SEASONAL DYNAMICS OF ZOOPLANKTON FUNCTIONAL GROUPS IN RELATION TO ENVIRONMENTAL FACTORS IN GENHEYUAN WETLAND OF NORTHEAST CHINA

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Abstract. In order to study the seasonal changes of the freshwater zooplankton functional groups and the impact of water environment in cold temperate wetlands in China, nine sampling sites were selected in Genheyuan nature reserve in spatiotemporal of 2020. The results showed that we found seven functional groups, including protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivore (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF). In spring, the PF (54.32%) and RF (39.5%) functional groups were dominant. In summer, the PF was contributing 93.2%. In autumn, the PF (54.64%) and RF (44.62%) were dominant. The seasonal succession was characterzed by PF+RF→PF+RF+RC→PF+RF+MCC, which indicates that the filter feeding zooplankton usually dominates in three seasons, resulting in a long-term poor trophic state of the water. Pearson correlation analysis and redundancy analysis multivariate statistical analysis showed that the chemical oxygen demand, dissolved iron and pH were the mainly influencing fators. Our finding has certain reference significance for the freshwater wetlands management and protection in the cold temperate zone.
Keywords: *Genheyuan, zooplankton, seasonal succession, cold-temperate zone, freshwater ecosystems*

Introduction

Wetlands are dynamic and highly productive ecosystems providing habitat for primary organisms such as zooplankton and phytoplankton which plays a critical role in aquatic systems (Mishra et al., 2021; Thakur and Das, 2022; Ba et al., 2022). Plankton is widely distributed in waters, has a small size and strong fecundity, can provide basic productivity for other organisms in the waters, and plays an important role in the material flow, energy flow and information flow of the ecosystem (Soulié et al., 2022). Zooplankton is found in almost all kinds of waterbodies. Compared with other aquatic animals, it is small in size, abundant in number and has strong metabolic activities (Kumari et al., 2022). It feeds on phytoplankton, bacteria, fragments and other organisms (Austin et al., 2022).

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Zooplankton is an important symbol of water ecological characteristics and an important component of aquatic organisms, playing a crucial role in the ecological processes of material transformation, energy flow and information transmission (Ju et al., 2015). As a secondary producer, its dynamic change directly affects the change of the whole ecosystem and the productivity of primary producers and senior consumers in the region (Xu, 1996). As a major link in the natural aquatic food chain, changes in its species and quantity will directly or indirectly affect the abundance and distribution of other aquatic organisms (Paquette et al., 2022). Zooplankton has a short life cycle and is vulnerable to environmental changes (Toklu et al., 2021). The changes of its community structure and function directly or indirectly reflect the status and development trend of water environment. In addition, changes in the zooplankton community can comprehensively reflect the results of water pollution over a long period of time, and some species can also serve as indicators of environmental pollution and water eutrophication (Saumen, 2021). In recent years, water ecological problems such as eutrophication have become increasingly prominent (Dexter et al., 2020; Evans et al., 2020). Using zooplankton community structure to evaluate and regulate water quality and repair polluted water has become one of the important contents of aquatic ecology research (Khangaonkar et al., 2021).

At present, the pollution of wetland ecological environment is becoming more and more serious, and more and more water bodies have problems such as eutrophication and algal blooms (Dyomin et al., 2021). Traditional monitoring methods usually reflect water quality and wetland biodiversity by using taxonomic groups as a whole, such as dividing aquatic organisms into phytoplankton (Li et al., 2022; Nguyen et al., 2022; Sun et al., 2022), zooplankton (Kumari et al., 2022; Xu et al., 2022; Kour et al., 2022), macroinverbrates (Velasco-Cruz and Smith, 2014; Tang et al., 2022; Lam-Gordillo et al., 2022) and fish (Lima, 2022; Falfushynska, 2022; Al-Chokhachy et al., 2022). This traditional classification method is difficult for zooplankton to accurately reflect their unique ecological functions in the aquatic ecosystem (Barber et al., 2022). Therefore, some ecologists put forward the concept of "functional group". On the basis of traditional classification, the zooplankton's body size, feeding habits and other characteristics are further classified, so that the species characteristics of zooplankton functional groups are closely related to water habitats. The connection can be better reflected (Hood et al., 2006).

The related research on zooplankton functional groups has been carried out relatively late, and a unified classification standard has not yet been formed (Huss et al., 2021). At present, many Chinese researchers have carried out in-depth research on phytoplankton functional groups, benthic functional groups and fish functional groups, but the research on zooplankton functional groups, especially freshwater zooplankton functional groups is still in the development stage. Initially, it mainly focused on marine ecosystems (Sun et al., 2010). In the later period, research on the functional groups of freshwater zooplankton was gradually carried out from large rivers, lakes, etc., but the research and analysis of the functional groups of zooplankton in swamps and wetlands in cold regions were less.

In recent years, the use of zooplankton community structure to evaluate and adjust water quality and remediation of polluted water bodies has become one of the important contents of water ecology research. At present, there are few studies on the zooplankton in the Greater Khingan Mountains. This study aims to through the research on the structural characteristics and functional group division of zooplankton in the Genhe

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Wetland, monitoring the characteristics of the water ecosystem in the Genhe River Basin has important practical significance for the protection and rational utilization of water resources in the Greater Khingan Mountains.

Materials and methods

Study area

Genheyuan national wetland park is located upstream of the Genhe river in the Greater Khingan Mountains region in China (*Fig. 1*). Many estuaries, marshes and flood wetlands are formed in flat areas. The wetland is widely distributed, which has become the typical area of forest swamp and river wetland in the northern part of the Greater Khingan Mountains. Genhe city, is located between 120°12´ ~ 122°55´E and 50°20´ ~ 52°30´N, is one of the highest city in China. Annual average temperature 5.3 ℃, extreme low temperature -58 ℃. Therefore, the Genheyuan wetland park is named as the natural museum of China's cold polar wetland and the Everest of China's environmental education.

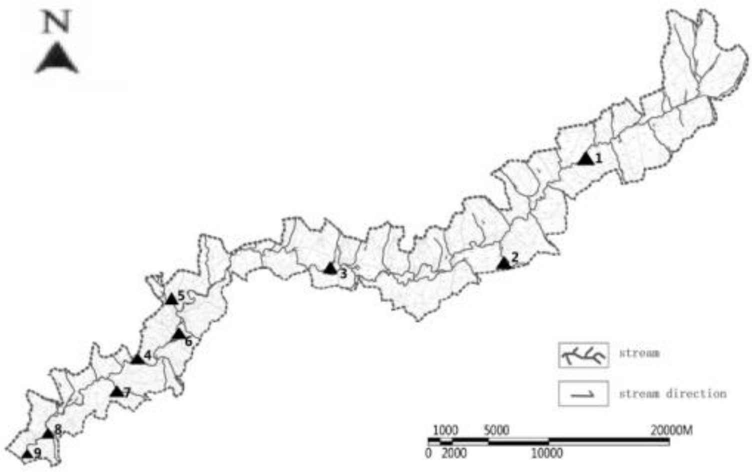

Figure 1. *Locations of sampling sites in Genheyuan National Wetland Park*

According to the climatic environment and the growth characteristics of aquatic organisms in the Great Hinggan Mountains, nine sampling sites (*Table 1*) were selected for sampling during spring (June), summer (August) and autumn (October) in 2020.

Table 1. *Coordinates of sampling sites in Genheyuan National Wetland Park*

Sampling sites	Longitude(E)	Latitude(N)
1#	122°24′13.1″	51°06′17.2″
2#	122°18′35.0″	51°01′26.2″
3#	122°04′48.1″	51°00′02.9″
4#	121°46′50.1″	50°54′23.0″
5#	121°49′37.7″	50°57′23.9″
6#	121°49′39.4″	50°56′13.5″
7#	121°43′41.8″	50°53′49.8″
8#	120°38′22.1″	50°51′03.6″
9#	121°35′48.7″	50°48′28.9″

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Sampling collection and laboratory analysis

At each sampling site, water temperature (WT), pH, oxidation-reduction potential (ORP) and dissolved oxygen (DO) were measured in the field using a portable multi-probe (YSI 6600, YSI Inc.). Water transparency (SD) and depth (D) were measured using Secchi disk and longline method. Triplicate water samples for chemical analyses were collected at each sampling sites and put on acid-washed plastic bottles, placed in ice box and transported to laboratory for further analysis. The concentration of total nitrogen (TN), total phosphorus (TP), ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Mn}) and dissolved iron (Fe^{3+}) and dissolved copper (Cu^{2+}) were measured according to the China standard methods (Shen et al., 1990; Zhang and Huang, 1991; SEPA, 1997; Zhao, 2005).

Zooplankton samples (20 L water filtered through 64 mm mesh size) were fixed with alcohol (75% concentration) and formaldehyde solution (4% concentration). Protozoa and rotifer samples were obtained by taking 1 L sub samples to form the 20 L pooled sample. The samples were preserved with Lugol's iodine and formaldehyde and allowed to sediment in 1 L jar for at least 48 hours. The supernatant water was carefully removed and the residue was then collected and made to a known volume of 30 mL. Identification and counting of the zooplankton specimen were using an inverted microscope (Leica, DM500, Germany) at 400× magnification following the species keys. We calculated zooplankton functional group biomass using dry weight (mg) obtained from length-weight relationship of filtered water volume (L) (Wang, 1961; Jiang and Du, 1979; CRG, 1979).

Description and classification of zooplankton functional group

According to the researchers, zooplankton functional groups are the morphological, behavioral or phonological characteristics that shape its ecological role and fitness in their living environment. Reproduction, mode of feeding, trophic level and interaction among organisms have been used to categorize zooplankton, however, size has been considered as the basic principle for classification of zooplankton functional group. The sampled zooplankton in the Genheyuan National Wetland Lake were classified into seven functional groups: protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF, body size<0.7 mm), middle copepodas and cladocera carnivore (MCC, body size 0.7-1.5 mm), large copepodas and cladocera carnivore (LCC, body size >1.5 mm) and large copepodas and cladocera filter feeders (LCF, body size >1.5 mm) (Zhao, 2020).

Data analysis

Statistical analyses were carried out using the IBM SPSS Statistics 22 software. Variation and correlation of environmental factors and biomass of zooplankton functional groups in different seasons were analyzed by using one-way ANOVA and Spearman analysis, respectively. Relationship between zooplankton functional groups biomass and environmental variables was done using CANOCO 5 software (Microcomputer Power, New York, USA). From the DCA results, the maximum gradient length of the axis did not exceed D51 three standard deviations hence prompting the use of redundancy analysis (RDA). All environmental variables (except pH) and zooplankton functional groups biomass was log (1 + x) transformed before analysis in order to normalize the data. During the RDA analysis, Monte Carlo simulation was employed to 130 test the significance of

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physico-chemical variable in explaining the zooplankton functional groups under unrestricted model of 999 permutations.

Results

Seasonal variation of environment factors

The mean values of physic-chemical variables obtained in Genheyuan Wetland Lake are presented in *Table 2*. The highest water temperature is in summer, which is obviously higher than that in spring and autumn (P<0.01). The mean values of pH were showed extremely significantly differences among three seasons (P<0.01). However, TP showed significantly different among three seasons (P<0.05). The lowest mean value of Cu^{2+} was observed in spring, and the highest value observed in summer (P<0.05). While, the highest mean values of WT, SD and COD_{Mn} were observed in summer and the lowest value reported in autumn.

Table 2. *Environmental factors of Genheyuan National Wetland Park*

Environmental factor	Spring	Summer	Autumn	***P*-value**
NH_4^+-N(mg/L)	0.04±0.11	0.28±0.12	0.12±0.02	0.462
TN(mg/L)	0.11±0.26	1.78±1.07	1.44±0.65	0.035
TP(mg/L)	0.37±0.20	0.36±0.21	0.21±0.09	0.024
COD_{Mn}(mg/L)	4.97±2.23	5.29±0.48	3.80±0.27	0.456
Cu^{2+}(mg/L)	0.05±0.02	0.20±0.01	0.17±0.10	0.043
Fe^{3+}(mg/L)	0.13±0.08	0.12±0.06	0.14±0.11	0.753
DO(mg/L)	9.52±1.27	9.17±0.67	10.33±0.44	0.264
pH	5.33±0.29	5.64±0.13	6.16±0.25	0.003
ORP(mv)	77.32±8.88	86.08±8.18	41.60±15.37	0.823
SD(m)	0.53±0.18	0.76±0.26	0.53±0.17	0.365
D(m)	0.53±0.18	0.76±0.26	0.53±0.17	0.276
WT(℃)	8.38±0.67	15.07±3.80	6.17±0.79	0.000

Water temperature (WT), pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), water transparency (SD), depth (D), total nitrogen (TN), total phosphorus (TP), ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Mn}) and dissolved iron (Fe^{3+}) and dissolved copper (Cu^{2+}). *P*-value from one-way ANOVA

Variation of zooplankton functional groups in Genheyuan Wetland Lake

A total of 24 zooplankton species belong to four taxonomic groups including protozoa (29.17%), rotifers (45.83%), cladocerans (12.5%) and copepods (12.5%) were identified in the Genheyuan Wetland Lake (*Table 3*). The biomass of zooplankton functional group showed seasonal and spatial variation (*Figs. 2 and 3*). Summer recorded the highest number of zooplankton species (19) followed by spring (18) and autumn (17). In summer (*Fig. 2b*), the dominant zooplankton functional groups was PF mainly composed by *Tetrahymena priformis* (43.17%) and *Paramecium bursaria* (37.55%), and RF which was presented by *Keratella cochlearis* (5.27%) and *Lecane luna* O.F. Muller (3.03%). While in spring (*Fig. 2a*), the dominant zooplankton functional group PF was only presented by *Lagynophrya conifera* (77%). In autumn (*Fig. 2c*), the dominant zooplankton functional group PF was contributed by *Kellicottica longispina* (56.82%) and RF was *Keratella cochlearis* (26.39%). The seasonal variation of zooplankton functional groups is characterized by PF+RF → PF+RF+RC → PF+RF+MCC (*Table 3*).

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***Table 3.** Zooplankton community structure composition, functional groups and percentage biomass (%) during three seasons in Genheyuan Wetland Lake*

Taxonomic group	Species	Functional groups	Percentage biomass (%)		
			Spring	Summer	Autumn
Pratozoa	*Strobilidium velox*	PF	2.13	-	-
	Strombidium viride	PF	2.79	-	2.97
	Tetrahymena priformis	PF	1.43	1.48	2.78
	Pinacio phora fluviatilis	PF	0.83	-	-
	Vorticella campanula	PF	3.75	0.62	1.58
	Paramecium bursaria	PF	0.45	0.77	1.31
	Lagynophrya conifera	PF	4.49	-	-
Rotifera	*Kellicottica longispina*	RF	2.74	2.03	4.51
	Polyarthra trigla	RF	0.50	-	-
	Keratella cochlearis	RF	-	4.12	27.71
	Trichocerca lamarck	RF	2.78	-	-
	Monostyla unguitata Fadeeu	RF	1.09	1.32	3.17
	Filinia maior	RF	-	0.19	-
	Trichocerca similis	RF	1.79	-	-
	Lecane luna O.F. Muller	RF	-	1.83	-
	Asplanchna girodide Guerne	RC	1.76	1.79	3.21
	Filinia longiseta	RF	-	0.98	-
	Monostyla lunaris Ehrenberg	RF	-	0.45	-
Cladocera	*Bosmina longirostris*	SCF	-	0.12	1.12
	Leptodora kindti	LCC	-	0.08	0.39
	Daphnia magna	LCF	0.11	0.14	0.43
Copepoda	*Cyclops strenuns*	LCC	-	0.06	0.45
	Microcyclops javanus	SCF	0.20	0.12	0.48
	Thermocyclops dybowskii	MCC	0.28	0.36	0.58

Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF)

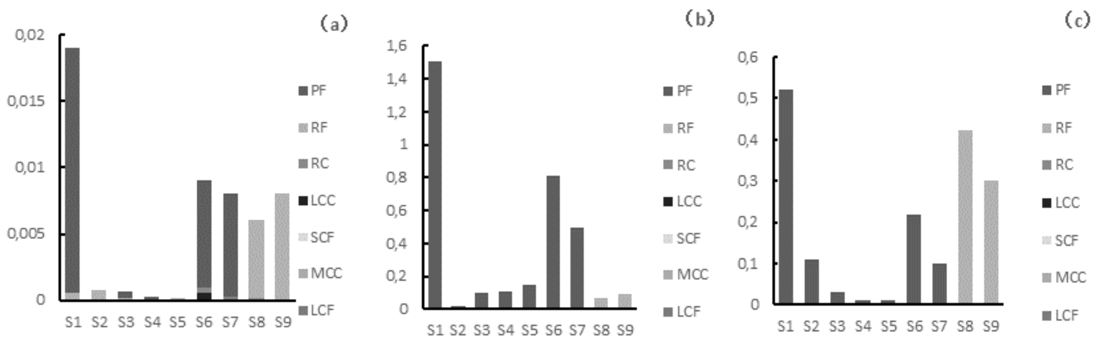

***Figure 2.** Spatial distribution of zooplankton groups biomass of spring (a), summer (b) and autumn (c). Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF)*

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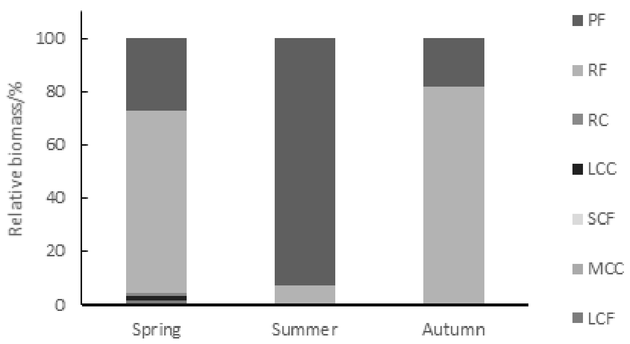

Figure 3. *Relative mean biomass of main zooplankton functional groups in Genheyuan Wetland Lake. Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF)*

Correlation of zooplankton functional groups and environmental factors

The Spearman correlation analysis of zooplankton functional groups biomass was shown in *Table 4*. Group SCF influenced RF, and group LCC influenced RC and LCF. PF and MCC demonstrated no correlation with other functional groups. Meanwhile, most environmental factors were correlated with zooplankton functional groups.

Table 4. *Spearman correlation of zooplankton functional groups biomass*

	PF	RF	RC	MCC	SCF	LCC	LCF
PF	1	.247	.132	.009	.081	-.039	.073
RF	.247	1	.342	.201	.345*	.306	.033
RC	.132	.342	1	.198	.067	.419*	.228
MCC	.009	.201	.198	1	.281	.260	-.100
SCF	.081	.345*	.067	.281	1	.355	.009
LCC	-.039	.306	.419*	.260	.355	1	.357*
LCF	.073	.033	.228	-.100	.009	.357*	1

Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF)

The Spearman correlation analysis of zooplankton functional groups biomass and environmental factors was shown in *Table 5*. As group LCC was significantly influenced by SD (r=0.376), WT (r=0.351), NH_4^+-N (r=0.493) and COD_{Mn} (r=-0.544). Groups SCF was negatively correlated with COD_{Mn} (r=-0.544). However, the ORP and NH_4^+-N was only significant positively correlated with group MCC (r=0.388) and LCF (r=0.408), respectively.

RDA analysis of zooplankton functional group with physico-chemical variables

As the detrended correspondence analysis (DCA) results were less than 3, redundancy analysis (RDA) was performed on zooplankton functional group biomass and environmental factors (*Fig. 4*). Axis 1 and Axis 2 explain 56.6% of the cumulative change rate of species data. The eigenvalues of the first 2 axes are 0.5132 and 0.4595,

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respectively, of which Axis 1 is the most important positive correlation. The environmental factor with a major effect are COD_{Mn}, Fe^{3+} and pH. The functional groups MCF and LCC were significantly negatively correlated with TN, pH and copper ion, and significantly positively correlated with COD_{Mn}, ORP and TP. Functional groups PF, MCC, RF and SCF were significantly positively correlated with Fe^{3+}, SD, PH and $Cu2^{+}$. The functional group RC was significantly positively correlated with DO, and significantly negatively correlated with WT.

Table 5. *Spearman correlation between zooplankton functional groups biomass and environmental factors*

	PF	RF	RC	MCC	SCF	LCC	LCF
WT	-0.183	0.103	0.258	-0.097	0.106	.351*	-0.05
SD	-0.077	0.01	-0.003	-0.012	0.342	.376*	0.21
pH	0.3	0.092	-0.203	0.19	0.051	-0.192	-0.124
ORP	0.152	-0.121	-0.258	.388*	-0.016	-0.309	-0.127
COD_{Mn}	0.223	-0.305	-0.145	-0.301	-.544**	-.544**	0.091
DO	-0.161	-0.127	0.033	0.146	-.419*	-0.15	0.182
Fe^{3+}	0.173	-0.02	-0.288	0.259	-0.144	-0.328	0.112
$Cu2^{+}$	-0.047	-0.141	0.14	-0.289	-0.252	-0.014	-0.045
TP	-0.077	-0.112	-0.067	-0.012	0.033	0.029	-0.151
TN	0.039	0.1	-0.058	0.082	-0.155	-0.169	-0.054
NH^{4+}-N	-0.271	0.196	0.138	-0.122	0.076	.493*	.408*

Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF). Water temperature (WT), pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), water transparency (SD), depth (D), total nitrogen (TN), total phosphorus (TP), ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Mn}) and dissolved iron (Fe^{3+}) and dissolved copper (Cu^{2+})

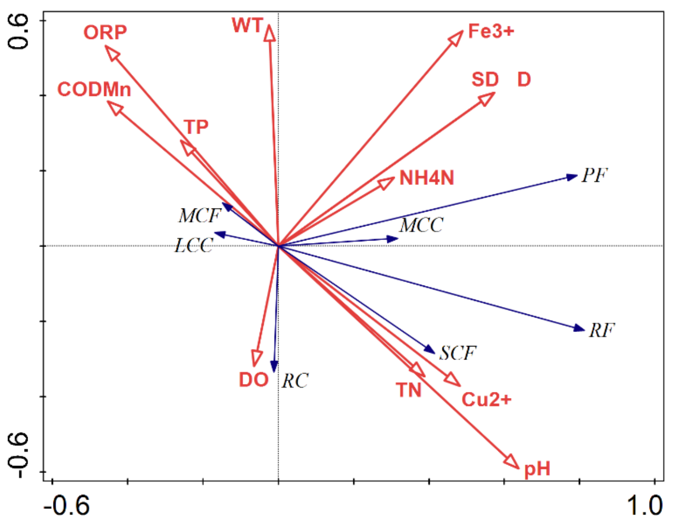

Figure 4. *Functional groups-environment biplot RDA. Protozoa filter feeders (PF), rotifer filter feeders (RF), rotifer carnivora (RC), small copepodas and cladocera filter feeders (SCF), middle copepodas and cladocera carnivore (MCC), large copepodas and cladocera carnivore (LCC) and large copepodas and cladocera filter feeders (LCF). Water temperature (WT), pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), water transparency (SD), depth (D), total nitrogen (TN), total phosphorus (TP), ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Mn}) and dissolved iron (Fe^{3+}) and dissolved copper (Cu^{2+})*

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Discussion

Compared with macrozooplankton (cladocerans, copepods), the species number, abundance and biomass proportion of small zooplankton (protozoa, rotifers) in Genheyuan National Wetland Park are higher. A total of 24 species of zooplankton were found in this study, among which rotifers are the most species, which is consistent with the species composition of zooplankton in the survey results of many large rivers in China, and has typical characteristics of zooplankton community composition in rivers (Tang et al., 2012; Bai et al., 2015). Because the Genheyuan National Wetland Park is located in the alpine region, the abundance and biomass of zooplankton are still very low in spring; the number of protozoa increases in summer, reaching the maximum biomass; Rotifer numbers and species peak in autumn, when zooplankton abundance is highest. In Genheyuan National Wetland Park, there are many small zooplankton protozoa and rotifers, with high abundance, but their biomass is relatively low; less cladocerans and copepods, which have a great impact on zooplankton abundance and biomass Has little effect. There were differences in zooplankton abundance and biomass at each sampling point. The 1# sampling point is a still-water lake with higher water temperature and nutrient levels than other sampling points, providing a more suitable environment for zooplankton to survive. Therefore, the 1# sampling point is much more abundant and biomass than other sampling points. In conclusion, the species number, abundance and biomass of zooplankton in Genheyuan National Wetland Park are all low, which is related to the excessive accumulation of humus such as litter in the forest area. The abundance and number of animals are distributed, and the river in the Genheyuan National Wetland Park is shallow and turbulent, which is not suitable for zooplankton to survive. Studies have shown that in freshwater ecosystems, the biomass of zooplankton is positively correlated with the residence time in the water environment where it is located (Asknes and Wassman, 1993).

At present, there are many studies on the seasonal changes of zooplankton in eutrophicated waterbodies in China, but few studies on the clear waterbodies. Water temperature, nutrient salt, upward effect of phytoplankton, downward effect of fish feeding, interspecific competition and hydrological changes are the main factors affecting the growth of zooplankton, as well as the distribution of zooplankton functional groups (Flores and Rossella, 1998). In tropical and subtropical regions, temperature has little influence on zooplankton, and the seasonal variation of zooplankton is not significant. The descending effect of fish feeding is the main factor affecting zooplankton (Ter Braak, 1986). In the water bodies with high feeding pressure, the biomass of zooplankton was dominated by small rotifers and small cladocerata, while the water bodies with low feeding pressure were dominated by large cladocerata and copepods (Huang et al., 2014). In temperate regions, temperature and nutrient salts are the main environmental factors, and the seasonal changes of zooplankton are significantly affected by them. Cladocerata and copepods have a significant positive correlation with water temperature (Wang et al., 2015). With the increase of water temperature in summer, cladohores and copepods will gradually increase, and eutrophication of water will lead to zooplankton miniaturization (Yuan et al., 2013). The eutrophicated water bodies were dominated by small rotifers and small cladocerata throughout the year. From the perspective of phylum zooplankton, the seasonal changes of zooplankton in the genheyuan wetland were not significant, and the changes were not significant from the perspective of functional group division. In spring, summer and autumn, the PF functional group was dominant, mainly composed of

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protozoa such as piriform tetrahydatid, which fed on algae, bacteria and debris, indicating that the water body was mostly nutrient-poor (Han, 1992).

The quality of the water environment determines the characteristics of biological populations and community structures, and biological populations and communities also respond to changes in water environment quality in a timely manner, which can objectively reflect changes in water quality. In the aquatic ecosystem, environmental factors have different effects on different organisms. At the same time, environmental factors do not act on organisms in isolation, but multiple environmental factors act together (Wang et al., 2020a). Among various environmental factors that affect organisms, there are factors that play a leading role. In Genheyuan National Wetland Park, the RDA analysis results of zooplankton and environmental factors showed that COD, Fe^{3+}, TN content, pH and water temperature were the main environmental factors affecting the structure and distribution of zooplankton community. Nitrogen and phosphorus and other nutrients generally indirectly affect the growth and distribution of zooplankton through phytoplankton (Yang et al., 2020). The increase of nutrient salt content is bound to cause the increase of phytoplankton density (i.e. the increase of chlorophyll a content), thus promoting the increase of zooplankton abundance and leading to the decrease of water transparency. In this study, total nitrogen is the main environmental factor affecting zooplankton abundance, which is consistent with the above results, but total phosphorus in water has a relatively weak impact on zooplankton functional groups structure (Wang et al., 2020b). The total nitrogen concentration in summer and autumn was significantly higher than that in spring, and the locations were similar in the sorting diagram, which was reflected in the similarity in ecological adaptation. They were more suitable for the growth environment with higher total nitrogen concentration and higher water temperature, while the locations were similar in the sorting diagram, which was more suitable for the growth environment with higher total nitrogen concentration and lower water temperature (Shaikh et al., 2021).

Water temperature is an important environmental factor that affects the growth, development, community composition and quantity of zooplankton in Genheyuan wetland lake. Each kind of zooplankton has its tolerance temperature range, beyond which it will affect its growth and distribution, and the tolerance temperature range of different species is also different (Holmes and Cáceres, 2020). The biomass of zooplankton functional group in Genheyuan wetland lake is highly correlated with water temperature, indicating that water temperature has a great influence on the growth and distribution of zooplankton. 1# sampling point is a still water lake, the water temperature is higher than other sampling points, and the biomass is also much higher than other sampling points, which proves the influence of water temperature on the growth and reproduction of zooplankton. As can be seen from the RDA sequencing diagram, rotifers are more suitable to grow in the growing environment with higher water temperature and higher pH value. The pH value of the river in Genheyuan national wetland park is low and the water quality is weakly acidic. Studies have shown that the acidic water quality is not suitable for the survival of zooplankton and has a certain impact on the abundance and biomass.

The pH of the river water in Genheyuan National Wetland Park is low, and the water quality is weakly acidic. Studies have shown that acidic water quality is not suitable for zooplankton to survive, and will have a certain impact on its abundance and biomass (Han, 1992). The functional groups PF and RF are in similar positions in the ranking diagram, and they are more suitable for the growth environment with lower total nitrogen

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content and higher pH. Among them, PF is one of the dominant functional groups, and its maximum number appears in autumn, and the pH of the water body in autumn is 6.16, higher than that in spring (pH=5.33) and summer (pH=5.64), which may be the direct reason that the number of functional group PF peaked in autumn.

Conclusions

According to the body size, feeding habits and the interaction between zooplankton, zooplankton in the freshwater ecosystem were divided into 10 functional groups, and 7 functional groups were found in the Genheyuan wetland reserve. In terms of the functional group biomass of zooplankton in different seasons, PF and RF were dominant in spring and autumn. In summer, PF was dominant. PF and RF are the most important and representative functional groups of zooplankton in the Genheyuan wetland reserve. This study has certain reference significance for the division of zooplankton functional groups and the management and protection of freshwater ecosystems, especially the wetland reserves of marsh, river and lake types in the cold temperate zone.

The influencing factors of zooplankton functional groups in the nature reserve of Genheyuan wetland are mainly the interaction between zooplankton functional groups and water environmental factors. The functional groups are significantly positively correlated with pH and negatively correlated with COD_{Mn} and Fe^{3+}.

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