Dynamic Characteristics of Rotifer Diversity and Community in the Pelagic Zone of Liuxihe Reservoir: Postprint

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Abstract

Liuxihe Reservoir is a large canyon-type water supply reservoir situated on the Tropic of Cancer. From 2013 to 2014, observations were conducted on the rotifer community and its environmental factors in the pelagic zone of this reservoir to analyze the diversity and community dynamics characteristics of rotifers in the pelagic zone. Liuxihe Reservoir ranges between oligotrophic and mesotrophic levels. Total phosphorus and transparency during the wet season (May-September) were both higher than during the dry season (October-April). The two-year average of total phosphorus was 0.019 mg/L, and transparency was 2.55 m. A total of 40 rotifer species were identified over the two years. The number of species detected per month fluctuated between 8-19, with an average of 13 rotifer species detected monthly. Keratella cochlearis, Polyarthra euryptera, Pompholyx sulcata, and Collotheca spp. were the dominant rotifer species. The annual mean total abundance of rotifers was 68.9 and 66.9 individuals/L in 2013 and 2014, respectively. Species richness was greater during the wet season than the dry season in both years, but the Simpson diversity index of the rotifer community was greater during the dry season than the wet season. Using Bray-Curtis distance to measure dissimilarity between communities, calculations showed that the average distance between rotifer communities during the dry season was greater than that during the wet season in both years, indicating higher similarity among rotifer communities during the wet season and greater variation during the dry season. The relatively stable changes in water temperature and water quality parameters during the wet season, along with more pronounced species dominance, resulted in greater similarity among communities during this period. Principal component analysis indicated that the major species of the genera Floscularia, Collotheca, Polyarthra, Trichocerca, Pompholyx, Asplanchna, and Ploesoma showed substantial differences in their annual distribution, while most other rotifer species showed minor differences

in their annual distribution, reflecting that the small annual temperature variation in the subtropical region of southern China can maintain the coexistence of many perennial species. Variance partitioning and RDA analysis of the community indicated that, relative to biological and chemical variables, physical environmental variables dominated the variation in the rotifer community in the pelagic zone of Liuxihe Reservoir. In terms of individual variables, water temperature and food were important factors affecting the structure of the rotifer community in the pelagic zone of Liuxihe Reservoir, while rainfall was a macroscale factor influencing variation in rotifer community structure. The vast majority of rotifers are filter-feeding, occupy the bottom of the food chain, are small in size, and have short life cycles. Rotifer communities exhibit similarities to phytoplankton in their response to changes in environmental factors.

Full Text

Preamble

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Rotifer Species Diversity and Community Structure in the Pelagic Zone of the Liuxihe Reservoir

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Abstract

The Liuxihe Reservoir is a large canyon-type drinking water reservoir located on the Tropic of Cancer in Guangdong Province. We investigated rotifer community dynamics and environmental variables monthly in the pelagic zone from 2013 to 2014. Using the R language platform (MASS, vegan, and packfor packages), we analyzed species diversity and community structure. The reservoir is an oligotrophic to mesotrophic water body, with annual average total phosphorus of 0.019 mg/L and water transparency of 2.55 m. Both total phosphorus and transparency were slightly higher in wet seasons (May to September) than in dry seasons (October to April). During the two-year investigation, 40 species were observed, with monthly species richness ranging from 8 to 19 (average 13). Dominant species included *Keratella cochlearis*, *Polyarthra euryptera*, *Pompholyx sulcata*, and *Collotheca* sp. Species richness was higher in wet seasons, while the Simpson diversity index showed the opposite pattern. Average total abundance was 68.9 and 66.9 individuals/L in 2013 and 2014, respectively. The average Bray-Curtis community distance was higher in dry seasons, indicating greater community similarity in wet seasons. Water temperature and other water quality variables were more stable during wet seasons, resulting in stronger species dominance and more similar rotifer communities. Principal component analysis revealed that *Ascomorpha*, *Asplanchna*, *Trichocerca*, *Pompholyx*, *Polyarthra*, *Collotheca*, and *Ploesoma* showed significant temporal variation. This rotifer community structure is representative of tropical and subtropical China, where smaller water temperature fluctuations allow more species to persist year-round. Variation partitioning and redundancy analysis (RDA) demonstrated that physical environmental variables (temperature, dissolved oxygen, Secchi depth, precipitation, and water retention time) explained community variance. Among all measured variables, water temperature and food availability were the two key factors explaining community structure variation, while precipitation was a macroscopic indirect factor affecting rotifer community variation. Most rotifer species are filter feeders at low trophic levels with small body sizes and short life spans, and their communities responded to environmental variation similarly to phytoplankton communities.

Keywords: rotifer community; species diversity; dynamic characteristics; community structure; Liuxihe Reservoir

Introduction

Rotifers are an important group of freshwater zooplankton that serve as a critical link in aquatic food webs and contribute significantly to secondary productivity. They play a vital role in connecting microbial loops to higher trophic levels [1-2]. Rotifer communities respond rapidly to environmental changes, making them valuable indicator species for water quality assessment [3-4]. Environmental factors including temperature, nutrient status, dissolved oxygen, and food availability are recognized as important influences on rotifer communities [5-7].

Reservoirs are semi-artificial water bodies formed by damming rivers in watersheds. Compared to natural water bodies such as rivers and lakes, reservoirs have unique characteristics in morphology, flow velocity, and depth, representing a special ecosystem type intermediate between rivers and lakes [8-9]. Canyon-type reservoirs, built in canyon regions, are primarily influenced by inflow from rainfall and water discharge regulation. For reservoirs, integrated environmental factors and relatively short hydraulic retention time are important influences on rotifer communities [10-11]. In China' s tropical and subtropical transition zones, wind has weak influence on water flow fields, while reservoir hydrodynamics and hydrological processes are significantly affected by seasonal rainfall patterns under monsoon climate influence. Rainfall-driven hydrological changes are considered macroscopic factors affecting reservoir rotifer community composition and dynamics [12-13].

Based on rainfall amount, the year is typically divided into two hydrological phases: wet season and dry season [14]. In southern China, the wet season begins in May. Increased rainfall raises water levels and brings inorganic and organic materials from the watershed into the reservoir via inflowing rivers, increasing suspended solids and decreasing transparency during early wet season, which reduces primary productivity and drives periodic ecosystem succession.

Canyon-type reservoirs show distinct habitat zonation from inflow rivers to the dam, with typical riverine, transition, and lacustrine zones. The lacustrine zone constitutes the main component of the pelagic zone, which refers to the open water area and represents the primary habitat type in tropical and subtropical reservoirs influenced by summer monsoons [13]. The pelagic zone has relatively stable water conditions, higher transparency than other areas, and nutrient cycling strongly influenced by biological communities themselves. Biological interactions such as interspecific competition among zooplankton and visually-guided predation pressure play more important roles in regulating community structure and dynamics.

Among zooplankton, rotifers are the smallest group. Most rotifers are herbivorous and sensitive to changes in phytoplankton communities driven by nutrient dynamics, so rotifer community changes largely reflect their responses to environmental conditions. The Liuxihe Reservoir (23°45 N, 113°46 E) is located in the tropical-subtropical transition zone and has a relatively stable pelagic zone, making it an ideal site for studying seasonal succession and patterns in zooplankton communities [15]. This study uses the Liuxihe Reservoir as a case study to investigate rotifer diversity and community dynamics in the pelagic zone of a large canyon-type reservoir under subtropical monsoon influence through monthly sampling and environmental monitoring from 2013-2014. The objectives are to analyze rotifer community structure characteristics and identify the main factors influencing rotifer diversity and community dynamics in large canyon-type reservoirs, providing a basis for ecological monitoring and water quality management in tropical and subtropical reservoirs.

1. Materials and Methods

1.1 Study Reservoir and Sampling

The Liuxihe Reservoir is an important drinking water source for Guangzhou City, formed by the confluence of two inflow rivers. It is a typical canyon-type reservoir under subtropical monsoon climate control with distinct dry (October-December) and wet seasons. The reservoir is currently in an oligotrophic to mesotrophic state, with phytoplankton dominated by dinoflagellates and diatoms, and fish populations dominated by silver carp and bighead carp [12, 16-17].

The sampling site was established at the reservoir dam in the pelagic zone (DB), which can well represent conditions in the reservoir' s open water area. Monthly sampling was conducted at the pelagic zone site from 2013 to 2014, with regular sampling except during strong typhoons. According to weather forecasts, sampling was completed before strong typhoons or heavy rains.

Qualitative zooplankton samples were collected by oblique tows using a plankton net with 64 m mesh size. Quantitative samples were collected using a water sampler at uniform intervals from surface to bottom according to field depth, then filtered through a 64 m plankton net with a filtered volume of 20 L. Zooplankton quantitative samples were fixed with formalin on site. Samples were identified and counted under a microscope following the classification system of Koste [18]. The March 2013 sample was missing.

During field sampling, environmental parameters including water temperature (Temp) and dissolved oxygen (DO) were recorded using a YSI multiparameter water quality meter. Water transparency (SD) was measured using a Secchi disk. Water samples were collected to measure total nitrogen (TN), nitrate nitrogen (NO3-N), nitrite nitrogen (NO2-N), ammonium nitrogen (NH4-N), total phosphorus (TP), phosphate phosphorus (PO4-P), and chlorophyll a (Chla). Chlorophyll a was extracted using repeated freeze-thaw methods [18]. Precipitation data were provided by the Liuxihe Power Generation Company. Water retention time (WRT) was approximated as the ratio of monthly reservoir capacity to monthly discharge volume.

1.2 Data Processing and Analysis

Data processing was performed using the R language platform and Excel. The Simpson diversity index was used to represent rotifer community species diversity. Community data analysis used the vegan package in R. Rotifer abundance data were preprocessed using Hellinger transformation before analysis.

Forward selection was used to remove autocorrelated variables and screen for environmental variables with significant effects on rotifer community structure. Variation partitioning analysis was applied to separate biological/chemical variables (dissolved inorganic nitrogen, chlorophyll a) from physical variables (temperature, precipitation, water retention time). Nonmetric multidimensional scaling (NMDS) was performed using Bray-Curtis distance. Stepwise regression was used to screen environmental variables with significant effects on total rotifer abundance.

2. Results

2.1 Physicochemical Indicators

In 2013 and 2014, total phosphorus and transparency in the Liuxihe Reservoir pelagic zone were higher in wet seasons than dry seasons. Total nitrogen and chlorophyll a concentrations showed random patterns between wet and dry seasons, with 2013 wet season values greater than dry season, while 2014 showed the opposite pattern (Figure 2).

2.2 Community Composition and Diversity

A total of 40 rotifer species were detected during the two-year study period. The main dominant species were *Keratella cochlearis*, *Polyarthra euryptera*, *Pompholyx sulcata*, and *Collotheca* sp. Monthly species richness ranged from 8 to 19, with higher richness in wet seasons than dry seasons in both years. However, the Simpson diversity index showed the opposite pattern, with higher values in dry seasons (0.71 and 0.56 in 2013 and 2014 dry seasons, respectively) compared to wet seasons (0.61 and 0.53, respectively) (Figure 3).

Stepwise regression of rotifer species richness indicated that richness was significantly related to total nitrogen, dissolved inorganic nitrogen, water temperature, and precipitation (Table 2).

2.3 Total Abundance and Dominant Species Dynamics

Average total rotifer abundance was 68.9 individuals/L in 2013 and 66.9 individuals/L in 2014. The timing of maximum abundance differed between years. Stepwise regression analysis showed that 2013 total abundance was related to all environmental factors except chlorophyll a concentration, while 2014 abundance was related to total nitrogen, dissolved inorganic nitrogen, dissolved oxygen, and transparency. Combined two-year abundance was related to total phosphorus and precipitation. Wet season abundance was related to total phosphorus, dissolved inorganic nitrogen, dissolved oxygen, and transparency (Table 3).

Dominant species showed seasonal distribution patterns, though peak timing varied between years. *Keratella cochlearis* was the absolute dominant species from January to March, declined rapidly in April, and showed no clear dominance from May to August. In 2013, *Pompholyx sulcata* and *Polyarthra euryptera* became dominant in May, while in September-October, *Pompholyx sulcata* and *Keratella cochlearis* were dominant. In 2014, *Polyarthra euryptera* peaked in January and became dominant, while *Pompholyx sulcata* dominated from March to May (Figures 4 and 5).

2.4 Community Structure Variation

Principal component analysis showed that *Trichocerca*, *Pompholyx*, *Ascomorpha*, *Asplanchna*, *Collotheca*, *Polyarthra*, and *Ploesoma* had large annual distribution differences, while most other species clustered near the origin, indicating smaller annual variation. The two principal axes explained 35.8% of community structure variation (cumulative eigenvalue). Among dominant species, only *Keratella cochlearis* showed relatively small annual variation, while other dominant species showed clear seasonal patterns.

NMDS analysis had a stress value of 0.198, indicating that community structure could not be well represented by few dimensions. Wet season sampling points distributed along axis 1, while dry season points distributed along axis 2, reflecting hydrological seasonality. Average Bray-Curtis distances within wet and dry seasons were 0.47 and 0.65 in 2013, and 0.55 and 0.66 in 2014, respectively. Dry season average distances were greater than wet season, indicating higher community similarity during wet seasons and greater variation during dry seasons (Figure 7).

Redundancy analysis with forward selection retained 8 significant variables from 12 environmental factors: precipitation, water retention time, temperature, dissolved oxygen, total nitrogen, dissolved inorganic nitrogen, phosphate, and chlorophyll a. The first two RDA axes explained 26.4% of community variation. Variation partitioning showed that physical variables (temperature, precipitation, water retention time) explained more community variation than biological/chemical variables. Physical variables dominated rotifer community structure variation in the Liuxihe Reservoir pelagic zone (Figure 8).

3. Discussion

Under subtropical monsoon climate influence, total phosphorus and transparency were higher in wet seasons than dry seasons. In southern China, increased rainfall during wet seasons brings abundant nitrogen and phosphorus from watershed soils into reservoirs. Water level changes directly affect transparency and chlorophyll a concentration, causing periodic ecosystem succession. From a physicochemical perspective, total nitrogen and chlorophyll a showed random patterns between seasons. Zooplankton abundance is generally low in the Liuxihe Reservoir pelagic zone, with rotifers being one of the dominant groups [19]. Rotifer community abundance and species composition respond to water quality changes, with species composition shifting when nutrient levels increase [20-22].

The Simpson diversity index and species richness showed different patterns between wet and dry seasons, as did average community distance, demonstrating rotifer community responses to these two hydrological phases. Precipitation and chlorophyll a were important factors influencing community structure. In southern China reservoirs, predation pressure typically affects rotifer communities, with filter-feeding fish exerting important top-down effects on zooplankton [23-25]. Water temperature can indirectly regulate fish predation intensity on rotifers and affect phytoplankton growth and density, thereby influencing food supply. Temperature also directly affects rotifer growth and reproduction. Thus, temperature is a key factor structuring rotifer communities in the Liuxihe Reservoir pelagic zone.

Food availability is another important factor [26-28]. Chlorophyll a reflects food levels to some extent. Variation partitioning showed food was a key factor, consistent with RDA results where forward selection retained more physical than biological/chemical variables. In natural waters, rotifer communities are strongly affected by physical disturbances such as rainfall and water exchange, which can cause community structure changes. Rainfall-driven hydrological changes are considered important factors affecting spatiotemporal variation in zooplankton diversity and community structure [13, 29-30].

Ascomorpha and *Ploesoma* showed large annual distribution differences, while other species showed smaller differences. Among dominant species, *Pompholyx sulcata*, *Collotheca* sp., and *Polyarthra euryptera* showed large annual variation, appearing mainly in wet seasons for the former two and dry seasons for the latter. This indicates rainfall has different effects on different rotifer species, serving as a macroscopic variable affecting community variation.

In summary, the Liuxihe Reservoir pelagic zone rotifer community shows distinct characteristics in Simpson diversity index, species richness, and average community distance between wet and dry seasons, reflecting responses to these hydrological phases. Physical environmental variables dominate community structure variation, with water temperature and food being key factors, while precipitation is a macroscopic variable affecting community variation.

References

[1] Wallace RL, Snell TW, Ricci C, Nogrady T. Rotifera vol. 1: biology, ecology and systematic // Segers H, Dumont HJ eds. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World 23. 2nd ed. Leiden: Backhuys Publishers, 2006: 1-299.

[2] Sharma BK. Rotifer communities of Deepor Beel, Assam, India: richness, abundance and ecology. Journal of Threatened Taxa, 2010, 2(8): 1077-1086.

[3] Gannon JE, Stemberger RS. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. Transactions of the American Microscopical Society, 1978, 97(1): 16-35.

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

[5] Castro BB, Antunes SC, Pereira R, Soares AVMM, Gonçalves F. Rotifer community structure in three shallow lakes: seasonal fluctuations and explanatory factors. Hydrobiologia, 2005, 543(1): 221-232.

[6] [Chinese reference on Hongze Lake rotifer community structure and environmental factors, 2014, 26(2): 269-276]

[7] Devetter M. Influence of environmental factors on the rotifer assemblage in an artificial lake. Hydrobiologia, 1998, 387/388(0): 171-178.

[8] [Chinese reference on reservoir ecosystem characteristics and water quality management applications, 2001, 21(6): 1034-1040]

[9] [Chinese reference on review and prospects of reservoir ecology research in China, 2010, 22(2): 151-160]

[10] [Chinese reference on rotifer community structure in Xikeng Reservoir, 2013, 34(6): 27-33]

[11] [Chinese reference on effects of hydraulic retention time on rotifer community structure in Zhuhai water transfer reservoirs, 2015, 21(3): 499-504]

[12] [Chinese reference on metazooplankton diversity and community structure in Liuxihe Reservoir, 2007]

[13] [Chinese reference on zooplankton community structure and seasonal variation in tropical eutrophic reservoirs, 2015, 27(6): 1049-1058]

[14] Han BP, Liu ZW. Tropical and Sub-Tropical Reservoir Limnology in China: Theory and Practice. New York: Springer, 2012: v-vi.

[15] [Chinese reference on interspecific relationships in Liuxihe Reservoir zooplankton community, 2010]

[16] [Chinese reference on spatiotemporal dynamics of limnological variables in Liuxihe Reservoir, 2009, 21(3): 387-394]

[17] [Chinese reference on comparison of phytoplankton community and succession mechanisms in two large reservoirs in South China, 2011]

[18] [Chinese reference on comparison and improvement of chlorophyll a extraction methods from phytoplankton, 2005, 24(1): 9-11]

[19] Lin QQ, Duan SS, Hu R, Han BP. Zooplankton distribution in tropical reservoirs, South China. International Review of Hydrobiology, 2003, 88(6): 602-613.

[20] Du X, Feng WS, Li W, Ye SW, Liu JS, Zhang TL, Li ZJ. Response of rotifer community to environmental changes in five shallow lakes in the middle reach of Changjiang River, China. Chinese Journal of Oceanology and Limnology, 2014, 32(5): 1083-1091.

[21] May L, Spears BM, Dudley BJ, Gunn IDM. The response of the rotifer community in Loch Leven, UK, to changes associated with a 60% reduction in phosphorus inputs from the catchment. International Review of Hydrobiology, 2014, 99(1-2): 65-71.

[22] [Chinese reference on rotifer distribution characteristics in Guangdong reservoirs, 2005, 25(5): 1123-1131]

[23] Devetter M, Sed' a J. Regulation of rotifer community by predation of *Cyclops vicinus* (Copepoda) in the Římov reservoir in spring. International Review of Hydrobiology, 2006, 91(1): 101-112.

[24] Lin QQ, Jiang XJ, Han BP, Jeppesen E. Does stocking of filter-feeding fish for production have a cascading effect on zooplankton and ecological state? A study of fourteen (sub)tropical Chinese reservoirs with contrasting nutrient concentrations. Hydrobiologia, 2014, 736(1): 115-125.

[25] Zhao SY, Sun YP, Han BP. Top-down effects of bighead carp (*Aristichthys nobilis*) and *Leptodora richardi* (Haplopoda, Leptodoridae) in a subtropical reservoir during the winter-spring transition: a mesocosm experiment. Hydrobiologia, 2016, 765(1): 43-54.

[26] Wang SB, Geng H. Forces driving the seasonal changes of a rotifer community in a eutrophic Chinese lake. Resources and Environment in the Yangtze Basin, 2013, 22(3): 343-352.

[27] Baião C, Boavida MJ. Environmental factors determining the structure of rotifer communities in a river-shed reservoir. Aquatic Ecology, 2000, 34(4): 369-377.

[28] Špoljar M, Habdija I, Primc-Habdija B, Sipos L. Impact of environmental variables and food availability on rotifer assemblage in the karstic barrage Lake Visovac (Krka River, Croatia). International Review of Hydrobiology, 2005, 90(5-6): 555-579.

[29] Choi JY, Jeong KS, Joo GJ. Rainfall as dominant driver of rotifer dynamics in shallow wetlands: evidence from a long-term data record (Upo Wetlands, South Korea). International Review of Hydrobiology, 2015, 100(1): 21-33.

[30] Offem BO, Samsons YA, Omoniyi IT, Ikpi GU. Dynamics of the limnological features and diversity of zooplankton populations of the Cross River System SE Nigeria. Knowledge and Management of Aquatic Ecosystems, 2009, 393(2): 1-19.

Figures

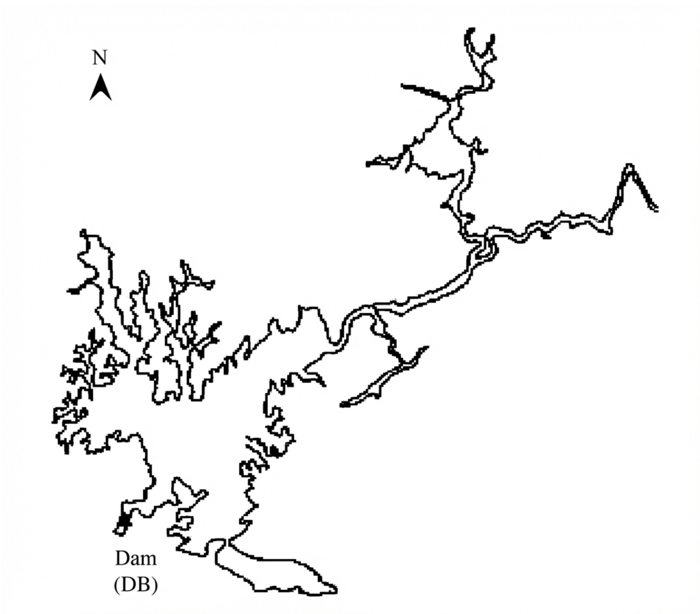

Figure 1: Figure 1

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