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# Evaluation of the Ecological Environment of the Fuhe River Based on the Diversity of Fish

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**Abstract**

This article takes the Fuhe River, which has water flowing into Baiyangdian all year round, as the research object. Through actual investigation and measurement of planktonic flora and fauna, benthic organisms, fish, and large vascular plants in the river, and based on fish diversity, the comprehensive evaluation index method is used to scientifically evaluate the ecological environment quality of the Fuhe River. The results showed that a total of 28 species of phytoplankton, 30 species of zooplankton, 11 species of benthic animals, 8 species of submerged plants, and 11 species of fish were detected in the survey area; From a diversity perspective, the diversity of the upstream and downstream river sections is higher than that of the downstream. Overall, the ecological environment quality of the Fuhe River in Baoding City ranges from medium to good, with good water quality in the upstream section and moderate water quality in the middle and downstream sections. This study provides a case study for the scientific evaluation of the ecological environment quality of the upper reaches of Baiyangdian.

**Keywords:** Baiyangdian, Fuhe River, diversity of fish, water ecology, evaluation

## 1. Introduction

Baiyangdian drainage basin is located in the middle of North China Plain, belonging to the Daqing River system of the Haihe River basin. Its control range is the middle and upper reaches of the Daqing River, with a total catchment area of 31200 km$^2$. The rivers entering Baiyangdian Lake mainly include the Baigou River, Pinghe River, Baohe River, Caohe River, Fuhe River, Tanghe River, Xiaoyi River, Zhulong River and the Yellow River to Hebei Lake Channel. Only the Baigou River, Fuhe River, Xiaoyi River and Baohe River have water flowing into Baiyangdian Lake all the year round, and water will flow into Baiyangdian Lake in other long-term periods of water interruption or diversion.

China is conducting research on water ecological health assessment methods for river basins and lakes, supporting the transition from water quality to water ecological target management, and also providing a basis for water ecological environment management in China. As the top of the food chain, fish play an important role in aquatic ecological environments. Further research is needed to construct a water ecological evaluation index system based on fish diversity.

In order to scientifically study the quality of the flowing water environment in the Fuhe River, this article takes the perennial water flowing into the Fuhe River as the research object. Through actual investigation and measurement of the river's planktonic flora and fauna, benthic organisms, fish, etc., and based on fish diversity, the comprehensive evaluation index method (Chen et al., 2022; Cao et al., 2018) is used to carry out research work, providing reference for the scientific evaluation of the water environment quality in the upper reaches of Baiyangdian Lake.

## 2. Materials and Methods

### *2.1 Sampling Locations*

According to the hydrological characteristics of the Fuhe River and the characteristics of the riparian zone, three sampling stations were set up in the Baoding basin of the Fuhe River (115°34′~116°00′E, 38°49′-38°55′N) (Figure 1), and based on the methods (Wang et al., 2023; Wang et al., 2022; Zhao et al., 2020) presented in the literature, the Fuhe River was divided into upper, middle and lower reaches, with the upstream as Station 1, the middle reaches as Station 2, and the lower reaches as Station 3. The water quality characteristics, phytoplankton, zooplankton, benthic organisms, macrophytes, and fish diversity were investigated from July 23 to July 29, 2023, in the summer of Fuhe River in Baoding City.

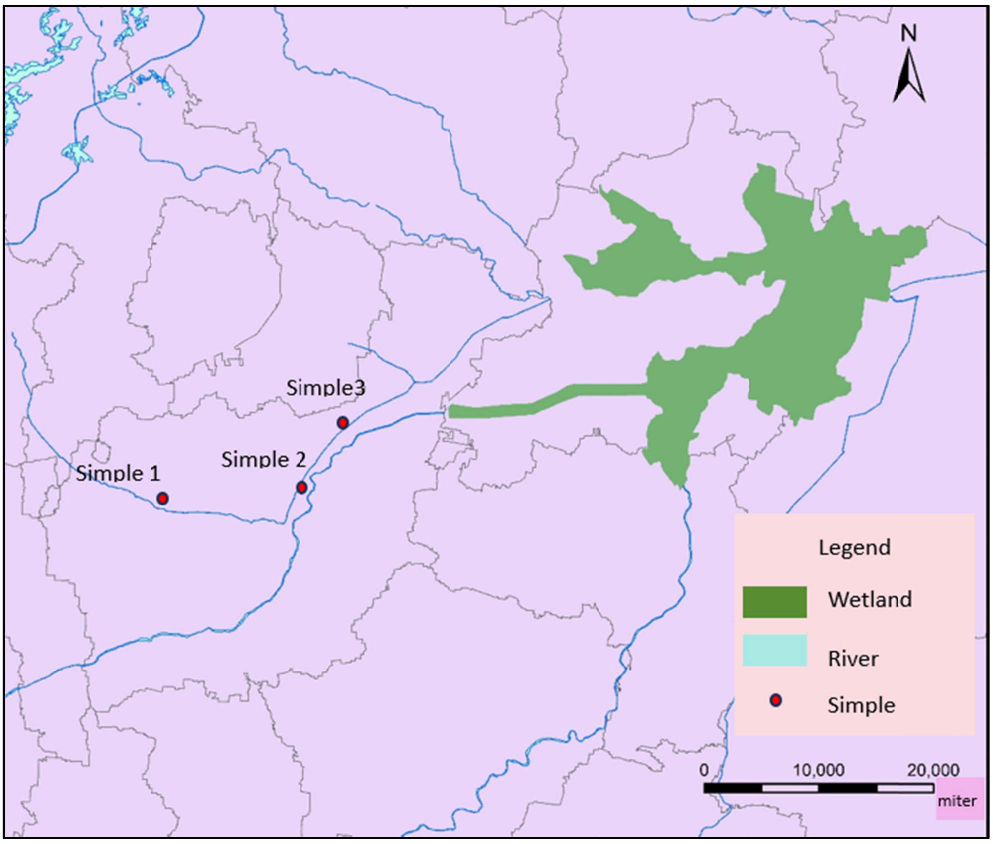


Figure 1. Distribution of sampling points

### *2.2 Sampling Methods*

#### 2.2.1 Phytoplankton

The phytoplankton collection method and sample disposal period will refer to the freshwater zooplankton regulation technology does not norms (SCT9402-2010), zooplankton collection using 5 L water collector were in the E, middle and lower fruit set a total of 15 water in a bucket, with a polyethylene collection bottle to take nine pills of 1 L of water flushed down in the net zooplankton, and finally take 1 water to open the valve to the network of the zooplankton and the first nine times the accumulated liquid collected in the 1 L polyethylene bottles. The zooplankton on the net and the liquid accumulated in the first nine times were collected in a 1 L polyethylene bottle.

#### 2.2.2 Zooplankton

Zooplankton collection methods and sample crystal processing refer to the "Freshwater Mixed Swimming Group E Object Straightening Technical Specification" (SCT9402-2010), to capture the zooplankton in the water such as dendrites, amphipods and other zooplankton, the use of microporous biological nets with a diameter of 0.030 mn, suspended by a fishing rod with a diameter of 2-meter. In the surface layer of the water to the filtration of

3-5 minutes, as a zigzag direction to the fruit of the collection of polyethylene bottles filled with 1 L of water to rinse floating animal nets, open the valve, collected in the sampling bottle. Open the valve and collect them in the sampling bottles. Add 49% alginate to dissolve and save, and leave it for 72 h to siphon the supernatant and concentrate it to 50 mL, which was used for quantitative analysis of zooplankton.

2.2.3 Benthic Organisms

The survey of benthic biological resources mainly included the characteristics of benthic organisms' species composition and quantitative changes, and the sampling was carried out in accordance with the "echnical guidelines for biodiversity monitoring-freshwater benthic macroinvertebrates" (HJ710.8-2014), using a mud collector with an open mouth area of 0.045 $m^2$, and sampling twice at each station. The samples were fixed with 75% ethanol and brought back to the laboratory for weighing, species identification, counting, statistics and analysis.

2.2.4 Large Vascular Plants

The large vascular plants are referred to the "Technical Guidelines for Biodiversity Observation of Terrestrial Vascular Plants" (H710.1-2014), The Technical Guidelines for Biodiversity Monitoring—Aquatic Vascular Plants (HJ710.12-2016).

Set up three 1 × 1 m plots for observation of aquatic plant communities at each sampling point, counted the number of individuals and the average number of rests in each sample, and then generalized the average to estimate the population as a whole, and recorded the indicators such as the main richness, dominant species, growth status, cover, type of anthropogenic disturbance activities, etc. of the community species on the way of investigation. During the survey, indicators such as community species richness, dominant species, growth status, cover, and type of anthropogenic disturbance activities were recorded.

2.2.5 Fish

Fish samples were collected in the shallow waters of the Fuhe River by self-collection, using the fruit sampling methods such as plunge net, skimmer net, ground cage and gill net. The samples were collected in accordance with the Trial Specification for Fishery Natural Resource Survey in Inland Water Cities, the Specification for Freshwater Fishery Resource Survey in Rivers, and the Technical Guidelines for Biodiversity Monitoring—Inland Water Fish (HJ710.7-2014).

*2.3 Test Fractionation Method*

2.3.1 Phytoplankton

The phytoplankton samples were analyzed and identified with reference to the "Freshwater Phytoplankton Flavoring Technical Regulations" (SCT9402-2010). 1 L of the collected water sample was added with 10 mL of Ruggier's test agent and left to stand for 72 h in a dark place, and then the supernatant was concentrated by siphon to 50 mL for phytoplankton quantitative and quantitative analyses, and 50 mL of the phytoplankton collected sample was sucked up and concentrated by pipette with a pipette gun with a measuring range of 0-100 µL. 1 mL was put onto a "10 × 10" 0.1 mL counting frame, covered with a coverslip, and observed under a microscope at 20× and 50× magnification. Pipette 1mL of the sample into a 0.1 mL counting frame of "10 × 10", cover it with a coverslip, and observe it under a microscope at 20× and 50× magnification for microscopic examination and counting, and then identify it by comparing with the iconography.

2.3.2 Zooplankton

The zooplankton samples were analyzed and identified with reference to the "Technical Specification for Freshwater Zooplankton Survey" (SCT9402-2010). 1L of water samples were preserved by adding 4% formaldehyde solution, and then left to stand for 72 h. The supernatant was concentrated to 50 mL by siphoning and used for the quantitative and qualitative zooplankton sorting. Pipette gun with a range of 0~1000 µL was used to suck up 50 mL of the zooplankton sample collection liquid night precipitation concentrated sample 1mL, put it on the "4 × 10" 1 mL counting frame, covered with a coverslip, and observed at 20× and 50× times microscope, microscopy, counting, and identification in the comparative illustration.

2.3.3 Benthic Organisms

Benthic organisms were analyzed and identified with reference to the "Technical Guidelines for Biodiversity Observation of Freshwater Benthic Macroinvertebrates" (H710.8-2014). The samples were placed in a 40-mesh sieve, and the bottom of the sieve was gently shaken in a basin of water to wash away the remaining mud in the samples, and then the sieve was washed and the samples were picked out of any debris, plant branches, leaves, etc., and the animals intermingled with the samples were carefully examined and selected. The samples that were visible to the naked eye on the sieve were poured into a white porcelain dish for sorting, and the samples were then analyzed.

2.3.4 Large Vascular Plants

For analysis of large vascular plants, refer to the "Technical Guidelines for Biodiversity Observation of Terrestrial Vascular Plants" (HJ710.1-2014) and "Technical Guidelines for Biodiversity Observation of Aquatic Vascular Plants" (HJ710.12-2016). Field-collected aquatic plants are made into waxy leaf specimens (or immersed specimens), which are then preserved in a specimen tree after identification. If the specimens were collected at different periods of growth, they need to be numbered separately and placed on a table. The flowers and fruits of some aquatic plants are small and fragile when dry, so they can be placed in a small paper bag and placed in a complete specimen with the plant's log. In the field, a hand-held magnifying glass can be used to observe the morphological characteristics of aquatic plants for identification. Since some aquatic plants produce few or no flowers or fruits in their growing areas, they can be collected and brought back to the laboratory. In the laboratory using a light microscope. In the laboratory, using light microscope, dissecting lens, dissecting equipments and tools such as floras and illustrated books of plants, the collected aquatic plant specimens can be identified by using morphological classification methods.

2.3.5 Fish

Fish samples were analyzed and identified with reference to the Specification for Freshwater Fishery Resources Survey of Rivers (HJ710.7-2014), and samples collected were identified on the spot, and biological indexes, such as Chinese name, scientific name, weight, body length, health condition, etc., were measured tail by tail and recorded in a book. Photographs are taken of each species and images are kept, indicating the sampling location. Prepare specimen bottles of different sizes, clean the surface of the samples, ensure that the samples are not decayed and the morphology is intact, spread and fix the samples, and put the fixed specimens into 5% formalin solution for preservation.

*2.4 Evaluation Method Construction*

2.4.1 Evaluation Methodology Determination

(1) Phytoplankton Diversity Index (Shannon-Wiener, H')

Planktonic plants are the primary producers of lakes and reservoirs, and the occurrence of eutrophic water blooms is the result of a large number of abnormal growth of phytoplankton, which is an indispensable part of the ecological environment quality evaluation of Baiyangdian Lake; Due to the uneven spatial distribution of phytoplankton and the significant differences in density of different species, a combination of quantitative and qualitative sampling methods is adopted to make their field sampling more representative (Table 1).

The Shannon Wiener diversity:

$$H' = P_i \sum_{n=1}^{S} \log_2 P_i \quad (1)$$

where, S: total number of species; The proportion of the number of individuals in the Pi i species to the total number of individuals.

Table 1. Scoring evaluation criteria for the H' index of phytoplankton diversity in Fuhe River, Baoding City

| Serial No. | Shannon Wiener Score | Evaluation Status | Natural Endowments |
|---|---|---|---|
| 1 | H' > 3.00 | Rich species and uniform individual distribution | 5 |
| 2 | 2.00 < H' ≤ 3.00 | High species richness and relatively uniform individual distribution | 4 |
| 3 | 1.00 < H' ≤ 2.00 | The species richness is relatively low, and the individual distribution is relatively uniform | 3 |
| 4 | 0.00 < H' ≤ 1.00 | Low species richness and uneven individual distribution | 2 |
| 5 | H' = 0.00 | Single species and basic loss of diversity | 1 |

(2) Zooplankton Abundance Index (Margalef, D)

Zooplankton is an important nutrient link in the food chain of aquatic ecosystems and an important component of the quality evaluation of the Baiyangdian water ecological environment. Due to the uneven spatial distribution of planktonic animals and the significant differences in density of different species, a combination of quantitative and qualitative sampling methods is adopted to make their field sampling more representative (Table 2).

The equation for calculating the richness index is:

$$D = \frac{S - 1}{\log_2 N} \quad (2)$$

where, D: richness index; N: total number of individuals; S: Total number of species.

Table 2. Scoring evaluation criteria for the richness index of zooplankton in Fuhe River, Baoding City

| Serial Number | Margalef Score | Pollution Level | Natural Endowments |
|---|---|---|---|
| 1 | $D > 6$ | Clean water | 5 |
| 2 | $4 < D \leq 6$ | Slightly polluted | 4 |
| 3 | $2 < D \leq 4$ | Moderately Polluted | 3 |
| 4 | $1 < D \leq 2$ | Severe pollution | 2 |
| 5 | $0 < D \leq 1$ | heavy pollution | 1 |

(3) BI Bioindex for Macrobenthic Invertebrates

Large benthic invertebrates, due to their sensitivity to water quality, easy identification and collection, long life cycle, and fixed location, are recognized as key biological groups for water ecological environment quality assessment. Therefore, they are widely used in water ecological health assessment both domestically and internationally, and are one of the most widely used groups in current water quality biological assessment. The biological index of freshwater benthic macroinvertebrates takes into account both "quality" (pollution tolerance value) and "quantity" (abundance, abundance); Meanwhile, the biological index includes the most relevant pollution resistance values to the sediment and overlying water environment (Table 3).

The calculation equation is:

$$BI = \sum_{i=1}^{S} \frac{n_i}{N} \times t_i \quad (3)$$

where, BI: biological index value; N: total number of individuals in a species; S: number of species; Ni: the number of individuals in the i-th taxonomic unit (usually at the genus or species level); Ti: Pollution resistance value of the i-th classification unit.

Table 3. Scoring evaluation criteria for the BI biological index of large benthic invertebrates in Fuhe River

| Serial Number | BI Score | Natural Endowments |
|---|---|---|
| 1 | $BI \leq 5.50$ | 5 |
| 2 | $5.50 < BI \leq 6.50$ | 4 |
| 3 | $6.50 < BI \leq 7.50$ | 3 |
| 4 | $7.50 < BI \leq 8.50$ | 2 |
| 5 | $BI \geq 38.50$ | 1 |

(4) Fish Ownership Index (FOEI)

Due to the wide distribution, easy identification, and high sensitivity to water quality of fish in nature, their role in maintaining the structure and function of aquatic ecosystems is significantly stronger. Fish indicators can include high-level information such as community structure and function, and can better represent the cumulative effects of various ecological stresses on biological indicators. Therefore, it is necessary to apply them in the evaluation of the health status of aquatic ecosystems.

Fish are an important nutritional link in the food chain of the Baiyangdian water ecosystem, belonging to consumers with high levels. They are an essential part of the Baiyangdian water ecological environment quality evaluation. The fish ownership index is the simplest and most effective comparison with historical data (Table 4).

$$\text{FOEI} = \frac{\text{FO}}{\text{FE}} \times 100\% \quad (4)$$

where, FOEI: Fish retention index; FE: The highest historical fish abundance in Baiyangdian Lake, with a total of 54 fish species surveyed in 1958; FO: richness of surveyed fish species.

Table 4. Scoring evaluation criteria for the FOEI of fish retention index in Fuhe River, Baoding City

| Serial Number | FOEI Score (%) | Natural Endowments |
|---|---|---|
| 1 | 75 < FOEI ≤ 100 | 5 |
| 2 | 50 < FOEI ≤ 75 | 4 |
| 3 | 30 < FOEI ≤ 50 | 3 |
| 4 | 10 < FOEI ≤ 30 | 2 |
| 5 | 0 < FOEI ≤ 10 | 1 |

(5) Large Vascular Plants Were Selected From the Submerged Phyllotaxy Quality Index (FQI)

Large aquatic plants are the ecological foundation of aquatic ecosystems, especially shallow rivers, lakes, wetlands, etc. They also provide suitable habitat conditions for other organisms to survive and are an important part of water ecological environment quality evaluation (Zesong et al., 2023; Meng et al., 2013; Huang et al., 2016; Wu, 2015; Yang et al., 2022; Xu et al., 2022; Li et al., 2013). The identification and counting of vascular plants were carried out using the sampling method of the "Guidelines for Biodiversity Observation Techniques for Aquatic Vascular Plants" (HJ710.12-2016). Taking into account the ecological characteristics such as biomass, richness, diversity, and coverage of submerged plants, as well as the convenience of calculation, a submerged plant flora quality index (FQI) was selected (Table 5).

The equation for calculating the quality index of plant flora is:

$$\text{FQI} = \overline{\text{C}}\sqrt{\text{N}_\text{n}} \quad (5)$$

where, $\overline{\text{C}}$: The average conservative coefficient of submerged plants at the sampling point; Nn: The number of species of submerged plants at the sampling point.

$$\overline{\text{C}} = \frac{\sum \text{C}_\text{i}}{\text{N}_\text{n}} \quad (6)$$

where, Nn represents the number of local species; Ci is the conservation coefficient of the species.

Table 5. Quality Index (FQI) Evaluation Level and Habitat and Scoring Standards of Fuhe Submerged Plant Flora in Baoding City

| FQI Score | Grade | Habitat Characteristics | Natural Endowments |
|---|---|---|---|
| 50~100 | Very good | Near native habitat | 5 |
| 35~49 | Good | High quality habitat | 4 |
| 20~34 | Preferably | Preserve most of the natural features | 3 |
| 9~19 | Same as | Preserve some natural features | 2 |
| 0~9 | Poor | Basically no natural features | 1 |

2.4.2 Single-Indicator Evaluation Methods

In this study, the weights of the indicators were determined through the expert scoring method (Table 6).

Table 6. Indicator system and weighting table for the evaluation of the water environment of the Fuhe River

| Indicator Layer | Weights |
|---|---|
| *Phytoplankton* | 0.20 |
| *Zooplankton* | 0.20 |
| *Macrobenthic organisms* | 0.10 |
| *Large vascular plants* | 0.15 |
| *Fishery* | 0.35 |

2.4.3 Determination of Evaluation Criteria

In this study, based on the above evaluation index system, the FEQI (Fuhe ecology quality index) was constructed by weighting and summing the evaluation indexes to characterize the quality status of the Fuhe ecology environment through the calculation of the index (Table 7).

$$FEQI = \sum_{i=1}^{n} (W_i \times B_i) \times 20 \quad (7)$$

where, FEQI: water ecological environment quality is the index value, the size of its value in the range of 0~100; $W_i$ indicates the evaluation indicators in the comprehensive evaluation index system of the weight value; $B_i$: evaluation indicators of the adjoining score; n: evaluation indicators.

Table 7. Grading of water ecological environment quality evaluation index of Fuhe River

| Grade | Water Ecological Environment Quality Index (FEQI) | Quality Status |
|---|---|---|
| I | $85 \leq FEQI \leq 100$ | Talented |
| II | $60 \leq FEQI < 85$ | Good |
| III | $40 \leq FEQI < 60$ | Medium |
| IV | $15 \leq FEQI < 40$ | Poor |
| V | $0 \leq FEQI < 15$ | Very poor |

## 3. Results

### *3.1 Results of the Survey*

#### 3.1.1 Phytoplankton Indicators

The water sample analysis for three locations in Fuhe River has been completed in July 2023.A total of 28 species of phytoplankton were identified, belonging to 6 phyla, 8 classes, 12 orders, 14 families, and 22 genera. Among them, 10 species were found in the phylum *Chlorophyta* (Chl.), accounting for approximately 35.71% of the total; There are 8 species in the *Bacillus* phylum, accounting for approximately28.57% of the total; *Cyanophyla* (*Cyanophyta*, *Cya*.)consists of 6 species, accounting for approximately 21.43% of the total; Two species of *Euglenophyta* (Eug.) account for approximately 7.14% of the total; 1 species of *Pyrroptata* (Pyrr.), accounting for approximately 3.57% of the total; 1 species of *Xanthophyta*, accounting for approximately 3.57% of the total; Among them, the dominant species are eyebrow algae and fishy algae (Figure 2). Due to the fact that the total number of phytoplankton species in the three phyla of *green algae*, *diatoms*, and *blue-green algae* exceeds 80% of the total number of phytoplankton species, the composition of phytoplankton species in the summer of Fuhe River is *green algae* diatom blue-green algae type. The average values of the Shannon Wiener diversity index (H') for phytoplankton in the upper, middle, and lower reaches are 1.76, 2.07, and 2.13, respectively. The diversity of phytoplankton in the upper reaches is the worst, so the diversity indicators for phytoplankton in the upper, middle, and lower reaches are assigned values of 3, 4, and 4, respectively.

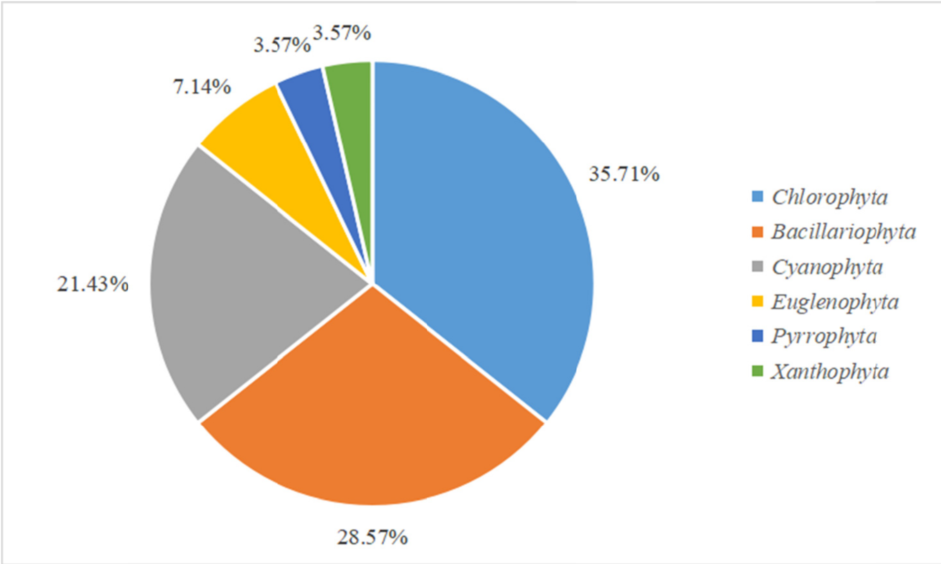


Figure 2. Percentage of phytoplankton species in the Fuhe River

3.1.2 Zooplankton Indicators

A total of 5 phyla and 30 species of planktonic animals have been identified, including 2 species in the phylum Annelida, 19 species in the phylum *Arthropoda*, 4 species in the phylum *Phylum Rotifera*, 1 species in the phylum *Nematoda*, and 3 species in the phylum *Protozooa* (Figure 3). The dominant species are the *Calyx Brachycephalus rotifer* and the *Isomeria*. The average values of the Margalef richness index (d) for the upstream, midstream, and downstream are 2.45, 1.69, and 1.84, respectively. Therefore, the diversity indicators of phytoplankton in the upstream, midstream, and downstream are assigned values of 3, 2, and 2, respectively. The richness index (d) of plankton in the upstream is significantly higher than that in the middle and downstream.

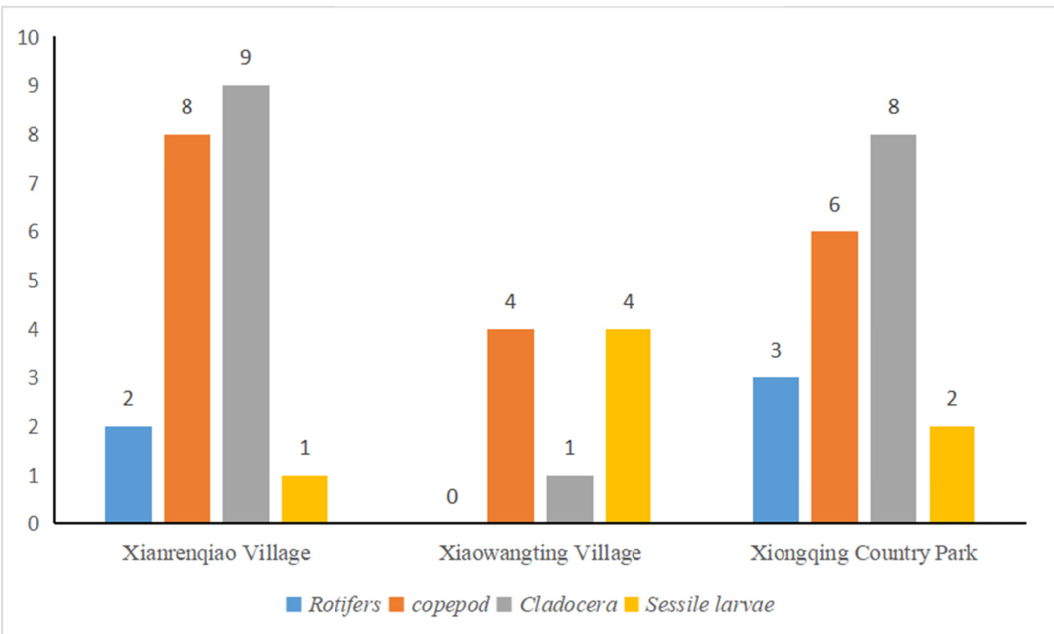


Figure 3. Number of zooplankton species at three sites in Fuhe River

#### 3.1.3 Indicators of Macrobenthic Organisms

A total of 11 species of benthic organisms were identified at 3 locations in Fuhe River, Baoding City (Table 8). Among them, 6 species were found at the sampling point in Xianrenqiao Village, 4 species were found at the sampling point in Xiaowangting Village, and 5 species were found in Xiongqing Suburban Park. The BI indices of large benthic organisms in the upstream, midstream, and downstream are 5.23, 6.33, and 5.68, respectively; The pollution levels are clean, lightly polluted, and lightly polluted, so the indicators of large benthic organisms in the upstream, middle, and downstream are assigned scores of 5, 4, and 4, respectively. The dominance and biodiversity index are calculated using the following equations (Table 9):

Shannon Wiener diversity index calculation equation:

$$H' = -\sum_{i=1}^{n} (P_i)(\ln P_i) \tag{8}$$

Pielou uniformity index calculation equation:

$$J = H'/\ln S \tag{9}$$

The Mchaughton dominance index calculation equation:

$$Y = \left(\frac{n_i}{N}\right) fi \tag{10}$$

Equation for calculating biodiversity threshold:

$$D_v = H' \times J \tag{11}$$

where, Pi represents the proportion of individuals of type i to the total number of individuals; S represents the total number of species; Ni is the density of the i-th species; N is the total number of individuals for all species; Fi is the percentage of the proportion of the occurrence of type i to the total proportion.

Table 8. Density and biomass of macrobenthic animals at three locations in Fuhe River

| Species | Xianrenqiao Village | | Xiaowangting Village | | Xiongqing Country Park | |
|---|---|---|---|---|---|---|
| | Quantity/index | Biomass/g | Quantity/index | Biomass/g | Quantity/index | Biomass/g |
| *Babylonia* | 1 | 0.4900 | 0 | 0 | 0 | 0 |
| *Parafossarulus striatulus* | 8 | 1.2744 | 12 | 2.1556 | 0 | 0 |
| *Bithynia fuchsianus* | 0 | 0 | 0 | 0 | 3 | 1.4556 |
| *Long horned snail* | 1 | 0.1180 | 0 | 0 | 0 | 0 |
| *Cipangopaludina chinensis* | 0 | 0 | 3 | 3.4900 | 0 | 0 |
| *bellamya aeruginosa* | 1 | 1.3880 | 0 | 0 | 1 | 1.3150 |
| *Angular ring ribbed screw* | 0 | 0 | 0 | 0 | 2 | 3.0120 |
| *Hard ring ribbed snail* | 0 | 0 | 0 | 0 | 1 | 0.8430 |
| *bellamya purificata* | 1 | 1.9350 | 0 | 0 | 4 | 8.7760 |
| *Chironomidae* | 2 | 0.0098 | 0 | 0 | 0 | 0 |
| *Triangular sail clam* | 0 | 0 | 4 | 5.7100 | 0 | 0 |

Table 9. Index of benthic biodiversity at three locations in Fuhe River

| Point | Density (ind./square meter) | Shannon-Weiner Index | Pielouevenness Index | Biodiversity Threshold |
|---|---|---|---|---|
| Xianrenqiao Village | 12 | 2.13 | 0.83 | 1.77 |
| Xiaowangting Village | 3 | 0.85 | 0.48 | 0.81 |
| Xiongqing Country Park | 8 | 2.12 | 0.75 | 1.79 |

#### 3.1.4 Index of "Large Vascular Plants"

Eight types of submerged plants were identified at three selected locations in Fuhe River, Baoding City. Each location can identify 3-4 types of submerged plants (Table 10). The quality index (FQI) of the submerged plant flora in the upstream, midstream, and downstream are 36, 32, and 34, respectively. Therefore, the indicators of "large vascular plants" in the upstream, midstream, and downstream are assigned values of 4, 3, and 3, respectively. The richness of submerged plants in the upstream is also slightly higher than that in the middle and downstream.

Table 10. Distribution of submerged plants

| Point | Submerged Plant | Wet Weight/g/m$^2$ | Density/Plant/m$^2$ | Coverage/% |
|---|---|---|---|---|
| Xianrenqiao Village | *Charophyte* | 2286.67 | 350 | 30% |
| | *Potamogeton pectinatus* L. | 1327.06 | 57 | 10% |
| | *Reed* | 1886.43 | 80.23 | 15% |
| | *Cattail* | 2219.09 | 165.72 | 20% |
| Xiaowangting Village | *Hornwort* | 76.19 | 5.71 | 40% |
| | *Bladderwort* | 89.22 | 132.44 | 20% |
| | *Water Caltrop* | 2066.67 | 58.10 | 10% |
| Xiongqing Country Park | *Hornwort* | 1304.76 | 76.19 | 40% |
| | *Lotus* | 5678.39 | 78.56 | 15% |
| | *Cattail* | 899.21 | 156 | 10% |
| | *Potamogeton pectinatus* L. | 914.29 | 13.33 | 15 |

### 3.1.5 Fish Indicators

This survey shows that the main fish species in the Fuhe River are first instar fish, with the majority being below second instar fish, accounting for approximately 83.3%. Fish above fifth instar are relatively rare. In the sampling, the maximum age of *grass carp* is 3 years old, and the maximum age of *carp* is 6 years old. The highest age for the main economic fish species, *crucian carp*, is 3 years old, while fish below 1 year old account for more than half. *Crucian carp* grow the fastest at ages 1 to 2, while *carp* grow the fastest at ages 2 to 3. A total of 11 fish species were identified at 3 sampling points in the Fuhe River Basin of Baoding City. 9 species were observed at the upstream points, 4 species were observed in the midstream, and 8 species were observed downstream (Table 11). The fish retention indices in the upstream, midstream, and downstream areas were 16.9%, 7.4%, and 14.8%, respectively (Figure 4). Therefore, assign values of 2, 1, and 2 to the upstream, middle, and downstream fish indicators.

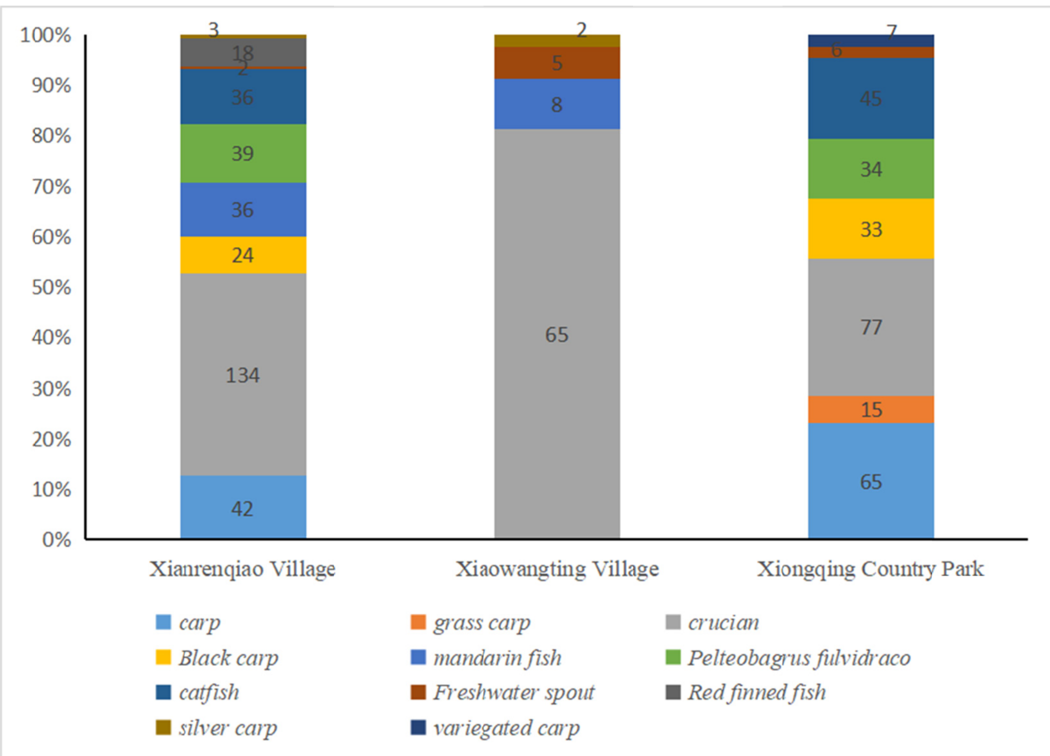


Figure 4. Fish species composition and percentage at three sites in the Fuhe River

Table 11. Composition of quantity and quality of main fish species

| Fish Name | Quantity (tail) | Weight (g) | Quantity Ratio% | Weight Ratio% |
|---|---|---|---|---|
| *Carp* | 42 | 50766.5 | 9.4 | 31.2 |
| *Grass carp* | 15 | 32237 | 3.4 | 19.8 |
| *Crucian* | 134 | 12831.32 | 30.0 | 7.9 |
| *Black carp* | 61 | 35898.3 | 13.7 | 22.1 |
| *Mandarin fish* | 36 | 12254.75 | 8.0 | 7.5 |
| *Yellow croaker* | 53 | 2756.7 | 11.9 | 1.8 |
| *Catfish* | 36 | 7564.5 | 8.1 | 4.66 |
| *Freshwater spout* | 2 | 1382.5 | 0.4 | 0.85 |
| *Red finned fish* | 63 | 6524.95 | 14.2 | 4 |
| *Silver carp* | 3 | 153.5 | 0.7 | 0.1 |
| *Silver carp* | 1 | 147 | 0.2 | 0.09 |
| Amount to | 446 | 162517.02 | 100 | 100 |

### *3.2 Evaluation Results*

After on-site investigation in the early stage and identification in the later stage, as well as the establishment of an evaluation index system, the water ecological environment quality status of three points in the upper, middle, and lower reaches of the Fuhe River was analyzed through FEQI scores from five indicators of phytoplankton, zooplankton, macrobenthic organisms, Large vascular plants, and fish, as shown in the table below (Table 12). The ecological environment quality of Fuhe River is generally in a moderately good state, with good upstream, medium midstream, and medium downstream.

Table 12. Classification of Water Ecological Environment Quality Status in the Upper, Middle and Lower Reaches of the Fuhe River

| Fuhe River | Point | FEQI Score | Quality Status | Grade |
|---|---|---|---|---|
| Upstream | Xianrenqiao Village | 60 | good | II |
| Middle reaches | Xiaowangting Village | 49 | medium | III |
| Downstream | Xiongqing Country Park | 48 | medium | III |

## 4. Discussion

### *4.1 Fish Community Structure and Spatial Distribution Are Differentiated*

This survey of fish resources in the Baiyangdian Lake includes 11 species, 1248 tails, with a total weight of 186547.14 g. *Cyprinidae* fish are the mainspecies, accounting for 57.40% of the total number; A comparative analysis of the species composition and quantity of fish at three locations in the Fuhe River Basin of Baoding City shows that the Xianrenqiao Village Basin and the Xiongqing Suburban Park Basin have more fish species suitable for flowing water habitats, while the Xiaowangting Village Basin has more fish species suitable for calm and slow flowing water; At the same time, all three sections of the water are mainly composed of omnivorous, benthic, sand and gravel loving fish, and fish that produce sticky and sinking eggs. The composition and distribution of fish communities show spatial differences, mainly reflected in the stable structure and abundant species of fish communities in the Xianrenqiao watershed, and there is a certain demand for water flow conditions.

### *4.2 Countermeasures and Suggestions for the Protection and Expansion of Fish Resources in the Fuhe River*

In the investigation of fish resources in the Baiyangdian Lake, the level of rural household waste treatment in the basin is generally low. Some townships and rural areas have set up simple garbage burial points, and most areas lack garbage collection. Small fish dominate in both species and quantity, playing a crucial role in energy flow and material cycling (Wang & Li, 2013; Wang, 2021; Luo et al., 2020; Chen et al., 2022). However, while small fish feed on a large amount of bait resources in rivers, they also compete with various fish species in terms of food and space.

Therefore, it is necessary to reasonably control small fish resources, prevent excessive population growth, and protect the diversity of fish communities. The following protection suggestions are proposed: (1) Strengthen monitoring and research on the composition and diversity changes of fish communities in the Baiyangdian Lake, timely grasp the development trend of fish communities, and accurately evaluate the health level of river ecosystems. (2) Conduct research on scientific ecological regulation measures to ensure the survival needs of fish habitats in the river water environment. (3) Strictly control the discharge of household waste in villages along the river, and maintain a good water quality environment for fish habitats. (4) Strengthen the inadequacy of landfill facilities along the river to prevent infiltration and pollution of water quality and environment for fish habitats in landfill areas.

## 5. Conclusion

This article provides an overall evaluation of the ecological environment of the Fuhe River of Baiyangdian based on fish diversity. A water ecological survey was conducted on the Fuhe River, with a focus on analyzing the distribution characteristics and diversity status of aquatic organisms, as well as the current status of fish diversity in the Fuhe River. The evaluation results show that the ecological environment quality of the Fuhe River is good in the upstream, moderate in the middle and downstream. Through research, it has been found that there are local differences in the density and biomass of aquatic organisms under different hydrological conditions; The biodiversity of Fuhe River tends to stabilize. Overall, the ecological environment quality of the Fuhe River ranges from moderate to good.

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**Authors Contributions**

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