Pol. J. Environ. Stud. Vol. 31, No. 4 (2022), 3955-3969
DOI: *10.15244/pjoes/146468* ONLINE PUBLICATION DATE: 2022-05-17

Original Research

A Study on the Correlation between the Spatial and Temporal Distribution of Phytoplankton Community and Environmental Factors in Changchun Section of the Yitong River

Ke Zhao[1], Xiaotian Bai[1], Ang Dong[1], Chunming Li[1], Hai Lu[2]*

[1]Key Laboratory of Songliao Aquatic Environment, Ministry of Education, Jilin Jianzhu University, Changchun 130118, China
[2]College of Civil Engineering and Architecture, Changchun Sci-Tech University, Changchun 130600, China

Received: 28 August 2021
Accepted: 9 February 2022

Abstract

In recent years, the Yitong River in Changchun City has been polluted by human activities to a certain extent, and therefore, it is necessary to monitor its water quality. Phytoplankton are sensitive to environmental changes and are an ideal biological indicator for environmental monitoring. This study studied the phytoplankton distribution in eight sampling sites of the Changchun section of the Yitong River from April to September 2019. The aim was to investigate the relationships between phytoplankton community structure's temporal and spatial distribution characteristics and water quality in the Changchun section of the Yitong River. Environmental factors such as the total nitrogen (TN), total phosphorus (TP), water temperature (WT), ammonia nitrogen (NH_3-N), chemical oxygen demand (COD_{Cr}), permanganate index (COD_{Mn}), and chl-a were measured and assessed. The results identified 161 species of phytoplankton belonging to eight phyla among eight sampling sites of the Changchun section of the Yitong River, including 67 species of *Chlorophyta*, 11 species of *Cyanobacteria,* and 51 species of *Bacillariophyta*. The percentage of *Cyanobacteria* phytoplankton abundance in the urban area was higher than that in the reservoir and the wet regions. From the temporal perspective, the total phytoplankton density and biomass peaked in summer, with the highest values recorded in June, followed by July. The study showed that TN, TP, and chl-a were the main environmental factors affecting the phytoplankton community structure in the Changchun section of the Yitong River.

Keywords: Changchun section of the Yitong River, phytoplankton, spatial and temporal distribution, community structure, environmental factor

*e-mail: haimm110@126.com

Introduction

Phytoplankton are primary producers in rivers sensitive to changes in the external environment. They have the characteristics of wide distribution and short life cycles [1-3]. Therefore, phytoplankton are an excellent biological indicator for environmental monitoring and are widely used in the biological monitoring of lakes, oceans, and rivers [4]. Since phytoplankton's spatial and temporal variations are closely related to environmental factors, it is essential to study the spatiotemporal phytoplankton community changes to understand the ecological function of the water environment [5, 6].

Studies have been conducted on the response relationships among phytoplankton and environmental factors; phytoplankton have been used for biological water quality evaluations [7-10]. Changes in the phytoplankton community can directly affect the structure and function of a water ecosystem. At the same time, the community structure of phytoplankton also experiences a noticeable characteristic change when the water trophic status fluctuates [11]. In actual water quality monitoring, phytoplankton can be used to evaluate trophic levels [12, 13]. However, in many studies, there are still some differences between the biological assessment of water quality and the results of water quality assessment, thereby leaving a gap in the comprehensive understanding of biological assessment [14]. This is because the structure of the phytoplankton community is affected by the trophic status of the water body and biological factors such as zooplankton, filter-feeding fish, and benthos [15]. In addition, when phytoplankton community biodiversity is used for water quality evaluation, there are no apparent boundaries among different water quality levels, and it is impossible to define water quality classes accurately[16]. Therefore, it is necessary to combine other water environmental factors for a comprehensive evaluation, which can act as a supplement to the biodiversity evaluation results.

As shown in Fig. 1, the Yitong River is located in Jilin Province in the northeast of China, with a total length of 342.5 km and a drainage area of 8440 km^2, and it flows into the Songhua River. The Yitong River is the most crucial in Changchun City. However, in recent years, due to the economic and social development of the Yitong River Basin, the water quality of the river has been deteriorating [17]. The Changchun section of the Yitong River is located in the middle reaches of the Yitong River. However, due to the need for flood control, the upstream section, the Xinlicheng Reservoir, controls the water discharged. Therefore, the Yitong River is short of water supply, leading to an interruption in the urban reach and severe tendencies for rivers to turn into lakes and reservoirs. The primary source of river water replenishment is from the sewage treatment plant. However, because the municipal sewage treatment plant does not reach the entire city, some sewage is discharged directly, thus causing water body pollution in the basin since the sewage is not treated. The river receives industrial and domestic wastewater from the whole city all year round, and the pollution is particularly severe. The monitoring data of the Yitong River over the years have shown that the water quality of the Changchun section of the Yitong River was Class V in 1999, in which class the river water was primarily suitable for agricultural and areas with general landscape requirements, and it continued to deteriorate. The water quality evaluation result in 2008 was inferior to Class V, black and odorous [18]. At present, there are few studies on the Yitong River in China, most of which have focused on water quality and sediment [19-21]. Therefore, there is a lack of studies on the phytoplankton community structure in the Changchun section of the Yitong River. This study analysed the phytoplankton community structure and

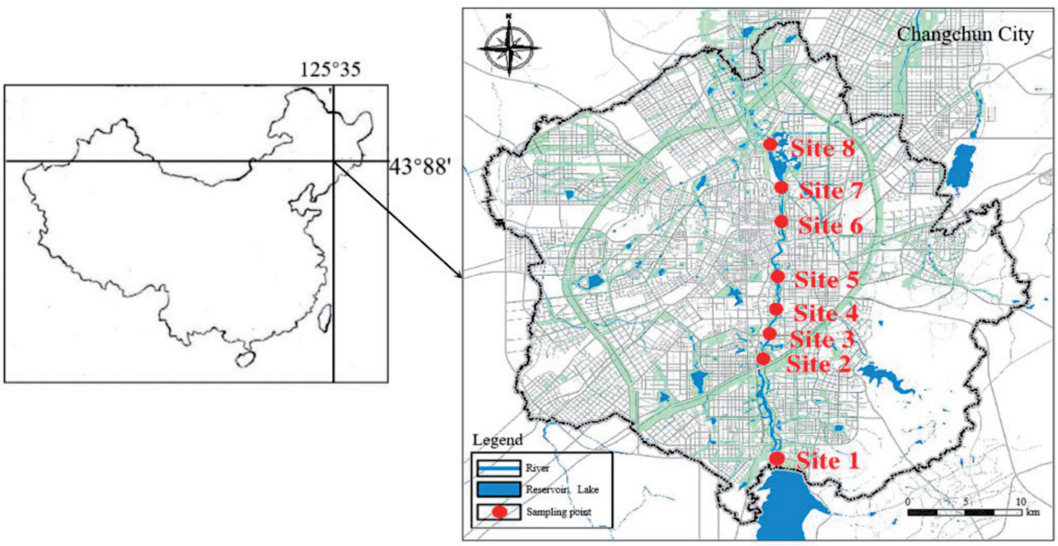

Fig. 1. Distribution of the experimental sampling (research) sites in the Changchun section of the Yitong River.

distribution characteristics of eight sampling sites in the Changchun section of the Yitong River from April to September 2019 to understand the background data of phytoplankton in the Yitong River Basin. In addition, the environmental factors were monitored to provide a theoretical basis and data support for the comprehensive management of the Yitong River in Changchun City.

Material and Methods

Sampling Sites

The research area of this study is located in Changchun City. The Yitong River originates from Yitong County, Jilin Province, with a total length of 383 km, and flows through Changchun City. It includes the upstream of the Xinlicheng Reservoir of the Yidan River and the downstream of the Xinkai River. The eight sampling sites were selected and sampled once a month regarding the ecological environment characteristics of the Yitong River in Changchun City. Sampling site 1 (S1) was located under the reservoir dam upstream of Changchun City; sampling sites S2-S7 were located in the urban area, while sampling site S8 was near the North Lake wetland, as shown in Fig. 1.

Sample Collection and Determination

Water quality samples were collected, preserved, and water quality indicators were determined according to the Water and Wastewater Monitoring Methods (Fourth Edition) [22]. After collecting the water samples, they were kept in foam boxes with ice to avoid light and keep them cold. The COD_{Cr}, NH_3-N, TP, and chl-a were determined using a 721E visible spectrophotometer (Shanghai Spectrumins instruments Co., Ltd, Shanghai, China); TN was determined using an ultraviolet spectrophotometer (SPEC ORD 200 PLUS, Analytik Jena AG, Jena, Germany); COD_{Mn} was determined by recording the consumption of potassium permanganate solution. The sampling and treatment methods of phytoplankton mainly refer to the "Technical specifications for investigating freshwater biology" (DB43/T432-2009). A one-litre water sample from the river at a depth of 0-0.5 m was stored in a bottle, fixed by adding 1.5% Lugol's solution and 4% formaldehyde solution. After 48-hour precipitation in the laboratory, it was condensed into 50 ml and stored in the bottle. According to the "Freshwater Algae of China, Systematics, Taxonomy, and Ecology", an Algacount S300 intelligent identification counter (Hangzhou Xunshu Science and Technology Co., Ltd., Hangzhou, China) was used to identify the phytoplankton species [23, 24]. The volume of the phytoplankton was measured using an optical, biological microscope according to the body type of phytoplankton, following the most approximate geometric figure to measure its length, height, diameter to obtain the average value according to the product formula to calculate the volume. The irregular-shaped phytoplankton were decomposed into several regular parts, measured, and the calculated volume and the total phytoplankton volume were obtained. The phytoplankton biomass was calculated based on the conversion relationship of fresh algae weight of 10^9 μm^3≈1 mg [25, 26].

Data Analysis and Processing

The data analysis was performed with MS Excel (Microsoft, Redmond, USA). The measurement of phytoplankton density was conducted according to the "Technical code of phytoplankton monitoring in inland waters (SL733-2016). The number of phytoplankton was determined under the optical, biological microscope (Olympus Corporation, Tokyo, Japan) to calculate the phytoplankton density.

The Shannon-Wiener (H') diversity index was used to characterise the phytoplankton community, and the McNaughton (Y) was calculated to determine the dominant species of phytoplankton [27, 28]. The calculation formula is as follows:

$$H' = -\sum(\frac{N_i}{N}) \times \ln(\frac{N_i}{N}) \quad (1)$$

$$Y = (\frac{N_i}{N}) \times (\frac{N_i}{N}) \quad (2)$$

where N is the total number of individuals in the same sample and Ni is the number of species, i.

The evaluation criteria for the H' value were: 0-1 for heavy pollution, 1-2 is α-medium pollution, 2-3 is β-medium pollution, and >3 is clean; Y>0.02 is the dominant species [29, 30].

SPSS 20.0 was used to analyse the Spearman correlation between density, biomass, and environmental factors. CANOCO5 was used for redundancy analysis (RDA) of the monthly dominant phytoplankton species and environmental factors.

Results and Discussion

Water Quality Parameters

The water quality parameters of the Changchun section of the Yitong River are shown in Fig. 2. The highest variability was found in the COD_{Cr} concentration throughout the study period; the annual average value was 48.61±20.19 mg/L. The monthly average concentration varied from 26.90±15.92 mg/L (April) to 112.88±55.47 mg/L (August). The yearly average values of TN and TP were 1.82±1.30 mg/L and 0.29±0.21 mg/L, respectively, which exceeded the class III standard of surface water functional zone in the basin. The maximum values of COD_{Mn} and chl-a were 10.15 mg/L±3.86 mg/L and 1.39 mg/L±0.73

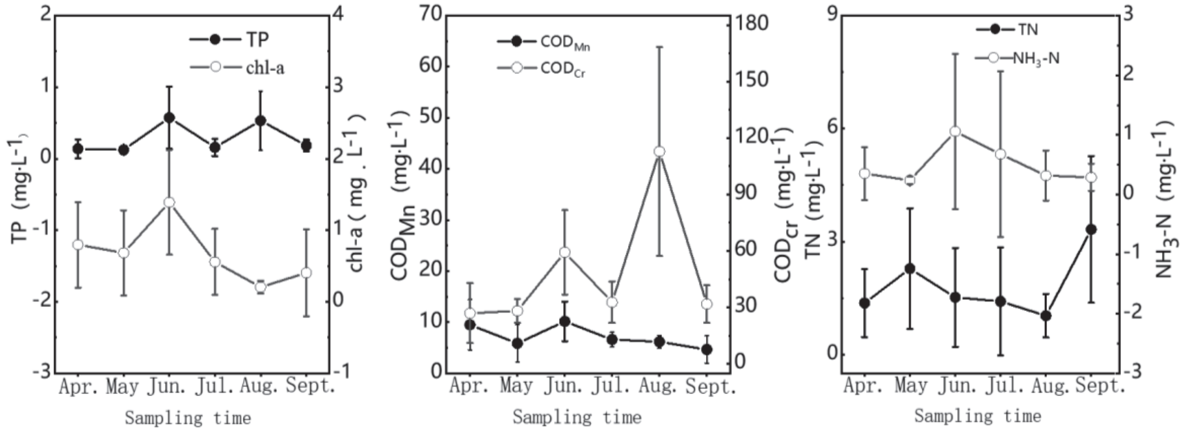

Fig. 2. Environmental parameters of the Changchun section of the Yitong River (mean±SD).

in June, and the minimum values were 4.66±2.67 mg/L in September and 0.20±0.09 mg/L in August, respectively. The concentration of NH_3-N increased from 0.35±0.44 mg/L in April to 1.06±1.30 mg/L in June and then decreased to 0.29±0.23 mg/L in September.

On the whole, the peak of each parameter occurred during summer, with an apparent spatial difference. The pollution sources in the region were complex, and there was a risk that the domestic sewage from the upstream and the drainage from the sewage treatment plant would directly enter the Yitong River. Therefore, the response relationship between the water environment quality and environmental capacity's spatial and temporal distribution had significant complexity and uncertainty.

Phytoplankton

Phytoplankton Species Composition

A total of 161 species (including varieties) belonging to eight phyla of phytoplankton were detected in the Changchun section of the Yitong River; 139 species and 22 genera were identified (see Appendix 1). The most abundant species belonged to the phyla *Chlorophyta*, followed by *Bacillariophyta* and *Euglenophyta*. In addition, 25 species of phytoplankton were repeatedly detected every month, including eight species of *Bacillariophyta*, seven species of *Chlorophyta,* and four species of *Cryptophyta* (see Table 1). *Pseudoanabaena sp.* and *Merismopedia minima* in *Cyanobacteria*, *Cyclotella sp.* in *Bacillariophyta*, *Chlamydomonas globosa* and *Ankistrodesmus acicularis* of *Chlorophyta*, *Komma caudata* of *Cryptophyta,* and *Euglena viridis* of *Euglenophyta* were dominant in phytoplankton communities at different stages (see Table 2).

Distribution Characteristics of Dominant Species of Phytoplankton

The monthly variations of dominant species (genera) at S1-S8 sampling sites in the Changchun section of the Yitong River are shown in Fig. 3. The degree of conspicuity of colours in the figure represents the density of dominant phytoplankton species in the sampling sites (red represents the maximum density, blue represents the minimum density). It can be seen from Fig. 3 that the dominant phytoplankton species in the Changchun section of the Yitong River differed slightly with the seasons. The dominant species were diatoms that

Table 1. Common species of phytoplankton in the Changchun section of the Yitong River.

Phyla	Species
Chlorophyta	*Chlamydomonas globosa, Chlamydomonas komma, Ankistrodesmus acicularis, Ankistrodesmus spiralis, Ankistrodesmus falcatus, Ocystis* sp., *Golenkinia, Scenedesmus quadricauda*
Bacillariophyta	*Cyclotella sp., Navicula exigua, Gomphonemaceae, Achnanthaceae, Gyrosigma, Cocconeis placentula var. euglypta, Synedra acusvar*
Cryptophyta	*Komma caudata, Cryptomons erosa Ehr, Cryptomonas marssonii, Cryptococcus Retroflexus*
Cyanobacteria	*Pseudoanabaena* sp., *Merismopedia minima*
Pyrrophyta	*Peridiniumpusillum*
Euglenophyta	*Trachelomonas, Euglena viridis*
Chrysophyta	*Dinobryon*

Table 2. Order of dominant species (genus) in the Changchun section of the Yitong River.

Serial number	April	May	June	July	August	September
1	*Stephanodiscus astraes var. minutula* ^{5,6}	*Cyclotella* sp. ^{3,4,5,6,7}	*Pseudanabaena* sp. ^{1,2,3,4,6,7}	*Pseudanabaena* sp. ^{1,3}	*Leptoiyngbya* sp. ^{3,5,7}	*Merismopedia minima* ^{3,4,5,6,7}
2	*Surirella ovata* ^{2}	*Pseudanabaena* sp. ^{3,4,5,6,7}	*Aphanizomenon* sp. ^{2,3,5,6,7}	*Merismopedia minima* ^{2,5,6,7}	*Pseudanabaena* sp. ^{2,4,5,6,7}	*Chlamydomonas globosa* ^{1}
3	*Chlamydomonas globosa* ^{2,3,7,8}	*Komma caudata* ^{2,8}	*Cyclotella* sp.^{4,5}	*Cyclotella* sp. ^{3,4,5,6,7}	*Merismopedia minima* ^{2,5,8}	*Pseudanabaena sp.* ^{1,3,4,5,8}
4	*Cyclotella* sp. ^{4,7}	*Ankistrodesmus acicularis*^{1}	*Anabaena sp.*^{1}	*Anabaena* sp. ^{8}	*Oscillatoria* ^{7}	*Cyclotella* ^{8}
5	*Komma caudata* ^{8}		Euglena viridis ^{2}	Komma caudata ^{4}	Cyclotella sp. ^{1}	*Melosira granulate* ^{6}
6	*Platymonas subcordiformis* ^{4}			Cryptomonas marssonii ^{8}	Melosira granulate ^{8}	

Note: The order of dominance was sorted from higher to lower, and the maximum value ranked the same species at different sampling sites. The superscript indicates the sampling sites where the dominant species were in a given month.

preferred to live in relatively low-temperature water in spring. On the other hand, *Cyanobacteria* that preferred to live in nutrient-enriched water in summer and early autumn were dominant. The dominant species overlapped without obvious alternations. This was related to the early autumn weather in Changchun City. There were many sunny days, a significant temperature difference between day and night, and a high temperature during the day [31]. The average water temperature at each sampling site on September 24 was 17.2ºC, and the weather was very suitable for the growth and propagation of thermophilic *Cyanobacteria* [32]. *Cyanobacteria*, *Chlorophyta,* and diatoms were the dominant species in the reservoir and wetland sites, and *Cryptophyta* was dominant occasionally.

In contrast, the dominant species in the urban section were mainly composed of *Cyanobacteria*, in which the *Pseudoanabaena* sp. was the most frequently detected. Moreover, the *Pseudoanabaena* sp. was the dominant species in competition under the condition of sufficient nitrogen [33], which was in good agreement with the detection results of total nitrogen exceeding

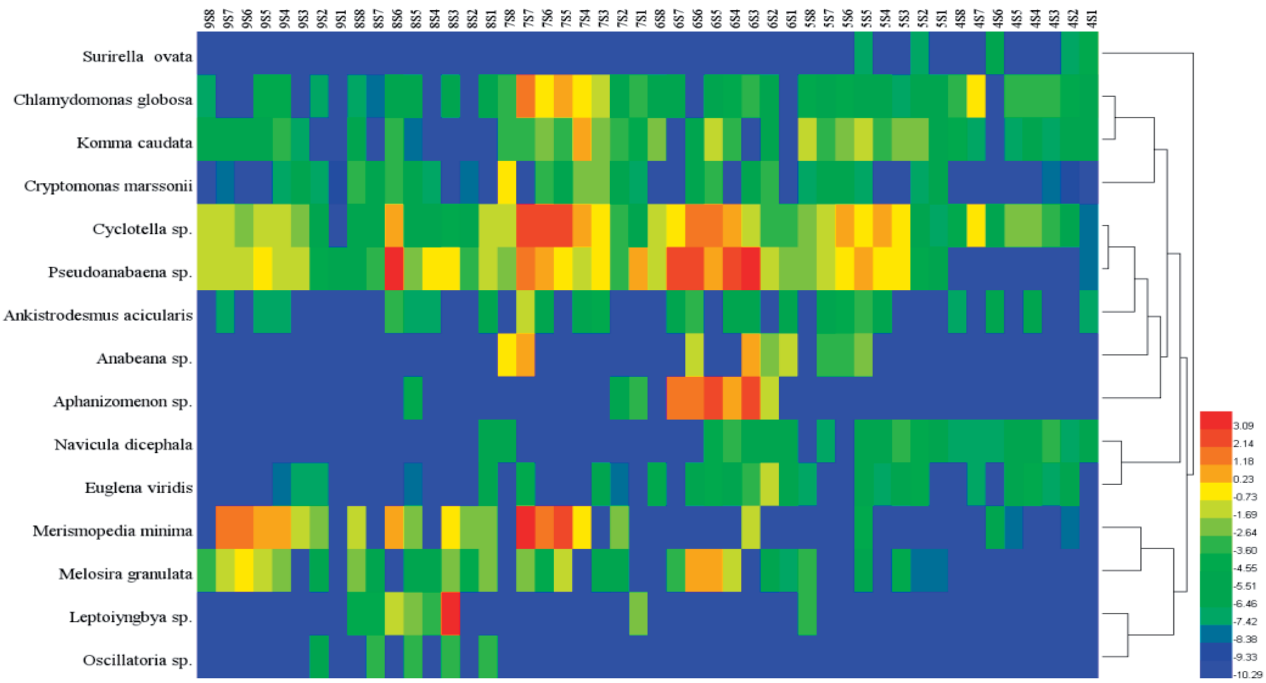

Fig. 3. Monthly variation of the density of dominant species (genera).
Note: Abscissa 4S1 indicates the S1 sampling site in April, and the ordinate is the dominant species (genus)

the standard in the Changchun section of the Yitong River. At the same time, in summer, the season of frequent rainfall, the water body was disturbed, and some tiny unicellular algae were hard to gather. Meanwhile, filamentous algae such as *Anabaena pseudo Anabaena* and *Leptoiyngbya* sp. had a robust anti-interference ability, quickly becoming an advantage.

Cyclotella sp. was found every month during the investigation period, which was the most common diatom in the Changchun section of the Yitong River. The reason was that although the Changchun section of the Yitong River was polluted in β-medium, because of the solid adaptability for different environments of diatoms, *Cyclotella* sp. could still exist universally in the Yitong River, see Section 3.2.5. Therefore, the water flow in the river was relatively slow except for August in 2019, which led to conditions for the enrichment of the *Cyclotella* sp. community. In addition, this month, the average density of phytoplankton reached 5.12×10^6 cells/L. Thus, the river was rich in nutrients, which provided a suitable habitat for the formation of *Cyclotella* sp. [34].

Phytoplankton Density

The phytoplankton density in the Changchun section of the Yitong River was mainly composed of *Cyanobacteria*, *Bacillariophyta,* and *Chlorophyta,* accounting for 36.13%, 28.71%, and 27.22% of the total phytoplankton density, respectively. The other phytoplankton were less (Fig. 4), such as *Xanthophyta, Chrysophyta, Gymnophyta, Cryptophyta, and Pyrrophyta*. *Cyanobacteria* accounted for the most significant proportion, and this phytoplankton density composition was relatively common in eutrophic water bodies, such as Taihu Lake and Chaohu Lake [35, 36].

The density of phytoplankton varied significantly at the sites. The wetland under the reservoir dam and Beihu Lake was lower density than other sites. The maximum value was 32.19×10^6 cells/L (S7 sampling site in July), and the minimum value was 0.12×10^6 cells/L (S1 sampling site in September), with a difference of nearly 270 times between the minimum value and the maximum value. The average total density of phytoplankton was 6.16×10^6 cells/L, suggesting eutrophication due to the enrichment in nutrients of the water body [37]. *Cyanobacteria*'s density peaked in summer and was higher in summer and early autumn than in spring (Fig. 5). This was mainly because the water temperature in summer (15ºC) and September of early autumn (11ºC) was significantly higher than that in spring (8.3ºC), and these conditions are suitable for *Cyanobacteria* reproduction and growth, thereby increasing *Cyanobacteria* density [38].

Phytoplankton Biomass

The temporal and spatial variations of phytoplankton biomass in the Changchun section of the Yitong River were prominent. The total phytoplankton biomass ranged from 0.06 mg C/L to 8.77 mg C/L, with an average of 1.93 mg C/L. The maximum value of phytoplankton biomass was 8.77 mg C/L at the S7 sampling site in July, and the minimum value of

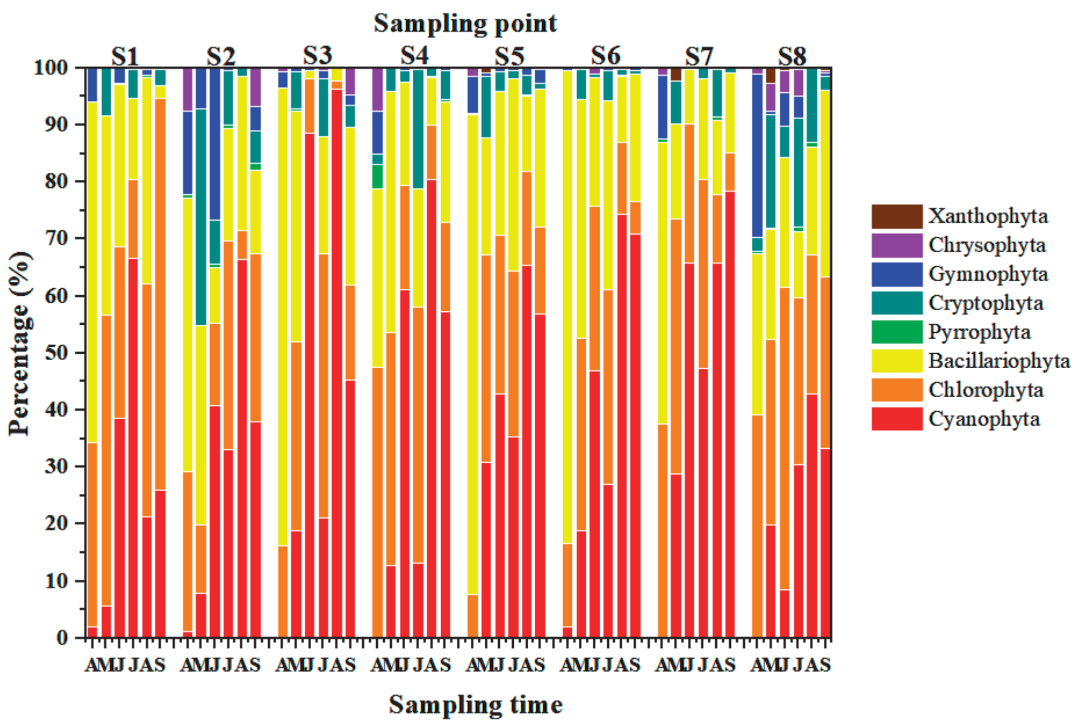

Fig. 4. Relative density percentage of phytoplankton.

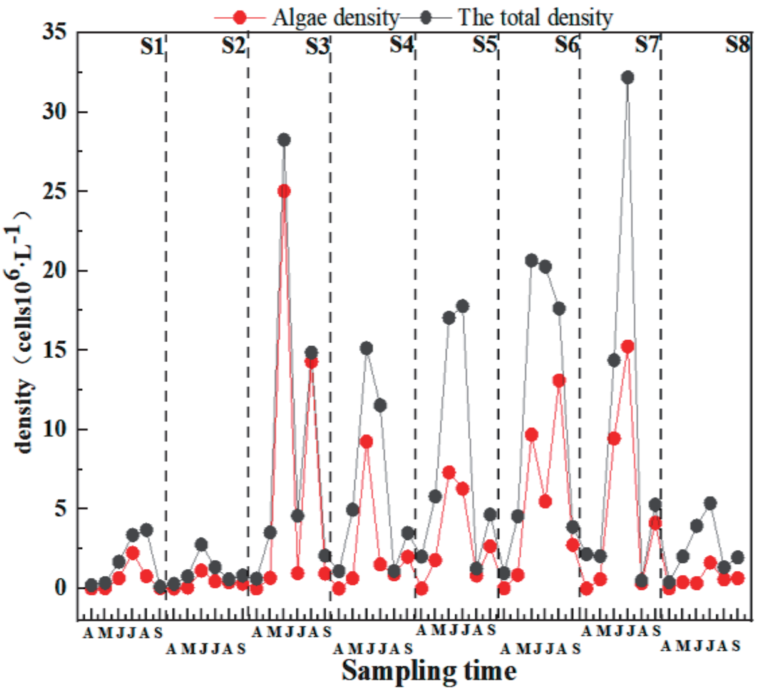

Fig. 5. Density and total density of phytoplankton *Cyanobacteria.*

0.06 mg C/L appeared at the S1 sampling site in September. After a significant change of water flow in August, the total biomass of phytoplankton at other sites, except the S1 sampling site, reached its peak in summer and then decreased significantly in August (Fig. 6).

During the study period, the average contribution rates of *Bacillariophyta*, *Chlorophyta*, *Cyanobacteria,* and *Euglenophyta* to total phytoplankton biomass were 46.23%, 27.80%, 2.96%, and 8.95%, respectively. In spring, summer, and autumn, the total biomass of phytoplankton in the urban area was higher than that

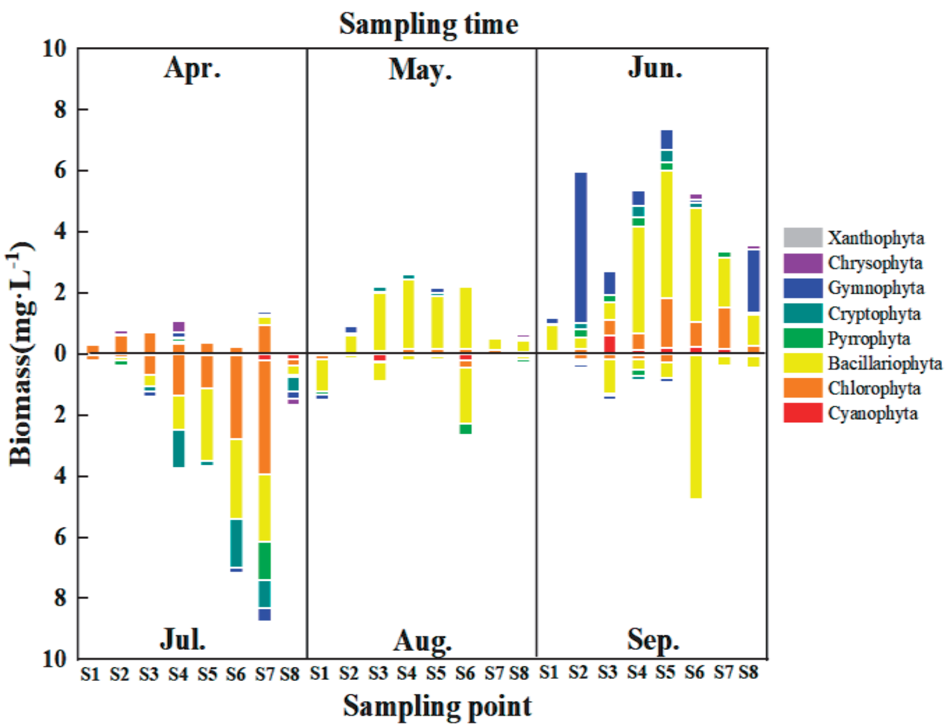

Fig. 6. Phytoplankton biomass in the Changchun section of the Yitong River.

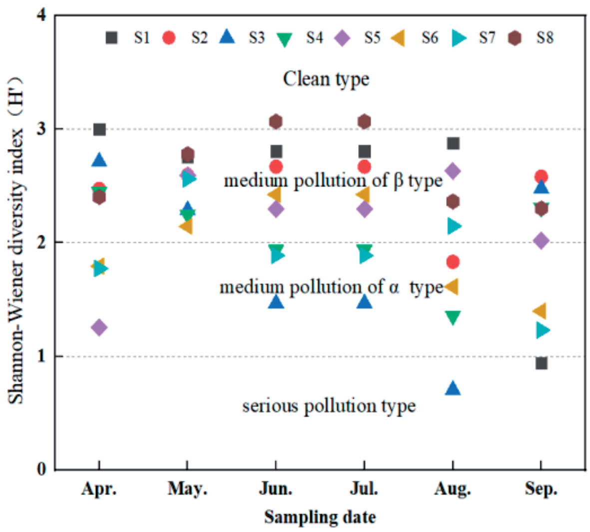

Fig. 7. Shannon-Wiener diversity index of phytoplankton.

under reservoir dams and wetland (Fig. 6), consistent with phytoplankton density.

Phytoplankton Diversity

The Shannon-Wiener index ranged from 0.70 to 3.07, with an annual average of 2.20 (Fig. 7). The maximum value of 3.07 appeared at the S8 sampling site in June and July, and the minimum value of 0.70 appeared at the S3 sampling site at the end of August. In August, due to abundant rains in the north and the even discharge of upstream reservoirs, the river flow increased, causing the overall water level of the Yitong River to rise, affecting the diversity and abundance of phytoplankton. As a result, the phytoplankton cluster state was destroyed. Except for an increase in biodiversity under the reservoir dam, the diversity index of the other sites decreased from the previous month [39].

The biological assessment of water quality showed that the Changchun section of the Yitong River was β-medium pollution. Spatially, the average values of the Shannon-Wiener index under the reservoir dam, urban area, and wetland site were 2.53, 2.07, and 2.66, respectively. Consequently, the biological evaluation of water quality at reservoir sites and wet sites was better than that in urban areas, which was in good agreement with the results of water quality detection.

Correlation Analysis between Phytoplankton and Environmental Factors

Correlation Analysis between River Algae Species and Environmental Factors

The common dominant species selected were phytoplankton species using environmental factors including chl-a, TN, TP, WT, NH_3-N, COD_{Mn}, and COD_{Cr} as the correlation between phytoplankton species and environmental factors were analysed from April to September. The species data were analysed using the detrended correspondence analysis (DCA). The gradient length of the first axis was 0.42. Therefore, the RDA analysis method was selected for correlation analysis. Before analysis, lg(x + 1) transformation was carried out so that the data presented a normal distribution.

The first and second axes accounted for 94.39% of the relationship between the species and their environment. From Table 3, based on the results of RDA analysis, it was found that the three environmental factors (TP, chl-a, and TN) had significant effects on the dominant common species, and all of them were positively correlated. From Fig. 8, except *Euglena viridis*, environmental factors were positively correlated with the most dominant common species. All environmental factors and most common dominant species were distributed on the right side of axis 1, and only *Euglena viridis* was on the left side of axis 1. On the upper side of axis 2, *Pseudoanabaena* sp. was positively correlated with TN and WT. There was a positive correlation between *Merismopedia minima* and TP, WT, and chl-a. While S1, S2, and S8 sampling sites were on the left side of axis 1, S3-S7 sampling sites were on the right side of axis 1. S1, S2, and S8 sampling sites were closely distributed, demonstrating that these three sampling sites had a similar ecological characteristic to the phytoplankton community.

Correlation between Phytoplankton Density and Environmental Factors

The Spearman correlation analysis of density and environmental factors is shown in Table 4. In this study, the total density of phytoplankton was significantly positively correlated with chl-a and COD_{Mn} (r = 0.738, p<0.05 and r = 0.714, p<0.05). The density of *Cyanobacteria* was significantly positively correlated with TN and COD_{Mn} (r = 0.714,

Table 3. Redundancy analysis of phytoplankton species and environmental factors.

Axis	Axis 1	Axis 2	Axis 3	Axis 4
Characteristic value	0.7719	0.1720	0.0460	0.0082
Cumulative percentage of species-environment relationship	77.19	94.39	98.99	99.81
Pseudo-canonical correlation	0.9346	0.8362	0.5661	0.2441

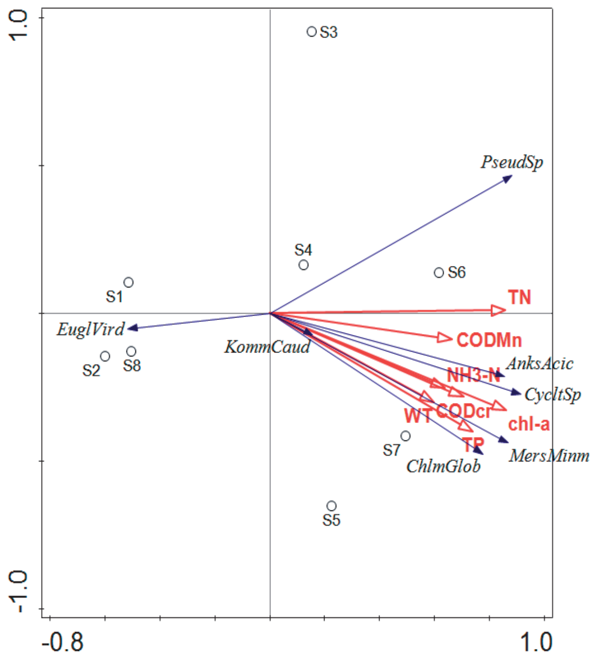

Fig. 8. RDA analysis of species and environmental factors.

$p<0.05$ and r = 0.714, $p<0.05$). *Chlorophyta* density was significantly positively correlated with NH_3-N and COD_{Cr} (r = 0.833, $p<0.05$ and r = 0.833, $p<0.05$), and was highly significantly positively correlated with chl-a (r = 0.857, $p<0.01$). The density of *Bacillariophyta* was significantly positively correlated with NH_3-N and COD_{Cr} (r = 0.738, $p<0.05$ and r = 0.762, $p<0.05$), and was highly significantly positively correlated with chl-a (r = 0.905, $p<0.01$). The phytoplankton density was positively correlated with TP and WT. The Spearman correlation analysis showed that the correlation between phytoplankton density and environmental factors in the Changchun section of the Yitong River basin was very significant.

Correlation between Phytoplankton Biomass and Environmental Factors

The Spearman correlation analysis showed that there were significant correlations between biomass and environmental factors. The results are shown in Table 5. According to the results of correlation analysis, the total biomass of phytoplankton was positively correlated with NH_3-N, chl-a, and COD_{Cr} (r = 0.810, $p<0.05$; r = 0.976, $p<0.01$; and r = 0.881, $p<0.01$, respectively). The biomass of *Bacillariophyta* had a significant correlation with chl-a (r = 0.929, $p<0.01$). *Chlorophyta* biomass was significantly positively correlated with TN, chl-a, and COD_{Mn} (r = 0.762, $p<0.05$; r = 0.833, $p<0.05$; and r = 0.762, $p<0.05$, respectively), and was significantly positively correlated with TP, NH_3-N, and COD_{Cr} (r = 0.905, $p<0.01$; r = 0.905, $p<0.01$; and r = 0.976, $p<0.01$, respectively).

Analysis of Phytoplankton Community Structure Characteristics at Different Sampling Sites in the River

As shown in Fig. 6, the contribution of diatoms to the total biomass of phytoplankton was the largest during the study period. Diatoms usually have large cell volumes, and compared with other algae species, diatoms can obtain a competitive advantage under the conditions of low temperature and weak light, which is why diatoms become the dominant species [40]. However, green algae were very sensitive to most water environmental factors, which may significantly differ in the abundance of phytoplankton in green algae [41]. At the same time, the results showed that the total

Table 4. Spearman correlation analysis results for density and environmental factors.

Items	TN	TP	NH_3-N	chl-a	COD_{Cr}	COD_{Mn}	WT
Total density	.690	.667	**.833***	**.738***	.690	**.714***	.500
Cyanobacteria density	**.714***	.524	.690	.595	.500	**.714***	.190
Chlorophyta density	.619	.690	**.833***	**.857****	**.810***	.595	.595
Bacillariophyta density	.571	.643	**.738***	**.905****	**.762***	.548	.500
Note: * Indicates that p < 0.05 is a significant correlation; ** indicates that p < 0.01 is a highly significant correlation.							

Table 5. Spearman correlation analysis results of biomass and environmental factors.

Items	TN	TP	NH_3-N	chl-a	COD_{Cr}	COD_{Mn}	WT
Total biomass	.643	**.810***	**.810***	**.976****	**.881****	.667	.405
Bacillariophyta biomass	.500	.524	.690	**.929****	.690	.429	.452
Chlorophyta biomass	**.762***	**.905****	**.905****	**.833***	**.976****	**.762***	.429

Note: * Indicates that $p<0.05$ is a significant correlation; ** indicates that $p<0.01$ is a very significant correlation.

density of phytoplankton in the urban area was high, but the Shannon-Wiener index was low. The phytoplankton density of the S8 sampling site was much lower than that of the S6 and S7 sampling sites, while the Shannon-Wiener diversity index of the S8 sampling site was higher than that of the S6 and S7 sampling sites. This showed that a better ecological wetland environment was more suitable for the survival of phytoplankton than in the urban area. In recent years, with the development of river treatment projects, the water environment of the Yitong River has been improved, and the ecological water supply has alleviated the phenomenon of river cutoff. It was rainy in August 2019, and the river flow was massive. At each sampling site in that month, the phytoplankton abundance was significantly lower than in July and was scoured by the upstream flow.

As a result, the proportion of *Cyanobacteria* abundance at each sampling site in August was more significant than in July. In Changchun City, higher temperatures are expected during summer. Therefore, during summer, the biomass of *Cyanobacteria* was generally higher than that in other seasons, which was related to the living habitat of *Cyanobacteria* in a high-temperature environment. However, the TN content in the Yitong River was high in summer, and *Cyanobacteria* had nitrogen fixation, so it was easy to bloom in summer [42].

At the S2 sampling site, which is a densely populated area, and the direct discharge of sewage, initial rainwater, and combined sewage flows into the river, the abundance of nutrients and organic matter leads to the river's high trophic level. Thus, the organic matter and nutrients in the water caused a large abundance of phytoplankton in the Changchun section of the Yitong River. During the study period, 10 species of *Cyanobacteria* were detected, including *Pseudoanabaena* sp., *Anabaena* sp., *Merismopedia minima*, *Merismopedia punctata*, *Aphanizomenon* sp., *Lyngbya*, *Leptoiyngbya* sp., *Microcystis*, *Oscillatoria,* and *Raphidiopsis*.

The most common species appeared in summer. The total density of phytoplankton at the S1 sampling site under the reservoir dam was low, while the Shannon–Wiener index of phytoplankton was high. The water body under the dam was mainly from the Xinlicheng Reservoir, with good water quality, more aquatic plants, far away from the urban area, and fewer human activities. The abundance of *Cyanobacteria*, which caused phytoplankton bloom, was the lowest, and the Shannon–Wiener index of phytoplankton was high at the S8 sampling site. Therefore, reducing the intake of nutrients and controlling the proportion of phytoplankton to *Cyanobacteria* in the urban area of the Yitong River can significantly improve the water quality and ecological environment in the urban area of the Yitong River. This was located in the west of Beihu Wetland in Changchun City and connected with the Yitong River. The wetland connected with the river played an indispensable role in river ecological restoration and river water self-purification. Wetlands abound with aquatic plants that effectively absorb toxins and nutrients from the water. Therefore, maintaining a certain amount of aquatic plants can inhibit the growth of *Cyanobacteria*, which can cause a phytoplankton bloom, and therefore improve the river biodiversity and make the ecology more stable [43].

Correlation Analysis between Phytoplankton Community Structure and Environmental Factors in the Changchun Section of the Yitong River

The abundance and biomass of phytoplankton in the Yitong River followed the seasonal cycle. In spring, phytoplankton experienced the freezing and thawing process of the river, and its abundance and biomass were at the lowest during the survey period (Figs 5 and 6). The reason may be that the ice layer above the surface of the Yitong River prevented the inflow of nutrients in winter, which affected the uptake of nutrients by phytoplankton. In addition, during the thawing process of the Yitong River, the optimal living conditions of phytoplankton could not be reached due to the low temperature. As a result, the phytoplankton abundance and biomass in summer were higher than in other seasons, and *Cyanobacteria* were the dominant species. In June, the abundance of *Cyanobacteria* in the Changchun section of the Yitong River was higher than that in other months. Considering the water temperature rising in June, the growth rate of *Cyanobacteria* was faster than that of other algae when the water temperature was higher than 20ºC [44].

Moreover, in the RDA analysis results (Fig. 8), there was a significant positive correlation between temperature and the dominant species of *Cyanobacteria*, indicating that temperature was one of the main factors affecting the growth of *Cyanobacteria* [45]. TN, TP, and chl-a were the main environmental factors that played a significant role in the phytoplankton community structure in the Changchun section of the Yitong River during the investigation period. The Spearman correlation analysis between biomass and environmental factors and between density and environmental factors showed that TN had a significant positive correlation with *Cyanobacteria* density. TP had a significant correlation with total phytoplankton biomass, which also significantly correlated with *Chlorophyta* biomass. According to the simultaneously obtained experimental results for water quality parameters, it can be seen that the TN and TP contents in the Changchun section of the Yitong River exceeded the water standard of the surface water functional area (class III), indicating that the nutrient salt content of nitrogen and phosphorus in the basin was rich. It also demonstrated that TN, TP, and phytoplankton density and biomass were positively correlated. With the rapid development of industry and agriculture in its surrounding areas, many external pollutants such as nutrients and organic matter flow into the river, resulting in the deterioration of river water quality [46]. This may be the main reason for the eutrophication of the Changchun section of the Yitong River, and this is consistent with Reed ML et al. [47] that nutrients such as nitrogen and phosphorus can significantly affect the growth of phytoplankton. At the same time, as shown in Fig. 2, among the environmental factors, the temporal and spatial difference of COD_{Cr} was the most obvious, and it exceeded the standard extensively. Therefore, attention should be paid to controlling the intake of nitrogen, phosphorus, and COD_{Cr} to prevent phytoplankton bloom in pollution control of the Changchun section of the Yitong River.

Conclusions

This study investigated the distribution characteristics of the phytoplankton community structure in the Changchun section of the Yitong River from April 2019 to September 2019. It showed that, 161 species of phytoplankton were found in eight phyla, among which were *Chlorophyta*>*Bacillariophyta*>*Euglenophyta*>*Cyanobacteria*>*Cryptophyta*>*Pyrrophyta*>*Chrysophyta*>*Xanthophyta*. There were many dominant species in the river. During the investigation, the dominant phytoplankton species in different seasons were consistent with their corresponding optimal living environment, with diatoms in spring and *Cyanobacteria* in summer. The density and biomass of phytoplankton ranged from 0.12×10^6 cells/L to 32.19×10^6 cells/L and from 0.06 mg C/L to 8.77 mg C/L, respectively. In terms of quantity, phytoplankton density was the highest in June, followed by July, and then in August and May. The Shannon-Wiener diversity index of phytoplankton in the Changchun section of the Yitong River and its variation pattern was used to evaluate the water quality of the investigated water area. According to the evaluation standard for a water body, the Changchun section of the Yitong River was classified as β-medium pollution. The RDA analysis and Spearman correlation analysis showed that TN, TP, and chl-a were positively correlated with most phytoplankton dominant species, biomass, and phytoplankton density. The causes of the results and possible water pollution problems were discussed. This study provided reference data for evaluating the Changchun section of the Yitong River. Therefore, the conclusion offers a reference for managing temperate rivers represented by the Changchun section of the Yitong River.

Acknowledgments

This work was supported by the Key R&D Program of the Department of Science and Technology of Jilin Province (NO. 20210203035SF).

Conflict of Interest

The authors declare no conflict of interest.

References

1. YANG W., DENG D.G., MENG X.L., ZHANG S. Temporal and Spatial Variations of Phytoplankton Community Structure in Lake Erhai, a Chinese Plateau Lake, with Reference to Environmental Factors. Russian Journal of Ecology, **50** (4), 352, **2019**.
2. ZHONG F., WU J., DAI Y.R., XIANG D.F., DENG Z.F., CHENG S.P. Responses of water quality and phytoplankton assemblages to remediation projects in two hypereutrophic tributaries of Chaohu Lake. J. Journal of Environmental Management, **248** (15), 1. **2019**.
3. FATMA A.R.Z., HANAN M.K., NABILA R.H. Assessment of phytoplankton community structure and water quality in the Eastern Harbor of Alexandria, Egyptian Journal of Aquatic Research, **46** (2), 145, **2020**.
4. Donauhanse. The EU Water Framework Directive Factsheet. Available online: http://icp.donauhanse.net/activities/donauhanse-factsheets.html (accessed on 03 June 2016).
5. REYNOLDS C.S., HUSSAR V., KRUK C., NASELLI-FLORES L., MELO S. Towards a functional classification of the freshwater phytoplankton review. Journal of Plankton Research, **24** (5), 417, **2020**.
6. ANDRÁS A., MARIA L., ANNE M.L., JUDIT P. Phytoplankton functional groups as indicators of human impacts along the River Loire (France). Hydrobiologia, **698** (1), 233, **2012**.
7. SCHAEFFER B.A., KURTZ J.C., HEIN M.K. Phytoplankton community composition in nearshore coastal waters of Louisiana. Mar. Marine Pollution Bulletin, **64** (8), 1705, **2012.**
8. NIU L.X., LUO X.X., HU S., LIU F., CAI H.Y., REN L., OU S.Y., ZENG D.N., YANG Q.S. Impact of anthropogenic forcing on the environmental controls of phytoplankton dynamics between 1974 and 2017 in the Pearl River estuary, China. Ecological Indicators, **116**, 1, **2020**.
9. RAMESH C.S., NEETU S., ANITA C. The influence of physico-chemical parameters on phytoplankton distribution in a headwater stream of Garhwal Himalayas: A case study. Egyptian Journal of Aquatic Research, **42** (1), 11, **2016**.
10. GE J.Z., SHI S.Y., LIU J., XU Y., CHEN C.S., BELLERBY R., DING P.X. Interannual Variabilities of Nutrients and Phytoplankton off the Changjiang Estuary in Response to Changing River Inputs. Journal of Geophysical Research Oceans, **125** (3), 1, **2020**.
11. GUO S.J., ZHU M. L., ZHAO Z.X., LIANG J.H., ZHAO Y.F., DU J., SUN X.X. Spatial-temporal variation of phytoplankton community structure in Jiaozhou Bay, China. Journal of Oceanology and Limnology, **37** (5), 1611, **2019**.
12. ABUZER C., OKAN K. On the relationship between ecology and phytoplankton composition in a karstic spring (Çepni, Bolu). Ecological Indicators, **7** (2), 497, **2006**.
13. LEPIST L., HOLOPAINEN A.L., VUORISTO H. Type-specific and indicator taxa of phytoplankton as a quality criterion for assessing the ecological status of finfish boreal lakes. Limnologica, **3** (3), 236, **2004**.

14. WAHLSTRÖM G., DANILOV R.A. Phytoplankton successions under ice cover in four lakes located in north-eastern Sweden: effects of liming. Folia Microbiologica, **48** (3), 379, **2003**.
15. ANTONI M., NARCÍS P. Effects of Mediterranean climate annual variability on stream biological quality assessment using macroinvertebrate communities. Ecological Indicators, **11**, 651, **2010**.
16. CHEN L.G., TSUI M.M.P., LAM J.C.W., HU C.Y. WANG Q., ZHOU B.S., LAM P.K.S. Variation in microbial community structure in surface seawater from Pearl River Delta: Discerning the influencing factors. Sci. Science of The Total Environment, **660** (10), 136, **2019**.
17. JI X.Y., ZHANG W.Z., JIANG M.Q., HE J., ZHENG Z. Black-odor water analysis and heavy metal distribution of Yitong River in Northeast China. Water Science & Technology, **76** (8), 2051, **2017**.
18. SELEIM M.E.S., MAHMOUD H.H., HESHAM R.A. M., NASR M.A., MOHAME E.G. An integrated water quality assessment of Damietta and Rosetta branches (Nile River, Egypt) using chemical and biological indices. Environmental Monitoring and Assessment, **192** (4), 228, **2020**.
19. GAO Y., WEI Z., LI S., DU C.Y., REN X., FAN W. Evaluation of Characteristics of Sediment Pollution in Changchun City Section of Yitong River. Environmental Engineering, **36** (5), 171, **2018** [In Chinese].
20. YU Y.Y., WU G.L., WANG C.Z., LU N., YUAN X., ZHU X.L. Pollution characteristics of antibiotics and antibiotic resistance of coliform bacteria in the Yitong River, China. Environmental Monitoring and Assessment, **191** (8), 516, **2019**.
21. JIANG S.X., ZHAI F.J., ZHANG C., WANG M.M., SHAN B.Q. Speciation Distribution and Risk Assessment of Heavy Metals in Sediments from the Yitong River City Area. Environmental Science, **41** (6), 2653, **2020** [In Chinese]..
22. MINISTRY OF ENVIRONMENTAL PROTECTION OF THE PEOPLE'S REPUBLIC OF CHINA. Method of Water and Wastewater Monitoring, 4th ed.; China Environmental Science Press: Beijing, China, 222, **2002** [In Chinese].
23. HU H.J., WEI Y.X. The Freshwater Algae of China, Systematics, Taxonomy and Ecology; Science Press: Beijing, China, 115, **2006** [In Chinese].
24. HASLE G., SOURNIA A. Phytoplankton Manual, Monographs on Oceanographic Methodology; UNESCO: Paris, France, 138, **1978**.
25. SUN J., LIU D.Y., QIAN S. B. Study on phytoplankton biomass: Phytoplankton measurement biomass from cell volume or plasma volume. Acta Oceanologica Sinica, **21** (2), 75, **1999**.
26. MINISTRY OF WATER RESOURCES OF THE PEOPLE'S REPUBLIC OF CHINA. Technical Code of Phytoplankton Monitoring in Inland Waters; China Water & Power Press: Beijing, China, 5, **2016** [In Chinese].
27. SHANNON C.E., WEAVER W. The Mathematical Theory of Communication; University of Illinois Press: Urbana, USA, 28, **1949**.
28. ZHAO S.Q., FAN Y.C., DAI Y.R., WANG F.H., LIANG W. Responses of phytoplankton community to abiotic environmental variables with the mitigation of eutrophication: A case study of Donghu Lake, Wuhan City. Journal of Lake Sciences, **31** (5), 1310, **2019** [In Chinese].
29. WHITTAKER R.H. Evolution and measurement of species diversity. Taxon, **21** (2-3), 213, **1972**.
30. SHEN Y.F., ZHANG Z.S., GONG X.J. New Technology of Micro-biological Monitoring.: China Architecture & Building Press: Beijing, China, 126, **1990** [In Chinese].
31. ZHOU D.P., QI Y., GAN L.L., GAO J. Analysis on PM_{10} Pollution and Meteorological Conditions in Changchun City. Meteorological and Environmental Research, **1** (6), 53, **2010**.
32. HU H., WEI Y. The Freshwater Algae of China: Systematics, Taxonomy and Ecology; Science Press: Beijing, China, 206, **2006** [In Chinese].
33. SHU H.L., ZHENG L.L., WENG X.Y., ZHUANG H.R. Allelopathic Effects between Pseudanabaena mucicola and Microcystis aeruginosa. Journal of Fujian Normal University (Natural Science Edition), **32** (2), 62, **2016** [In Chinese].
34. MASAHIRO M., KOICHI S., YOSHIMASA A., MOTOI M., FUMIO I. Competitive growth characteristics between Microcystis aeruginosa and Cyclotella sp. accompanying changes in river water inflow and their simulation model. Phycological Research, **64** (3),12129, **2016**.
35. LI D., LI X.W., NIU Z.C., WANG X., SHI W., YU H.X. Structure of Phytoplankton Community and Relationship between Phytoplankton Community and Water Quality in Taihu Lake. Ecology and Environmental Sciences, **23** (11), 1814, **2014** [In Chinese].
36. MENG R.X., LIU Z.Q. An Evaluation of Water Pollution and Eutrophication of the Chaohu Lake by Means of Phytoplankton. Acta Hydrobiologica Sinica, **12** (1), 13, **1988** [In Chinese].
37. WANG C.H., HAN B.P., HU R., LIN Q.Q. Phytoplankton Community Structure and Eutrophication of Reservoirs in Guangdong Province, China. Chinese Journal of Ecology, **24** (4), 402, **2005** [In Chinese].
38. REYNOLDS C.S. The Ecology of Freshwater Phytoplankton; Cambridge University Press: Cambridge, England, 120, **1984**.
39. TORNÉS E., PÉREZ M.C., DURÁN C., SABATER S. Reservoirs override seasonal variability of phytoplankton communities in a regulated Mediterranean river. Science of the Total Environment, **475** (15), 225, **2014**.
40. WANG S.Y., ZHANG X.X., TIAN S.M., CAO Y.T., CHEN R.X. Study on phytoplankton community structure characteristics and its influencing factors of lakes in arid regions of the Yellow River basin during ice-sealing period. Shuili Xubao, **51** (9), 1070, **2020** [In Chinese]..
41. TIAN Y.L., JIANG Y., LIU Q., XU D.X., LIU Y., SONG J.X. The impacts of local and regional factors on the phytoplankton community dynamics in a temperate river, northern China. Ecological Indicators, **123** (1), 1, **2021**.
42. HUO S.L., ZHANG H.X., MA C.Z., XI B.D., ZHANG J.T., HE Z.S., LI X.C., WU F.C. Algae community response to climate change and nutrient loading recorded by sedimentary phytoplankton pigments in the Changtan Reservoir, China. Journal of Hydrology, **571** (1), 311, **2019**.
43. GUO X.Q., YU Y., ZHU H.R., ZHAO X.G., LIU X.B. Multivariate analysis of phytoplankton community structure in Changli Gold Coast National Nature Reserve of Hebei Province in Spring, 2019, IOP Conference Series: Earth and Environmental Science, **467**, 012141,**2020**.
44. GOGOI P., DAS S.K., SARKAR S.D., CHANU T.N., MANNA R.K., SENGUPTA A., RAMAN R.K., SAMANTA S., DAS B.K. Environmental factors driving

phytoplankton assemblage pattern and diversity: insights from Sundarban eco-region, India. Ecohydrology and Hydrobiology. **21** (2), 354, **2021**.
45. PADMINI D., KEVIN R.A., GERT L.D., HEIN R.S., ESPEN B., ANDREY V.D., IRINA P.P., ERIK S. Climate effects on temporal and spatial dynamics phytoplankton and zooplankton in the Barents Sea. Progress In Oceanography, **185**, 1, **2020**.
46. CHEN S., XIE Q., FU M., JIANG T., WANG Y.M., WANG D.Y. Structural Characteristics of Zooplankton and Phytoplankton Communities and Its Relationship with Environmental Factors in a Typical Tributary Reservoir in the Three Gorges Reservoir Region. Environmental Science, **42** (5), 2303, **2021** [In Chinese].
47. REED M.L., PINCKNEY Q.L., KEPPLER C.J., BROCK L.M., HOGAN S.B., GREENFIELD D.I. The influence of nitrogen and phosphorus on phytoplankton growth a nd assemblage composition in four coastal, southeastern USA systems. Estuarine Coastal & Shelf Science. **177**, 71, **2016**.

Appendix 1

Species of Phytoplankton Identified
in the 8 Research Sites of the Changchun Section of Yitong River

Number	Species phytoplankton	Number	Species phytoplankton
1	*Pseudoanabaena* sp.	2	*Tabellaria fenestrata*
3	*Microcystis* sp.	4	*Tabellaria flocculosa*
5	*Anabaena* sp.	6	*Melosira granulata*
7	*Spirulina* sp.	8	*Melosira granulata var. angustissima*
9	*Raphidiopsis* sp.	10	*Melosira varians*
11	*Merismopedia punctata*	12	*Melosira islandica subsp. Helvetica*
13	*Merismopedia tenuissima*	14	*Cocconeis placentula*
15	*Aphanizomenon* sp.	16	*Diatoma vulgare*
17	*Cylingrospermum* sp.	18	*Fragilaria virescens*
19	*Lyngbya* sp.	20	*Fragilaria brevistriata*
21	*Leptoiyngbya* sp.	22	*Synedra acus*
23	*Scenedesmus quadricauda*	24	*Synedra amphicephala*
25	*Scenedesmus biguga*	26	*Synedra affinis*
27	*Scenedesmus dimorphus*	28	*Synedra ulna*
29	*Scenedesmus platydiscus*	30	*Cymatopleura solea*
31	*Scenedesmus ecornis*	32	*Navicula viridula*
33	*Pediastrum duplex*	34	*Navicula graciloides*
35	*Pediastrum tetras*	36	*Navicula dicephala*
37	*Pediastrum biradiatum var.longecornutum*	38	*Navicula gastrum*
39	*Chlorogonium elongatum*	40	*Navicula exigua*
41	*Chlorogonium elegans*	42	*Navicula carinifera*
43	*Mougeotia* sp.	44	*Navicula verecunda*
45	*Klebsormidium scopulinum*	46	*Navicula anglica*
47	*Kirchneriella* sp..	48	*Navicula radiosa*
49	*Thorakomonas* sp.	50	*Navicula simples*
51	*Gonium sociale*	52	*Cymbella husteddtii*
53	*Dicloster acuatus*	54	*Cymbella cistula*
55	*Micractinium* sp.	56	*Cymbella delicatula*
57	*Characium* sp.	58	*Cymbella affinis*
59	*Golenkinia* sp.	60	*Cymbella perpusilla*

61	*Nephrocytium agardhianum*	62	*Cymbella ventricosa*
63	*Ankistrodesmus acicularis*	64	*Stauroneis pygmaea Krieg*
65	*Ankistrodesmus falcatus*	66	*Gomphonema* sp.
67	*Ankistrodesmus spiralis*	68	*Gomphonema parvulum*
69	*Oocystis* sp.	70	*Gomphonema olivaceum*
71	*Actinastrum* sp.	72	*Nitzschia sigmoidea*
73	*Gloeoactinium limneticum*	74	*Nitzschia sublinearis*
75	*Coelastrum* sp.	76	*Nitzschia palea*
77	*Stigsoclonium* sp.	78	*Nitzschia stagnorum*
79	*Eudorina* sp.	80	*Achnanthes exigua*
81	*Pandorina morum*	82	*Achnanthes delicatula*
83	*Schroederia setigera*	84	*Nitzschia sigmoidea*
85	*Schroederia spiralis*	86	*Surirella ovata*
87	*Schroederia nitzschioides*	88	*Surirella robusta*
89	*Treubaria crassispina*	90	*Diploneis purlla*
91	*Chodatella wratislaviensis*	92	*Peridiniopsis cunningtonii*
93	*Chodatella quadriseta*	94	*Gyrosigma spencerii*
95	*Attheya zachariasi*	96	*Pinnularia borealis*
97	*Crucigenia quadrata*	98	*Rhopalodia gibba*
99	*Crucigenia fenestrata*	100	*Glenodinium pulvisculus*
101	*Crucigenia tetrapedia*	102	*Glenodinium gymnodinium*
103	*Crucigenia apiculata*	104	*Ceratium hirundinella*
105	*Tetrastrum staurogeniaeforme*	106	*Gymnodinium* sp.
107	*Tetrastum glabrum*	108	*Peridinium pusillum*
109	*Tetraedron minimum*	110	*Peridiniopsis cunningtonii*
111	*Tetraedron hastatum*	112	*Chroomonas caudata*
113	*Tetrastrum hastiferum*	114	*Chroomonas* sp.
115	*Tetraedron caudatum*	116	*Cryptomonas erosa*
117	*Tetraedron trigonum*	118	*Cryptomonas marssonii*
119	*Tetraedron trilobulatum*	120	*Cryptomonas reflexa*
121	*Carteria globosa*	122	*Chroomonas acuta Uterm*
123	*Chlamydomonas komma*	124	*Cryptomonas obovata*
125	*Chlamydomonas microsphaera*	126	*Trachelomonas* sp.
127	*Chlamydomonas reinhardi*	128	*Phacus pyrum*
129	*Chlamydomonas globosa*	130	*Phacus granum*
131	*Chlamydomonas braunii*	132	*Phacus anomatus*
133	*Chlamydomonas ovalis*	134	*Phacus longicauda*
135	*Chlamydomonas simplex Pasch*	136	*Euglena pisciformis*
137	*Dictyosphaerium ehrenbergianum*	138	*Euglena acus*
139	*Closteriopsis* sp.	140	*Euglena viridis*
141	*Closterium gracile*	142	*Euglena polymorpha*

143	*Pteromonas angulosa*	144	*Euglena oxyuris*
145	*Pteromonas gelenkiniana var.subquadrata*	146	*Strombomonas* sp.
147	*Penium spirostriolatum*	148	*Strombomonas fluviatilis*
149	*Cosmarium bioculatum*	150	*Dinobryon* sp.
151	*Cosmarium subtumidum*	152	*Uroglena sp.*
153	*Schroederia setigera*	154	*Mallomonas producta*
155	*Chlorella vulgaris*	156	*Mallomonas elegans*
157	*Selenastrum bibraianum*	158	*Ophiocytium* sp.
159	*Cyclotella* sp.	160	*Chrysochromulina parva*
161	*Stephanodiscus astraes var. minutula*		