PHYTOPLANKTON IN RELATION TO PHYSICO-CHEMICAL FACTORS IN POYANG LAKE, JIANGXI

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Keywords: Poyang Lake, Phytoplankton, Community structure, Environmental factors, Water quality evaluation

Abstract

Changes of phytoplankton structure and water quality were investigated in Poyang Lake from March 2014 to December 2019.The number of identified species in Poyang Lake was 187 belonging to 87 genera and 8 phyla (excluding undetermined species). Among them, Cyanophyta (74 species) had the maximum number of species, followed by Bacillariophyta (51 species) and Chlorophyta (36 species). The average numbers of phytoplankton cells were counted $2783.85 \pm 458.5 \times 10^4$ cells/l. A total of 20 dominant species were identified in Poyang Lake, including 6 of Cyanobacteria, 6 of Diatoms, 7 of Chlorophyta, 1 of Cryptophyta and 1 of Dinoflagellates. Among phytoplankton, Cyanophyta cell density was the highest, accounting for 91.06%. Chlorophyta and diatoms accounted for 5.52 and 2.09%, respectively. The cell density of Xanthophyta was the lowest, accounting for only 0.03%. The four seasons showed obvious changes, and the order was summer - autumn - spring - winter. Algae were the most common, including green algae 153 (53%), diatoms 74 (26%), cyanobacteria 17 (17%), similar to other domestic studies.

Introduction

The water system of Poyang Lake is the largest fresh water lake in China, with a total basin area of about 3,210 sq. km. (Qian *et al*. 2016). Protecting the "clean water of one lake" of Poyang Lake is a national demand to guarantee the ecological and environmental security of China and strengthening the research on the ecological environment of Poyang Lake is an urgent demand for the sustainable economic development of Jiangxi Province (Wang *et al*. 2021). With the rapid economic development in the Poyang Lake Basin, large number of industrial and agricultural wastewater and domestic sewage have been discharged from the surrounding areas, leading to changes in the water environment of Poyang Lake (Pu and Lin 2021). Nitrogen and phosphorus content in the water has increased sharply, leading to rapid growth of some phytoplankton and frequent phytoplankton outbreaks in the eutrophic water bodies (Yang *et al*. 2020).

Phytoplankton play the role of primary producer in aquatic food chain and are important indicator of ecosystem health and integrity. However, due to the massive proliferation of phytoplankton, both the physico-chemical factors and phytoplankton in Poyang Lake are in the eutrophication stage, and the availability of phytoplankton in Poyang Lake is constantly changing and in an unstable stage. It is important to know when the blooms of phytoplankton occur.

From the first field survey to the present experiment time, phytoplankton research in Poyang Lake can be divided into four stages: The initial stage of phytoplankton research (before 1985), the stage of quantitative investigation of phytoplankton community (1985-1999), the stage of

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phytoplankton community model (1999-2005), the stage of phytoplankton community classification system/eutrophication evaluation (2005-2012), the combination of phytoplankton community structure and lake management policy formulation Phase (2012-present time) (Li and Chen 2020, Liu *et al.* 2020).

The present study aimed to study the phytoplankton community structure, physico-chemical properties and the correlation with environmental factors in Poyang lake from March 2014 to December 2019, and to analyze the cell density of phytoplankton species in different seasons (Jia *et al.* 2020). It would provide basic information and reference system for evaluating the effect of lake restoration and management, ecotourism and ecological island construction, and provide first-hand information for evaluating the possibility of ecosystem change.

Materials and Methods

Poyang lake is the largest freshwater lake, and located in the middle reaches of the Yangtze River in China. Its geographical coordinates are 28°52′05″N-29°06′50″N, 116°10′33″E-116°25′05″E from March 2014 to December 2019. The sampling points are shown in Fig. 1. Samples were taken once a month in the second half of the month. Physical and chemical factors were measured on site, and indexes such as pH of water, temperature, dissolved oxygen and conductivity were measured with HQD series portable instrument produced by Hach Company (Zhang *et al.* 2019). Transparency was measured with Sachter's disk, and water depth was measured with HONDEX sonar depth sounder made by Hama Company in Japan. At the same time, 1L water sample was collected and brought back to the laboratory with Hach DR3900. The indexes of total nitrogen, total phosphorus, permanganate, ammonia, nitrogen, nitrite and nitrate were determined by the instrument (Wu *et al.* 2019).
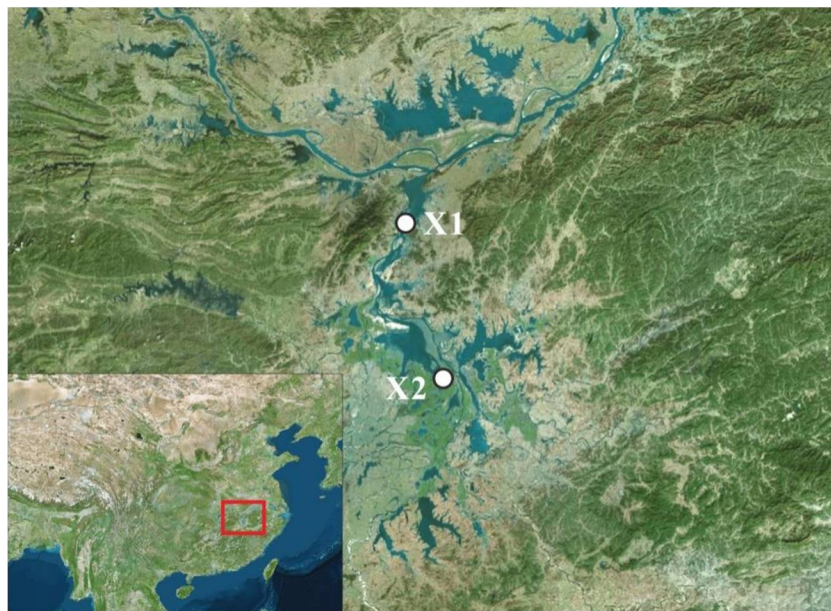

Fig. 1. Sampling site of Poyang Lake.

The sample was fixed in a 50 ml tube with 2% Lugol solution to determine the phytoplankton population. After fixing the reagent for 24 hrs, Sedgwick - Raffter Chamber was used for light microscopy (Nikon Eclipse NI, Japan); four groups of phytoplankton, namely cyanobacteria, chlorobacteria, diatoms, and dinoflagellates were observed, divided into taxonomic star cell analysis and taxonomic military analysis (Cao *et al.* 2018, Liu *et al.* 2019). A number of water quality monitors (YSI 5700, YSI Inc., USA) were used for on-site measurement of water temperature, pH, DO, and electrical conductivity. Samples obtained on site were refrigerated and sent to the laboratory for water quality analysis as soon as possible. T-N, T-P, BOD, COD, SS, NO_3-N, NH_3-N, PO_4-P and Chl-a were analyzed according to the Water Pollution Process Test Standard. Water quality data were analyzed at each study site in order to study the variability between the sites (Qu *et al.* 2018, Ding *et al.* 2019). The statistical analysis of the relationship between phytoplankton and water quality factors in this study was SPSS 12.0 which was used for Pearson correlation analysis. The data of temperature and rainfall were collected from Jiangxi meteorological stations of National Climatic Data Center.

Results and Discussion

Monthly changes of precipitation and average temperature in Jiangxi Climate Data Center of meteorological station from 2014 to 2019 are presented in Fig. 2. The maximum precipitation in 2016 was 1,626.8 mm, while the minimum precipitation in 2019 was 1100.1 mm, a difference of 526.7 mm. In six years, precipitation from June to September accounted for 54% of the annual precipitation, while in 2019, the precipitation was less than 50%, only 42%. The average temperature was 14.7°C degrees in 2019 and 13.8°C in 2015, with a difference of about 1°C.
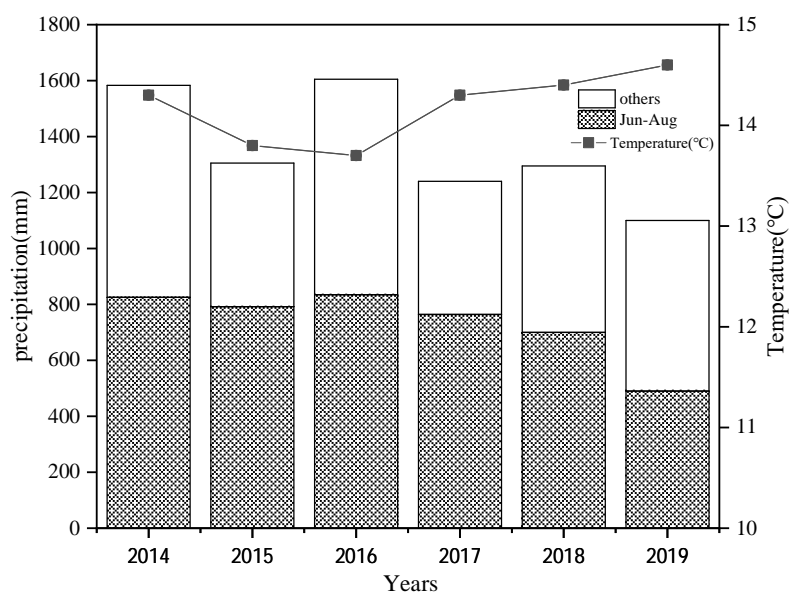

Fig. 2. Variation in annual total precipitation and temperature on Poyang Lake.

The annual change rates of water temperature, DO, pH, Chl-*a*, T-N, T-P, BOD, COD, SS, turbidity, NO_3-N, NH_3-N and PO_4-P for 6 years are shown in Table 1. The annual mean water temperature was similar from 2015 to 2019, being 13.8 and 14.7°C, respectively (except for 2014).

Table 1. Monthly average of water environmental factors of Poyang Lake from March 2014 to December 2019.

	2014		2015		2016		2017		2018		2019	
	X1	X2	X1	X2	X1	X2	X1	X2	X1	X2	X1	X2
Temperature (°C)	14.2	14.6	13.6	14.0	13.4	13.8	14.3	14.5	14.4	14.6	14.6	14.7
DO (mg/l)	8.2	8.3	10.2	9.9	10.9	11.7	11.1	10.8	10.4	10.2	10.0	9.4
pH	7.5	7.5	7.4	7.3	8.1	7.8	7.7	7.7	7.8	7.9	7.6	7.4
Chl-a (mg/m^3)	29.2	32.4	49.1	40.2	60.2	59.7	35.5	38.2	28.9	28.7	51.0	44.4
T-N (mg/l)	4.129	4.063	4.734	4.483	4.673	4.477	4.111	3.957	4.434	4.455	4.191	4.094
T-P (mg/l)	0.258	0.238	0.267	0.259	0.182	0.172	0.097	0.109	0.115	0.129	0.108	0.123
BOD (mg/l)	4.1	4.0	5.3	5.1	5.1	5.2	3.5	3.6	3.9	4.3	3.7	4.4
COD (mg/l)	8.1	8.1	8.9	8.4	9.1	9.1	7.5	7.6	7.5	7.6	7.1	7.1
SS (mg/l)	36.8	48.5	38.3	40.8	14.3	25.1	13.4	29.2	18.6	24.1	10.0	19.8
Turbidity (NTU)	45	78	41	58	14	21	12	20	11	17	10	44
NO$_3$-N (mg/l)	2.703	2.708	2.323	2.294	2.400	2.404	2.214	2.231	2.241	2.261	1.830	1.871
NH$_3$-N (mg/l)	0.541	0.460	1.363	1.376	1.378	1.099	1.053	0.932	1.307	1.196	1.273	1.097
PO$_4$-P (mg/l)	0.152	0.124	0.136	0.117	0.108	0.082	0.038	0.035	0.040	0.038	0.033	0.027

There was little change from 2015 to 2019, and the temperature in 2019 was slightly higher than that in the previous year. The range of dissolved oxygen was between 3.7 and 17.6 mg/l, with an increasing trend in summer. Except for 2016, it was below 8 mg/l in summer. The average dissolved oxygen was 10.0 mg/l, and the average annual Ia level of the environmental water standard was maintained during the 6 years. pH values were found to range from 6.2 to 9.1, with an average of 7.6, similar to previous studies of 6.7 and 7.4. The pH value of 2014 increased continuously from 2014 to 2016, and then gradually decreased to the level of 2015, both of which showed certain performance.

T-N ranged from 1.749 to 9.916 mg/l, and continued to decrease from January to September, but showed an upward trend after September. In 2015 and 2016, the highest values in winter and spring were 0.570 and 0.695 mg/l, respectively and in 2017 and 2019, the average values were 0.106 and 0.120 mg/l, respectively which showed a decreasing trend. This might be due to the large-scale manual processing facility carried out in October 2016. The average BOD at these two points was 4.3 mg/l, ranging from 1.3 to 11.6 mg/l. Except for 2015, high records were generally recorded in July. The average COD of the two points was 7.9 mg/l, and the range was 2.5 ~ 16.4 mg/l. SS and turbidity showed no significant changes except in 2014 and 2015. In 2014 and 2015, the average value caused by the project was on the high side, and the further downstream, the higher the average value. After 2016, the change of meters was found to increase in July and August. The mean values of NO_3-N at these two points were 2.290 mg/l and between 0.789 and 4.530 mg/l, high in winter and low in summer, and both have declined since 2014. Like NO_3-N, NH_3-N has a higher value in winter and a higher value in the downstream, ranging from 0.026 to 5.737 mg/l. The mean value of PO_4-P at two points was 0.078 mg/l, ranging from 0.001 to 0.384 mg/l, and continued to decrease since 2016. Similar to T-P, this might be due to the establishment of total phosphorus treatment facilities. Although nutrients such as PO_4-P were reduced after the construction of the dam, the reduction of turbidity also led to the formation of algae in the water system (Chen and Chen 2015). Poyang lake has a large drainage area, but its main branches are narrow and are greatly affected by rainfall. Point sources are located near the main streams, which undergo rapid physical and chemical changes. It indicates that the tidal current of Poyang Lake is more sensitive to the change of water environment factors than physical factors, and its community structure and available water amount change.

A total of 20 dominant species were identified in Poyang Lake, including 6 of Cyanobacteria, 6 of Diatoms, 7 of Chlorophyta, 1 of Cryptophyta and 1 of Dinoflagellates. Among phytoplankton, Cyanophyta cell density was the highest, accounting for 91.06%. Chlorophyta and diatoms accounted for 5.52 and 2.09%, respectively. The cell density of Xanthophyta was the lowest, accounting for only 0.03%. The four seasons showed obvious changes, and the order was summer - autumn - spring - winter.

Monthly variation of number of phytoplankton species presented in Fig. 2 showed that there was in total 288 species in the studied take. A total of 83 species were identified in 2014, including 7 cyanobacteria (8%), 27 diatoms (33%), 34 chlorophyta (41%) and 15 others (18%). A total of 114 species were identified in 2015, including 9 cyanobacteria (8%), 27 diatoms (24%), 61 chlorobacteria (54%) and 17 others (15%). A total of 114 species were identified in 2016, including 9 cyanobacteria (8%), 57 diatoms (22%), 62 chlorobacteria (54%) and 18 others (16%). A total of 115 species were identified in 2017, including 10 cyanobacteria (9%), 32 diatoms (28%), 57 chlorobacteria (50%) and 16 others (14%). A total of 131 species were identified in 2018, including 8 cyanobacteria (6%), 39 diatoms (30%), 65 chlorobacteria (50%) and 19 others (15%). A total of 163 species were identified in 2019, including 7 cyanobacteria (4%), 49 diatoms (30%), 76 chlorophyta (47%) and 31 others (19%). There were as many as 34 species in 2014 and 61 species of cyanobacteria in 2015, which doubled and increased, and then showed a similar

level. Compared with 2014, the total number of cyanobacteria species in 2019 increased by about two times, presenting a variety of species on the whole, which is the difference of survey frequency and season.
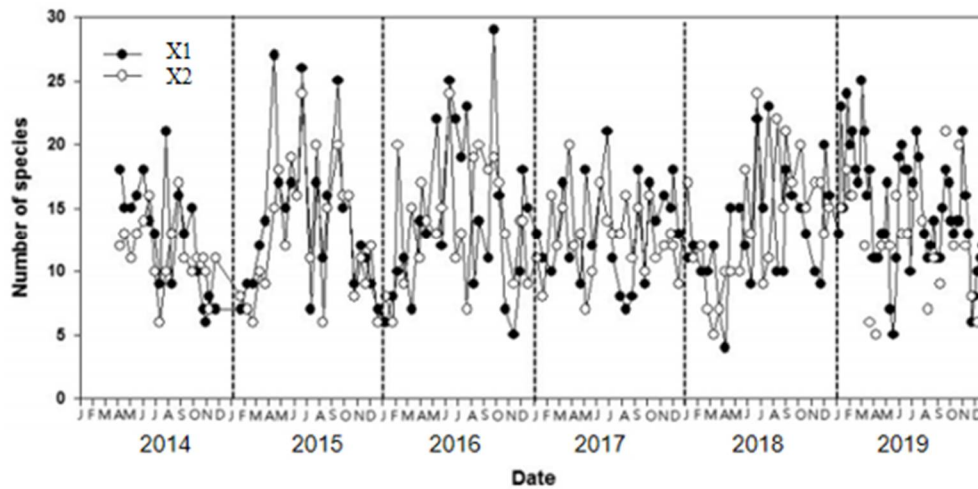

Fig.2. Monthly variation of number of species in Poyang Lake.

In the past 6 years, the number of diatoms was low because of the increase of the dominance in winter and spring, but the dominance of green algae and other algae decreased after December, while the number of diatoms increased. The change of the number of diatoms was different with the different dominance. When the summer comes, the number of species decreases, which is the advantage of cyanobacteria, and then increases in the autumn. The values of the two sites showed that the upstream sites with lower dominance points had more species of Y1. The species of X1 point ranged from 4 species (December 2018) to 29 species (September 2016), and the species of X2 point ranged from 5 species (December 2019) to 24 species (June 2018).

Over the course of six years of the study, dominant genera included *Cyclotella* sp., *Stephanodiscus* sp., *Aulacoseira* sp.*, Skeletonema* sp.*, Nitzschia* sp.*, Synedra* sp.*, Melosira* sp.*, Pandorina* sp.*, Micractinium* sp.*, Actinastrum* sp.*, Pediastrum* sp.*, Coelastrum* sp.*, Eudorina* sp. Among the genera Cryptomonas (Table 2), the *Tephanodiscus* sp. and *Aulacoseira* sp. had the maximum dominant periods. The dominant period of harmful algae changes every year. In 6 years, the proportion of algae stocks is 13%; and this reaches the maximum of 95% in 2019 in late summer when the water temperature is higher than 25°C, which is the dominant period.

Temperature is one of the important factors for phytoplankton reproduction in water, which has a great influence on the growth of phytoplankton. Different phytoplankton have their own optimum growth temperature. In 2007, Liu *et al.* studied the phytoplankton community structure in Poyang Lake and found that the phytoplankton cell density and biomass were positively correlated with water temperature. Similarly, with the increase of water temperature from 2015 to 2019, both the cell density and biomass of cyanobacteria increased. Compared with other phytoplankton, cyanobacteria had stronger tolerance to higher temperature, the optimal growth temperature of cyanobacteria was 25 - 30°C, the optimal growth temperature of chlorophyta was 20 - 25°C, and the optimal growth temperature of diatoms was 14 - 18°C. *Microcystis* sp. of

Table 2. Correlation coefficient(r) of phytoplankton and chlorophyll a(Chl. a) and chemical parameters(n=134-163).

		Chl. a	WT	pH	DO	EC	BOD	COD	SS	T-N	T-P	Turbidity	NO_3-N	NH_{3-n}	PO_4-P
X1	Cyanophyta	0.337**	0.337**	0.187*	-0.174*	-0.139	0.010	0.122	-0.013	-0.246**	-0.065	0.016	-0.249**	-0.212**	-0129
	Bacillariophyta	0.541**	-0.505**	0.335**	0.621**	0.455**	0.468**	0.318**	0.019	0.547**	0.308**	-0.080	0.430**	0.420**	0.224**
	Chlorophyta	0.339**	0.413**	0.032	-0.200*	-0.066	0.342**	0.429**	0.055	-0.169*	0.049	0.054	-0.305**	-0.113	-0.041
	Others	0.363**	-0.092	-0.000	0.067	0.140	0.147	0.037	-0.128	0.162*	-0.033	-0.105	0.001	0.240**	-0.048
	Total	0.778**	-0.185*	0.384**	0.431**	0.348**	0.543**	0.467**	0.012	0.358**	0.259**	-0.062	0.019*	0.285**	0.129
X2	Cyanophyta	-0.050	0.304**	0.159	-0.089	-0.233**	0.009	0.112	-0.012	0.285**	-0.138	-0.052	-0.182*	-0.278**	-0.121
	Bacillariophyta	0.592**	-0.378**	0.413**	0.494**	0.294**	0.282**	0.353**	-0.023	0.377**	0.297**	-0.088	0.306**	0.252**	0.237**
	Chlorophyta	0.126	0.399**	0.082	-0.178*	-0.164	0.273**	0.216*	-0.019	-0.202*	-0.034	-0.060	-0.303**	-0.148	-0.098
	Others	0.161	0.030	0.096	0.012	0.078	0.267**	0.181*	-0.069	-	-0.009	-0.074	-0.058	0.069	-0.077
	Total	0.606**	-0.211*	0.464**	0.423**	0.207*	0.361**	0.432**	-0.036	0.265**	0.248**	-0.118	0.186*	0.158	0.074**

cyanobacteria could still grow normally at water temperature greater than 35°C. Other studies have shown that cyanobacteria generally have a growth advantage when the water temperature exceeds 20°C. From 2015 to 2019, the average annual water temperature showed an increasing trend, which had a certain impact on the temperature-sensitive phytoplankton. For example, the species of Cyanobacteria positively correlated with temperature indicating that the species of Cyanobacteria in this study were richer and more diverse than that in 2014.

Correlation analysis of Poyang Lake data at two points showed that phytoplankton stocks at two points were significantly correlated with Chl-*a*, pH, DO, EC, BOD, COD, T-N, T-P, and WT but was negatively correlated with turbidity (Table 2). The annual average storage of point X1 ranged from 4,387 to 14,677 cells/ml, and the average storage in 2016 was 14,677 cells/ml. The annual average storage capacity of X2 was 3,361-17,347 cells/ml, the same as that of X1, which peaked at 17,347 cells/ml in 2016.It was from January to March that the temperature began to significantly affect the growth of algae, which was consistent with previous studies.

From March 2014 to December 2019, water quality and phytoplankton changes in the upper and lower reaches of Poyang Lake were studied. During the same period, the average water temperature at both sites was 18.2°C, which remained at 16.3°C from 2014 to 2019 and rose by 0.7 to 17.3°C in 2015. During the survey period, phytoplankton species composition was divided into 288 groups, including 17 groups of cyanobacteria, 74 groups of diatoms and 154 groups of green algae. The population densities of these two sites ranged from 500 to 29,950 cells/ml, at X1 from 850 to 29,725 cells/ml, and at X2 from 500 to 29,950 cells/ml. The mean densities of the two points at the upstream point were shown to be 8,180 cells/ml and 7,530 cells/ml at X2. Among the dominant species are the very high *Stephanodiscus*, with a dominant frequency of 59% compared to 22% for *Rhombus*. The dominant frequency of cyanobacteria on the whole was 17%, X1 was 19%, which was 2% higher than X2. Among them, the dominant frequency of *Microcystis* was 6%, while the dominant frequency of X1 locus was 7%, which was 2% higher than that of downstream X2 locus. The stock proportion of X1 point was as follows: diatoms accounted for 52%, green algae for 24% and cyanobacteria for 21% of the total; At X2, 65% of diatoms, 18% of green algae and 13% of cyanobacteria were found, indicating that the stock proportion of cyanobacteria upstream of X1 point was higher. The purpose of this study was to understand the phenomenon of phytoplankton drift and the reasons for the change of water quality factors, and to provide reliable data for the characteristics of Poyang Lake, which will provide basic data for the evaluation of aquatic ecosystem changes in future.

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