Community structure of two rotifer populations and ecological assessment of water quality in Miyun Reservoir

Jiangqi Qu 1, Runjing Xu 1, Haochen Yang 1,2, Yichao Li 2, Xudong Shao 2, Qing Liu 2, and Qingjing Zhang 1*

1 Department of Fisheries Ecology and Environmental, Beijing Key Laboratory of fishery Biotechnology, Beijing Fisheries Research Institute, Beijing, China
2 Dalian Ocean University, Dalian, China
*Corresponding author’s e-mail:Zhangqingjing@bjfishery.com.cn

Abstract. In order to understand the changes in the ecological environment of Miyun Reservoir after the South-to-North Water Transfer Project, our study investigated the changes in the composition and structure of two indicator species in the Miyun Reservoir and applied the rotifer biological assessment method to analyse the changes of water ecological environment. Our results showed that a total of 10 species of the genera Trichocerca and Brachionus were identified during the investigation with an average annual abundance of 542.124 ind./L and 102.68 ind./L, respectively. Among them, T. pusilla and T. cylindrica were the dominant species of the genus Trichocerca, and the majority of Brachionus species were B. diversicornis, B. angularis, B. caudatus. Variance results showed that there were significant differences in the abundance of these two rotifer populations at different inter-annual and spatial scales during the survey. The biological evaluation indicated that the water quality has gradually changed from eutrophication to oligotrophication after the South-to-North Water Transfer Project, and the ecological environment was maintained well. Our results will provide necessary ecological parameters for water environment protection and ecological safety management of Miyun Reservoir.

1. Introduction
Zooplankton is an important aspect of the water ecosystem[1]. It is not only an essential food organism for filter-feeding fish but also a predator of small algae and microbes[2]. Rotifers are sensitive to environmental changes due to their rapid reproduction rate, short growth and development time, high food conversion efficiency, and the considerable number of fertile eggs[3]. Therefore, as a good environmental indicator, they can timely reflect the changes in water quality and the nutritional status of water bodies and are widely used in the detection and ecological evaluation[4]. The genus Brachionus often indicates eutrophic water bodies with rich organic matter[5], while the genus Trichocerca rotifer usually indicates oligotrophic water[6]. In recent years, the rotifer biological evaluation method based on the ratio of these two rotifer species proposed by Sládeček[7] has been widely used in water environment assessment.

Miyun Reservoir is one of the most important waters receiving areas in the middle route of the South-to-North Water Diversion Project[8]. Since Danjiangkou Reservoir and Miyun Reservoir are located in two different ecological geographical locations in the north and south of China, the water transfer will certainly have some ecological impact on the original water area ecological environment. Therefore, this study investigated the population structure of these two species of rotifers in Miyun Reservoir and...
evaluated how the ecological environment of Miyun Reservoir changed after the South-to-North Water Transfer from the perspective of ecology, so as to provide a scientific basis for water reservoir environmental protection and ecological safety management.

2. Materials and Methods

2.1. Sample collection and identification
Seven sampling sites were set in Miyun Reservoir, which was CHK, CHB, KZX, JG, YL, BHK and BHB. During the investigation, the regular collection was conducted once a month. Samples were collected, fixed, species identification and community analysis by the technical specifications of freshwater plankton investigation.

2.2. Biological evaluation methods
Rotifer biological evaluation index[7]: \( Q_{BT} = \frac{\text{total numbers of } Brachionus \text{ species}}{\text{total numbers of } Trichocerca \text{ species}} \). \( Q_{BT} < 1.0 \) for oligotrophic type; \( 1.0 < Q_{BT} < 2.0 \) for mesotrophic type; \( Q_{BT} > 2.0 \) for eutrophic type.

2.3. Statistical analysis methods
Excel 2010 and SPSS v23 were used for data statistics and variance analysis.

3. Results

3.1. Characteristics of rotifer community composition
As shown in Table 1, during the investigation, 10 species of the genus Trichocerca were identified. The identified species \( T. \text{pusilla} \) and \( T. \text{cylindrica} \) had the highest frequency. We also identified 10 species of the genus Brachionus. Among them, \( B. \text{diversicornis} \), \( B. \text{angularis} \), \( B. \text{caudatus} \), and \( B. \text{falcatus} \) appeared most frequently during the survey.

| Genus Trichocerca          | Genus Brachionus          |
|----------------------------|---------------------------|
| \( T. \text{spp.} \)       | \( B. \text{diversicornis} \) |
| \( T. \text{pusilla} \)    | \( B. \text{spp.} \)      |
| \( T. \text{longiseta} \)  | \( B. \text{forficula} \) |
| \( T. \text{elongata} \)   | \( B. \text{calyciflorus} \) |
| \( T. \text{capucina} \)   | \( B. \text{angularis} \) |
| \( T. \text{disonnuttalli} \) | \( B. \text{urceolaris} \) |
| \( T. \text{rousseleti} \)  | \( B. \text{rubens} \)   |
| \( T. \text{similis} \)    | \( B. \text{caudatus} \)  |
| \( T. \text{cylindrica} \) | \( B. \text{falcatus} \)  |
| \( T. \text{bicristata} \) | \( B. \text{budapestiensis} \) |

3.2. Temporal and spatial changes of rotifer population structure
As shown in Figure 1., the annual average abundance of genus Trichocerca was 542.124 ind./L. The species \( T. \text{pusilla} \) and \( T. \text{cylindrica} \) were the most abundant species. The variance results showed that the density of genus Trichocerca during the investigation period has obvious differences in different inter-annual and spatial scales (P < 0.05).

As shown in Figure 2., the average annual abundance of genus Brachionus was 102.68 ind. /L. The more abundance of the genus Brachionus species was \( B. \text{diversicornis} \), \( B. \text{angularis} \) and \( B. \text{caudatus} \). The variance results showed that there were significant differences in the density of the genus Brachionus at different inter-annual and spatial scales during the survey (P<0.05).
3.3. Rotifer biological evaluation

As shown in Table 2, the QB/T ratio range was from 0.16 to 3.7. The results of the biological evaluation index showed that the water body of Miyun reservoir was eutrophication at the initial stage of water transfer. With the continuous water transfer, the water body of the reservoir gradually changed from eutrophication to oligotrophication state.

| Years | 2016 | 2017 | 2018 | 2019 | 2020 |
|-------|------|------|------|------|------|
| Total Numbers of T. | 21   | 31   | 6    | 35   | 33   |
| Total Numbers of B. | 79   | 46   | 1    | 13   | 7    |
| QB/T Values | 3.761 | 1.48 | 0.16 | 0.371 | 0.2 |

4. Discussion

In this paper, the results showed that the community of the genus Brachionus and Trichocerca had obvious temporal changes in Miyun Reservoir. The higher abundance of these two species of rotifer was from June to September. Previously reports indicated that the periodic and regional changes on the temporal scale led to significant differences in plankton population density[9]. Generally, the water temperature has a great influence on the density of the rotifer community[10]. Appropriate water temperature (> 20°C) has a great promotion on the growth, reproduction, and incubation of dormant eggs of rotifers[11]. In the early stage of the South-to-North Water Transfer Project, the unstable water
environment led to the low abundance of the two species of rotifers, while the density of both rotifers increased as the water quality gradually stabilized. Moreover, the habitat environment of the sampling sites may be the main factor for the significant difference in the abundance of the two rotifers on the spatial scale[12]. For example, the sampling site CHK is located at the upstream inlet, with large water flow and frequent water agitation after water diversion. However, the sampling site YL was originally shallow water with abundant aquatic plants, which died out after the diversion. Therefore, these changes in the water environment and habitat had a greater impact on the growth and reproduction of rotifers and the development of pregnant eggs.

Rotifers have a strong sensitivity to environmental changes[13]. The index Q_{BT} showed that the water quality state was a eutrophication state at the initial stage of water transfer. As the reservoir capacity increased, the capacity of the water body was also continuously strengthened[14]. Some species suitable for living in nutrient-rich and poor-nutrient waters have the characteristics of fast reproduction speed and short generation time[15]. The growth rate of these species is greater than the average level of the population, and they occupy the niche of those sensitive species[16]. As a result, the water quality had changed from a eutrophication state to oligotrophication state. Our results suggesting that the bioindicator Q_{BT} based on the rotifer population structure changes is suitable for water quality monitoring and ecological environment assessment of water source reservoirs.

5. Conclusion
Rotifers as an important indicator organism for water quality evaluation, their communities and structure were sensitive to ecological environment changes. Our results showed that the composition and abundance of these two rotifer species in Miyun Reservoir had undergone significant changes in the temporal and spatial scales after the water transfer. The changes in the water environment and habitat were the primary factors that caused the changes in the rotifer abundance. The rotifer biological index Q_{BT} showed that the nutrient level of the reservoir water body changed from eutrophication to oligotrophication state, and the water quality was improved after water transfer.

Acknowledgments
Beijing Academy of Agriculture and Forestry Sciences young scholar fund (QNJJ202020); Beijing modern agricultural industrial technology system project (BAIC08-2021).

References
[1] D. O. Hessen, T. C. Jensen, and B. Walseng, “Zooplankton Diversity and Dispersal by Birds; Insights From Different Geographical Scales,” Front. Ecol. Evol., vol. 7, 2019, doi: 10.3389/fevo.2019.00074.
[2] C. Scherer, A. Weber, S. Lambert, and M. Wagner, “Interactions of Microplastics with Freshwater Biota,” in Freshwater Microplastics: Emerging Environmental Contaminants?, M. Wagner and S. Lambert, Eds. Cham: Springer International Publishing, 2018, pp. 153–180. doi: 10.1007/978-3-319-61615-5_8.
[3] D. Liang, Q. Wang, N. Wei, C. Tang, X. Sun, and Y. Yang, “Biological indicators of ecological quality in typical urban river-lake ecosystems: The planktonic rotifer community and its response to environmental factors,” Ecological Indicators, vol. 112, p. 106127, May 2020, doi: 10.1016/j.ecolind.2020.106127.
[4] M. Kruk and E. Paturej, “Indices of trophic and competitive relations in a planktonic network of a shallow, temperate lagoon. A graph and structural equation modeling approach,” Ecological Indicators, vol. 112, p. 106007, May 2020, doi: 10.1016/j.ecolind.2019.106007.
[5] R. M. Moreno-Gutierrez, S. S. S. Sarma, A. S. Sobrino-Figueroa, and S. Nandini, “Population growth potential of rotifers from a high altitude eutrophic waterbody, Madín reservoir (State of Mexico, Mexico): The importance of seasonal sampling,” 2018, Accessed: Jun. 26, 2021. [Online]. Available: https://pubag.nal.usda.gov/catalog/6458501
[6] H.-J. Oh et al., “Comparison of taxon-based and trophi-based response patterns of rotifer community to water quality: applicability of the rotifer functional group as an indicator of water quality,” Animal Cells and Systems, vol. 21, no. 2, pp. 133–140, Mar. 2017, doi: 10.1080/19768354.2017.1292952.

[7] V. Sládeček, “Rotifers as indicators of water quality,” Hydrobiologia, vol. 100, no. 1, pp. 169–201, Jan. 1983, doi: 10.1007/BF00027429.

[8] L. Zhang, Z. Zou, and W. Shan, “Development of a method for comprehensive water quality forecasting and its application in Miyun reservoir of Beijing, China,” Journal of Environmental Sciences, vol. 56, pp. 240–246, Jun. 2017, doi: 10.1016/j.jes.2016.07.017.

[9] J. R. Woodward, J. W. Pitchford, and M. A. Bees, “Physical flow effects can dictate plankton population dynamics,” Journal of The Royal Society Interface, vol. 16, no. 157, p. 20190247, Aug. 2019, doi: 10.1098/rsif.2019.0247.

[10] J.-Y. Choi and S.-K. Kim, “Responses of Rotifer Community to Microhabitat Changes Caused by Summer-Concentrated Rainfall in a Shallow Reservoir, South Korea,” Diversity, vol. 12, no. 3, Art. no. 3, Mar. 2020, doi: 10.3390/d12030013.

[11] Y. Li, L. Liu, S. Cui, and F. Chen, “Long-term effects of nutrient changes on rotifer communities in a subtropical lake,” Limnology, vol. 20, no. 2, pp. 191–201, Apr. 2019, doi: 10.1007/s10201-018-0567-x.

[12] G. Chaparro, Z. Horváth, I. O’Farrell, R. Ptacnik, and T. Hein, “Plankton metacommunities in floodplain wetlands under contrasting hydrological conditions,” Freshwater Biology, vol. 63, no. 4, pp. 380–391, 2018, doi: 10.1111/fwb.13076.

[13] L. May and R. L. Wallace, “An examination of long-term ecological studies of rotifers: comparability of methods and results, insights into drivers of change and future research challenges,” Hydrobiologia, vol. 844, no. 1, pp. 129–147, Nov. 2019, doi: 10.1007/s10750-019-04059-2.

[14] W. Shao et al., “The coordination of routine and emergency water resources management: progress in China,” Water International, vol. 43, no. 7, pp. 943–962, Oct. 2018, doi: 10.1080/02508060.2018.1511201.

[15] H. Özbay, A. E. Yaprak, and N. Turan, “Assessing water quality in the Ceyhan River basin (Turkey) with the use of aquatic macrophytes,” Chemistry and Ecology, vol. 35, no. 10, pp. 891–902, Nov. 2019, doi: 10.1080/02757540.2019.1668928.

[16] R. M. Pringle et al., “Predator-induced collapse of niche structure and species coexistence,” Nature, vol. 570, no. 7759, pp. 58–64, Jun. 2019, doi: 10.1038/s41586-019-1264-6.