Distribution Features of Phytoplankton and Its Correlation with Environmental Factors of Baima Lake

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Abstract. In order to deal with the degradation of ecological function in Baima Lake, 11 Sampling sites were set up in 2014, 2016 and 2017 in Huaian City, Jiangsu Province. Sampling was conducted monthly to monitor and analyze the temporal and spatial changes of phytoplankton community structure in the lake. The results showed that 119 species of phytoplankton were identified in 2014, 109 species in 2016 and 114 species in 2017, belonging to 8 phyla. Phytoplankton abundance got top in summer and bottom in winter. Its spatial distribution was higher in northwest and central, and lower in northeast and south. The health status of lakes in different years was evaluated by Shannon-Wiener diversity index, Pielou evenness index and SI pollution index. Baima Lake is a medium-eutrophic (moderate) water body. Pearson correlation analysis was carried out between phytoplankton and environmental factors.

1. Introduction

Phytoplankton are a tiny plant that suspend in water. Because of its small size, short life cycle and fast reproduction speed, phytoplankton are vulnerable to various environmental factors and change in a short period[1]. In water, phytoplankton can reflect the water environment changes, for example, it can better reflect the eutrophication level compared with physical and chemical indicators[2-3].

At present, the relationship between phytoplankton community structure, diversity, ecological distribution and environmental impact factors is a hot topic at home and abroad[4-7]. However, little research has been carried out on the relationship between phytoplankton and environmental factors in Baima Lake, so it is necessary to make up for this vacancy.

Baima Lake is located in the downstream of the Huaihe River Basin. It belongs to Jinhu, Hongze, Chuzhou and Baoying counties (districts), 119°02′E~119°12′E, 33°09' N~33°19'N.The lake area is about 113.4km^2, the average annual precipitation is 956 mm and the average annual evaporation is 810 mm. The main rivers entering and leaving the lake include Caoze River, Xunhe River, Huahe River, Yongji River, Wenshan River, Xinhe River, Yunxi River, etc.

Baima Lake plays an irreplaceable role in ensuring the local residents' living water, social and economic development and ecological environment balance[8]. In recent years, a series of human activities have caused the degradation of the ecological environment of Baima lake and severely weakened the comprehensive function of the lake, such as illegal encroachment of waters, illegal sand mining and random discharge of sewage around the lake[9]. Based on the data of 2014, 2016 and 2017 phytoplankton ecological survey, the objective of this paper is to analyze the changes of phytoplankton community structure to reflect the current status of Baima Lake water environment quality, providing scientific support for the lake management.

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2. Methods

According to the area, topographic profile, cultivation distribution and main rivers entering and leaving Baima Lake. 11 sampling sites were set up in the study, with sampling frequency once a month, in 2014, 2016 and 2017.

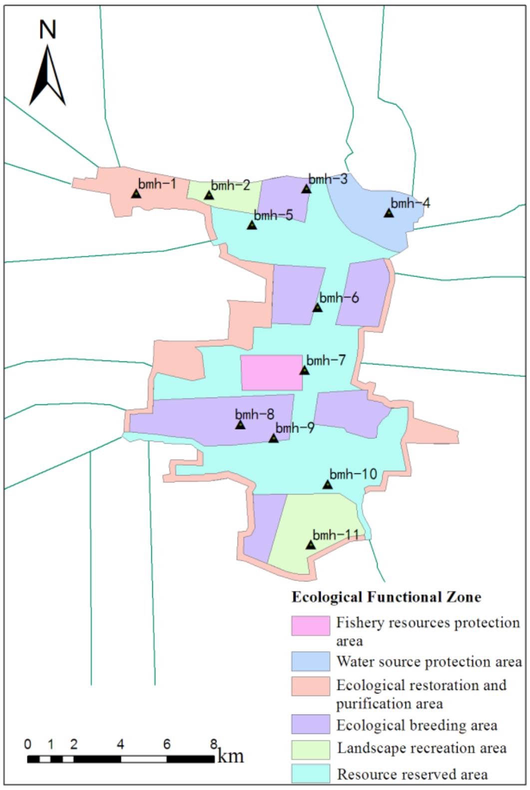


Figure 1. Phytoplankton Monitoring Points in Baima Lake

In addition to phytoplankton, other analytical indicators in water samples include water temperature, transparency, conductivity, pH, dissolved oxygen (DO), total phosphorus (TP), total nitrogen (TN), ammonia nitrogen (NH3-N), permanganate index (CODMn).The monitoring of various ecological indicators was in accordance with the local standard of Jiangsu province, "lake water ecology monitoring standard" (DB32/T3202-2017).

Phytoplankton can be used as a biological indicator to indicate water quality, because the changes in the community structure of phytoplankton are one of the direct consequences of the evolution of the water environment. In this paper, Shannon-Wiener diversity index, Pielou evenness index and SI pollution index were used to evaluate the water quality of Baima Lake[10].

Shannon-Wiener diversity:

$$H' = -\sum_{i=1}^{S} \frac{n_i}{N} \log_2 \frac{n_i}{N} \tag{1}$$

Pielou evenness index:

$$J = \frac{H'}{H_{\max}} \tag{2}$$

SI pollution index:

$$SI = \frac{\sum s \times h}{\sum h} \tag{3}$$

Diminance:

$$Y = \frac{n_i}{N} \times f_i \quad (4)$$

Where n_i is the number of individuals of No.*i* kind of phytoplankton, N is the total number of individuals, and S is the total number of species in the sample. H_{max} is $\log_2 S$, which represents the maximum value of the diversity index. s is the indicator level of algae pollution, and h is the estimated quantity level of the algae. f_i is the frequency that No.*i* species appears at each station, and species with a Y value bigger than 0.02 are the dominant species.

3. Results and Discussion

3.1. Species Composition and Dominant Species

The phytoplankton identified in each year mainly belongs to *Chlorophyta, Bacillariophyta, Cyanophyta* and *Euglenophyta.* The dominant species are shown in Table 1. The dominant species in 2014 were *Chlorella sp., Cyclotella sp., Melosira granulata var. angustissima, Syndera Acus, Kephyrion ovale,* Chroomonas acuta, *Pseudanabaena catenata, and Phormidium sp*. The dominant species in 2016 is similar to that in 2017. Compared to 2014, there are another three species: *Scenedeamus quadricauda, Crypomonas erosa and Aphanizomenon gracile.*

Table 1. Dominant Species of Phytoplankton of Baima Lake in Different Years

Phytoplankton species	2014		2016		2017	
	f	Y	*f*	Y	*f*	Y
Chlorella sp.	1	0.1265	1	0.1152	1	0.0989
Scenedeamus quadricauda	-	-	1	0.0204	1	0.0288
Cyclotella sp.	1	0.1716	1	0.1293	1	0.1341
Melosira granulata var. angustissima	1	0.0332	1	0.045	1	0.0498
Synedra acus	1	0.0406	1	0.0548	1	0.0542
Kephyrion ovale	0.91	0.0225	0.91	0.0221	1	0.0364
Chroomonas acuta	1	0.0394	1	0.0392	1	0.0391
Crypomonas erosa	-	-	0.91	0.0232	1	0.0256
Aphanizomenon gracile	-	-	0.73	0.0229	0.73	0.0209
Pseudanabaena catenata	0.91	0.0236	0.91	0.0295	0.91	0.0213
Phormidium sp.	1	0.1863	1	0.1458	1	0.1483

f is the frequency that No.*i* species appear;Y indicates Phytoplankton species' diminance

3.2. Temporal and Spatial Distribution of Phytoplankton

Fig.2 reflects the monthly changes in phytoplankton abundance of Baima Lake in 2014, 2016 and 2017, and the trends during each year are basically similar. In 2014 and 2016, The average abundance at January was the lowest in that year, and the lowest in 2017 appeared in February. The average abundance of phytoplankton in the whole lake has increased significantly from June to August every year, and both peaked in August, then began to decline in September, and fell to a relatively low level in December. Among them, the abundance of phytoplankton reached a maximum of three years in August 2014, which was 47.3×10^6cells/L. In January, there was a three-year minimum of 1.70×10^6 cells/L. The lowest value per year was at the range of 1.5×10^6 cells/L ~ 3.5×10^6cells/L, but the peak value was significantly lower than the previous year.

The phytoplankton abundance in Baima Lake was the highest in summer, followed by autumn, and the abundance was the lowest in winter. This is because green algae, diatom and cyanobacteria dominate phytoplankton species in Baima Lake. The optimum temperature for green algae growth is 30 ℃ ~ 35 ℃, the optimum temperature of diatom is 20 ℃, the optimum temperature of cyanobacteria is 40 ℃, and in the local temperature range, the higher the temperature, the faster the green algae and cyanobacteria reproduce, so phytoplankton abundance could reach the highest value in summer.

The interannual variations of spring and winter abundance were not much different. The phytoplankton abundance in summer 2016 was significantly lower than that in 2014, and in 2017, the abundance in summer declined remarkablely compared to 2016. This change was due to the fact that after the implementation from fish to lake in 2016, the flow of the lake accelerated, the amount of fishing bait in the lake decreased, and the problem of eutrophication of the lake was alleviated, which greatly reduced the abundance of phytoplankton in Baima Lake in summer.

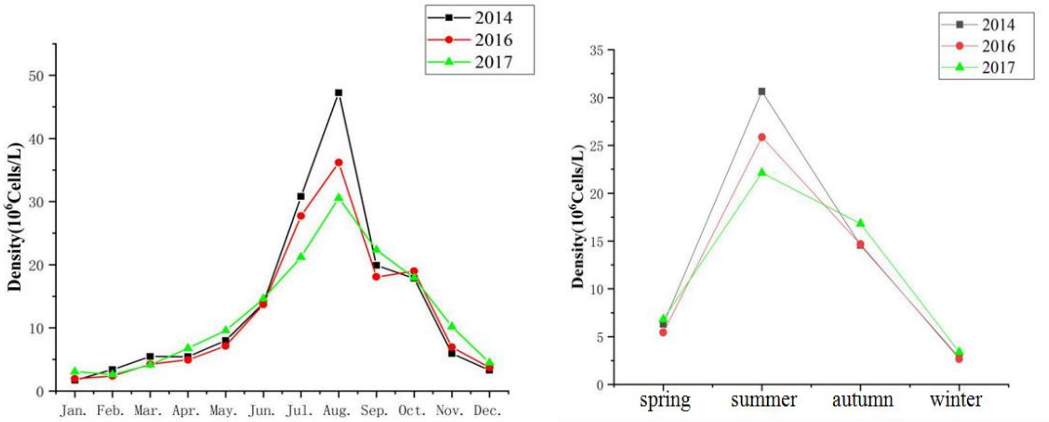
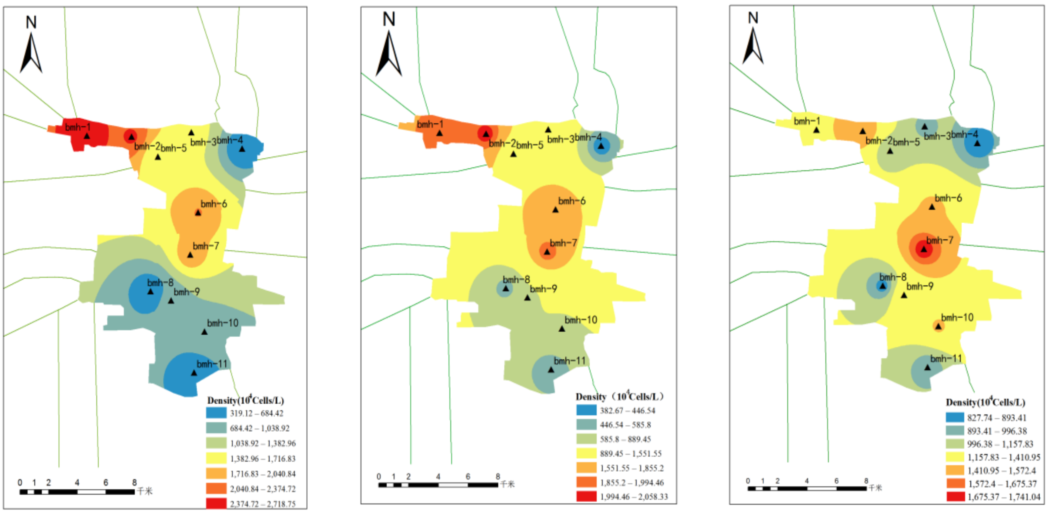
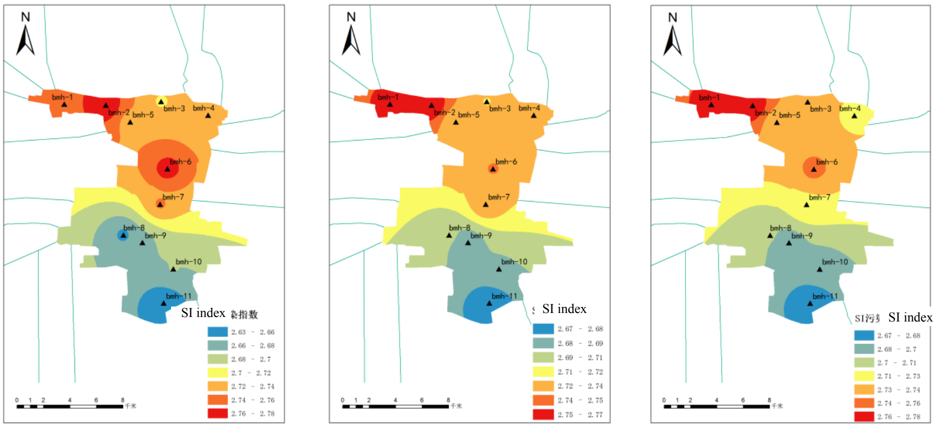


Figure 2. Monthly (left) and Seasonal (right) Variation of Phytoplankton Abundance in Baima Lake



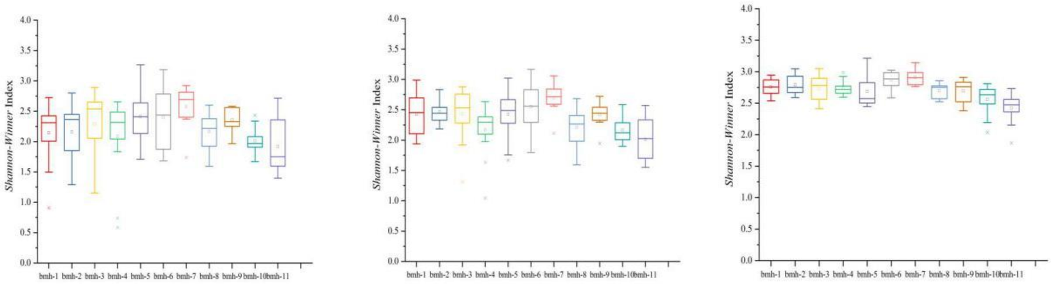
2014 **2016** **2017**

Figure 3. Spatial Distribution Difference of Phytoplankton Abundance



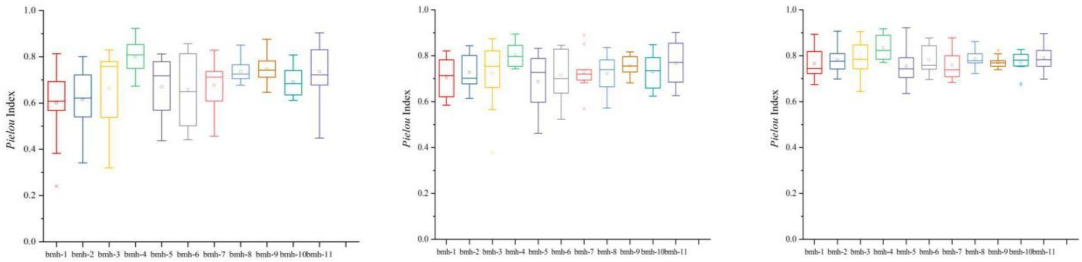
2014 **2016** **2017**

Figure 4. SI pollution index distribution difference



2014 **2016** **2017**

Figure 5. Shannon-Wiener diversity index distribution difference



2014 **2016** **2017**

Figure 6. Pielou evenness index distribution difference

Fig.3 and Fig.4 respectively show the spatial difference of phytoplankton abundance and SI pollution index in Baima Lake for three years. Fig.5 and Fig.6 respectively show the spatial difference of Shannon-Wiener diversity index and Pielou evenness index.

Based on the spatial distribution of phytoplankton abundance, Shannon-Wiener diversity index, Pielou evenness and SI pollution index in 2014, 2016 and 2017, the following points could be summarized:

To the waters in the northwestern part of Baima Lake, especially in the landscape entertainment area, the annual abundance was the largest, and the SI index also reached the top of all measurement sites. The annual abundance of the northeastern part of Baima Lake was always relatively small, but the Pielou evenness was always the largest of all sites; The annual abundance of the waters in the central fishery resource conservation area was second only to the northwest, and the Shannon-Wiener diversity index was the largest in all three years. The average annual phytoplankton abundance in the southern part of Baima Lake was relatively small. The diversity index and the SI pollution index in the southern landscape entertainment area were the smallest over all functional areas, indicating that the water quality in the south was better.

3.3. Valuation Index

The water quality of Baima Lake was evaluated by Shannon-Wiener diversity index, Pielou evenness index and SI pollution index[11-12]. Compared with 2014 and 2016, the diversity index and Pielou evenness index in Baima Lake increased slightly in 2017, indicating that the stability of phytoplankton community structure kept increasing. The pollution index of 2017 was slightly lower than that of 2016, indicating that after the implementation of returning fishery to lake, the water body of Baima Lake is still medium-rich (medium) water, but the water quality has improved to some extent.

Table 2. Comparison of water quality evaluation of Baima Lake in different years

	Shannon-Wiener diversity index	Pielou evenness index	SI pollution index
2014	2.23(Mild pollution)	0.69(Mild pollution)	2.83(Severe pollution)
2016	2.36(Mild pollution)	0.73(Mild pollution)	2.84(Severe pollution)
2017	2.71(Mild pollution)	0.78(Mild pollution)	2.72(Severe pollution)

3.4. Correlation Analysis

Pearson correlation analysis was carried out on the dominant species abundance and water physicochemical index data of phytoplankton at 11 sites in Baima Lake in 2017 (12 months). The physical and chemical indicators were temperature, transparency, conductivity, TN, TP, etc. A total of 9 variables, the results are shown in Table 3.

In 2017, there were 11 dominant species of algae, each of them was significantly positively correlated with water temperature. Among them, the correlation coefficient of *Cyclotella sp.* with temperature was the highest, 0.775. The correlation coefficient of *Chlorella sp.*, *Scenedeamus quadricauda* and *Phormidium sp.* between temperature exceeds 0.6. This also well explains the seasonal variation of phytoplankton abundance. The higher the temperature, the more favorable it is for the growth of phytoplankton in Baima Lake, so the phytoplankton abundance was the largest in summer and the smallest in winter. There were 7 species of phytoplankton with extremely significantly negative correlation with DO, The 6 species of phytoplankton showed a extremely significantly positive correlation with the conductivity, and 5 species of phytoplankton and NH_3-N showed a extremely significantly negative correlation. *Kephyrion ovale* had a very significantly correlation with all environmental factors except conductivity.

Pearson correlation analysis showed that temperature is the main factor affecting the growth of phytoplankton, followed by DO, conductivity and pH. A large number of studies have shown that different DO, conductivity, pH and transparency of water bodies can affect the structure of phytoplankton community. For example, diatom communities need different conductivity optimum values to survive, so the water conductivity will affect the phytoplankton community structure. Transparency mainly affects the growth of phytoplankton by affecting the light absorption and scattering of water. With the reproduction of phytoplankton, the pH value of water will change. The pH value also has an important influence on the structure and distribution of phytoplankton community. pH and DO concentration can reflect the growth of algae and changes of water environment[13-14]. Water nutrients (TP, TN, NH_3-N) and permanganate index are also important factors affecting the spatial and temporal variation of phytoplankton. It is necessary to control the pH range and inflow of nitrogen and phosphorus, which is beneficial to the water quality of Baima Lake improvement.

Table 3. Correlation analysis between dominant phytoplankton species and environmental factors

	Temperatu-re	Transparency	Conductivi-ty	pH	DO	TP	TN	NH_3-N	COD_{Mn}
Chlorella sp.	0.656**	-0.008	0.469**	-0.206*	-0.378**	-0.098	-0.11	-0.347**	-0.025
Scenedeamus quadricauda	0.606**	-0.227**	0.364**	-0.101	-0.242**	-0.094	-0.095	-0.331**	-0.222*
Cyclotella sp.	0.775**	0.06	0.561**	0.018	-0.258**	-0.189*	-0.113	-0.402**	0.035
Melosira granulata var. angustissima	0.543**	-0.155	0.383**	0.044	-0.049	-0.091	0.054	-0.196*	0.037
Synedra acus	0.438**	0.409**	0.202*	-0.403**	-0.517**	-0.184*	-0.352**	-0.307**	-0.284**
Kephyrion ovale	0.324**	0.502**	0.000	-0.342**	-0.414**	-0.369**	-0.343**	-0.190*	-0.329**
Chroomonas acuta	0.493**	0.133	0.223*	-0.227**	-0.355**	-0.233**	-0.151	-0.220*	-0.176*
Crypomonas erosa	0.459**	0.026	0.219*	-0.215*	-0.306*	-0.153	-0.113	-0.200*	-0.205*
Aphanizomenon gracile	0.303**	-0.223*	0.238**	0.228**	0.127	-0.084	-0.109	-0.167	0.006
Pseudanabaena catenata	0.227**	-0.092	0.083	-0.189*	-0.328**	-0.032	-0.085	-0.188*	-0.175*
Phormidium sp.	0.632**	-0.204*	0.44**	0.121	-0.017	-0.103	0.01	-0.296**	0.007

Note:* represents a significant level of 0.05(double tailed test);**represents a very significant level of 0.01(double tailed test)

4. Conclusion

The distribution characteristics of phytoplankton in Baima Lake in 2014, 2016 and 2017 were discussed, and the correlation analysis was carried out with environmental factors. The main conclusions are as follows:

The abundance of phytoplankton in Baima Lake was the highest in summer and the lowest in winter, and the interannual variation of abundance in spring and autumn was not remarkable. The phytoplankton abundance in 2016 and 2017 was significantly lower than that in 2014, indicating that the lake water nutrition management has achieved initial results.

Baima Lake belongs to medium-eutrophic (moderate) water body. The average annual abundance of phytoplankton showed the characteristics of "larger in the northwest and middle, smaller in the northeast and south". And the Shannon-Wiener diversity index of central fishery resource protection area was the largest, the Pielou eveness index in the northeast was the smallest. The SI pollution index of the landscape entertainment area in the northwest was the largest over all sampling sites, while the SI index of the southernmost landscape entertainment area was the smallest. Though the overall water quality has improved, but the water pollution in the northwest is still serious.

Temperature is the main factor affecting the phytoplankton abundance in Baima Lake. DO, conductivity, pH, water nutrients, COD_{Mn} and transparency are also important factors affecting the spatial and temporal variation of phytoplankton.

5. Acknowledgement

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