temperatures and low precipitation. The meteorological data were obtained from the China Meteorological Data Service Center [19]. Poyang Lake is a typical large, shallow river-connected lake characterized by significant seasonal variations in hydrological conditions. During the wet season, the water depth is less than 6 m in approximately 85% of the lake area. Furthermore, the water level and surface area fluctuate drastically between the wet and dry seasons [20]. Influenced by variations in hydrological conditions and nutrient distribution, the ecological status exhibits distinct spatial heterogeneity across different lake regions. The phytoplankton community in Poyang Lake is dominated by diatoms, and cyanobacteria blooms mainly occur in local waters with high nutrient concentrations and relatively slow water flow [21]. This study focuses on the Nanchang section of Poyang Lake, which is located in the southwestern part of the lake and accounts for approximately 10% of its total area. The study area includes water bodies within Xinjian District, Nanchang County, and Jinxian County. Based on the overall structural characteristics of the Nanchang Lake District, it has been divided into three areas: A, B, and C. The sampling sites are shown in Figure 3, including Wuhu Branch (1-WH), Nanji Mountain (2-NJ), Dongsha Lake (3-DS), Jinxi Liu Jia (4-JX), Nanhu Village (5-NH), Qinglan Lake (6-QL), Cao Jia (7-CJ), Junshan Lake (8-JS) and Baiqi Mountain (9-BQ). Area A, comprising sites 1–3, is located in the northern central part of the lake. Area B, comprising sites 4–7, is located in the central lake area and connected Qinglan Lake (QL). Area C, comprising 8–9, is located in Junshan Lake (JS), a relatively isolated sub-lake.

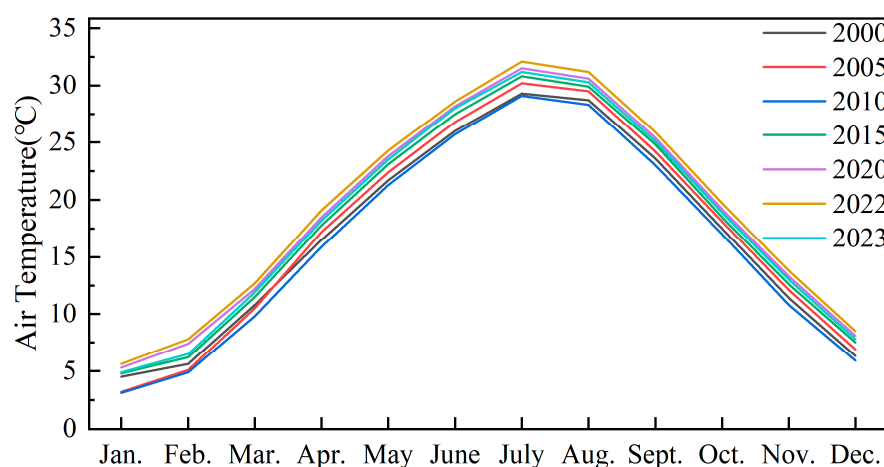


Figure 1. Monthly mean air temperature in the Poyang Lake basin in selected years (2000, 2005, 2010, 2015, 2020, 2022, and 2023). Data source: the China Meteorological Data Service Center (<http://data.cma.cn>).

2.2. Sample Collection and Identification

Two sampling campaigns for phytoplankton and water quality were conducted in the Nanchang Lake District of Poyang Lake in July 2022 and July 2023. Quantitative phytoplankton samples were collected using an acrylic water sampler (DXKJ-1L, Xiamen Dengxun Instrument Equipment Co., Xiamen, China) to collect 1 L of surface lake water. The samples were fixed on site using Lugol's solution (Lugol's iodine solution, 5%, Shanghai Enzyme-linked Biotechnology Co., Ltd., Shanghai, China) and formalin solution (formaldehyde solution, 37%, Shanghai Macklin Biochemical Technology Co., Ltd., Shanghai, China), left to stand for 48 h, concentrated to 50 mL, and then mixed thoroughly for phytoplankton identification and counting [22,23]. We used a portable water quality analyzer (YSI Pro Quatro, YSI Incorporated, Yellow Springs, OH, USA) to measure dis-

solved oxygen (DO) and pH on site, while water transparency (SD) was measured using a Secchi disk (SD20, Shanghai Jingmi Instrument Co., Ltd., Shanghai, China). The water samples were brought back to the laboratory to determine and analyze the content of total nitrogen (TN), total phosphorus (TP), ammonia nitrogen ($\text{NH}_3\text{-N}$), nitrate nitrogen ($\text{NO}_3\text{-N}$), and the permanganate index (COD_{Mn}). The testing methods for each water quality indicator were referenced from reference [24]. All samples were measured at the National Engineering Laboratory for Lake Pollution Control and Ecological Restoration, Chinese Research Academy of Environmental Sciences.

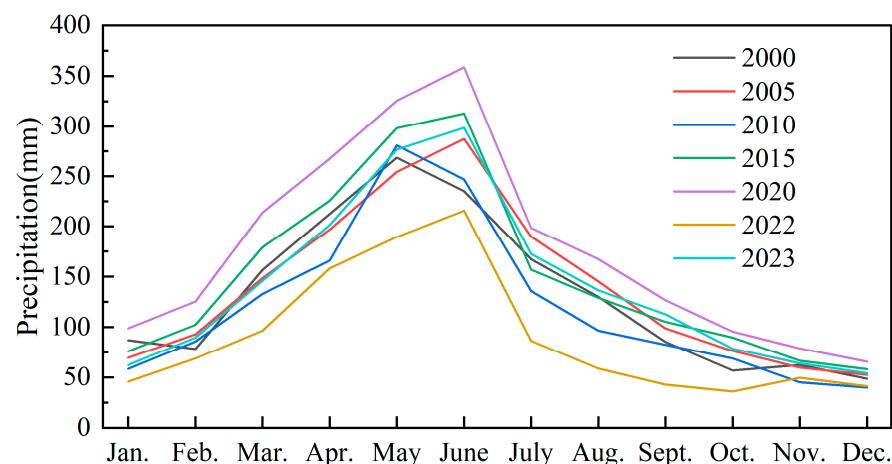


Figure 2. Monthly total precipitation in the Poyang Lake basin in selected years (2000, 2005, 2010, 2015, 2020, 2022, and 2023). Data source: the China Meteorological Data Service Center (<http://data.cma.cn>).

2.3. Analysis of Phytoplankton Community Structure

The dominance index (Y) describes the dominant species in the phytoplankton community. The Shannon–Wiener biodiversity index (H'), Margalef species richness index (D), and Pielou evenness index (J) describe the characteristics of the phytoplankton community and assess water quality in the lake. The calculation formulas are as follows:

$$Y = \frac{n_i}{N} \times f_i$$

$$H' = -\sum \frac{n_i}{N} \ln \frac{n_i}{N}$$

$$D = \frac{(S - 1)}{\ln N}$$

$$J = \frac{H'}{\ln S}$$

In the formulas, n_i is the number of individuals of the i -th species; N is the total number of individuals of all species; f_i is the frequency of occurrence of the i -th species of algae at each sampling site; S is the total number of algae species; $Y \geq 0.02$ indicates that the species is dominant. The common criteria for judging water quality based on phytoplankton diversity are shown in Table 1 [25–27].

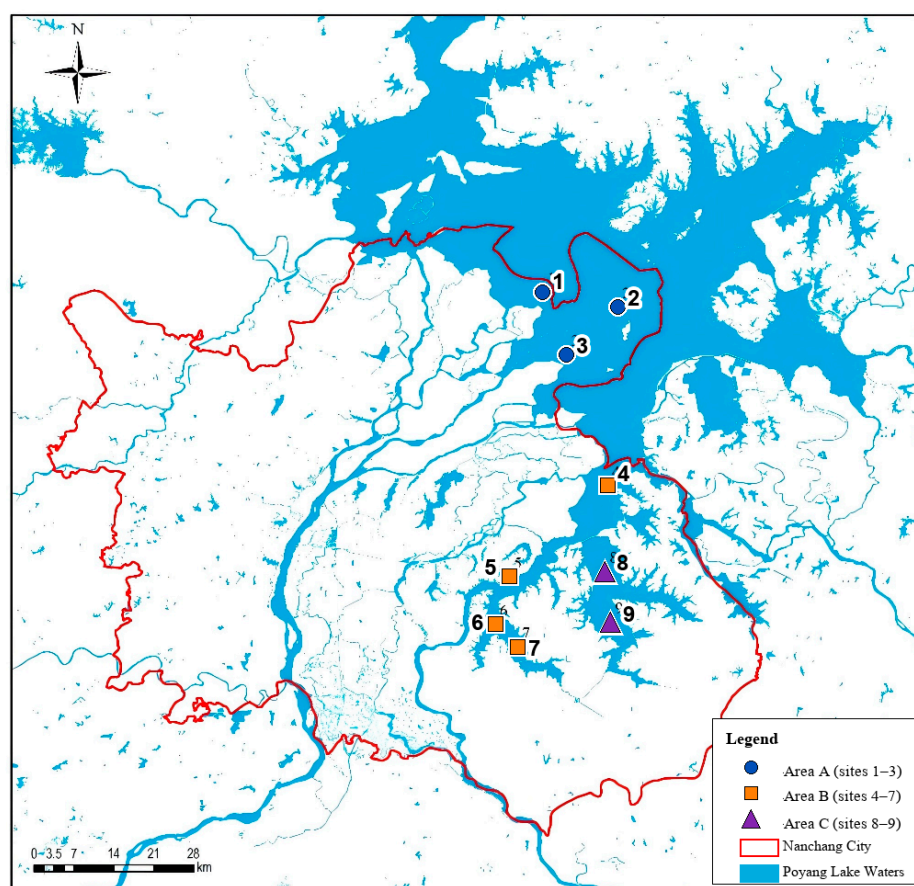


Figure 3. Distribution of sampling sites in the Nanchang Lake District of Poyang Lake. Different symbols indicate Area A (sites 1–3), Area B (sites 4–7), and Area C (sites 8–9). Data source: Natural Earth(<http://www.naturalearthdata.com/downloads/10m-cultural-vectors/10m-admin-0-countries/>), accessed on 24 June 2026).

Table 1. Diversity indexes for water quality assessment.

Water Quality Status	Heavy Pollution	α -Moderate Pollution	β -Moderate Pollution	Light Pollution	No Pollution
Shannon–Wiener (H')	<1.0	1.0~2.0	2.0~3.0	3.0~4.5	>4.5
Pielou (J)	<0.1	0.1~0.3	0.3~0.5	0.5~0.8	>0.8
Margalef (D)	<1.0	1.0~2.0	2.0~3.0	3.0~4.0	>4.0

2.4. Statistical Analysis

The basic data were organized, calculated, and charted using Excel 2023 (Microsoft Corporation, Redmond, WA, USA) and Origin 2024 (OriginLab Corporation, Northampton, MA, USA). R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) was used to test for spatial variability in environmental factors across different lake areas via replacement multivariate analysis of variance (PERMANOVA). Detrended correspondence analysis (DCA) was performed on the phytoplankton and environmental factors dataset, with a maximum gradient length of less than 3. Redundancy analysis (RDA) was used to explore the relationship between dominant phytoplankton communities and environmental factors. SPSS Statistics 26.0 (IBM Corp., Armonk, NY, USA) was used to perform Spearman correlation analysis of phytoplankton and environmental factors. ANOVA was used to test the effects of location (A, B, and C) and time (2022 and 2023) on phytoplankton density

and biomass in the Nanchang Lake area. Except for pH, the data were converted using $\log(x + 1)$ prior to statistical analysis [28–30].

3. Results

3.1. Characteristics of Environmental Factors

As shown in Table 2, NJ had the highest pH value in 2022, and NH had the lowest. JS had the highest SD, and NJ and DS had the lowest. JS had the highest DO content, while QL had the lowest. TN and TP concentrations exhibited the same distribution pattern, maximum values occurred at NJ and minimum values occurred at BQ. The maximum $\text{NH}_3\text{-N}$ and COD_{Mn} concentrations occurred at NJ, and the minimum values were observed at JX and WH. The highest $\text{NO}_3\text{-N}$ content and N/P ratio values were observed at WH, and the lowest values were observed at NH and DS.

Table 2. Main environmental parameters at each sampling site in Nanchang area of Poyang Lake (2022/2023).

Serial Number	Area	Sampling Point	pH	SD	DO	TN	TP	$\text{NH}_4^+\text{-N}$	$\text{NO}_3^-\text{-N}$	COD_{Mn}	N/P
				cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
1	A	WH	7.13/7.53	20/20	5.27/0.99	1.48/1.35	0.06/0.12	0.30/0.62	1.02/0.16	3.49/11.98	24.67/11.00
2	A	NJ	7.34/7.14	5/10	4.85/3.97	3.82/2.04	0.35/0.13	1.78/0.12	0.22/1.38	14.86/5.55	10.91/15.87
3	A	DS	6.84/7.18	5/10	5.01/2.89	1.62/2.37	0.22/0.10	0.26/0.52	0.91/0.97	9.34/11.46	7.53/24.42
4	B	JX	6.87/7.77	5/15	4.82/2.56	1.23/0.49	0.11/0.07	0.12/0.16	0.61/0.29	6.08/5.06	11.18/7.43
5	B	NH	6.74/7.89	18/30	4.76/1.28	1.46/1.69	0.12/0.07	0.37/0.12	0.06/1.08	8.45/6.72	12.17/25.87
6	B	QL	7.01/8.84	20/35	4.74/1.40	1.67/2.35	0.17/0.08	0.47/0.18	0.15/0.81	9.04/2.08	9.82/28.98
7	B	CJ	7.00/7.30	20/10	4.76/0.80	1.58/1.61	0.14/0.08	0.51/0.18	0.12/0.34	7.90/5.62	11.29/19.82
8	C	JS	7.10/8.10	121/70	5.61/1.01	0.50/0.23	0.03/0.03	0.18/0.10	0.27/0.09	4.03/2.51	16.67/7.98
9	C	BQ	7.12/8.52	116/90	5.21/0.99	0.45/0.35	0.02/0.03	0.21/0.15	0.10/0.05	4.11/4.30	22.50/12.20

The 2023 survey revealed that QL had the highest pH value, while NJ had the lowest. The lowest SD values occurred at NJ and DS, and the highest value occurred at BQ. NJ had the highest DO content, while CJ had the lowest. JS had the lowest values for TN, TP and $\text{NH}_3\text{-N}$, while DS, NJ, and the WH had the highest values, respectively. The N/P ratio is highest at QL, and the COD_{Mn} content is lowest there. The maximum COD_{Mn} content occurred at the WH, and the minimum N/P ratio occurred at the JX.

The results of the PERMANOVA analysis revealed significant differences in water quality properties among the northern lake area (Area A), the central and QL (Area B) and JS (Area C) ($p < 0.05$). Overall, water quality is better in Lake Area C, while it is slightly poorer in Lake Area A, especially in the NJ area. From a temporal perspective, the survey showed that nutrient and organic matter levels in Lake Area C were generally higher in 2022 than in 2023.

3.2. Phytoplankton Community Structure

3.2.1. Phytoplankton Species Composition

During the two summer surveys, a total of 97 phytoplankton species belonging to 7 divisions were identified. The dominant groups were Chlorophyta, Bacillariophyta, Cyanobacteria. Chlorophyta accounted for the largest proportion, with 44 species representing 45.36% of the total. This was followed by Bacillariophyta, with 17 species accounting for 17.53%, and Cyanobacteria, with 16 species accounting for 16.49%. We found four species from Cryptophyta, three from Xanthophyta, and two from Dinophyta. From a spatial perspective (Figure 4a), except for WH (20.53%) and JX (30.14%), Cyanobacteria dominated all other sites with an abundance exceeding 60%. Between 2022 and 2023 (Figure 4b,c),

Cyanobacteria remained dominant in the lake, though their relative abundance decreased from 90.35% to 50.94%. Chlorophyta increased from 2.85% to 21.03% and Xanthophyta increased from 0.73% to 9.91%. From a spatial perspective, phytoplankton community structures of Areas A, B, and C are generally similar. However, Area A shifted from being dominated by Cyanobacteria (88.86%) in 2022 to being dominated by Chlorophyta (33.72%) in 2023, resulting in a more balanced community structure. In Area B, the relative abundance of Cyanobacteria decreased from 91.64% to 49.58%, while the relative abundances of other algae increased, with Xanthophyta rising from 0.42% to 14.93%. In Area C, the algal community structure showed little change between the two surveys, but Xanthophyta and Dinophyta were observed in 2023.

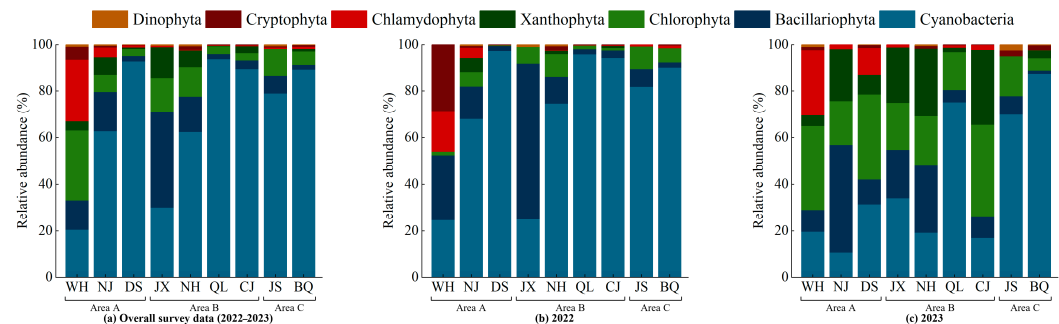


Figure 4. Spatial variation in phytoplankton community composition in the Nanchang area of Poyang Lake. (a) Overall survey data from 2022 to 2023; (b) 2022; (c) 2023. Sampling sites WH, NJ, and DS belong to Area A; JX, NH, QL, and CJ belong to Area B; JS and BQ belong to Area C.

Analysis of the dominant species of phytoplankton in different areas of Nanchang Lake region (Table 3) showed that the dominant species were mainly concentrated in four divisions: Cyanobacteria, Bacillariophyta, Chlorophyta, and Xanthophyta. JS (Area C) had six dominant species, with *Phormidium tenue* exhibiting the highest dominance (0.56). Northern lake (Area A) and QL (Area B) both have four dominant species, with *Microcystis flos-aquae* having the highest dominance at 0.72 and 0.78. The dominant species unique to northern lake areas were *Navicula* spp. and *Tribonema affine*. *Tribonema minus* was only dominant in QL area. JS region's unique species were *Phormidium tenue*, *Pseudanabaena voronichinii*, *Planktothrix* sp. and *Chlorella vulgaris*. *Microcystis flos-aquae* was the dominant species in the entire lake.

Table 3. Phytoplankton dominant species and dominance in Nanchang area of Poyang Lake.

Dominant Species		Dominance in Area		
Division	Species	Area A	Area B	Area C
Cyanobacteria	<i>Microcystis flos-aquae</i>	0.72	0.78	0.05
	<i>Merismopedia</i> sp.	—	0.02	0.03
	<i>Phormidium tenue</i>	—	—	0.56
	<i>Pseudanabaena voronichinii</i>	—	—	0.05
	<i>Planktothrix</i> sp.	—	—	0.04
Bacillariophyta	<i>Aulacoseira granulata</i>	0.02	0.03	—
	<i>Navicula</i> spp.	0.02	—	—
Xanthophyta	<i>Tribonema affine</i>	0.02	—	—
	<i>Tribonema minus</i>	—	0.02	—
Chlorophyta	<i>Chlorella vulgaris</i>	—	—	0.02

3.2.2. Phytoplankton Density and Biomass

Results from the phytoplankton density and biomass survey conducted in the Nanchang Lake area from 2022 to 2023 show that phytoplankton density at each sampling site in 2022 ranged from 1.32 to 69.97×10^6 cells/L, averaging 23.93×10^6 cells/L. The highest density was recorded at the QL, while the lowest density was observed at the WH. In 2023, the range of phytoplankton density at various sites in the lake area was between 1.66 and 9.67×10^6 cells/L, with an average of 4.68×10^6 cells/L. The lowest density was observed at the JS and the highest at the QL. From a spatial perspective (Figure 5a), the highest average phytoplankton density was in Area B (QL), at 17.48×10^6 cells/L. The second-highest density was in the northern lake (Area A) at 13.48×10^6 cells/L. The lowest density was at JS (Area C) at 9.21×10^6 cells/L. From a temporal perspective (Figure 5b), the average phytoplankton density in the lake area in 2022 was significantly higher than in 2023. Analysis of variance (ANOVA) results indicated that time significantly affected phytoplankton density ($p < 0.05$). Additionally, the density of phytoplankton in Areas A, B, and C decreased significantly in 2023 compared to 2022. The average density decreased by 82.43%, 84.24%, and 57.34% in Areas A, B, and C, respectively. During the summer of 2022, the range of phytoplankton biomass at various lake sites was 2.37 to 25.24 mg/L, with an average of 9.11 mg/L. The highest biomass was recorded at the NJ, and the lowest was recorded at the WH. In the summer of 2023, phytoplankton biomass at various lake sites ranged from 1.59 to 19.21 mg/L, averaging 6.33 mg/L. The minimum biomass was observed at JS and the maximum was observed at the WH. Phytoplankton biomass decreased in all three lake areas in 2023 compared to 2022, 8.22% in Area A, 52.73% in Area B, and 22.63% in Area C. The spatial distribution characteristics of phytoplankton biomass across the lake areas were as follows: Area A > Area B > Area C (Figure 5a). Overall, phytoplankton density and biomass were higher in 2022 than in 2023, and the patterns of change were similar across the different lake areas.

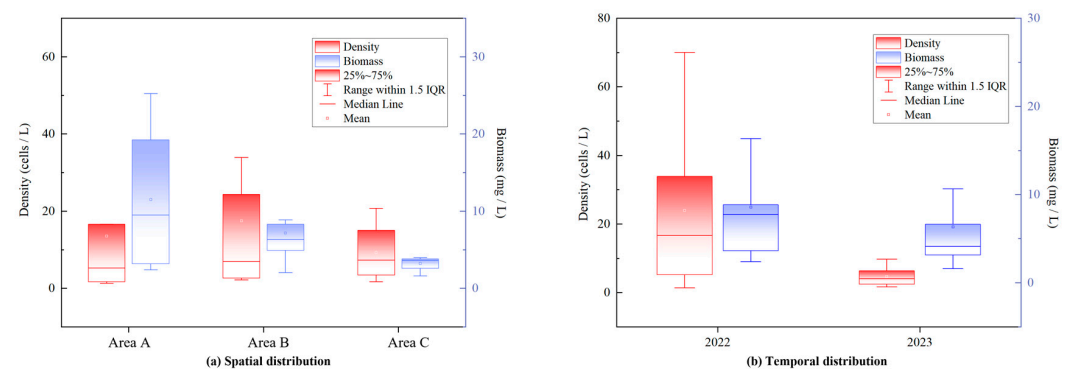


Figure 5. Spatial and temporal distribution of phytoplankton density and biomass in Nanchang area of Poyang Lake. (a) Spatial distribution based on overall survey data from 2022 to 2023; (b) temporal distribution by year. Note: A represents Area A (sites 1–3 in Figure 3); B represents Area B (sites 4–7 in Figure 3); C represents Area C (sites 8–9 in Figure 3).

3.2.3. Phytoplankton Diversity Analysis

Multivariate analysis of variance (MANOVA) of phytoplankton diversity indices in the Nanchang Lake area revealed that survey time significantly impacted the Shannon–Wiener (H'), Pielou (J), and Margalef (D) indices ($p < 0.05$). However, the spatial location of the lake did not significantly affect the phytoplankton diversity indices ($p > 0.05$). Average H' , J , and D values in the lake area were higher in the summer of 2023 than 2022, indicating greater stability in the phytoplankton community structure that year. Figure 6 illustrates the spatial distribution of community structure stability across three areas: northern lake (Area A) > QL (Area B) > JS (Area C). According to the criteria for evaluating aquatic ecosystem

health using diversity indices (Table 1), Shannon–Wiener biodiversity index (H') showed that Area A was classified as β -moderate pollution, and Areas B and C were classified as α -moderate pollution. Margalef species richness index (D) showed that all three areas were classified as light pollution. These results suggested that the overall water quality of the Nanchang lake area was moderately polluted. According to Pielou evenness index (J), all three areas were in the lightly polluted zone. This indicated that despite the low number of phytoplankton species in the Nanchang lake area, they were distributed relatively evenly.

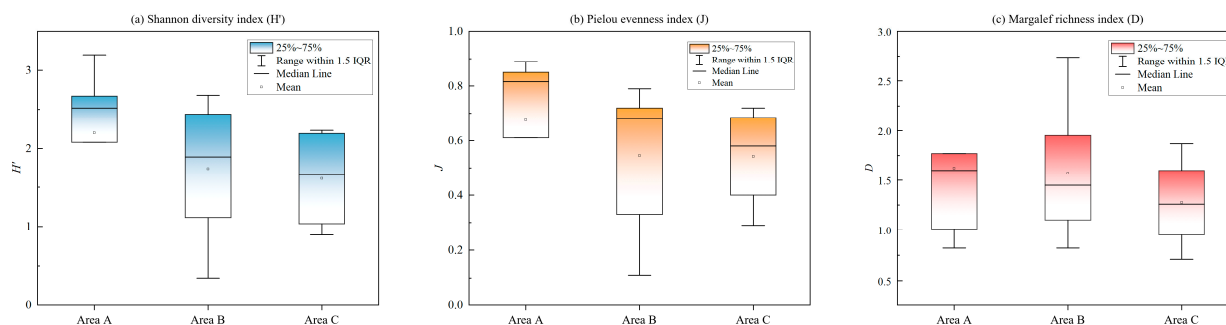


Figure 6. Spatial variations in phytoplankton diversity indices in the Nanchang area of Poyang Lake. (a) Shannon diversity index (H'); (b) Pielou evenness index (J); (c) Margalef richness index (D). Area A, Area B, and Area C correspond to the lake regions defined in Figure 3.

3.3. Correlation Analysis Between Phytoplankton and Environmental Factors

Spearman correlation analysis was performed between phytoplankton data from each sampling site and environmental factors (Figure 7). Phytoplankton density showed positive, but non-significant, correlations with TN ($r = 0.57$, $p = 0.11$), TP ($r = 0.46$, $p = 0.21$), and the N/P ratio ($r = 0.60$, $p = 0.09$). Phytoplankton biomass showed a highly significant positive correlation with TN ($p < 0.01$), with a correlation coefficient of 0.85; it also showed significant positive correlations with TP, $\text{NH}_3\text{-N}$, and $\text{NO}_3\text{-N}$ ($p < 0.05$); COD_{Mn} was positively correlated with phytoplankton biomass with correlation coefficients of 0.60 ($p = 0.08$). Therefore, TN, TP, $\text{NH}_3\text{-N}$, and $\text{NO}_3\text{-N}$ can be considered key factors affecting the growth of phytoplankton in lakes. At the same time, SD is also considered a major factor affecting phytoplankton growth, while pH, DO, and COD_{Mn} concentrations vary significantly at different times and in different lakes. Their impact on phytoplankton should not be overlooked.

3.4. Analysis of Phytoplankton Communities and Their Influencing Factors

RDA was used to investigate the impact of environmental factors on the structure of phytoplankton communities in lakes based on differences in lake environmental conditions. Figure 8 shows that SD showed the strongest correlation with the variation in phytoplankton community structure in the RDA model, followed by TN, $\text{NO}_3\text{-N}$, and TP. It is important to note that SD in this context is an integrated parameter reflecting both underwater light availability and the shading effect of suspended particles including phytoplankton. The correlation analysis revealed that pH and SD are negatively correlated with most phytoplankton communities, while TN, TP, $\text{NO}_3\text{-N}$, and $\text{NH}_3\text{-N}$ are positively correlated with them. *Mougeotia* sp., *Phormidium tenue*, *Cymbella* sp. and *Synedra* sp. are positively correlated with pH, SD, and negatively correlated with COD_{Mn} and $\text{NH}_3\text{-N}$. *Trachelomonas abrupta* and *Strombomonas ensifera* exhibited strong correlations with environmental factors, which showed negative correlations with pH and SD and positive correlations with $\text{NO}_3\text{-N}$ and DO. Comparing differences across lake areas reveals that JS, BQ, and NH were primarily influenced by SD and pH. In contrast, NJ and QL were associated with DO and N/P content. DS and JX were primarily influenced by $\text{NO}_3\text{-N}$, DO, and COD_{Mn} content.

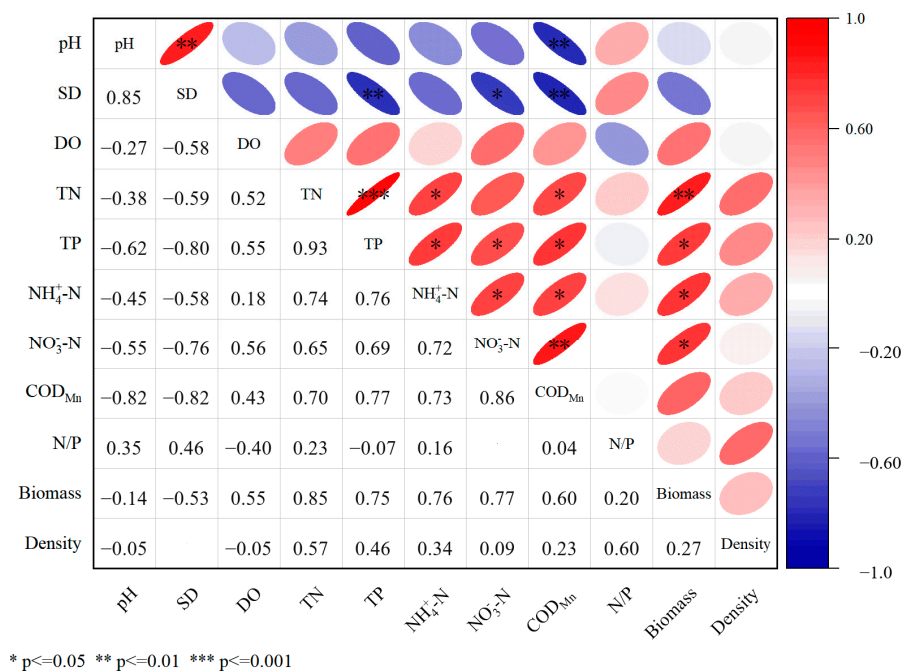


Figure 7. Correlation analysis between phytoplankton and environmental factors (note: p describes the significance of the difference between two variables, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; the color of the ellipse indicates positive or negative correlation; the depth of color indicates the degree of significance).

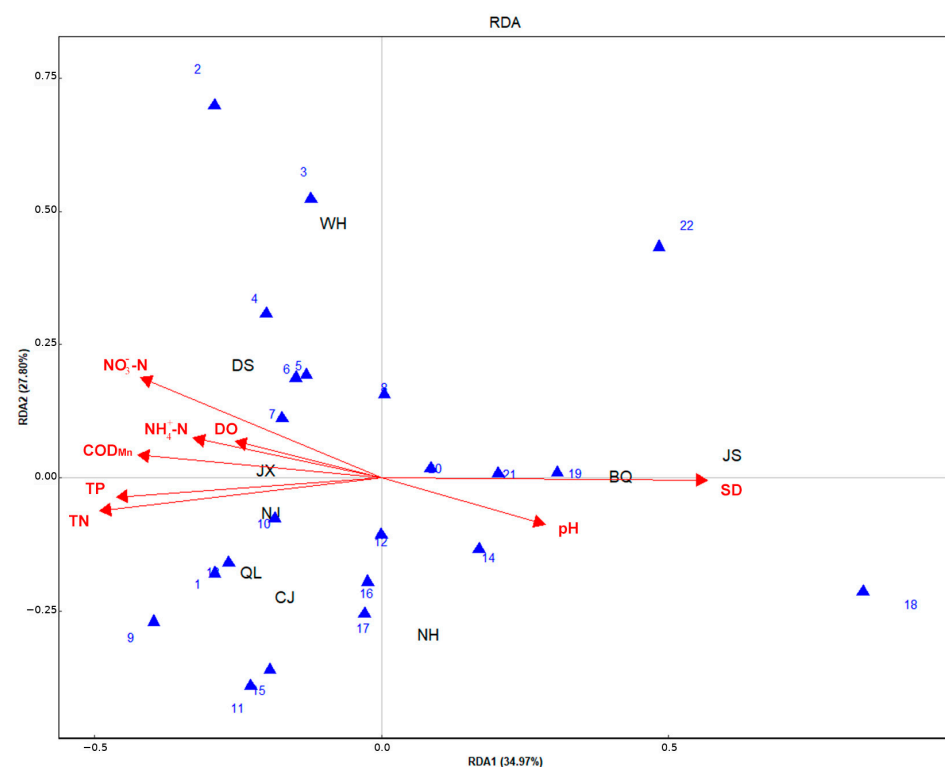


Figure 8. RDA between dominant phytoplankton communities and environmental factors during summer 2022–2023 in Nanchang area of Poyang Lake. Note: 1: *Surirella robusta*; 2: *Phacus circulator*; 3: *Trachelomonas planctonica*; 4: *Euglena* spp.; 5: *Trachelomonas abrupta*; 6: *Strombomonas ensifera*; 7: *Chlamydomonas* sp.; 8: *Phacus pyrum*; 9: *Aulacoseira granulata*; 10: *Navicula* spp.; 11: *Microcystis flos-aquae*; 12: *Cyclotella* spp.; 13: *Tribonema minus*; 14: *Synedra* sp.; 15: *Pediastrum duplex*; 16: *Tribonema affine*; 17: *Cryptomonas ovata*; 18: *Mougeotia* sp.; 19: *Phormidium tenue*; 20: *Planktothrix* sp.; 21: *Cymbella* sp.; 22: *Peridinium ecpatiewskyi*.

4. Discussion

4.1. Distribution Characteristics and Influencing Factors of Phytoplankton Communities

In the 2022–2023 survey, a total of 97 species of phytoplankton belonging to seven divisions were collected in the Nanchang Lake area of Poyang Lake. The average density of phytoplankton was 14.31×10^6 cells/L, and the average biomass was 7.72 mg/L, similar to the results of the 2021 survey of the disc-shaped lake in Poyang Lake [31]. This study found that phytoplankton density and biomass were higher in 2022 than in 2023, with similar patterns of change across different lake regions. This phenomenon may be related to the extreme drought that occurred in the Poyang Lake basin in the summer of 2022. The drought reduced water exchange in the area, leading to the accumulation of nutrients and the proliferation of algae [18]. Of the three areas, JS (Area C) had the lowest phytoplankton density and biomass. The between-year differences in phytoplankton density and biomass were less pronounced in this lake. This may be because JS is a relatively isolated barrier lake, making it less susceptible to reduced water exchange caused by drought in the watershed. The survey found the relative abundance of eutrophic Cyanobacteria reached 83.90%. Since both surveys were conducted in the summer, the high temperatures were conducive to the growth and reproduction of Cyanobacteria and other species [32]. *Microcystis flos-aquae* reached dominance levels of 0.72 and 0.78 in the northern lake area and QL, respectively. Meanwhile, *Phormidium tenue* reached a dominance level of 0.56 in JS. These results suggest that Cyanobacteria are abundant and dominant in the lake area [21]. Cyanobacteria prone to blooms, Chlorophyta that thrive in eutrophic water, and Bacillariophyta that tolerate low-light conditions currently dominate the phytoplankton community in the lake area. This indicates that the lake as a whole is trending toward eutrophication [33–35]. In addition, compared with the first scientific expedition to Poyang Lake in 1983, recent surveys have rarely reported Chrysophyta, and none were found in this survey. Dinophyta that commonly proliferates in mesotrophic or oligotrophic water bodies was only collected in two species [36], with reduction in species and distribution area compared to previous surveys further indicating that the lake is becoming eutrophic.

The survey results suggest that concentrations of TN and TP are the primary drivers of spatial and temporal differences in phytoplankton communities. During the two summer surveys, Area A had the highest average phytoplankton biomass and density, as well as the lowest SD. Area C exhibited the opposite characteristics. N and P nutrient concentrations exhibited similar patterns. Areas A and B are located near the mouths of the Gan river and Fu river, respectively. It is reasonable to infer that the rivers carry high concentrations of nutrients. Water transparency (SD) is another key factor closely linked to phytoplankton distribution. In this study, the low SD observed in Area A is likely attributed to a combination of high sediment input and resuspension from river inflows [37,38], as well as the high phytoplankton biomass itself. The significant negative correlation between SD and phytoplankton biomass suggests a potential feedback loop that nutrient enrichment promotes algal growth, which in turn reduces water clarity. Conversely, the high SD in the isolated Area C indicates clearer water, which may favor different algal groups and partly result from lower overall phytoplankton density.

4.2. Potential Influences of High Temperature and Drought on Phytoplankton Communities and Environmental Conditions

In both surveys, TN and TP concentrations were higher in 2022 than in 2023. Significant temporal differences were also detected in phytoplankton density and biomass. The average phytoplankton biomass in the summer of 2022 (9.11 mg/L) was higher than that recorded in the summer of 2023 (6.33 mg/L), and the higher biomass in 2022 was predominantly associated with Cyanobacteria, particularly *Microcystis flos-aquae*. In the reference year (2023),

the reduction in overall biomass coincided with a more balanced community structure, in which the relative biomass contribution of Chlorophyta and Xanthophyta increased. These patterns are consistent with the possibility that the 2022 high-temperature-drought event may have favored cyanobacterial dominance and increased total phytoplankton biomass, potentially through reduced water volume and increased nutrient concentration. However, this interpretation is based on a comparison of only two years, and the possible contributions of other unmeasured environmental factors cannot be excluded.

Comparison with data reported for the same period in previous years showed that nutrient concentrations, phytoplankton density, and biomass in the Nanchang Lake area were generally higher in 2022 [6,12,31,39,40]. Field observations also indicated that water levels in several parts of the lake were lower than those observed in previous years and that drying and hydrological isolation occurred at some locations. These conditions may have reduced water exchange and self-purification capacity, potentially contributing to nutrient accumulation. In addition, reduced runoff and enhanced evaporation under high-temperature and drought conditions could have further decreased lake water volume.

The marked shift in phytoplankton community structure observed in the summer of 2022—particularly the high relative abundance of Cyanobacteria—coincided temporally with one of the most severe regional high-temperature-drought event in decades. While site-specific water temperature data are not available for direct correlation, this extreme climate event provides a plausible explanatory context [41]. The concomitant drought may have led to a drastic reduction in lake water level, potentially triggering a pronounced “concentration effect” where reduced water volume could have increased nutrient concentrations, thereby alleviating resource limitation [42,43]. Furthermore, shallower water columns promote more uniform and higher water temperatures and stabilize the water column, creating more stable thermal stratification. This, in turn, could promote the accumulation of phytoplankton biomass and the formation of dense surface phytoplankton [44,45]. Firstly, the documented regional heatwave itself established a thermal context favorable to cyanobacteria, particularly *Microcystis*, which are known to exhibit optimal growth rates and competitive advantages at elevated temperatures [46,47]. Therefore, the 2022 phytoplankton assemblage may have been shaped by a cascade of events associated with the heat–drought event, in which high temperature may have acted as a trigger and drought-induced hydrological and physicochemical changes may have acted as the amplifiers. However, this interpretation cannot be confirmed from the present two-year dataset.

The extremely high temperatures and drought in the lake area during the summer of 2022 may therefore have contributed to the higher-than-normal concentrations of nitrogen and phosphorus, as well as the relatively high phytoplankton biomass [48–50]. The return to a more balanced community structure and lower overall biomass in 2023, under more typical climatic conditions, is consistent with this integrated interpretation. However, this single recovery observation does not constitute definitive proof, and further investigations incorporating extended time-series data, continuous water temperature records, and hydrological observations are required to substantiate this inference.

5. Conclusions

(1) In 2022–2023, a total of 97 species of phytoplankton belonging to seven divisions were monitored in Nanchang Lake Area, Poyang Lake. The main groups were Chlorophyta, Bacillariophyta, and Cyanobacteria. The average density of phytoplankton was 14.31×10^6 cells/L, and the average biomass was 7.72 mg/L. *Microcystis flos-aquae* was the dominant species throughout the entire lake.

(2) The spatial heterogeneity of the Nanchang Lake area of Poyang Lake significantly impacts the distribution of phytoplankton communities. Phytoplankton density

and biomass are much higher in Area A than in Area C. Area A is primarily influenced by nitrogen and phosphorus nutrients, as well as DO. In contrast, the main environmental factors affecting Area C are pH and SD.

(3) The comparison between 2022 and 2023 suggests that high temperatures and drought may have influenced phytoplankton communities. The extreme drought may have contributed to a substantial drop in Poyang Lake's water level, which may, in turn, have contributed to an increase in nitrogen and phosphorus concentrations. Phytoplankton density and biomass were also notably higher in the summer of 2022 compared to 2023. However, given the limited temporal scope of the dataset (only two years), a definitive attribution of these changes solely to the drought event is not possible. Correlation and RDA analyses revealed that pH, TN, TP, and NO₃-N are key environmental factors associated with the distribution of phytoplankton communities. Water transparency (SD) exhibited the strongest statistical association with community variation; however, its role is complex, as it both influences light availability for phytoplankton and is concurrently reduced by high algal biomass. Future research incorporating long-term monitoring data, continuous water temperature and hydrological records, and observations across multiple drought and non-drought years is necessary to validate these preliminary observations and fully elucidate the underlying mechanisms.

Author Contributions: Conceptualization, Q.Z., C.L. and C.Y.; methodology, Y.C., K.M., and Q.Z.; software, Y.C. and K.M.; validation, Q.Z., C.L. and C.Y.; formal analysis, Y.C. and K.M.; investigation, L.Z. and Z.Y.; resources, Q.Z., C.L. and C.Y.; data curation, Y.C. and K.M.; writing—original draft preparation, Y.C. and K.M.; writing—review and editing, Q.Z., C.L. and C.Y.; visualization, Y.C. and K.M.; supervision, Q.Z., C.L. and C.Y.; project administration, Q.Z. and C.L.; funding acquisition, C.L. and C.Y. All authors have read and agreed to the published version of the manuscript.

Funding: Supported by Central Funds for Water Pollution Prevention and Control, Investigation and evaluation of water ecological quality of in Poyang Lake (HSH2023G005).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare that they have no competing interests.

References

1. Naselli-Flores, L.; Padisák, J. Ecosystem services provided by marine and freshwater phytoplankton. *Hydrobiologia* **2023**, *850*, 2691–2706. [[PubMed](#)]
2. Yu, H.; Shi, X.; Zhao, S.; Sun, B.; Liu, Y.; Arvola, L.; Li, G.; Wang, Y.; Pan, X.; Wu, R.; et al. Primary productivity of phytoplankton and its influencing factors in cold and arid regions: A case study of Wuliangsuhai Lake, China. *Ecol. Indic.* **2022**, *144*, 109545. [[CrossRef](#)]
3. Fernández-González, C.; Tarran, G.A.; Schuback, N.; Woodward, E.M.S.; Arístegui, J.; Marañón, E. Phytoplankton responses to changing temperature and nutrient availability are consistent across the tropical and subtropical Atlantic. *Commun. Biol.* **2022**, *5*, 1035. [[CrossRef](#)] [[PubMed](#)]
4. Siegel, D.A.; Behrenfeld, M.J.; Maritorena, S.; McClain, C.R.; Antoine, D.; Bailey, S.W.; Bontempi, P.S.; Boss, E.S.; Dierssen, H.M.; Doney, S.C.; et al. Regional to global assessments of phytoplankton dynamics from the SeaWiFS mission. *Remote Sens. Environ.* **2013**, *135*, 77–91. [[CrossRef](#)]
5. Zhou, J.; Li, S.N.; Wang, X.J.; Kong, F.X.; Shi, X.L. Spatial distribution characteristics of picophytoplankton and its impact factors during wet season in Lake Poyang. *J. Lake Sci.* **2016**, *28*, 537–544. [[CrossRef](#)]
6. McDowell, R.W.; Luo, D.; Pletnyakov, P.; Upsdell, M.; Dodds, W.K. Anthropogenic nutrient inputs cause excessive algal growth for nearly half the world's population. *Nat. Commun.* **2025**, *16*, 1830.
7. Wu, Y.S.; Zhu, Y.J.; Pang, Y.; Xu, J.X.; Xu, J. Driving factors of phytoplankton functional groups and applicability of water quality evaluation: A case study of Lake Luoma. *Res. Environ. Sci.* **2023**, *36*, 1915–1926.

8. Yang, Y.L.; Guo, L.G.; Yin, C.J.; Gong, L.; Luo, Z.F.; Xu, S.L. Study on the seasonal succession of phytoplankton functional groups in Eryuan West Lake of Dali City, Yunnan Province. *J. Environ. Eng. Technol.* **2023**, *13*, 625–631.
9. Yue, E.X.; Zhao, L.; Qian, P.Y.; Liu, Y.; Li, X.H.; Zhao, H.Q.; Ye, X.C. Impact of hydrological drought on hydrological connectivity in the Lake Poyang flood plain system. *J. Lake Sci.* **2026**, *38*, 353–366.
10. Wang, D.Y.; Han, J.C.; Li, R.; Tang, X.Q. Nutritional characteristics in the water body of the Dongting Lake area, nutrient conditions, and associated improvement measures under the extreme drought in 2022. *J. Lake Sci.* **2023**, *35*, 1970–1980.
11. Tong, J.W.; Luo, Z.J.; Luo, S.K.; Guo, D.S.; Zhang, F.C.; Yang, X.F.; Nie, X.R.; Zhao, H.L. Temporal and Spatial Evolution of Ecosystem Health in the Poyang Lake Basin and Responses of Regional Connections. *J. Environ. Sci.* **2026**, *47*, 2468–2481. [\[CrossRef\]](#)
12. Liu, X.; Qian, K.M.; Tan, G.L.; Xing, J.S.; Li, M.; Chen, Y.W. Phytoplankton community structure and its succession in isolated lakes of Poyang-Junshan Lake. *J. Environ. Sci.* **2014**, *35*, 2557–2564.
13. Liu, X.; Lu, Q.; Zhou, Y.; Li, K.; Xu, Y.; Lv, Q.; Qin, J.; Ouyang, S.; Wu, X. Community characteristics of phytoplankton and management implications in Poyang Lake Basin. *Limnology* **2020**, *21*, 207–218. [\[CrossRef\]](#)
14. Liu, S.; Wu, Y.; Xu, G.; Cheng, S.; Zhong, Y.; Zhang, Y. Characterizing the 2022 extreme drought event over the Poyang Lake Basin using multiple satellite remote sensing observations and in situ data. *Remote Sens.* **2023**, *15*, 5125. [\[CrossRef\]](#)
15. Lyu, Z.Z.; Gao, H.; Gao, R.; Ding, T. Extreme characteristics and causes of the drought event in the whole Yangtze River Basin in the midsummer of 2022. *Adv. Clim. Change Res.* **2023**, *14*, 642–650. [\[CrossRef\]](#)
16. Wang, W.; Shi, K.; Wang, X.; Wang, S.; Zhang, D.; Peng, Y.; Li, N.; Zhang, Y.; Zhang, Y.; Qin, B.; et al. A record-breaking extreme heat event caused unprecedented warming of lakes in China. *Sci. Bull.* **2023**, *68*, 578–582. [\[CrossRef\]](#)
17. Li, X.; Peng, S.; Deng, X.; Su, M.; Zeng, H. Attribution of lake warming in four shallow lakes in the middle and lower Yangtze River Basin. *Environ. Sci. Technol.* **2019**, *53*, 12548–12555. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Li, W.X.; Jiang, M.L.; Xu, L.G.; Hu, S.P.; You, H.L.; Zhou, Q.P.; Chen, Z.; Zhang, L. Spatial and temporal characteristics of phytoplankton in Lake Poyang and its response to extreme flood and drying events. *J. Lake Sci.* **2024**, *36*, 1001–1013. [\[CrossRef\]](#)
19. China Meteorological Administration. China Meteorological Data Service Centre. Available online: <http://data.cma.cn> (accessed on 24 June 2026).
20. Li, Y.; Zhang, Q.; Zhang, L.; Tan, Z.; Yao, J. Investigation of water temperature variations and sensitivities in a large floodplain lake system (Poyang Lake, China) using a hydrodynamic model. *Remote Sens.* **2017**, *9*, 1231. [\[CrossRef\]](#)
21. Qian, K.M.; Liu, X.; Duan, M. Distribution and its influencing factors of bloom-forming Cyanobacteria in Poyang Lake. *China Environ. Sci.* **2016**, *36*, 261–267.
22. Ministry of Ecology and Environment of the People's Republic of China. *Technical Guidelines for Water Ecological Monitoring—Aquatic Organism Monitoring and Evaluation of Lakes and Reservoirs (On Trial): HJ 1296-2023*; Ministry of Ecology and Environment: Beijing, China, 2023.
23. Hu, H.J.; Wei, Y.X. (Eds.) *Chinese Freshwater Algae—System, Classification and Ecology*; Science Press: Beijing, China, 2006.
24. Ministry of Environmental Protection of the People's Republic of China; Editorial Board of Water and Wastewater Monitoring and Analysis Methods (Eds.) *Water and Wastewater Monitoring and Analysis Methods*, 4th ed.; China Environmental Science Press: Beijing, China, 2002.
25. Shannon, C.E. A mathematical theory of communications. *Bell Syst. Tech. J.* **1948**, *27*, 379–423, 623–656. [\[CrossRef\]](#)
26. Pielou, E.C. Shannon's formula as a measure of specific diversity: Its use and misuse. *Am. Nat.* **1966**, *100*, 463–465.
27. Margalef, R. Temporal succession and spatial heterogeneity in phytoplankton. In *Perspectives in Marine Biology*; Buzzati-Traverson, A.A., Ed.; University of California Press: Berkeley, CA, USA, 1958; pp. 323–349.
28. Shen, H.T.; Liu, C.Q. Canonical correspondence analysis of phytoplankton community and its environmental factors in the Lake Baiyangdian. *J. Environ. Sci.* **2008**, *20*, 773–779. [\[CrossRef\]](#)
29. Dörnhöfer, K.; Klinger, P.; Heege, T.; Oppelt, N. Multi-sensor satellite and in situ monitoring of phytoplankton development in a eutrophic-mesotrophic lake. *Sci. Total Environ.* **2018**, *612*, 1200–1214. [\[PubMed\]](#)
30. Toporowska, M.; Ferencz, B.; Dawidek, J. Impact of lake—Catchment processes on phytoplankton community structure in temperate shallow lakes. *Ecohydrology* **2018**, *11*, e2017.
31. Wu, Q.; Zhu, Z.G.; Chen, Y.W.; Zhou, W.X. Phytoplankton community structure characteristics and evaluation of water quality health status in dish-shaped lakes in Poyang Lake. *J. Nanchang Inst. Technol.* **2023**, *42*, 12–27.
32. Savadova, K.; Mazur-Marzec, H.; Karosienė, J.; Kasperovičienė, J.; Vitonytė, I.; Toruńska-Sitarz, A.; Koreivienė, J. Effect of increased temperature on native and alien nuisance cyanobacteria from temperate lakes: An experimental approach. *Toxins* **2018**, *10*, 445. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Huszar, V.L.M.; Silva, L.H.S.; Domingos, P.; Marinho, M.; Melo, S. Phytoplankton species composition is more sensitive than OECD criteria to the trophic status of three Brazilian tropical lakes. *Hydrobiologia* **1998**, *369*, 59–71. [\[CrossRef\]](#)

34. Wu, R.; Zhang, S.; Liu, Y.; Shi, X.; Zhao, S.; Kang, X.; Quan, D.; Sun, B.; Arvola, L.; Li, G. Spatiotemporal variation in water quality and identification and quantification of areas sensitive to water quality in Hulun lake, China. *Ecol. Indic.* **2023**, *149*, 110176. [\[CrossRef\]](#)
35. Qu, S.; Zhou, J. Phytoplankton community structure and water quality assessment in Xuanwu Lake, China. *Front. Environ. Sci.* **2024**, *11*, 1303851. [\[CrossRef\]](#)
36. Cantonati, M.; Tardio, M.; Tolotti, M.; Corradini, F. Blooms of the dinoflagellate *Glenodinium sanguineum* obtained during enclosure experiments in Lake Tovel (N. Italy). *J. Limnol.* **2003**, *62*, 79–87. [\[CrossRef\]](#)
37. Shen, M.; Cao, Z.; Xue, K.; Liu, D.; Qi, T.; Ma, J.; Duan, H. Natural and human activities driving the spatiotemporal variability of water clarity in lakes across Eastern China. *Int. J. Appl. Earth Obs. Geoinf.* **2022**, *114*, 103037. [\[CrossRef\]](#)
38. Lei, S.; Shi, S.; Qu, Y.P.; Liu, Y.W.; Liao, J.Y.; Zhang, Y.; Zhang, Y.; Li, S.Y.; Dong, G.X. Characteristics of extreme drought in the Poyang Lake Basin in 2022 and implications for future response. *J. Hydraul. Eng.* **2023**, *54*, 333–346.
39. Peng, N.Y.; Dai, G.F.; Zhang, W. Differences in nutrition condition and algae population in different areas of Poyang Lake. *J. Lake Sci.* **2018**, *30*, 1295–1308. [\[CrossRef\]](#)
40. Tao, Z.Y.; Yu, Z.J.; Chen, W.J.; Zhang, Y.P.; Huang, J.F.; Zhu, G.G. Phytoplankton community structure and its relationship with environmental factors in Junshan Lake. *Jiangsu Agric. Sci.* **2018**, *46*, 274–279.
41. Huisman, J.; Codd, G.A.; Paerl, H.W.; Ibelings, B.W.; Verspagen, J.M.; Visser, P.M. Cyanobacterial blooms. *Nat. Rev. Microbiol.* **2018**, *16*, 471–483. [\[CrossRef\]](#) [\[PubMed\]](#)
42. Jankowski, T.; Livingstone, D.M.; Bührer, H.; Forster, R.; Niederhauser, P. Consequences of the 2003 European heat wave for lake temperature profiles, thermal stability, and hypolimnetic oxygen depletion: Implications for a warmer world. *Limnol. Oceanogr.* **2006**, *51*, 815–819. [\[CrossRef\]](#)
43. Huang, Q.; Li, N.; Li, Y. Long-term trend of heat waves and potential effects on phytoplankton blooms in Lake Qiandaohu, a key drinking water reservoir. *Environ. Sci. Pollut. Res.* **2021**, *28*, 68448–68459. [\[CrossRef\]](#)
44. Zou, L.H.; Zou, W.; Zhang, Q.J.; Li, Y.; Gong, Z.J.; Zhang, Y.J.; Lu, S.B.; Cai, Y.J. Characteristics and driving factors of spatiotemporal succession of macrozoobenthos in Poyang Lake. *China Environ. Sci.* **2021**, *41*, 2881–2892.
45. Li, A.M.; Li, Y.K.; Shao, R.Q.; Shen, J.; Qian, L.; Zhang, C.; Wang, X.F.; Fang, P.J. Population Size Dynamics and Distribution of Wintering Cranes in Poyang Lake. *J. Ecol. Rural Environ.* **2022**, *38*, 77–86.
46. Joehnk, K.D.; Huisman, J.E.; Sharples, J.; Sommeijer, B.E.; Visser, P.M.; Stroom, J.M. Summer heatwaves promote blooms of harmful cyanobacteria. *Glob. Change Biol.* **2008**, *14*, 495–512.
47. Paerl, H.W.; Otten, T.G. Harmful cyanobacterial blooms: Causes, consequences, and controls. *Microb. Ecol.* **2013**, *65*, 995–1010. [\[CrossRef\]](#) [\[PubMed\]](#)
48. Nong, X.; Shao, D.; Xiao, Y.; Zhong, H. Spatio-temporal characterization analysis and water quality assessment of the south-to-north water diversion project of China. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2227. [\[PubMed\]](#)
49. Yan, G.; Yin, X.; Wang, X.; Zhang, Y.; Wang, E.; Yu, Z.; Ma, X.; Huang, M. Effects of summer and autumn drought on eutrophication and the phytoplankton community in Dongting Lake in 2022. *Toxics* **2023**, *11*, 822. [\[CrossRef\]](#) [\[PubMed\]](#)
50. Zhang, M.; Shi, X.; Chen, F.; Yang, Z.; Yu, Y. The underlying causes and effects of phytoplankton seasonal turnover on resource use efficiency in freshwater lakes. *Ecol. Evol.* **2021**, *11*, 8897–8909. [\[CrossRef\]](#) [\[PubMed\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.