Zooplankton Distribution and Water Environment Characteristics in Upper Ili River Valley Reservoirs: A Case Study of Qapqal Reservoir (Postprint)

Authors: Peng Liang

Date: 2022-04-14T00:00:00+00:00

Abstract

To investigate the water environmental quality status of upstream reservoirs in the Ili River Valley of Xinjiang, zooplankton and physicochemical indicators of the water environment in Qiapuqihai Reservoir were surveyed and analyzed in June 2019 (high-water period), September 2019 (normal-water period), and December 2019 (low-water period) based on methods including biodiversity index, comprehensive trophic state index, and redundancy analysis (RDA). The results showed that: (1) A total of 37 zooplankton species were identified in Qiapuqihai, including 17 protozoa, 10 rotifers, 4 cladocerans, and 6 copepods; the dominant species mainly included Strobilidium sp., Centropyxis sp., Tintinnopsis wangi, Synchaeta sp., and Polyarthra vulgaris, totaling 5 species; the abundance of zooplankton in the high-water, normal-water, and low-water periods was 580.40 ind · L-1, 152.68 ind · L-1, and 137.01 ind · L-1, respectively, and the biomass was 0.550 mg · L-1, 0.018 mg · L-1, and 0.007 mg · L-1, respectively, with both maximum abundance and biomass occurring in the high-water period. (2) The zooplankton diversity indices exhibited typical spatiotemporal distribution characteristics; the Shannon-Wiener index (H) and Margalef index (D) showed an increasing trend from the reservoir tail to the dam front during the high-water period, while being highest in the middle of the reservoir during the normal-water and low-water periods, with mean values of H and D being 1.19 and 0.82, respectively. (3) RDA results indicated that water temperature (WT), chemical oxygen demand (CODMn), and nutrient concentrations such as total nitrogen (TN), total phosphorus (TP), nitrate nitrogen (NO-3 -N), nitrite nitrogen (NO-2 -N), ammonium nitrogen (NH+4 -N), and orthophosphate (PO34- -P) were the main environmental factors influencing the variation in zooplankton community structure. The integrated results of the biodiversity index and comprehensive trophic state index indicated that the water quality of Qiapuqihai Reservoir

was in an oligotrophic-mesotrophic state with good environmental quality, and could serve as overwintering, spawning, and feeding grounds for fish.

Full Text

Zooplankton Distribution and Water Environment Characteristics in the Upper Ili River Valley Reservoir: A Case Study of Qapchy Lake

PENG Liang[1], RU Huijun[1], TAO Ling[1], DAI Lili[1], LI Gu[1], LI Rong[1], LI Xiaoli[1], YU Yang[2]

[1] Yangtze River Fisheries Research Institute, Chinese Academy of Fishery Sciences, Wuhan 430223, Hubei, China
[2] Yili River Basin Development and Construction Administration, Urumqi 835109, Xinjiang, China

Abstract

To investigate the water environmental quality of upstream reservoirs in the Ili River Valley, Xinjiang, we conducted a survey of zooplankton and physicochemical water environment indicators in Qapchy Lake during July (wet season), September (normal season), and December (dry season) in 2019. Biodiversity indices, comprehensive trophic state index, and redundancy analysis (RDA) were employed to assess the aquatic environment. The results showed: (1) A total of 37 zooplankton species were identified, including 17 protozoa, 10 rotifers, 4 cladocerans, and 6 copepods. The dominant species included *Strobilidium* sp., *Centropyxis* sp., *Tintinnopsis wangi*, *Synchaeta* sp., and *Polyarthra vulgaris*. Zooplankton abundance was 580.40 ind $\cdot$ L^{-1} in the wet season, 152.68 ind $\cdot$ L^{-1} in the normal season, and 137.01 ind $\cdot$ L^{-1} in the dry season. Biomass was 0.550 mg $\cdot$ L^{-1}, 0.018 mg $\cdot$ L^{-1}, and 0.007 mg $\cdot$ L^{-1} respectively, with maximum values occurring in the wet season. (2) Diversity indices exhibited typical spatial-temporal distribution patterns. The Shannon-Wiener index (H) increased from the reservoir tail to the dam during the wet season, while it was highest in the middle section during normal and dry seasons. (3) RDA analysis indicated that water temperature, CODMn, and nutrient concentrations (TN, TP, NO_3^--N, NO_2^--N, NH_4^+-N, PO_4^{3-}-P) were the main environmental factors affecting zooplankton community structure. Based on biodiversity and trophic state indices, Qapchy Lake was in an oligotrophic to mesotrophic state with good water quality, suitable as a habitat for fish overwintering, spawning, and feeding.

Keywords: zooplankton; distribution characteristics; comprehensive trophic state index; redundancy analysis; Qapchy Lake

1. Introduction

Zooplankton serve as a critical "middle link" in aquatic food webs, playing a key role in energy flow, material cycling, and information transfer in aquatic ecosystems. In natural lakes and reservoirs, zooplankton not only contribute to ecosystem productivity but also serve as sensitive indicators of environmental conditions due to their rapid response to water quality changes. Understanding the relationship between zooplankton community structure and water environmental factors helps to grasp the environmental status and functional characteristics of lake and reservoir ecosystems, providing guidance for the development and utilization of fishery resources.

The Ili River Valley is located in the mid-latitude inland region, characterized by a continental temperate semi-arid climate. The valley is surrounded by three mountain ranges that gradually converge from west to east, forming a westward-opening triangle. This unique topography makes it the region with the highest rainfall in Xinjiang and the area with the highest winter temperatures in northern Xinjiang. The annual average temperature ranges from 3.5–9.5 °C, with annual precipitation averaging 215–505 mm in valley areas and 505–800 mm in mountainous regions. The abundant water resources and high terrain provide favorable conditions for hydropower development, making reservoir construction the primary mode of water resource utilization in the Ili River.

Indigenous fish species in Ili River Valley reservoirs have formed substantial populations. For example, the annual catch of *Perca schrenkii* in Qapchy Lake reached 20.87 t in 2018, accounting for 69.57% of the total annual catch, making the reservoir an important habitat for indigenous fish proliferation and conservation. Therefore, comprehensive understanding of the ecological environment of fish habitats is essential for protecting indigenous fish resources. Currently, research on zooplankton and water environment in Ili River Valley reservoirs is limited, with only a few studies reporting on plankton and water quality. Particularly after the construction of numerous reservoirs in the region in recent years, research on reservoir water ecology in the Ili River area is lacking. Consequently, this study was conducted in 2019 to investigate zooplankton distribution and water environment characteristics in Ili River Valley reservoirs, aiming to understand the dynamics of zooplankton and water quality, comprehensively assess water quality status, and provide baseline data for indigenous fish conservation and reservoir fisheries development.

2. Materials and Methods

2.1 Sampling Sites and Sampling Time Qapchy Lake is located on the Tekes River in the Ili River Valley, Xinjiang, and is a typical valley-type reservoir formed by water conservancy construction. The reservoir was constructed in 1961, began impoundment in 2005, and became operational in 2006. The reservoir runs west-east, with high mountains to the north and farmland/grassland forming the drawdown zone after impoundment. The region has an average annual temperature of 8.8 °C, extreme maximum temperature of 38 °C, extreme minimum temperature of -32 °C, average annual precipitation of 334.02 mm, and average annual evaporation of 1,276 mm. The runoff is significantly regulated by glaciers, with gentle interannual variation favorable for water resource utilization.

Sampling was conducted in July (wet season), September (normal season), and December (dry season) in 2019. Due to ice cover during the dry season, only three regions (dam front, middle, and tail) were sampled. In July and September, 10 sampling sites were established across the reservoir (Figure 1 [Figure 1: see original paper]). In July, stratified sampling points were set at the reservoir center with depths of 0.5 m, 5 m, 10 m, 15 m, 20 m, 25 m, and 30 m.

2.2 Sample Collection, Processing, and Identification Sample collection and processing followed the methods described in "Research Methods for Freshwater Plankton in China." Both qualitative and quantitative samples were collected.

Qualitative samples: A No. 25 plankton net (64 m mesh) was used to collect samples from the surface water in an "∞" pattern for 3–5 minutes. The concentrated sample was placed in plastic bottles and fixed with 2–3 mL of formaldehyde solution.

Quantitative samples: Two types of quantitative samples were collected. One type involved collecting 10 L of surface water with a water sampler, filtering through a No. 25 plankton net (64 m mesh), and preserving the concentrate in 2–3 mL formaldehyde solution. The other type involved collecting 1 L of surface mixed water in plastic bottles, fixing with Lugol' s solution, and bringing back to the laboratory for sedimentation for 48 hours before concentration to 30 mL.

During sampling, water transparency was measured using a Secchi disk. A Hach HQ40d portable multi-parameter water quality meter was used to measure water temperature (WT), pH, dissolved oxygen (DO), and conductivity at 0.5 m depth.

2.3 Physicochemical Factor Analysis Methods Quantitative and qualitative samples were thoroughly mixed and examined under a microscope (Olympus BX53). Samples collected with the plankton net were used to detect Cladocera and Copepoda, while concentrated samples were used to detect Rotifera and Protozoa. Species identification followed "Freshwater Rotifers in China," "Fauna Sinica: Freshwater Cladocera,""Fauna Sinica: Freshwater Copepoda,"and "Modern Biomonitoring Techniques Using Freshwater Microbiota."

Total nitrogen (TN), total phosphorus (TP), nitrate nitrogen (NO_3^--N), nitrite nitrogen (NO_2^--N), ammonium nitrogen (NH_4^+-N), permanganate index (CODMn), and orthophosphate (PO_4^{3-}-P) were measured according to "Monitoring and Analysis Methods for Water and Wastewater." Chlorophyll a (Chl a) was determined using the acetone extraction method.

2.4 Data Processing and Analysis Methods Zooplankton abundance was calculated using the formula:

$$N = \frac{V_1 \times n}{V_2 \times V_3}$$

where N is the number of individuals per liter of water (ind · L^{-1}), V_1 is the concentrated volume (mL), n is the counted number of individuals, V_2 is the sampling volume (L), and V_3 is the counting volume (mL).

Biomass was calculated based on fresh weight: 0.00005 mg per protozoan, 0.003 mg per rotifer, 0.02 mg per cladoceran, 0.0012 mg per copepodid, and 0.003 mg per adult copepod.

Diversity indices were calculated using the Shannon-Wiener index (H) and Margalef index (D):

$$H' = -\sum_{i=1}^{S} P_i \log_2 P_i$$

$$D = \frac{S-1}{\log_2 N}$$

where P is the proportion of individuals of species i (N /N), N is the total number of individuals, and S is the number of species.

Student' s t-test was used to analyze differences in environmental factors. Surfer 18.0 software was used to map spatial distributions of zooplankton standing stock. Redundancy analysis (RDA) was performed using Canoco 4.5 software to analyze relationships between dominant species abundance and environmental factors. Origin 2019b was used for graphing.

Dominant species were determined using the dominance index (Y):

$$Y = \frac{n_i}{N} \times f_i$$

where n is the number of individuals of species i, N is the total number of individuals, and f is the frequency of occurrence across sampling sites. Species with $Y \geq 0.02$ were considered dominant.

The comprehensive trophic state index was calculated as:

$$\mathrm{TLI}(\Sigma) = \sum_{j=1}^{m} W_j \times \mathrm{TLI}(j)$$

where TLI(Σ) is the comprehensive trophic state index, W is the weight of parameter j, m is the number of parameters, and TLI(j) is the trophic state index of parameter j.

3. Results

3.1 Environmental Factors Seasonal variations in physicochemical factors are shown in Table 1 . During the dry season, Qapchy Lake was ice-covered with water temperature at 1.87 °C. The wet season had the highest temperature, ranging 19.70–21.46 °C, while the normal season was around 8.14 °C. Chl a concentration was highest in the wet season (1.611–4.667 $g \cdot L^{-1}$), followed by the normal season (0.813–1.094 $g \cdot L^{-1}$), and lowest in the dry season (0.135–2.519 $g \cdot L^{-1}$). CODMn values ranged 1.081–1.607 $mg \cdot L^{-1}$ during the study period. pH varied from 7.89 to 8.44, indicating slightly alkaline conditions overall. The water environmental quality generally met surface water standards.

3.2 Species Composition and Seasonal Changes of Dominant Species A total of 37 zooplankton species were identified across the three hydrological periods, including 17 protozoa (45.95%), 10 rotifers (27.03%), 4 cladocerans (10.81%), and 6 copepods (16.21%). Species composition varied among hydrological periods, but protozoa dominated in both abundance and dominant species, followed by rotifers, with cladocerans and copepods being less abundant. The dry season had the fewest species (17), the wet season had 29 species, and the normal season had 32 species (copepod larvae not included).

Dominant species and their dominance values are shown in Table 3 . The common dominant species were *Strobilidium* sp., *Centropyxis* sp., *Tintinnopsis wangi*, *Synchaeta* sp., and *Polyarthra vulgaris*. The number of dominant species varied significantly by season, with more dominant species in the wet season than in normal and dry seasons. In the wet season, dominant species included *Strobilidium* sp., *Centropyxis* sp., *Tintinnopsis wangi*, *Synchaeta* sp., and *Polyarthra vulgaris*, with *Centropyxis* sp., *Synchaeta* sp., and *Polyarthra vulgaris* being the main dominants (dominance values: 0.035, 0.034, and 0.032 respectively). In the normal season, dominant species were *Strobilidium* sp. and *Centropyxis* sp. In the dry season, only *Tintinnopsis wangi* was dominant (dominance value: 0.026). The absolute dominant species throughout the year were *Strobilidium* sp., *Centropyxis* sp., and *Polyarthra vulgaris*.

3.3 Spatial and Temporal Distribution of Zooplankton Abundance and Biomass Average zooplankton abundance in Qapchy Lake was 580.40 $ind \cdot L^{-1}$ in the wet season, 152.68 $ind \cdot L^{-1}$ in the normal season, and 137.01 $ind \cdot L^{-1}$ in the dry season. Biomass was 0.550 $mg \cdot L^{-1}$, 0.018 $mg \cdot L^{-1}$, and 0.007 $mg \cdot L^{-1}$ respectively, showing significant seasonal differences with wet season > normal season > dry season (Figure 2 [Figure 2: see original paper]).

Spatial distribution patterns varied by hydrological period. In the wet season, zooplankton biomass was highest at the dam front (1.350 $mg \cdot L^{-1}$) and decreased gradually toward the reservoir tail (0.060 $mg \cdot L^{-1}$). In the normal season, biomass was highest at the right bank of the middle section (0.730 $mg \cdot L^{-1}$) and lower at sites farther from the right bank. In the dry season, the pattern was similar to the wet season, showing a gradual increase from reservoir tail to dam front. The spatial distribution of abundance matched that of biomass (Figure 3 [Figure 3: see original paper]).

Vertical distribution in the wet and normal seasons showed that both abundance and biomass increased with depth, reaching maximum values at 10 m depth (wet season: 979.56 $ind \cdot L^{-1}$; normal season: 712.81 $ind \cdot L^{-1}$), then decreased with further depth increase. Biomass peaked at 0.730 $mg \cdot L^{-1}$ in the wet season and 0.120 $mg \cdot L^{-1}$ in the normal season at 10 m depth. All depth layers showed higher values in the wet season than in the normal season.

3.4 Spatial and Temporal Distribution Characteristics of Diversity Indices The Shannon-Wiener index (H) and Margalef index (D) showed typical spatial-temporal patterns (Figure 4 [Figure 4: see original paper]). In the wet season, H ranged 1.25–2.51 (mean: 1.94), increasing from reservoir tail to dam front. In the normal season, H ranged 0.46–1.77 (mean: 1.19), with the lowest values in the middle section. In the dry season, H ranged 0.24–1.48 (mean: 0.82), with the highest values in the middle section. The D index showed similar patterns, with mean values of 0.97, 0.48, and 0.34 in wet, normal, and dry seasons respectively.

3.5 Comprehensive Trophic State Index Using Chl a, TP, TN, SD, and CODMn as evaluation parameters, the comprehensive trophic state index (TLI(Σ)) was calculated for each season. The classification standard defines $TLI(\Sigma) < 30$ as oligotrophic, $30 \leq TLI(\Sigma) \leq 50$ as mesotrophic, and $TLI(\Sigma) > 50$ as eutrophic. Results showed TLI(Σ) values of 28.78 (wet season), 29.32 (normal season), and 30.12 (dry season), indicating that Qapchy Lake is in an oligotrophic to mesotrophic state with low eutrophication risk (Figure 5 [Figure 5: see original paper]).

3.6 Relationship Between Zooplankton Community Structure and Environmental Factors Based on dominant species and occurrence frequency, 15 common zooplankton species and total zooplankton abundance were selected for RDA analysis. Detrended correspondence analysis (DCA) showed a maximum gradient length of 2.67, indicating linear response and suitability for RDA. The first two axes explained 58.7% of the variation in zooplankton abundance, with environmental factors clearly separating the three hydrological periods (Figure 6 [Figure 6: see original paper]).

Tintinnopsis wangi was positively correlated with pH and negatively correlated with transparency. *Synchaeta* sp. and *Polyarthra vulgaris* were positively correlated with CODMn and negatively correlated with transparency. *Centropyxis* sp. was negatively correlated with CODMn. Water temperature was the primary factor affecting seasonal changes in zooplankton abundance.

4. Discussion

4.1 Characteristics of Zooplankton Community and Changes in Dominant Species in Qapchy Lake Qapchy Lake has a continental temperate semi-arid climate, and its zooplankton species are typical of continental temperate water bodies. The community was dominated by small species—rotifers (*Synchaeta* sp., *Polyarthra vulgaris*) and protozoa (*Strobilidium* sp., *Tintinnopsis wangi*, *Centropyxis* sp.)—with fewer cladocerans and copepods. This pattern is consistent with other valley-type reservoirs such as Shuifeng Reservoir and Xiangshui Reservoir. Although dominant species varied among hydrological periods, the annual dominant species appeared in all periods, differing from results for Hongshan Reservoir in Xinjiang. This may be related to water level fluctuations: Hongshan Reservoir has limited water resources and no perennial river input, resulting in large water level fluctuations, whereas Qapchy Lake receives abundant upstream inflow year-round with relatively stable water levels.

Zooplankton biomass and abundance showed a consistent pattern of wet season > normal season > dry season, aligning with seasonal patterns in most valley-type reservoirs. This is likely because zooplankton reproduction and growth are temperature-dependent, with faster growth in warmer seasons. Most valley-type reservoirs have higher water temperatures in summer (wet season) and lower temperatures in winter (dry season). The average biomass of 0.550 $mg \cdot L^{-1}$ in the wet season was much lower than the 2006 summer survey result, possibly due to reservoir operation time and fish stocking activities. The reservoir had only been operating for 4 months by summer 2006, and the ecosystem may not have stabilized. Additionally, various fishery activities (stocking of silver carp, bighead carp, and indigenous fish) have altered the aquatic environment.

Spatial distribution patterns varied by season. In the wet season, zooplankton abundance increased from reservoir tail to dam front, likely because upstream snowmelt floods enter through the reservoir tail, slowing down and creating favorable conditions such as sediment settlement, reduced scouring, and increased transparency. In the normal season, the highest biomass occurred at the right bank of the middle section, possibly due to abundant detritus food resources. Field observations revealed that the right bank is relatively flat, consisting of submerged farmland and grassland that becomes inundated during wet and normal seasons, providing rich organic matter.

Vertical distribution showed that both abundance and biomass increased with depth, peaking at 10 m before decreasing. This pattern, similar to that in Sanbanxi and Aha reservoirs, may be related to thermal stratification and the distribution of phytoplankton and bacteria.

4.2 Indication of Zooplankton on Water Environment in Qapchy Lake Diversity indices are important indicators of community succession status, reflecting water pollution conditions. H values indicated moderate pollution in the wet and normal seasons and severe pollution in the dry season. D values indicated severe pollution across all seasons, reflecting low zooplankton richness. This may be because Qapchy Lake is located in the upper reaches of the Tekes River with snowmelt inflow and inherently low temperatures, resulting in naturally low zooplankton richness. Therefore, using diversity indices alone may overestimate the trophic status.

The comprehensive trophic state index, based on Chl a, showed that Qapchy Lake is in an oligotrophic to mesotrophic state with low eutrophication risk. Environmental factors clearly separated zooplankton abundance among hydrological periods, indicating that zooplankton in Qapchy Lake are significantly influenced by seasonal water quality changes. Dominant species abundance was correlated with water temperature, nutrients, and CODMn, demonstrating strong responses to water quality.

Water temperature not only affects zooplankton growth and reproduction but also influences feeding. Different zooplankton populations have different optimal pH requirements. *Tintinnopsis wangi* and *Centropyxis* sp. showed opposite pH preferences, with the former favoring lower pH and the latter favoring higher pH. Within suitable pH ranges, protozoan population growth rates are positively correlated with pH.

Nitrogen and phosphorus concentrations are key environmental factors affecting zooplankton species composition and abundance. Zooplankton serve as bioindicators of water status, with generally higher abundance in eutrophic than in oligotrophic waters. In this study, the protozoan dominant species *Tintinnopsis wangi* was positively correlated with TP and PO_4^{3-}-P, while *Centropyxis* sp. was negatively correlated with TN and NO_3^--N, consistent with findings from Tangpu Reservoir.

5. Conclusion

1. A total of 37 zooplankton species were identified across 10 monitoring sections, including 17 protozoa, 10 rotifers, 4 cladocerans, and 6 copepods. Dominant species included *Strobilidium* sp., *Centropyxis* sp., *Tintinnopsis wangi*, *Synchaeta* sp., and *Polyarthra vulgaris*.

2. RDA analysis revealed that water temperature, CODMn, and nutrient salts (NO_3^--N, NO_2^--N, NH_4^+-N, PO_4^{3-}-P) significantly influenced zooplankton community structure changes in Qapchy Lake.

3. Both biodiversity indices and comprehensive trophic state index indicated that Qapchy Lake is in an oligotrophic to mesotrophic state with low eutrophication risk. The water environment of this upper Ili River reservoir is minimally disturbed by human activities such as grazing and cultiva-

tion, maintaining relatively good conditions suitable as a habitat for fish spawning and reproduction.

References

[1] Ye L, Chang C, García Comas C, et al. Increasing zooplankton size diversity enhances the strength of top-down control on phytoplankton through diet niche partitioning[J]. *Journal of Animal Ecology*, 2013, 82(5): 1052-1061.

[2] Thompson P L, Davies T J, Gonzalez A. Ecosystem functions across trophic levels are linked to functional and phylogenetic diversity[J]. *PLoS One*, 2015, 14(7): e0220213, doi: 10.1371/journal.pone.0220213.

[3] Johnson C L, Runge J A, Curtis K A, et al. Biodiversity and ecosystem function in the gulf of Maine: Pattern and role of zooplankton and pelagic nekton[J]. *PLoS One*, 2011, 6(1): e16491, doi: 10.1371/journal.pone.0016491.

[4] Li Y, Chen F. Are zooplankton useful indicators of water quality in subtropical lakes with high human impacts?[J]. *Ecological Indicators*, 2020, 113: 106167, doi: 10.1016/j.ecolind.2020.106167.

[5] Jeppesen E, Nõges P, Davidson T A, et al. Zooplankton as indicators in lakes: A scientific based plea for including zooplankton in the ecological quality assessment of lakes according to the European Water Framework Directive (WFD)[J]. *Hydrobiologia*, 2011, 676(1): 1-9.

[6] Yang X, An D, Zhou H, et al. Daily variation of winter precipitation in Ili River Valley of Xinjiang from 2012 to 2017[J]. *Journal of Glaciology and Geocryology*, 2020, 42(2): 609-619.

[7] Aibibulla T, Abdushalik N, Kurban A. Evaluation of the status quo of animal and plants resources after reservoir construction in Turks River and protection measures[J]. *Journal of Anhui Agricultural Sciences*, 2011, 39(27): 16688-16690.

[8] Barbarossa V, Schmitt R J P, Huijbregts M A J, et al. Impacts of current and future large dams on the geographic range connectivity of freshwater fish worldwide[J]. *Proceedings of the National Academy of Sciences*, 2020, 117(7): 3648-3655.

[9] Li J, Liu Y, Liu S, et al. Main problems and countermeasures of reservoir dam construction in Xinjiang in the new period[J]. *Arid Land Geography*, 2020, 43(6): 1409-1416.

[10] Fishery Expedition Team of Chinese Academy of Sciences. *Hydrobiological Resources and Fishery Development in Xinjiang*[M]. Beijing: Science Press, 1989.

[11] Wu L, Feng W, Chen X, et al. Community structure characteristics of zooplankton in Yili Region of Xinjiang in summer[J]. *Chinese Journal of Applied*

Ecology, 2008, 19(1): 163-172.

[12] Yin J, Xu Y. Analysis of climate change characteristics in Yili Valley[J]. *Desert and Oasis Meteorology*, 2007, 1(6): 20-23.

[13] SC/T 9102.3-2007. *The Specification for Ecological Environment Monitoring of Fisheries, Part 3: Freshwater*[S]. Beijing: China Agriculture Press, 2007.

[14] Zhang Z, Huang X. *Research Methods for Freshwater Plankton in China*[M]. Beijing: Science Press, 1991.

[15] Wang J. *Freshwater Rotifers in China*[M]. Beijing: Science Press, 1961.

[16] Jiang X, Du N. *Fauna Sinica: Arthropoda, Crustacea, Freshwater Cladocera*[M]. Beijing: Science Press, 1979.

[17] Shen J. *Fauna Sinica: Arthropoda, Crustacea, Freshwater Copepoda*[M]. Beijing: Science Press, 1979.

[18] Shen Y, Zhang Z, Gong X, et al. *Modern Biomonitoring Techniques Using Freshwater Microbiota*[M]. Beijing: China Architecture & Building Press, 1990.

[19] State Environmental Protection Administration. *Monitoring and Analysis Methods for Water and Wastewater*[M]. 4th ed. Beijing: China Environmental Science Publishing House, 2002.

[20] Jin X, Tu Q. *Lake Eutrophication Investigation Specification*[M]. 2nd ed. Beijing: China Environment Science Press, 1990.

[21] Wei H. Plankton composition and primary productivity in Shuifeng Reservoir[J]. *Chinese Journal of Fisheries*, 2021, 34(1): 73-80.

[22] Ren M, Guo Y, Zhang Q, et al. *Fisheries Resources and Fishery of River Yili*[M]. Harbin: Heilongjiang Science and Technology Press, 1998.

[23] Bai L, Zhang Z, Wang L, et al. Analysis of plankton community and fishery resources in Xiangshui Reservoir[J]. *Journal of Dalian Ocean University*, 2020, 35(2): 280-287.

[24] Yuan L, Sun L, Zhu X, et al. Ecological features of zooplankton community of Hongshan Reservoir in Xinjiang[J]. *Arid Land Geography*, 2011, 34(6): 1002-1008.

[25] Lü Q, Hu X, Nie X, et al. Impact of water fluctuations on the succession of zooplankton in Poyang Lake[J]. *Acta Ecologica Sinica*, 2020, 40(4): 1486-1495.

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

[27] Gui P, Yu F, Wei J. The spatial-temporal distribution characteristics of zooplankton in Queshan Reservoir[J]. *Ecological Science*, 2019, 38(2): 199-205.

[28] Hu Y, Li Q, He Y, et al. Spatial and temporal distribution characteristics and influencing factors of metazooplankton in Aha Reservoir, Guizhou Province[J]. *China Environmental Science*, 2020, 40(1): 227-236.

[29] Romare P, Berg S, Lauridsen T, et al. Spatial and temporal distribution of fish and zooplankton in a shallow lake[J]. *Freshwater Biology*, 2003, 48(8): 1353-1362.

[30] Haberman J, Haldna M. How are spring zooplankton and autumn zooplankton influenced by water temperature in a polymictic lake?[J]. *Proceedings of the Estonian Academy of Sciences*, 2017, 66(3): 264-278.

[31] Luo X. Analysis of variation on temperature and precipitation in recent 52 years and future projection in Jimunai County, Xinjiang[J]. *Chinese Agriculture Science Bulletin*, 2014, 30(5): 297-302.

[32] Li Y, Li Q, Chen W, et al. Dynamic changes of metazooplankton community structure in Sanbanxi Reservoir, Guizhou Province[J]. *Journal of Lake Sciences*, 2016, 28(2): 340-349.

[33] Wu L, Tang H, Gong Y, et al. Temporal-spatial distribution of zooplankton community in the main stem of Three Gorges Reservoir under normal operation[J]. *Journal of Hydroecology*, 2021, 42(1): 58-65.

[34] Loiterton B, Sundbom M, Vrede T. Separating physical and physiological effects of temperature on zooplankton feeding rate[J]. *Aquatic Sciences*, 2004, 66(1): 123-129.

[35] Lu J, Zhang H, Li D, et al. Population growth and production estimation of planktonic ciliates in an experimental ecosystem of a shrimp pond[J]. *Journal of Fishery Sciences of China*, 1997, 4(5): 50-54.

[36] Burns C W, Galbraith L M. Relating planktonic microbial food web structure in lentic freshwater ecosystems to water quality and land use[J]. *Journal of Plankton Research*, 2007, 29(2): 127-139.

[37] Hu J, Liang L, Chi S, et al. Effects of environmental factors on the protozoan community in a water supply reservoir[J]. *Journal of Hydroecology*, 2019, 40(4): 30-41.

[38] Li X. Bank erosion and collapse of Qapchy Reservoir and its protective measures[J]. *Technical Supervision in Water Resources*, 2017, 25(6): 158-159.

[39] Mi G, Yan X, Zhang X, et al. Construction and planning of facility fishery in Qapchy Lake[J]. *Water Resources and Hydropower Engineering*, 2006, 37(11): 115-116.

[40] Kuang Q, Ma P, Hu Z, et al. Study on the evaluation and treatment of lake eutrophication by means of algae biology[J]. *Journal of Safety and Environment*, 2005, 5(2): 87-91.

Note: Figure translations are in progress. See original paper for figures.