DYNAMIC CHANGES AND DRIVING FACTORS OF ZOOPLANKTON COMMUNITIES IN THE EAST TAIHU LAKE, CHINA

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Abstract- An investigation was conducted from December 2017 to May 2018 to study zooplankton community in the East Taihu Lake. In the research, 72 species of zooplankton were found, including 32 species of rotifers, 20 species of copepods and 20 species of cladocerans. The most dominant species are Keratella quadrala, Cyclops vicinus Uljanin, and Mesocyclops leuckarti (Claus). The average abundance of zooplankton was 91.81 ind/L and the average biomass of zooplankton was 0.202 mg/L. Both The biomass and abundance of zooplankton are more in spring and less in winter. According to the Pearson correlation analysis, the environmental factors that mainly affecting the zooplankton community are water temperature, dissolved oxygen content, electrical conductivity, chlorophyll a concentration and transparency. Through comparison of different functional areas, it is concluded that the zooplankton community in the fishery farming area has the lowest biomass for the weight of every individual is very small, and the rotifers account for the majority of zooplankton; the biomass of zooplankton in the macrophytes cover area is lower than that in the open water area.

Key words- East Taihu Lake; Zooplankton; Water Physical and Chemical Factors; Fshery Farming Area; Macrophytes

East Taihu Lake is a long and narrow shallow lake on the east side of Dongshan Peninsula and in the southeast of Taihu Lake. It is located in the south of Suzhou. As the main water outlet channel of Taihu Lake, it has a series of ecosystem service functions such as flood control and landscape entertainment and water supply and aquaculture. At the same time, the East Taihu Lake is also an important source of water for the Shanghai and Suzhou.

Zooplankton community is an important part of lake ecosystem. As primary consumers, zooplankton preys on phytoplankton and filters water, which plays an important role in maintaining the health and safety of water quality. At the same time, zooplankton is also an important food source for fish. Some physical and chemical factors of aquatic ecosystem, such as nutritional status, habitat type, water turbidity, prey pressure, etc. and food sources are the main factors affecting the community structure of zooplankton [1-3].

In recent years, multiple changes have taken place in the physical and chemical status and ecosystem of East Taihu Lake due to the global climate change, eutrophication of water and the increase of human disturbance. These changes are mainly manifested in the decrease of aquatic plants, the turbidity of water body, eutrophication and the increase of algae [5,6]. The change of primary producers and secondary producers in East Taihu Lake also had an important impact on The water quality. There are few reports on how the zooplankton community structure responds to these environmental changes and how it plays a role in this process in the East Taihu Lake. Some studies have shown that the changes of macrophytes communities, water quality and aquaculture industry will have a certain impact on zooplankton communities. As an important part of freshwater ecosystem, zooplankton is the basis of lake ecosystem research. Its filter-predatory mode can help to eliminate algae and other organic suspended particles in water and improve the transparency of water. The change of zooplankton community structure and density is closely related to the water environment situation. Learning the relationship between zooplankton community change and environmental factors and understanding the composition and change of zooplankton community structure is of great significance to the protection of water quality and ecosystem in East Taihu Lake.

This research analyzed the differences in the composition of zooplankton community and the effects of physical and chemical factors on zooplankton community and different habitat types based on the survey of the composition and spatiotemporal changes of zooplankton in the East Taihu Lake, which has important reference value and academic significance on the water quality protection and ecosystem health management.

I. MATERIALS AND METHODS

1.1 Overview of the research area

East Taihu Lake (latitude 31°05′-32°08′, longitude 119°08′-121°55′), is a shallow narrow lake bay on the east side of Dongshan Peninsula in the southeast of Taihu Lake, which connect with the West Taihu Lake by its narrow lake surface. The lake area is approximately 172km^2. Its length is 30km, and its maximum width is 9km, with the average water depth of 1.2-1.3m. It is a typical shallow-water lake in the middle and lower reaches of the Yangtze River in China.

1.2 Sample sites setting and sampling time

12 sampling sites were set up in the East Taihu Lake for the comparation of the effects of different habitats and water physical and chemical factors on the community structure of zooplankton, the functional divisions listed in Table 1. The zooplankton community structure was investigated and the

physical and chemical factors of the water were analyzed monthly from December 2017 to May 2018 (combining the GPS positioning system).

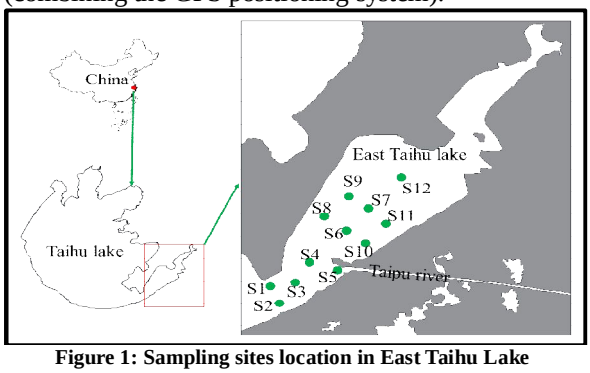


Figure 1: Sampling sites location in East Taihu Lake

Table 1. Functional divisions and survey of sampling sites

Site	Functional divisions	Overview of macrophytes
1	Entrance boundary	A small amount of submerged and floatingleaf macrophytes
2	Entrance boundary channel	-
3	Buffer transition zone	submerged and floatingleaf macrophytes
4	Next to the water source	-
5	Export boundary	Very few emergent plant
6	In front of the backup water source	Very few submerged and floatingleaf macrophytes
7	Behind the backup water source	Very few submerged and floatingleaf macrophytes
8	Fishery area 1	submerged and floatingleaf macrophytes
9	Fishery area 2	submerged and floatingleaf macrophytes
10	Shallow ecological wetland	submerged and floatingleaf macrophytes and emergent plant
11	Emergency water source	A small amount of submerged macrophytes
12	The end of the lack	-

1.3 Research methods

1.3.1 Determination of physical and chemical factors of water

The water quality index was measured on-site using a HACH multi-parameter water quality analyzer (HQ40d). The main indexes were pH, Conductivity, DO, water temperature, and transparency (SD) were measured with a Seychelles disk. Collect 500ml surface water (0.5m underwater) using the water collector (HQM-l), and then brought back to the laboratory to analyze the total nitrogen (TN), total phosphorus (TP) and chlorophyll a (Chl.a) and other nutrient indicators. TN uses alkaline potassium persulfate ultraviolet spectrophotometry (HJ 636-2012), TP uses ammonium molybdate spectrophotometry (Shimadzu, UV-2450), and Chl.a uses phytoplankton fluorescence instrument Phyto-PAM (Heinz Walz GmbH, Effeltrich , Germany) Determination. The turbidity index was measured by HACH portable turbidity meter (1900C). The total solid suspended matter (TSS) was measured by filtering certain water samples, the difference between the mass and the dry weight of the film before and after the film was divided by the volume of filtered water. The drying temperature was 105. °C, lasting for 4 hours.

1.3.2 Collection and processing of zooplankton

(1) Qualitative sample

Using the 25# plankton net to collect (mesh 0.064mm), drag the zooplankton net several times below the surface of the water, collect the water sample concentrated in the net head in 50ml specimen bottle, and fixed with Rugol reagent to be brought back to the laboratory for microscopic examination.

(2) Quantitative samples

The surface and middle water samples were collected by 2L water collector. The filters were filtered and concentrated by 25# plankton net. The filters were put into 500ml capacity bottle and washed with filtered water for three times. The filters were also put into the bottle and fixed with Lugol reagent. After sufficient precipitation (setting time: 48h), it was concentrated to 50ml. Before quantification, the concentrated water sample was shaken well, 1ml was absorbed and injected into 1ml plankton counting box. The whole sample was counted under the microscope. Each sample repeated for three times and its average value was obtained.

1.4 Data Processing

The diversity, richness and evenness of the zooplankton community were calculated monthly to analyze the community structure characteristics. The calculation formula is as follows:

Shannon-Weiner Index : $H' = -\sum_{i=1}^{S} P_i \log_2 P_i$

Margalef Index：D=(S-1)/lnN

Pielou Index：$J=H'/\log_2 S$

The dominance of a certain zooplankton：$Y = f_i P_i$, when $Y>0.02$, it's dominant species.

In the formula:

N-Number of individuals in 1L water （ind/L)

S- Total number of species

P_i - i specie proportion of individuals in the community

f_i - Frequency of occurrence of i specie

The correlation between zooplankton and physical and chemical factors of water was analyzed by SPSS 22.0, and the significant level was set to $P<0.05$.

2 Results and analysis

2.1 Temporal and spatial changes of physical and chemical factors in the waters of East Taihu Lake are as follows.

Table 2: Seasonal variation and average value of physical and chemical factors of water at each sampling site in East Taihu Lake

Sampling site	T (℃)	Cond (S/m)	DO (mg/L)	TSS (mg/L)	Tur	SD (m)	TP (mg/L)	TN (mg/L)	Chl.a (μg/L)
1	11.20 (5.7-23.1)	415 (392-458)	10.98 (9.02-12.52)	32.06 (18.95-56.67)	43.73 (68.2-29.0)	0.32 (0.22-0.40)	0.085 (0.066-0.113)	1.369 (0.592-2.924)	54.21 (31.75-86.37)
2	11.29 (5.8-22.1)	421 (385-464)	10.99 (8.89-12.56)	46.03 (16.27-85.33)	59.02 (98.3-33.4)	0.29 (0.22-0.40)	0.090 (0.061-0.126)	1.261 (0.627-1.862)	44.67 (36.06-55.4)
3	10.98 (5.6-22.3)	418 (371-469)	10.98 (8.90-12.51)	42.32 (31.34-89.33)	47.10 (110.0-25.3)	0.34 (0.20-0.50)	0.077 (0.051-0.113)	1.290 (0.720-2.103)	46.38 (29.05-62.92)

4	11.21 (5.7-22.4)	422 (383-479)	11.03 (8.97-12.46)	37.23 (17.23-58.00)	49.17 (23.8-76.4)	0.32 (0.20-0.48)	0.093 (0.048-0.161)	1.226 (0.592-1.777)	48.00 (32.89-66.63)
5	11.64 (5.5-22.9)	428 (395-483)	10.83 (8.82-12.25)	43.71 (36.32-54.67)	58.93 (47.6-71.8)	0.26 (0.20-0.35)	0.091 (0.056-0.116)	1.312 (0.615-1.777)	47.91 (27.34-61.04)
6	11.57 (5.7-22.1)	423 (385-463)	10.92 (8.88-12.45)	37.80 (13.72-64.00)	44.10 (23.4-79.3)	0.36 (0.30-0.50)	0.088 (0.071-0.156)	1.341 (0.697-1.987)	48.54 (24.18-60.5)
7	11.87 (5.9-21.9)	421 (389-458)	10.84 (8.98-12.33)	30.08 (21.03-52.67)	40.20 (27.5-70.1)	0.35 (0.30-0.45)	0.079 (0.061-0.092)	0.992 (0.534-1.345)	46.38 (35.07-56.27)
8	12.07 (5.9-23.1)	400 (380-431)	10.72 (9.42-11.70)	11.35 (4.57-18.67)	15.20 (9.3-27.3)	0.62 (0.45-0.70)	0.048 (0.041-0.056)	0.876 (0.743-1.010)	35.05 (25.76-47.18)
9	12.18 (6.0-23.1)	398 (390-409)	10.48 (9.18-11.70)	11.43 (1.46-16.15)	15.70 (8.13-29.0)	0.63 (0.46-0.70)	0.059 (0.042-0.087)	0.789 (0.394-0.998)	40.95 (27.81-57.76)
10	12.53 (5.8-24.2)	417 (380-450)	10.57 (9.11-11.38)	16.95 (3.80-34.67)	21.05 (14.0-28.4)	0.64 (0.50-0.80)	0.051 (0.038-0.063)	1.048 (0.534-1.515)	28.11 (21.36-36.63)
11	12.35 (6.2-23.8)	401 (377-431)	10.53 (8.52-12.12)	14.42 (6.07-17.33)	17.32 (11.4-30.8)	0.69 (0.50-0.90)	0.053 (0.030-0.057)	0.964 (0.521-1.296)	35.81 (19.23-61.86)
12	12.31 (6.0-22.6)	419 (394-461)	10.75 (9.26-12.24)	35.26 (21.49-87.33)	41.00 (18.9-99.8)	0.38 (0.20-0.60)	0.084 (0.076-0.100)	1.090 (0.731-1.928)	44.26 (22.65-77.38)

2.2 Changes and analysis of zooplankton community structure

The diversity and richness of zooplankton community is higher in spring than in winter, and the evenness is lower in spring than in winter. The dominant species of rotifers is Keratella quadrala in winter and Asplanchna in spring; Cyclops vicinusUljanin, Mesocyclops leuckarti and Nauplius are dominant species both in winter and in spring; Cladocera appear as dominant species only in spring.

Table 3: Variation of zooplankton community structural parameters in the East Taihu Lake

	17-12	18-1	18-2	18-3	18-4	18-5
H′	2.707	2.830	3.201	3.103	3.506	3.862
D	3.102	4.288	4.837	8.284	7.908	9.077
J	0.958	0.666	0.718	0.587	0.673	0.712

Table 4: Changes in dominant species of zooplankton

	17-12	18-1	18-2	18-3	18-4	18-5
Keratella quadrala	0.341	0.025	0.049	-	0.102	-
Polyarthra trigla	-	-	0.096	-	-	-
Brachionus calyciflorus Pallas	-	-	0.022	-	-	-
Asplanchna	-	-	-	0.033	0.028	-
Cyclops vicinusUljanin	0.180	-	0.108	0.029	-	0.064
Mesocyclops leuckarti	0.190	-	0.042	0.856	0.027	0.110
copepodid stage	-	0.021	0.358	0.327	0.085	0.117
Nauplius	0.043	-	0.051	0.158	0.029	0.086
Moina micruraKurz	-	-	-	-	-	0.158
Moina macrocopaStraus	-	-	-	-	-	0.135
Diaphanosoma brachyurum	-	-	-	-	-	0.023
Bosmina longirostris	-	-	-	-	0.334	-

2.3 Relationship between zooplankton community and physical and chemical factors of water

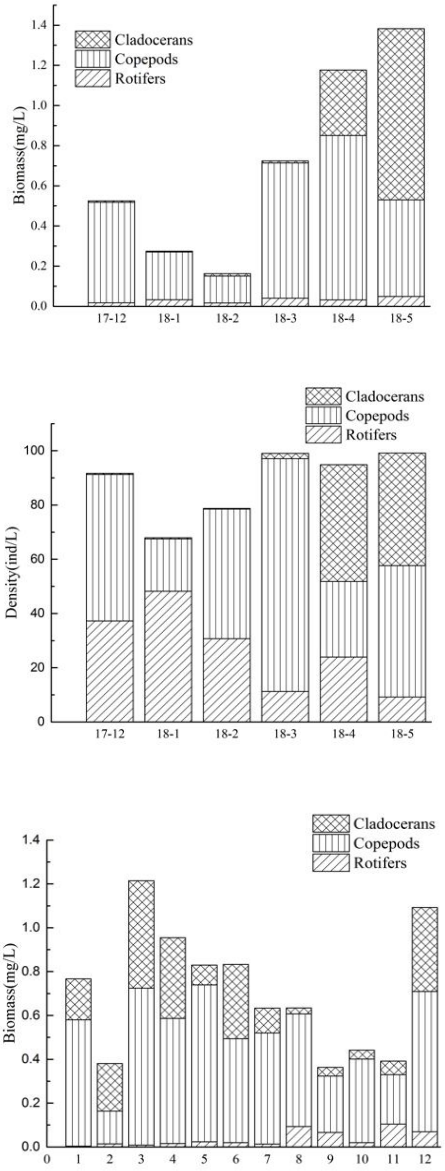
Table 5: Pearson correlation analysis between zooplankton biomass and water physical and chemical factors

water physical and chemical factors	Biomass of Rotifers	Biomass of Copepods	Biomass of Cladocerans	Total biomass
T	0.153	0.210	0.552**	0.465**
DO	-0.073	-0.149	-0.588**	-0.437**
Cond	-0.036	0.368**	0.650**	0.608**
SD	0.246*	-0.185	-0.427**	-0.341**
TSS	-0.286*	0.213	0.723	0.522**
Tur	-0.304*	0.198	0.699**	0.497**
TN	-0.159	0.132	0.439**	0.320**
TP	-0.253	0.067	0.065	0.057
Chl.a	0.060	0.244*	0.509**	0.455**

* indicates a significant correlation at the 0.05 level (both sides) and ** indicates a significant correlation at the 0.01 level (both sides).

According to the Pearson correlation analysis between zooplankton biomass and water physical and chemical factors, the rotifer's biomass was significantly negatively correlated with TSS and turbidity, and positively correlated with SD; Copepod's biomass and conductivity were extremely significant positive correlation and significant positive correlation with Chl.a concentration; The Cladoceran's biomass was significantly positively correlated with temperature, conductivity, turbidity, TN and Chl.a concentration, and was significantly negatively correlated with DO and SD; Total biomass was significantly positively correlated with temperature, conductivity, TSS, turbidity, total nitrogen and Chl.a concentration, and was significantly negatively correlated with DO and SD.

2.4 Temporal and spatial changes of zooplankton community



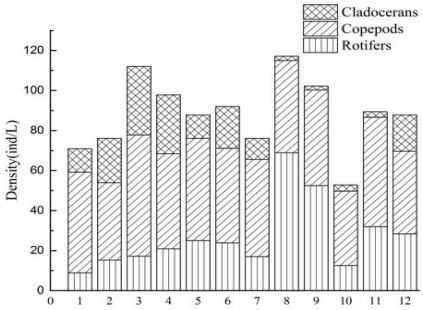


Figure 2: Temporal and spatial variation of zooplankton's density and biomass in East Taihu Lake

A total of 72 species of zooplankton were detected in this research, including 32 species of rotifers, 20 species of copepods, and 20 species of cladocerans. The total density and biomass of zooplankton showed a trend of less in winter and more in summer. Rotifers and copepods are the main components of zooplankton community in winter, 48.72% and 50.82% of the total respectively. The biomass of copepods accounts for the majority of zooplankton biomass. Since spring, the biomass and density of the zooplankton have increased. The copepods have a great advantage in both abundance and biomass in winter and spring. Select S4 and S5 as open deep-water area (Z1), S6 and S12 as open shallow water area(Z2), S8 and S9 as fishery areas(Z3), S3 and S10 as macrophytes covered areas(Z4), and make comparison of the zooplankton biomass in March, April and May (spring). By comparison, the biomass and density of zooplankton community in the fishery area are lower than that in the open water area and macrophytes cover area. The biomass of zooplankton community in the macrophytes cover area is significantly lower than that in the open water area, and the density is slightly lower than that in the open area.

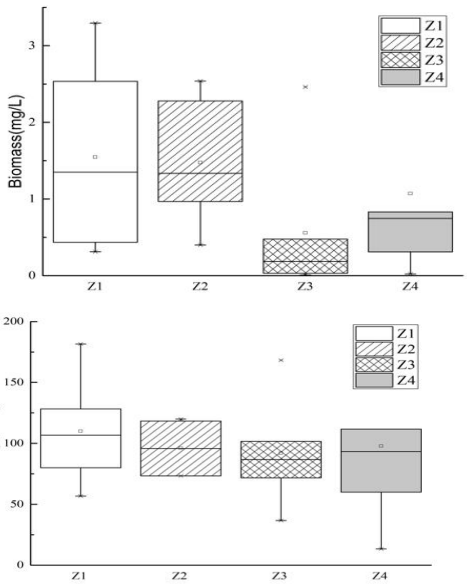


Figure 3: Differences in zooplankton biomass and density between fishery areas, macrophytes cover areas and open water areas

DISCUSSION

3.1 Effects of physical and chemical factors on zooplankton community

From the Pearson correlation analysis of zooplankton's biomass and water physical and chemical factors, the main factors are water temperature, DO, electrical conductivity, Chl.a and SD. Seasonal changes in zooplankton community structure are closely related to water temperature [8,9]. Lin Qing[10] surveyed on the zooplankton community in the Dishui Lake found that the density and biomass of zooplankton in the drip lake showed a gradual increasing trend from spring to summer, reached to the peak in summer and then decreased along with water temperature. Copepods show strong dependence on water temperature [11]. The water temperature in the East Taihu Lake has obviously seasonal changes. The water temperature in winter is low, which is not good for the growth and reproduction of zooplankton. Therefore, the density and biomass of zooplankton are lower in winter. After the increasing of temperature in spring, the densist and biomass of zooplankton have increased obviously, the Margalef index and Shannon-Weiner index of zooplankton community also increased, indicating that the community structure became more stable; In winter, cladocerans barely appeared, but there is a significant increasing of the density and biomass of cladocerans since spring. When the density of cladocerans increased by a certain number, the biomass increasd more. It can be seen that with the increase of temperature, the individual's volume and weight also change when the temperature is suitable for its growth and reproduction.

Most Cladocerans are filter feeders, including organic debris and suspended particulate matter; algae, bacteria and organic debris are also the main food of copepods [12, 13], and Chl.a mainly exists in algae. In this study, the biomass of zooplankton is positively correlated with Chl.a, indicating that the increase of algae is conducive to the growth of zooplankton. In this study, zooplankton biomass was positively correlated with total TSS and turbidity, and negatively correlated with SD. Linear regression analysis of Chl.a, SD, turbidity, TSS and zooplankton biomass (see Fig. 4) showed that zooplankton biomass increased with the increase of water turbidity, indicating that zooplankton biomass could be significantly increased with the increase of zooplankton's food (algae, bacteria, organic debris, etc.). Although zooplankton can eliminate the turbidity of lake, it is possible that the increased feeding capacity of zooplankton cannot offset the increase of suspended organic matter content, even far below the increase of turbidity, so even if zooplankton biomass increases, it cannot reduce the turbidity of water body; On the other hand, zooplankton also contribute the turbidity, which leads to a certain correlation between zooplankton's biomass and water turbidity [14]. This study confirms this viewpoint.

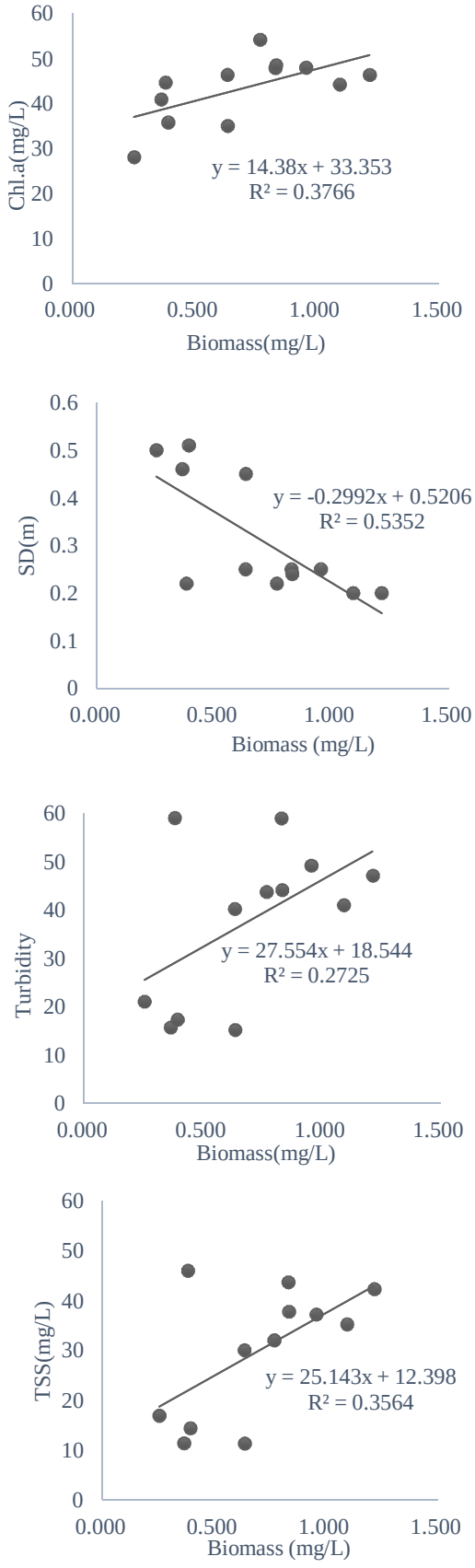


Figure 4: Linear regression analysis of Chl.a, SD, turbidity, TSS and zooplankton biomass

3.2 Effects of fish predation on zooplankton community

The existing of planktonic diets fish have a dramatic impact on zooplankton's density, biomass and community structure [12]. Compared to algae, filter-feeding fish are more likely to prey on large copepods. Phytoplankton cells are rarely found in the stomach of golden sardines at all growth stages, compared to a large number of copepods in all sardine life stages [15]. The selective feeding of zooplankton to the phytoplankton is achieved by the width of the scorpion and the escape ability of the zooplankton. Large zooplankton (copepods, cladocerans) usually have poor escape ability and more sensitive to the predation [16]. The fishery products are mainly fish, shrimps and crabs in the East Taihu Lake. From the comparison of the biomass and density of zooplankton in the fishery area and other areas, the zooplankton's biomass in the fishery area was the lowest, although the density was close to other areas. It showed that the zooplankton was smaller in the fishery area than other areas. As shown in Figure 1, the rotifers accounted for the majority of the zooplankton density in the fishery area, but the large-size zooplankton did not dominate the density, which is consistent with the previous research results.

3.3 Effects of macrophytes on zooplankton community

Through the study of zooplankton community in the Lake Jiwai in northern Ethiopia, Mesfin Gebrehiwot [17] found that the zooplankton community in the Emergent Macrophytes covered area (reed, pupa) have larger density and diversity. Macrophytes can provide a microenvironment for the zooplankton community, which can provide food and living space [18]. However, the allelochemical released by macrophytes can inhibit the growth of algae by destroying its photosynthetic system [19], and the algae are affected by the community structure and seasonal changes of macrophytes [20]. In this study, the zooplankton's biomass in the macrophytes cover area was lower than that in the open water area. The reason is likely to be that the macrophytes can purify the water and reduce the algae content. The zooplankton did not have enough food, Cause Both its density and biomass were low, but this viewpoint needs further explanation.

RESULTS

This study mainly analyzed the temporal and spatial variation of zooplankton community in the East Taihu Lake and its relationship with environmental factors. The composition of zooplankton community in the East Taihu Lake is quite different temporally and spatially. In terms of time, zooplankton community was mainly composed of rotifers and copepods in winter, and cladocerans rarely appeared. In spring, cladocerans had a significant increase trend; Zooplankton's density and biomass are higher in spring than in winter. In terms of space, zooplankton community was mainly composed of rotifers in fishery area and the size was smaller and the biomass was the lowest; The zooplankton;s biomass in themacrophytes covered area was lower than that in the open water area. Through the correlation analysis and regression analysis of the physical and chemical factors of water and zooplankton biomass, the main environmental factors are water temperature, DO, electrical conductivity, Chl.a and turbidity; Comparing zooplankton's biomass and density, fish predation and habitat types had a greater impact on zooplankton community.

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