ISSN: 1813-4890

An analysis of the structure characteristics of plankton community of Poyang Lake in South China Agricultural University

Wending Liu, Wenqing Xiong, Haixing Zhang, Zijun Wu, Yanping Zhang [a]

Jiangxi Fisheries Research Institute, Nanchang Key Laboratory of Special Aquatic Breeding and Healthy Aquaculture, Nanchang Jiangxi 330000, China)

[a]zhangyanpingxie@163.com

Abstract

In order to reveal the plankton community structure and water quality of Poyang Lake in South China Agricultural University (here in after referred to as Huanong-Poyang Lake), a monthly plankton survey was conducted from October 2019 to February 2020, with a total of 3 sampling sites. The results showed that 53 species of phytoplankton were collected from 6 phyla, 34 genera. The density of phytoplankton ranged from 2.93×10^7-4.57×10^7cells/L, with an average of 3.76×10^7 cells/L. The Shannon-Wiener diversity index of phytoplankton ranged from 2.01 to 3.41, Margalef richness index ranged from 2.32 to 3.54 and Pielou evenness index ranged from 0.44 to 0.76. The Person correlation analysis showed that water temperature, dissolved oxygen and pH were the main environmental factors affecting phytoplankton. Moreover, a total of 32 species zooplankton from 3 phyla were detected, and the density ranged from 82 -231cells/L, with an average of 124 cells/L. The Shannon-Wiener diversity index of zooplankton ranged from 2.22 to 3.28, Margalef richness index ranged from 3.05 to 4.32, Pielou evenness index ranged from 0.77 to 0.79 and B/T index was between 1.25 and 2.00. The results of person correlation analysis indicated that water temperature and pH were the main environmental factors affecting zooplankton.

Keywords

Huanong-Poyang Lake; phytoplankton; zooplankton; community structure; water quality evaluation.

1. Introduction

Plankton has the characteristics of small body, large quantity, fast metabolism and vigorous life activities [1]. As an important component of the aquatic ecosystem, plankton plays a crucial role in the process of material circulation, energy flow and information transmission in the aquatic ecosystem [2]. The species composition and diversity of plankton can measure the characteristics of its community structure, which in turn is closely related to water environmental factors. The investigation and analysis of plankton community structure can reflect the ecological conditions and nutritional status of water bodies [3]. As primary producers, phytoplankton is closely related to the nutrient state of water body and has an indicative effect. The dominant species of phytoplankton are commonly different in lakes with different nutrient states [4]. Zooplankton is also extremely important organism in the aquatic ecosystem, which can not only serve as high-quality food for many economic fish, but also regulate and control the occurrence and development of algae and bacteria. The species composition and abundance of zooplankton can reflect the degree of eutrophication of water bodies [5]. Therefore, the characteristics of plankton community structure can be used as a basis to evaluate the degree and harm of eutrophication in water. It is of practical significance to investigate the plankton community structure.

South China Agricultural University has a total of five lakes, are Hongze Lake, Poyang Lake, Shaoyang Lake, Ningyin Lake and West Lake, of which Poyang Lake area is the largest, about 3000 square meters of artificial lake, also known as "wetland park", mainly rely on rainfall and artificial water to maintain water level. Poyang Lake (113.348-113.350E, 23.155-23.157N) is about 300m away from the main entrance of South China Agricultural University, which is surrounded by administrative buildings, teaching buildings, dormitories and restaurants. The quality of its water environment directly affects the quality of life of surrounding residents and the campus water ecological environment. It is of great significance to understand and evaluate the plankton and water environment status of Huanong-Poyang Lake.

In the study, the species abundance and diversity index of plankton in Huanong-Poyang Lake in Huanong were investigated and the water quality was preliminarily evaluated from September 2019 to January 2020, aiming to provide reference for water environment protection and optimization of Huanong-Poyang Lake.

2. Investigation and research methods

2.1. Sampling time and sampling point

According to the *Technical Regulations for Lake Investigation* [6] and *Technical Specifications for Freshwater Biological Investigation* [7], three stations were set up in Huanong-Poyang Lake, South China Agricultural University, Tianhe District, Guangzhou, to carry out plankton field surveys from September 2019 to January 2020 (Fig.1), with a sampling frequency of once a month.

Fig.1 Sampling sites of Huanong-Poyang Lake

2.2. Phytoplankton collection and treatment

2.2.1. Phytoplankton collection

Phytoplankton collection includes qualitative and quantitative collection. Qualitative collection: use a phytoplankton collection net with aperture of 0.02mm to drag it in the shape of "∞" at a depth of about 0.5m for 3-5 minutes at a speed of 20-30cm/s, store the collected samples in a specimen bottle and mark them, and immediately fix them with 5% Lugols solution. Quantitative collection: collect water samples with 5L plexiglass water sampler in the middle of the water body, and then take 1L mixed water sample in the specimen bottle, and add 10-15ml 5% Lugols solution.

2.2.2. Phytoplankton treatment

Phytoplankton treatment includes qualitative treatment and quantitative treatment. Qualitative treatment: Drop a small amount of sample on a slide with a pipette gun, cover the slide, observe with microscope and take photos for identification. Quantitative treatment: the collected water sample was left for 48h, concentrated to 30ml by siphon method after precipitation, shook well and absorbed 0.1ml concentrated sample by pipette gun into 0.1ml phytoplankton technical frame, covered with cover glass and placed under microscope for counting.

2.3. Zooplankton collection and treatment

2.3.1. Zooplankton collection

Qualitative collection: a zooplankton collection net with aperture of 0.064mm was dragged in the shape of "∞" at the depth of about 0.5m at the water collection point for 3-5 minutes at a speed of 20-30cm/s. The collected samples were stored in a specimen bottle and 3ml formaldehyde was added. Quantitative collection: collect 50Lwater samples in the middle of the water body with 5L plexiglass water sampler, mix it in a bucket, filter it in zooplankton net, concentrate to 20ml, store it in a specimen bottle and add 1ml formaldehyde.

2.3.2. Zooplankton treatment

Qualitative treatment: drop a small amount of evenly mixed sample on a slide with a pipette gun, cover the slide and place it under a microscope for identification. Quantitative treatment: drop 1ml of sample into 1ml of plankton technical frame with pipette, cover the cover glass and place it under microscope for counting. The counting calculation method is referred to the *Freshwater Plankton Research Methods* [8].

In addition, the physical and chemical indexes of water at the sampling point were measured on site. Water temperature, pH, dissolved oxygen were determined using YSI water quality analyzer, transparency and depth were determined using Secchi disc.

2.4. Data analysis

2.4.1. Plankton diversity analysis

The dominant species of plankton is determined according to its dominance value (Y). Y > 0.02 means dominant specie, and its calculation formula is as follows:

$$Y = \frac{ni}{N} \cdot fi$$

In the formula, ni is the total number of the i species at the sampling point. N is the total number of plankton at the sampling point. fi is the frequency at which type i occurs at the sampling point.

Margalef index (D) [9] was used to calculate species richness, and water quality was divided into four categories according to D value: more than 4 represents clean; 3-4 represents light pollution; 1-3 represents moderate pollution; 0-1 represents heavy pollution. Its calculation formula is as follows:

$$D = (S - 1)/\mathrm{In}N$$

In the formula, S is the total number of plankton species in the sample, and N is the total number of all plankton species.

Shannon-Winner index was used to calculate species diversity, and water quality was divided into four categories [10]: H '≤1, representing heavy pollution and eutrophication; 1 < H '≤2, representing medium pollution nutrient type; 2 < H '≤3, representing the nutritive type of clear pollution; H '> 3, representing clean nutrient-poor type. Its calculation formula is as follows:

$$H` = -\sum_{i-1}^{s} Pi \log_2 Pi$$

In the formula, S is the total number of plankton species in the water sample, and Pi is the ratio of the number of individuals of the i species to the total number of individuals.

The Pielou index was used to calculate the uniformity of plankton, and the water quality was divided into four categories according to the J value [10] : 0-0.3 is severe pollution; 0.3-0.5 is moderate pollution; 0.5-0.8 is light pollution; more than 0.8 is considered non-polluting. Its calculation formula is as follows:

$$J = H`/\log_2 s$$

In the formula, H' is Shannon-Winner index and S is the total number of plankton species in the water sample.

2.4.2. Evaluation of water nutrition degree

According to Sladecek (1983) [11] pollution classification method, brachiauda (B) is mostly eutrophic species, and heterauda (T) is almost poor trophic species. The ratio(Q) of brachiauderus species (B) to heterauderus species (T) is used to characterize the trophic degree of water: $Q < 1$ means oligotrophic, $1 \le Q \le 2$ means mesotrophic, and $Q > 2$ means eutrophic.

2.4.3. Statistical analysis

SPSS 22.0 software was used to analyze the correlation between environmental factors and plankton density. All images were drawn using Graph Pad Prism 8.02 software.

3. Result

3.1. State of water environment

The results of physicochemical indexes of Huanong-Poyang Lak are shown in Figure 2.

During the investigation period, the water temperature of Poyang Lake varied from 19.3℃ to 31.8℃, with an average of 24.1℃, which has the characteristics of typical subtropical waters. The pH value of the water varied from 7.29-8.33, with an average of 7.80, indicating that the water was weakly alkaline. The concentration of dissolved oxygen ranged from 7.01 to 9.76mg/L, with an average of 8.41mg/L. The average water depth is 0.84m, with a variation range from 0.56m to 0.95m. The average transparency is 0.39m and varies between 0.22 and 0.60.

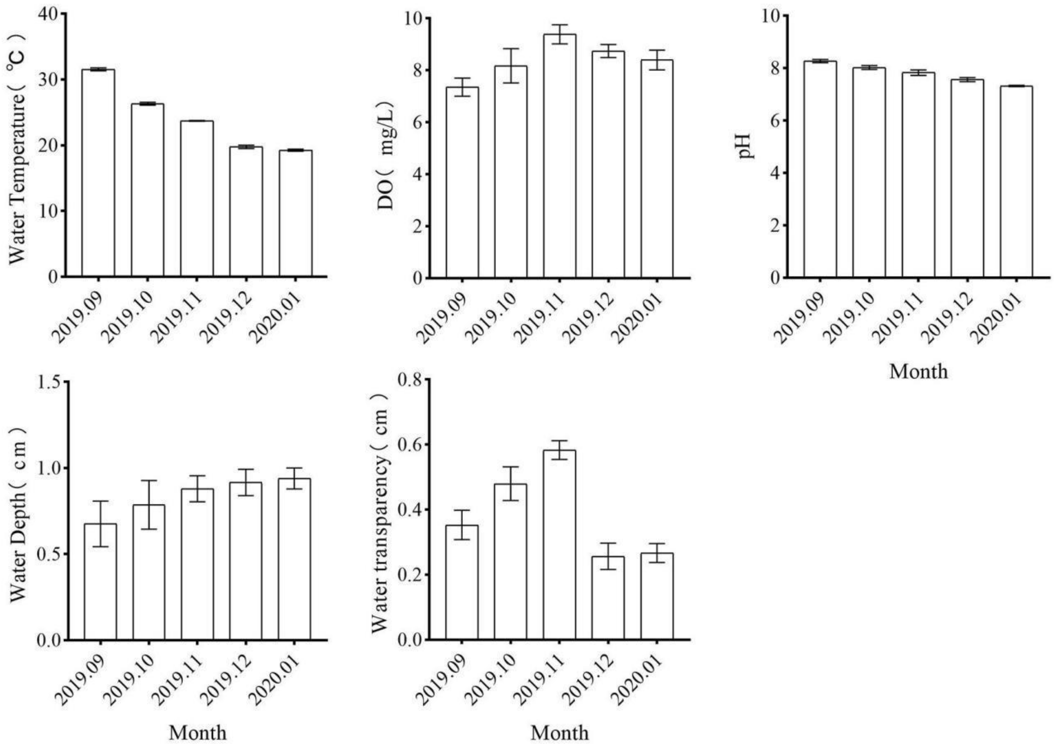

Fig. 2 Variation of environmental factors of Poyang Lake in Huanong-Poyang Lake

ISSN: 1813-4890

3.2. Analysis of phytoplankton

3.2.1. Phytoplankton species composition

A total of 53 species of phytoplankton belonging to 6 phylum, 34 genera were identified from Huanong-Poyang Lake (Table 1), including 21 species of chlorophyta belonging to 13 genera, 18 species of bacillariophyta belonging to 9 genera, 8 species of cyanophyta belonging to 7 genera, 2 species of euglenophyta belonging to 2 genera, 3 species of pyrrophta belonging to 2 genera, and 1 species of cryptophyta belonging to 1 genus. The species of the above 6 phylum accounted for 39.62%, 26.47%, 15.09%, 3.77%, 5.66% and 1.89% respectively (Figure 3).

Tab 1. Phytoplankton species of Huanong-Poyang Lake

	September 2019	October 2019	November 2019	December 2019	January 2020
Chlorophyta					
Scenedesmus					
S. dimorphus	+	+		+	
S. javaensis	+				
S. bicaudatus		+	+	+	
S. quadricauda					+
Pediastrum					
P. simplex	+		+		+
P. boryanum		+		+	
P. duplex	+	+			+
P. teras				+	
Teraedtron					
T. trigonum		+			+
T. minimum	+		+	+	
Opcystis					
Opcystis sp.	+	+	+	+	+
Tetraspora					
Tetraspora sp.	+	+	+	+	+
Staurastrum					
S. gemelliparum	+		+	+	+
S. lunatum	+	+			
Coelastrum					
Coelastrum sp.		+		+	
Selenastrum					
S. capricornutum	+			+	
S. westii	+		+		+
Chlorella					
C. ellipsoidea	+	+	+	+	+
Crucigenia					
C. quadrata		+	+	+	+
Golenkinia					
G. radiata	+	+	+	+	+
Chlamydomonas					
Chlamydomonas sp.	+		+		+
Bacillariophyta					
Melosira					

ISSN: 1813-4890

M. granulata	+	+	+		
M. varians	+	+		+	+
Synedra					
S. acus	+	+	+	+	+
Pinnularia					
P. rangoonensis					+
Surirella					
S. bifrons		+	+	+	
Cyclotella					
C. catenata	+	+	+	+	+
C. meneghiniana	+		+	+	
Gyrosigma					
G. acuminatum	+	+	+	+	+
G. parkerii		+		+	+
G. attenuatum			+	+	+
Nitzschia					
N. lorenziam	+	+	+	+	+
N. longissima	+	+	+	+	+
Navicula					
N. capitatoradiata	+	+	+	+	+
N. reichardiana		+			
N. cincta			+	+	+
Cymbella					
C. aspera	+	+	+	+	+
Cyanophyta					
Chroococus					
C. turgidus	+				+
Merismopedia					
M. punciata	+	+	+	+	
M. minima	+	+	+	+	+
Pseudanabaena					
Pseudanabaena sp.	+		+	+	+
Microcystis					
M. densa		+	+	+	+
Lyngbya					
Lyngbya sp.		+		+	+
Raphidiopsis					
Raphidiopsis sp.	+	+	+	+	+
Aphanocapsa					
Aphanocapsa sp.	+	+	+	+	+
Euglenophyta					
Euglena					
E. genicilata				+	+
Phacus					
Phacus sp.	+	+	+		
Pyrrophta					
Ceratium					

C. hirundinella	+				
Gymnodimium					
G. mitratum	+				
G. aeruginosum	+			+	+
Cryptophyta					
Cryptomonas					
C. ovata	+	+			+

Note: + Indicates the occurrence of a dominant species

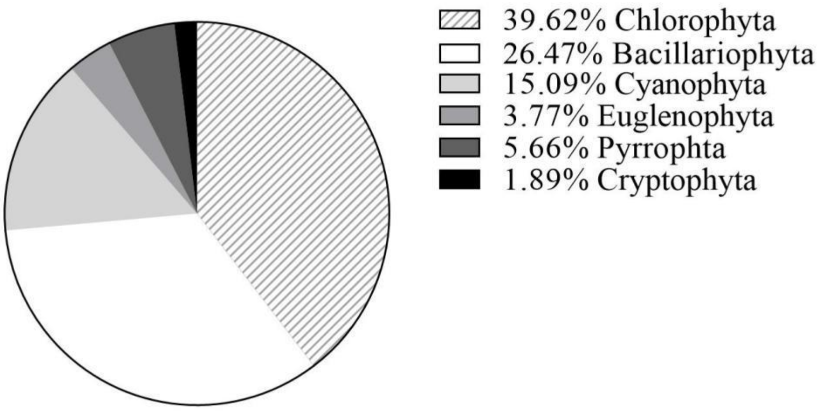

Fig. 3 The proportions of species of phytoplankton in each phylum of Huanong-Poyang Lake

3.2.2. Phytoplankton abundance

The changes of the abundance of 6 phylum species in Huanong-Poyang Lake during the survey period are shown in Figure 4. The total abundance of phytoplankton from September 2019 to January 2020 ranged from 2.93×10^7-4.57×10^7 cells/L, with an average value of 3.76×10^7 cells/L. The total abundance was the highest in November 2019 and the lowest in January 2020. The average abundance of chlorophyta was the highest during the investigation period (1.82×10^7 cells/L). The average abundance of cyanophyta was 1.64×10^7 cells/L. The lowest was cryptophyta (3.97×10^3 cells/L). The relative abundance of phytoplankton in Huanong-Poyang Lake is shown in Figure 4. The average relative abundance of chlorophyta was the highest (48.02%), and its showed a decreasing trend. The proportion of cyanophyta was 43.66%, and the proportion gradually increased. The next were bacillariophyta, euglenophyta and pyrrophta, accounting for 7.45%, 0.44% and 0.43%. Cryptophyta accounted for the lowest proportion (0.01%).

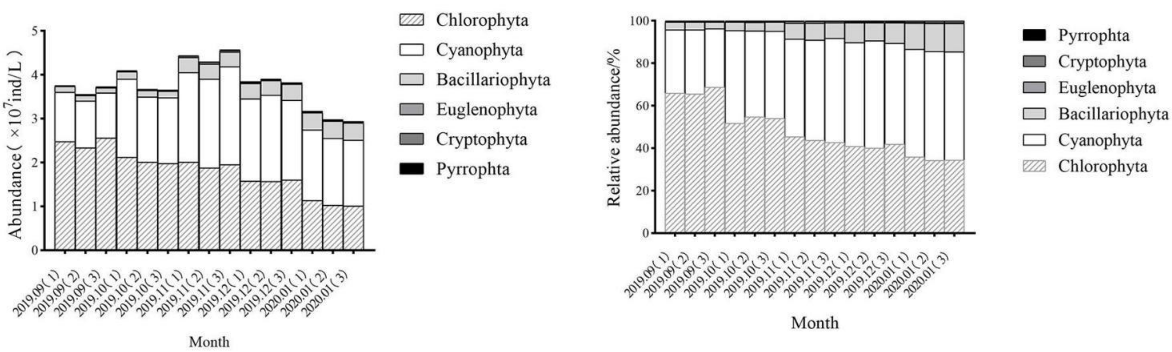

Fig.4 Changes in the abundance and relative abundance of phytoplankton of Huanong-Poyang Lake

3.2.3. Phytoplankton dominant species

A total of 8 dominant phytoplankton species (Y≥0.02) were found during the investigation, as shown in Table 2. 4 species were chlorophyta, including *S. dimorphus*, *P. duplex*, *C. ellipsoidea* and *C. quadrata*. There are 2 species of bacillariophyta: *P. platycephala* and *N. reichardiana*. There are 2 species of cyanophyta: *M. minima* and *Pseudanabaena sp*. From the perspective of temporal distribution, *S. dimorphus* and *P. duplex* were in the dominant position in each survey month. Then followed by *C. ellipsoidea*, only in October 2019, ist dominance was less than 0.02.

Tab. 2 Dominant species and dominance of phytoplankton of Huanong-Poyang Lake

Dominant species	Dominance（Y）				
	2019.09	2019.10	2019.11	2019.12	2020.01
Scenedesmus dimorphus	0.34	0.25	0.27	0.19	0.17
Pediastrum duplex	0.17	0.12	0.16	0.10	0.08
Chlorella ellipsoidea	0.02		0.08	0.03	0.05
Crucigenia quadrata		0.02			
Pinnularia platycephala				0.04	0.03
Navicula reichardiana	0.04	0.03			
Merismopedia minima	0.05			0.04	
Pseudanabaena sp.	0.07	0.03	0.05		

3.2.4. Phytoplankton diversity analysis

The Shannon-Wiener diversity index (H ') of phytoplankton ranged from 2.01 to 3.41, with an average of 2.65±0.34. Margalef richness index (D) ranged from 2.32 to 3.54, with an average value of 2.97±0.31. The Pielou evenness index (J) ranged from 0.54 to 0.76, with an average of 0.63±0.07.

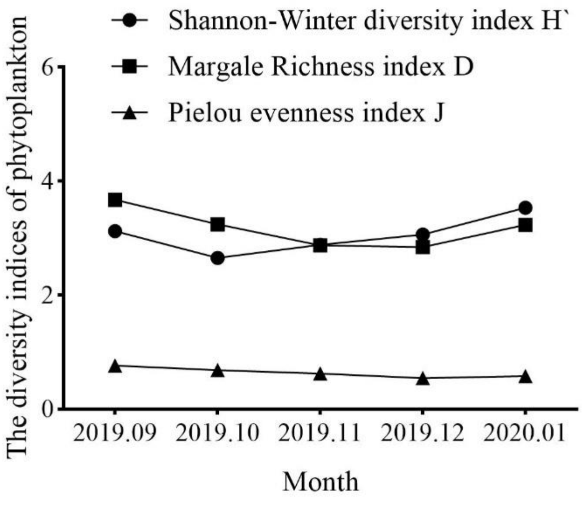

Fig.5 Diversity indices of phytoplankton of Huanong-Poyang Lake

3.2.5. Correlation analysis between phytoplankton and physicochemical factors in water

The Pearson correlation between phytoplankton and environmental factors showed that there was a significant positive correlation between green algae and temperature and pH ($P < 0.01$), a significant positive correlation between diatom and DO ($P < 0.05$), and a significant negative correlation between dinoflagellate and temperature and pH ($P < 0.05$). Margale richness index was significantly negatively correlated with DO ($P < 0.05$), and evenness index J was significantly positively correlated with temperature ($p < 0.05$).

Tab. 3 Pearson correlation analysis of phytoplankton density with environment factors of Huanong-Poyang Lake

	Temperature	pH	DO	Depth	Transparency
Chlorophyta	0.926*	0.997**	-0.633	-0.861	0.425
Bacillariophyta	-0.653	-0.381	0.942*	0.774	0.387
Cyanophyta	-0.930	-0.874	0.871	0.967**	-0.260
Euglenophyta	0.158	0.309	0.408	0.102	0.814
Pyrrophta	-0.900*	-0.921*	0.550	0.794	-0.680
Cryptophyta	0.090	0.205	0.458	0.176	0.834
Total phytoplankton	0.226	0.529	0.298	-0.051	0.688
Shannon-Wiener diversity index (H ')	-0.412	-0.652	0.045	0.344	-0.75
Margalef richness index (D)	0.751	0.465	-0.937*	-0.818	-0.190
Pielou evenness index (J)	0.980*	0.831	-0.862	-0.946	0.290

Note: * indicates that the value has a statistically significant correlation (P < 0.05); ** indicates that the value has a statistically significant correlation (P < 0.01).

3.3. Zooplankton

3.3.1. Zooplankton Species composition

A total of 32 species of rotifera, arthropoda and protozoa were collected from Huanong-Poyang Lake, belonging to 3 phyla and 12 families (Table 4). It includes 22 species of rotifera in 7 families, 4 species of cladocerans in 2 families, 5 species of copepods in 2 families, and 1 species of protozoa in 1 family. Rotifers were the dominant group in Huanong-Poyang Lake, and their species accounted for 68.75% (Fig. 5).

Tab. 4 Zooplankton species of Huanong-Poyang Lake

Zooplankton	September 2019	October 2019	November 2019	December 2019	January 2020
Rotifera					
Brachionidae					
B. calyciflorus	+	+	+	+	+
B. budapestiensis	+	+	+	+	+
B. angularis	+	+	+	+	+
B. forficula	+		+	+	+
B. diversicornis	+	+			+
B.leydigi	+		+	+	
B.falcatus		+	+	+	
K. cochlearis	+	+		+	
K. valga	+	+	+	+	+
E. senta	+	+		+	
Trichocercidae					
Trichocerca bicristata	+	+	+	+	+
T. capucina	+	+	+	+	+
T. cylindrica	+	+	+	+	
T. longiseta	+	+	+		+
Lecanidae					
	+	+	+		+

Lecane luna					
Filiniidae					
Filinia. longiseta	+	+			+
F. brachiata				+	
Synchaetidae					
Polyarthra vulgaris	+	+			
Conochilidae					
Conochiloides dossuarius	+	+			+
Asplanchnidae					
Asplanchna priodonta	+	+	+	+	+
A. brightwelli	+	+		+	+
A. multiceps	+		+	+	
Arthropoda					
Cladocerans					
Bosminidae					
Bosminopsis deitersi	+			+	+
Sididae					
Diaphanosoma brachyurum	+	+	+	+	+
D. leuchtenbergianum	+	+	+		+
Moina mircura	+		+	+	
Copepods					
Cyclopidae					
Acanthocyclops bicuspidatus	+	+	+		
Mesocydops leuckarti	+		+		+
M. varicans	+	+			
Calanidae					
Calanus sinicus	+	+	+	+	
Protozoa					
Difflugia sp.	+	+	+	+	+

Note: + indicates the occurrence of a dominant specie

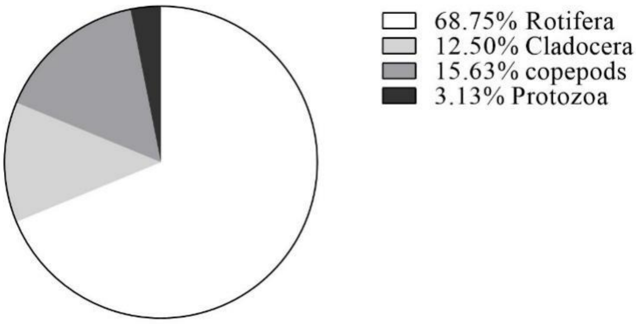

Fig. 6 The proportions of species of zooplankton in each phylum of Huanong-Poyang Lake

3.3.2. Zooplankton abundance

During the investigation period, the abundance changes of zooplankton in Huanong-Poyang Lake were shown in Figure 7. From September 2019 to January 2020, the total abundance of zooplankton fluctuated in the range of 82 cells /L to 231cells /L, with an average value of 124 cells/L, among which the total abundance was the highest in September 2019 and the lowest in January 2020, and the total abundance of zooplankton showed a gradual decline. The average abundance of rotifers was the highest (119.2 cells/L), then the copepods(10.8 cells/L) and cladoceras(7.6 cells/L). Protozoa had the lowest value (1.8 cells/L). The relative abundance of zooplankton in Huanong-Poyang Lake is shown in Figure 7. The relative abundance of rotifers was the highest, which was 83.63%. Copepods and cladoceras were the next, accounting for 9.13% and 5.80%, respectively. The proportion of protozoa was the lowest (1.80%).

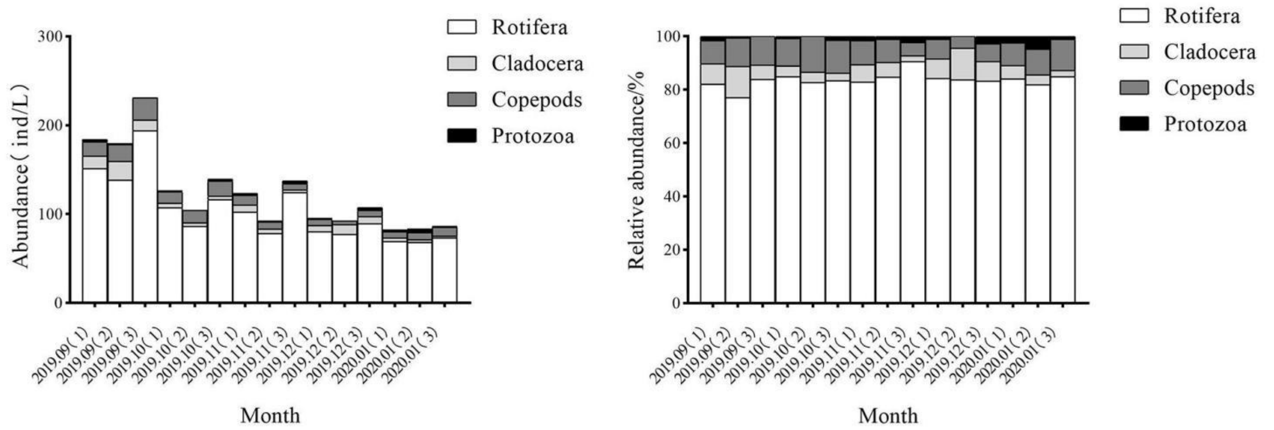

Fig.7 Changes in the abundance and relative abundance of zooplankton of Huanong-Poyang Lake

3.3.3. Zooplankton dominant species

A total of 15 dominant zooplankton species (Y≥0.02) were found during the investigation, as shown in Table 5, including 11 species of rotifers: *B. calyciflorus, B. budapestiensis, B. angularis, B. falcatus, B. forficula, K. valga, T. bicristata, T. capucina, T. longiseta, L. luna, A. priodonta.* 2 species of cladocerans: *D. brachyurum* and *D. leuchtenbergianum* and 2 species of copepods: *A. bicuspidatus* and *C. sinicus*. Furthermore, *B. calyciflorus*, *B. puda* and *B. ceratoides* were in the dominant position in each survey month, and the total dominance of these three species was always higher than 0.3.

Tab. 5 Dominant species and dominance of zooplankton of Huanong-Poyang Lake

Dominant species	Dominance（Y）				
	2019.09	2019.10	2019.11	2019.12	2020.01
B. calyciflorus	0.25	0.23	0.26	0.17	0.14
B. budapestiensis	0.15	0.16	0.18	0.12	0.11
B. angularis	0.12	0.13	0.14	0.10	0.08
B. falcatus		0.02			
B. forficula					0.03
K. valga	0.02				0.02
T. bicristata	0.05	0.06	0.05	0.04	0.05
T. capucina	0.03	0.03			
T. longiseta			0.02		
L. luna	0.02	0.03			

A. priodonta	0.04	0.04	0.05	0.03	0.04
D. brachyurum	0.04	0.03	0.04	0.03	
D. leuchtenbergianum	0.02				
A. bicuspidatus		0.02			
C. sinicus	0.06	0.07	0.06	0.05	0.05

3.3.4. Zooplankton diversity index

The Shannon-Wiener diversity index (H ') of zooplankton ranged from 2.22 to 3.28, with an average of 2.84±0.28. The Margalef richness index (D) ranged from 3.05 to 4.32, with an average of 3.52±0.49. The Pielou evenness index (J) ranged from 0.57 to 0.79, with an average of 0.68±0.07, with the highest value in October 2019 and the lowest value in January 2020.

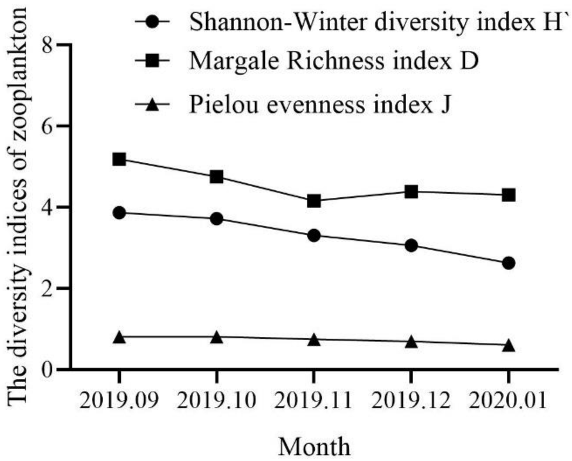

Fig. 8 Diversity indices of zooplankton of Huanong-Poyang Lake

3.3.5. Water quality assessment of zooplankton B/T index

The B/T values of zooplankton ranged from 1.25 to 2.00, with an average of 1.58±0.28. According to Sladecek (1983) 's classification method of rotifer pollution levels and the criteria for judging lake eutrophication degree, the water quality of Huanong-Poyang Lake is medium eutrophication type.

Tab. 6 The B/T index of zooplankton of Huanong-Poyang Lake

Month	B/T index
September 2019	1.50
October 2019	1.25
November 2019	1.50
December 2019	2.00
January 2020	1.67

3.3.6. Correlation analysis between zooplankton and physicochemical factors in water

The Pearson correlation analysis between zooplankton and environmental factors showed that the total density and aroma index of rotifers, copepods, zooplankton were significantly positively correlated with temperature and pH ($P < 0.01$), and negatively correlated with water depth ($P < 0.05$). The richness index D was negatively correlated with DO and water depth ($P < 0.01$), and the evenness index was positively correlated with pH ($P < 0.05$).

Tab.7 Correlation analysis between various factors of water environment a zooplankton of Huanong-Poyang Lake

	Temperature	pH	DO	Depth	Transparency
Protozoa	0.554	0.325	-0.501	-0.465	-0.113
Rotifera	0.981**	0.933*	-0.797	-0.936*	0.235
Cladocera	0.766	0.761	-0.630	-0.727	-0.078
Copepods	0.993**	0.924*	-0.779	-0.933*	0.418
Total number of Zooplankton	0.975**	0.924*	-0.791	-0.927*	0.220
Aroma index H '	0.932**	0.981**	-0.700	-0.904*	0.443
Margale Richness index D	0.862	0.738	-0.988**	-0.964**	-0.14
Evenness index J	0.868	0.969**	-0.576	-0.820	0.544

4. Discussion

4.1. Phytoplankton

Phytoplankton is the most important component of aquatic ecosystem. As the primary producer, phytoplankton can convert solar energy into chemical energy in organic matter, and its species composition characteristics can reflect the state of water environment quality [12]. In this study, 53 species of phytoplankton were identified, mainly chlorophyta, bacillariophyta and cyanophyta. During the survey period, the density of chlorophyta and cyanophyta was the highest among the phytoplankton, accounting for more than 80% of the total, followed by bacillariophyta, accounting for 7.45%, indicating that Huanong-Poyang Lake was a pattern of chlorophyta - cyanophyta - bacillariophyta. In addition, from September 2019 to January 2020, the proportion of chlorophyta decreased while that of cyanophyta and bacillariophyta increased, which may be caused by different physical and chemical factors, nutrient salt levels and water levels in water bodies [4, 13, 14]. The number of rhabdogloea and microcystis in cyanophyta, as well as pediastrum and crucigenia in chlorophyta increase with the rise of water temperature [15], while bacillariophyta have strong adaptability to environmental changes and good tolerance to low temperature [14]. Yu Yexin et al. [4] analyzed the characteristics of phytoplankton community and its water quality in the Hanjiang River, and found that the density and biomass of phytoplankton were affected by various environmental factors. Water temperature was one of the main environmental factors affecting the distribution of phytoplankton community structure and functional community in the lower Hanjiang River, and chlorophyta was significantly positively correlated with temperature, while cyanophyta and bacillariophyta were not obvious. This is similar to the results of this study. The acidity and alkalinity of water column have an important impact on the composition and distribution of phytoplankton. Alkaline water is conducive to photosynthesis of algae and generally has a high primary productivity [16]. In this study, the density of chlorophyta is significantly positively correlated with pH. Nutrient levels such as N and P were not measured in this survey, so the relationship between nutrient levels and phytoplankton will not be further discussed.

When the dominant species in the water are scenedesmus, chlorella, crucigenia, synedra, and merismopedia, it indicates that the lake or reservoir is eutrophic. In addition, when the total number of phytoplankton exceeds 1,000,000 index/L, the lake is eutrophic [17]. The results of this investigation showed that there were 8 dominant species, including 4 chlorophyta, 2 cyanophyta and 2 bacillariophyta. The dominant degree and frequency of occurrence were the highest among the *S. dimorphus* and *P. duplex*. The other eutrophic indicator species, including *C. quadrata, M. minima* and *C. ellipsoidea* were detected during the investigation. From the composition of phytoplankton dominant species, the water nutrition level of Huanong-Poyang Lake is higher. Wu Jie et al. [18] discussed the succession and eutrophication control measures of phytoplankton in West Lake. In 2000, the number of phytoplankton individuals in West Lake reached 10^9 /L, of which cyanophyta were the largest, accounting for more than 75%, followed by chlorophyta and bacillariophyta. The high amount of algae and the absolute dominance of cyanophyta community indicated that West Lake was in a serious state of eutrophication. Compared with this study, although the total density of phytoplankton in Huanong-Poyang Lake is two orders of magnitude smaller than that West Lake, it has reached the eutrophic level. In addition, the phytoplankton community structure of Huanong-Poyang Lake is similar to West Lake, with the struture of chlorophyta - cyanophyta – bacillariophyta . In conclusion, we should pay close attention to the changes of phytoplankton community structure and density in Huanong-Poyang Lake, and monitor the water environment in time to prevent the deterioration of water quality.

4.2. Zooplankton

As the primary consumers in the food chain of aquatic ecosystem, zooplankton, on the one hand, affects the change of fishery resources through the upward effect, and on the other hand, regulates the primary productivity of water through the downward effect [20]. Its community composition is mainly directly influenced by phytoplankton and secondary consumers and indirectly influenced by environmental factors. This study found that rotifers were the main zooplankton in Poyang Lake, followed by copepods and cladocerans. This may be due to the fact that rotifers are small, have a short reproductive cycle, and can quickly adapt to changes in the physical and chemical environment of water [21]. According to Brooks' size efficiency hypothesis [22], fish give priority to zooplankton with larger individuals in feeding selection. Therefore, under the fish predation pressure, species with smaller individuals of zooplankton usually take advantage. And there is trend that zooplankton transforms from large species to small species. In this survey, the number of rotifers accounted for more than 80%, occupying the main components of zooplankton, which is in line with the distribution law of rotifers in the eutrophic water environment [23]. Brachionidae and polyarthra are indicators of water eutrophication [24], which reflects that the water column of Huanong-Poyang Lake is in a state of high nutrient level. In addition, the results of B/T index further indicated that the nutrient level of water is high. The zooplankton abundance of Huanong-Poyang Lake was 123cells/L, which was higher than that of Xifeng River Reservoir with poor nutrition, lower than that of Poyang Lake with high nutrient level [25], and the same as that of Yuqiao Reservoir [23], which was mainly related to nutrient salt level and physical and chemical factors. Liu Qiao et al. [26] found that most rotifers prefer water environments with high water temperature, electrical conductivity and pH value, which is consistent with the results in this study that rotifers species are positively correlated with temperature and pH.

In this study, Shannon-Wiener diversity index (H '), Margalef richness index (D) and Pielou evenness index (J) of zooplankton of Huanong-Poyang Lake were 2.84, 3.52 and 0.68 respectively. According to the relevant evaluation index criteria [4, 19], Shannon-Wiener diversity index (H ') of Huanong-Poyang Lake was between 2-3, indicating light pollution and medium nutrient type. The Margalef richness index (D) is between 3 and 4, indicating light pollution. The Pielou evenness index (J) is between 0.5-0.8, which means light pollution. Based on the analysis of phytoplankton and zooplankton community structure and diversity index, Huanong-Poyang Lake is in a state of light to moderate pollution, and has a risk to transform to eutrophication.

5. Conclusion

(1) A total of 53 species of phytoplankton were detected from 6 phyla in Huanong-Poyang Lake from October 2019 to February 2020, among which chlorophyta, cyanophyta and bacillariophyta were the dominant groups. The main dominant species were *S. dimorphus*, *P. duplex*, *C. ellipsoidea*, *C. quadrata, P. platycephala*, *N. reichardiana,*, *M. minima* and *Pseudanabaena sp*. The average density of phytoplankton was 3.76×10^7 cells/L.

(2) A total of 32 species of zooplankton were detected from 3 phyla, among which rotifers were the dominant group. The dominant species are *B. calyciflorus, B. budapestiensis, B. angularis, B. falcatus, B. forficula, K. valga, T. bicristata, T. capucina, T. longiseta, L. luna, A. priodonta, D. brachyurum*, *D. leuchtenbergianum*. *A. bicuspidatus* and *C. sinicus*. The average abundance of zooplankton was 124 cells/L.

(3) Based on the analysis results of community structure and diversity index of phytoplankton and zooplankton, Huanong-Poyang Lake was in a state of light to moderate pollution, and has a risk to transfrom to eutrophication.

References

[1] Maranon E. Cell size as a key determinant of phytoplankton metabolism and community structure, Annual Review of Marine Science, 2015, 7: 241-64.

[2] T. Zhang, X.H. Ma, G.P. Wang, et al. Community structure and spatial distribution of plankton in the PoYang lake national nature reserve, China, Acta hydrobiologica sinica, 2014, 38(1): 158-165.

[3] G.T. Wang, B.B. Chen, M. Wang, et al. Seasonal variation of phytoplankton community in the Tianhe Reservoir of the Daluoshan Mountain in southern Zhejiang Province, China and its indication to water quality, Chinese Journal of Applied Ecology, 2021,32(06): 2227-2240.

[4] Y.X. Yu, Y. Li, L.J. Xiang, et al. Phytoplankton assemblage characteristic and its indication on water quality in the lower reaches of the Hanjiang River, Environmental Monitoring in China, 2022,38(01): 124-135.

[5] W. W. Min, F. J. Huang, W. Wang, et al. Community structure of zooplankton in Chishui River in autumn and its relationship with environmental factors, Journal of Anhui Agricultural Sciences, 2021, 49(11): 75-79.

[6] Nanjing Institute of Geography and Limnology. Chinese Academy of Sciences. Technical regulations for lake survey, Beijing: Science Press,2015.

[7] Department of Ecology, Ministry of Environmental Protection. Technical Regulations for the National Survey of Freshwater Biological Species Resources (Trial), Beijing: Ministry of Environmental Protection,2010.

[8] Z. S. Zhang, X. F. Huang. Methods for studying freshwater plankton, Beijing: Science Press,1991.

[9] C.H. Du. Community structure and functional groups of plankton and water quality evaluation in Hanjiang River, Wuhan: Huazhong Agricultural University,2020.

[10] X.C. Jing, Q. Y. Tu. Lake eutrophication Survey Specification, 2nd edition, Beijing: China Environmental Science Press,1990.

[11] Sladecek. V. Rotifers as indicators of water quality, Hydrobiologia,1983. 100(1):169-201.

[12] R. Zeng, Y.J. Li, J. M. He, et al. Investigation of Phytoplankton Community Structure and Seawater Quality in Lingshui Bay in Spring and Autumn, Journal of Tropical Biology, 2021, 12(2): 167-175.

[13] H. F. Bai, Y. R. Wang, J. X. Song, et al. Spatio-temporal characteristics and influencing factors of phytoplankton community structure in the Shaanxi Section of Weihe River, China, Acta Scientiae Circumstantiae, 2021, 41(8): 3290-3301.

[14] X. D. Shi, X. H. Ruan, Y. N. Xing, et al. Canonical correspondence analysis between phytoplankton community and environmental factors in winter and summer in shallow lakes of plain river network Areas, Suzhou, Environmental Science, 2008(11): 2999-3008.

[15] H. Y. Yang, W. Zhou, Y. M. Qiao, et al. Community structure of phytoplankton and its relationship with environmental factors in Erhai Lake, Environmental Science and Technology, 2021, 44(07): 123-132.

[16] H. H. Jakobsen, E. Blanda, P. A. Staehr, et al. Development of phytoplankton communities: Implications of nutrient injections on phytoplankton composition, pH and ecosystem production, Journal of Experimental Marine Biology and Ecology, 2015, 473: 81-89.

[17] Q. J. Pang, B. Y. Li. Evaluation of water eutrophication in Dongping Lake, Water Resources Protection, 2003, (05):42-44.

[18] J. Wu, Z. M. Yu. The succession of phytoplankton and the ecological effects of eutrophication control measures in Hangzhou West Lake, China Environmental Science, 2001, (06): 61-65.

[19] Q. J. Kuang, P. M. Ma, Z. Y. Hu, et al. Study on the evaluation and treatment of lake eutrophication by means of algae biology, Journal of Safety and Environment, 2005, (02):87-91.

[20] H. Q. Shen, Y. J. Xu, J. X. Wang, et al. Interannual variation of and factors influencing the summer zooplankton community in the Yangtze River Estuary in the summers of 2017-2018, Journal of Fishery Sciences of China, 2020, 27(03): 327-335.

[21] S. S. Gong, J. W. Wu, Y. Chai, et al. Structural characteristics and seasonal changes in zooplankton community in Changhu Lake, Fisheries Science, 2021, 40(3): 329-338.

[22] J. L. Brooks, S. I. Dodson. Predation, body size, and composition of plankton, Science, 1965, 150(3692): 28-35.

[23] X.Y. Wang, X. Y. Zhang, Y. Lei, et al. Multivariate analysis of the relationship between zooplankton community structure and water environment factors in Yuqiao reservoir, Journal of Fujian Normal University (Natural Science Edition), 2021, 37(04): 32-40.

[24] G. R. Chen, P. Zhang, X. F. Xie, et al. Zooplankton and its relationship with water quality in Huizhou West Lake, Lake Science, 2008, 20(3): 351-356.

[25] J. Q. Chen, K. Zhao, Y. Cao, et al. Zooplankton community structure and its relationship with environmental factors in Poyang Lake. Acta Ecologica Sinica, 2020, 40(18): 6644-6658.

[26] Q. L. Liu, Z. Y. Wang, J. B. Liao, et al. Spatial-temporal characteristics of zooplankton community structure and analysis for the impact factors in the Shanmei Reservoir,Fujian Province, Lake Science, 2022, 34(6): 2039-2054.