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Macrobenthic Community Structure and Water Quality Evaluation in Ulungu River Basin (Northwest China)

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Abstract: In this study, the composition and structure of the macrobenthic community in the Ulungu River Basin was investigated and the water quality status of the basin was evaluated. In May and August 2022, and October 2023, the macrobenthic and water environmental factors at 11 sample sites in the basin were investigated, and the water quality of the basin was evaluated by the Shannon–Wiener index, FBI, and BMWP index. A total of 6101 macrobenthic organisms were collected; these organisms belonged to 3 phyla, 7 classes, 14 orders, 57 families, and 117 genera. Arthropod species accounted for the largest number of species (87.9%). A total of nine dominant species were found: *Micronecta* sp., *Eukiefferiella* sp., *Baetis* sp., *Polypedilum* sp., *Saetheria* sp., *Ephemerella* sp., *Limnodrilus* sp., *Ephemera* sp., and *Hydropsyche* sp. At the temporal level, the average density and biomass of macrobenthos were in the order of August > October > May; at the spatial level, the average density was greater in the tributaries than in the main stream, and the average biomass was greater in the main stream than in the tributaries. The mean values of the Shannon—Wiener index and Margalef richness index were as follows: August > October > May at the temporal level; the mean values of the Pielou evenness index were as follows: May > October > August at the temporal level. At the spatial level, the overall mean value of each diversity index indicated that the tributaries had larger diversity indices than the main stream. The water quality evaluation results revealed that the overall water quality level of the Ulungu River Basin ranges from light pollution to poor quality. Human interference activities greatly impact the water quality of the basin. To restore the ecology of the basin, it is necessary to strengthen the management and control of pollution sources.

Keywords: Ulungu River; macrobenthos; community structure; evaluation of water quality

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1. Introduction

Freshwater ecosystems are fragile [1], and water quality is an important factor related to freshwater ecological conditions and biodiversity [2]. At present, watershed development and anthropogenic pressure are increasingly causing the degradation of aquatic ecosystems [3], and changes in freshwater ecosystems will cause changes in the communities of fish, algae, and invertebrates in the water. Therefore, it is necessary to use reliable methods and indicators to regularly monitor the water quality status of freshwater ecosystems. In fact, the freshwater resources available to humans are very limited, and precious freshwater resources should be protected.

The Ulungu River is an important inland river in the southern part of the Altai Mountains in the Junggar Basin in Northwest China. It originates in Qinghe County, flows from east to west through Fuyun County and Fuhai County, and finally flows into Ulungu Lake, the second largest freshwater lake in Xinjiang. The Ulungu River Basin has a total length of 821 km and a drainage area of 61,400 km^2 [4]. It is in a cold temperate zone with an arid continental climate. It relies mostly on mountain rainfall and ice and snow meltwater to replenish water [5]. It is the main water source for Fuhai and Qinghe Counties. The Ulungu River and the Irtysh River were originally two independent water systems. However, due to the new construction of the "Diversion of the Irtysh River" project in 1986~1987, a 3-km-long canal was dug, causing the Ulungu River to become a tributary of the Irtysh River. Ulungu Lake also became an affiliated water body of the Irtysh River. The Ulungu River Basin is rich in fish resources, especially the Ulungu Lake as one of the important fishing grounds in inland China. Commercial fish such as Pond Smelt (*Hypomesus olidus*), Common Bream (*Abramis brama*), and Northern Pike (*Esox lucius*) live in the basin and are being captured [6]. In recent years, due to the continuous growth of social and economic development, the increase in population, the continuous expansion of urbanization and agriculture and animal husbandry, and the poor stability of surface runoff in the Ulungu River Basin, residents near the basin have experienced water shortages, agricultural irrigation, and the interruption of the Ulungu River [7]. These conditions seriously threaten the survival and reproduction of aquatic organisms in the basin.

Macrobenthos refers to aquatic animals that live at the bottom of water bodies for all or most of their life history. They are individual benthic animals that cannot pass through a 0.5 mm aperture mesh [8]. Macrobenthos are an important part of freshwater bodies. They are in the middle link in food webs of the ecosystem and are crucial in material exchange and energy flow in the ecosystem. Changes in their community structure will affect fish and other important aquatic organisms through the food chain [9–11]. In aquatic environments, macrobenthos have limited mobility and may also respond to changes in water quality through changes in species composition or population dynamics [12]. Macrobenthos are among the most important groups of organisms used to determine river water quality and ecological conditions [13]. Compared with zooplankton and fish, because they live on the bottom of the water for a long time, they are key links in the ecosystem and have strong regional characteristics and weak migratory ability [14]; therefore, they are sensitive to changes in the ecological environment. The quality of the environment directly affects their growth, reproduction, species distribution, and community composition [15]; most of these species are large and easy to identify and collect, so they can be used as indicator species for evaluating water quality. Macrobenthos have been widely used as biological indicators of river water quality in temperate regions [16]. Using macrobenthos to assess river ecological health is the mainstream method for the biological assessment of water quality [17], and it is also an indispensable prerequisite for river ecosystem restoration and management [18].

At present, there are few studies on macrobenthos in the Ulungu River. Existing studies have reported only macrobenthos in affiliated lakes and reservoirs in the Ulungu River Basin [19]. In this study, the composition and structure of the macrobenthic community in the Ulungu River Basin were investigated to determine the basin's community changes. The Shannon–Wiener index, FBI, and BMWP were used to conduct a biological evaluation of the water quality of the Ulungu River Basin to determine its water pollution status. The impacts of various environmental factors on macrobenthos were also analyzed. This study is expected to provide an important reference for the protection of the Ulungu River Basin ecosystem and provide a reference and scientific basis for the protection of important commercial fish and other aquatic biological resources in the basin.

2. Materials and Methods

2.1. Study Area and Sample Collection

According to the geographical and water system characteristics of the Ulungu River Basin, 11 sampling points were set up in the basin: tributaries—the Daqing River Bridge (S1), Qinggri River Twin Bridges (S2), Agashi Aobao Township (S3), Tucker Shiken Town (S4), and Ihigen Village (S5); and main streams—the Ertai Bridge (S6), Qiakultu Town

(S7), Yerk Kala (S8), Dure Town (S9), Kalamagai Town (S10), and Fuhai Bridge (S11). The specific distribution of sampling points is shown in Figure 1. The sampling times were May, August 2022, and October 2023. A D-type net with a 60-mesh aperture and a net port width of 25 cm was used to collect macrobenthos. The collection was repeated three times, and 0.25 m^2 was quantitatively collected at each sampling point. The collected samples were placed on a white disk, clean water was added, and various types of macrobenthos were selected on site. The selected macrobenthos were placed into 50 mL specimen bottles filled with a fixative (7% formalin solution). Most of the macrobenthos were identified to the genus level, and a few species were identified to the family level or higher. The identification methods used were *Economic Animals of China* [20] and *Chironomid Larvae of Northern China* [21]. The identified samples were counted and weighed to calculate the density and biomass per square meter.

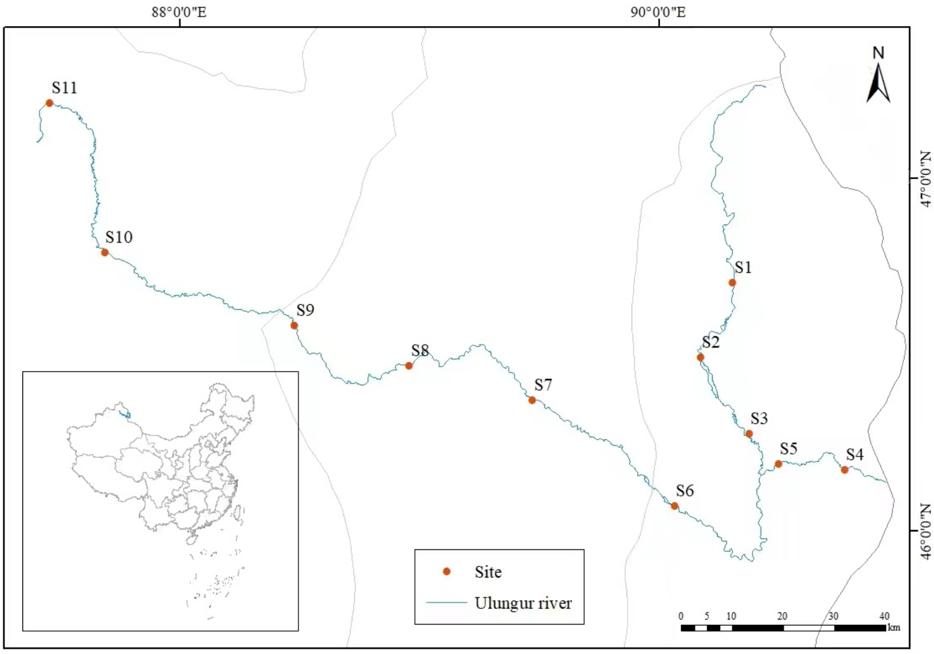

Figure 1. Distribution of sampling points in the Ulungu River.

2.2. Determination of Environmental Factors

The American Jinquan Multi-Parameter Water Quality Sonde (YSI 556MPS) (YSI Inc., Yellow Springs, OH, USA) was used to measure water temperature (WT), dissolved oxygen (DO), conductivity (Cond), salinity (SAL), and pH.

2.3. Data Analysis

1. Dominant species

It was determined according to the dominance value (Y). $Y > 0.02$ was considered the dominant species. The calculation formula [22] is as follows:

$$Y = (N_i/N) \times F_i \quad (1)$$

In the formula, N_i is the number of individuals of the i-th species, N is the total number of individuals of all species, and F_i is the frequency of occurrence of the i-th species.

2. Calculation of the biological indices

For the Shannon—Wiener diversity index, the calculation formula [23] is as follows:

$$H' = -\sum_{i=1}^{s} (N_i/N) \times \log_2(N_i/N) \quad (2)$$

For the Margalef richness index, the calculation formula [23] is as follows:

$$d = (S - 1) / \log_2 N \tag{3}$$

For the Pielou uniformity index, the calculation formula [23] is as follows:

$$J = H' / \log_2 S \tag{4}$$

In the formula, N_i is the number of individuals of the i-th species, N is the total number of individuals of all species, and S is the number of species.

For the family-level biotic index (FBI), the calculation formula [24] is as follows:

$$\mathrm{FBI} = \sum_{i=1}^{F} n_i t_i / N \tag{5}$$

In the formula, n_i is the number of individuals in the i-th family, t_i is the pollution resistance value of the i-th family, and N is the total number of individuals in each family.

With respect to the biological monitoring working party (BMWP) score system, the calculation formula [25] is as follows:

$$\mathrm{BMWP} = \sum_{i=1}^{n} t_i \tag{6}$$

In the formula, t_i is the sensitivity value of the i-th family.

The water quality evaluation standards for the various biological indices are shown in Table 1 [9,25,26].

Table 1. Water quality evaluation standards for various indices.

H′		FBI		BMWP	
Value	**Level**	**Value**	**Level**	**Value**	**Level**
>3	Clean	0.00~3.75	Healthy	≥81	Healthy
2~3	Light pollution	3.51~5.00	Good	51~80	Good
1~2	Moderate pollution	5.01~5.75	General	25~50	General
		5.76~7.25	Poor	10~24	Poor
0~1	Heavy pollution	7.26~10.00	Very poor	0~9	Very poor

2.4. Data Processing

The statistics and calculations of the species composition, abundance, biomass, dominance value, and various biological indices of macrobenthos were completed through Microsoft Excel 2010. A visual analysis of density, biomass, and various indices was completed using Origin 2018. A one-way analysis of variance and nonparametric tests were completed using IBM SPSS Statistics 25.

3. Results

3.1. Environmental Factors

In May, Kalamagai Town (S10) had the highest water temperature and the lowest dissolved oxygen; the water temperature of the Qinggri River Twin Bridges (S2) was the lowest, but the dissolved oxygen was the highest. The conductivity of Tucker Shiken Town (S4) was the highest, and that of the Qinggri River Twin Bridges (S2) was the lowest. The salinity of Tucker Shiken Town (S4) was the highest, and the Daqing River Bridge (S1) and the Qinggri River Twin Bridges (S2) were the lowest. The pH of the Ertai Bridge (S6) was the highest, and the Qinggri River Twin Bridges (S2) were the lowest.

In August, the water temperature of Fuhai Bridge (S11) was the highest, and that of Ihigen Village (S5) was the lowest. Dissolved oxygen was the highest in Ihigen Village (S5) and the lowest at the Ertai Bridge (S6). The conductivity and salinity were the highest in Kalamagai Town (S10) and the lowest in Tucker Shiken Town (S4). The pH was the highest in Kalamagai Town (S10) and the lowest at the Qinggri River Twin Bridges (S2).

In October, the water temperature in Kalamagai Town (S10) was the highest and the dissolved oxygen was the lowest. The Daqing River Bridge (S1) had the lowest water temperature, but the highest dissolved oxygen. The conductivity was the highest in Agashi Aobao Township (S3) and the lowest at the Daqing River Bridge (S1). Salinity was the highest in Kalamagai Town (S10) and the lowest at the Daqing River Bridge (S1). The pH was the highest in Dure Town (S9) and the lowest at the Daqing River Bridge (S1).

According to the average value of environmental factors in different months, the water temperature was higher in August than in May than in October. Dissolved oxygen was higher in October than in May than in August, which was contrary to the trend of water temperature. The conductivity and salinity were higher in August than in October than in May, and the pH value was higher in August than in May than in October. The specific changes in environmental factors are shown in Table 2.

Table 2. Environmental factors of the Ulungu River Basin.

Site/Parameters		Water Temperature/°C	Dissolved Oxygen/mg/L	Conductivity	Salinity/ppt	pH
May	S1	10.4	13.63	64.6	0.04	7.38
	S2	7.1	14.21	58.6	0.04	7.15
	S3	12.8	12.27	227.8	0.14	7.45
	S4	15.6	9.84	326.0	0.19	7.57
	S5	15.2	10.47	306.5	0.18	7.79
	S6	13.7	11.26	146.1	0.09	7.90
	S7	13.8	10.85	163.3	0.10	7.65
	S8	14.0	8.79	192.4	0.12	7.89
	S9	15.2	8.43	294.2	0.17	7.74
	S10	20.8	5.37	279.6	0.14	7.62
	S11	20.6	6.70	303.5	0.16	7.83
	M ± SD	14.5 ± 3.75	10.2 ± 2.60	214.8 ± 92.51	0.1 ± 0.05	7.6 ± 0.22
August	S1	21.4	5.09	224.5	0.11	8.42
	S2	19.4	5.11	1426.0	0.81	7.37
	S3	22.1	5.09	327.8	0.17	8.29
	S4	22.6	7.01	93.6	0.05	8.17
	S5	18.0	7.31	293.0	0.16	7.98
	S6	23.7	5.08	369.9	0.18	8.46
	S7	24.3	5.94	394.6	0.19	8.29
	S8	24.3	6.91	465.0	0.23	8.32
	S9	23.7	6.92	920.0	0.46	8.30
	S10	29.4	6.47	2105.0	0.98	8.61
	S11	37.2	6.21	764.0	0.32	8.48
	M ± SD	24.2 ± 4.98	6.1 ± 0.85	671.2 ± 579.96	0.3 ± 0.29	8.2 ± 0.32
October	S1	7.9	21.62	103.0	0.07	6.15
	S2	9.4	12.75	329.2	0.23	7.17
	S3	11.4	20.97	1167.0	0.80	7.19
	S4	9.8	11.54	174.2	0.12	6.30
	S5	11.3	10.49	223.8	0.15	7.13
	S6	13.7	12.55	362.3	0.22	6.78
	S7	14.7	10.73	435.4	0.26	6.92
	S8	12.6	16.00	444.4	0.28	7.07
	S9	14.4	15.15	469.7	0.29	8.08
	S10	15.8	7.04	561.0	0.33	7.00
	S11	14.1	14.95	229.0	0.14	6.66
	M ± SD	12.3 ± 2.40	14.0 ± 4.20	409.0 ± 274.25	0.3 ± 0.19	7.0 ± 0.49

3.2. Macrobenthos

A total of 6101 macrobenthos were collected in the three surveys; these organisms belonged to 3 phyla, 7 classes, 14 orders, 57 families, and 117 genera. The proportion of the number of individuals in different taxa was as follows: arthropods had the largest number, accounting for 89.7%, followed by annelids, accounting for 8.4%, and mollusks had the smallest number, accounting for 1.9%. Insecta accounted for the largest proportion of arthropods, among which Diptera (51.4%) accounted for the highest proportion, followed by Hemiptera (14.5%) and Ephemeroptera (12.5%) (Figure 2). The larvae of Chironomidae in Diptera were common in almost all stations in different months. The EPT species were mainly distributed in the tributaries in May, and the density tended to increase in August, and its distribution spread to the middle of the basin. Hemiptera was mainly composed of Corixidae and Aphelocheiridae. In May, it is mainly distributed in the main stream, and the density increased as a whole in August and October, and it was evenly distributed in the whole basin (Figure 3). Ephemeroptera was mainly distributed in tributaries in May, and its density increased in August. It was distributed at all sites except Fuhai Bridge (S11), but still accounted for a relatively high proportion in tributaries. In October, its density decreased to lower than that in May, and it was mainly distributed in the main stream. Decapoda was only discovered on the Fuhai Bridge in August and October. Amphipods were mainly Gammaridae, found in Tucker Shiken Town (S4) and Dure Town (S9) in May, only in Agashi Aobao Township (S3) in August, and distributed at the Ertai Bridge (S6) and Dure Town (S9) in October. Odonata were mainly distributed in the main stream in May and October, and were distributed at the Daqing River Bridge (S1), Tucker Shiken Town (S4), and Kalamagai Town (S10) in August, but in small numbers. A total of 9 dominant species (Y > 0.02) were found in the survey, and the dominant species in May were *Micronecta* sp., *Baetis* sp., and *Ephemerella* sp. The dominant species in August were *Eukiefferiella* sp., *Polypedilum* sp., *Micronecta* sp., *Saetheria* sp., and *Baetis* sp. The dominant species in October were *Limnodrilus* sp., *Micronecta* sp., *Ephemera* sp., and *Hyclropsyche* sp. The common dominant species in the three-season survey was *Micronecta* sp.

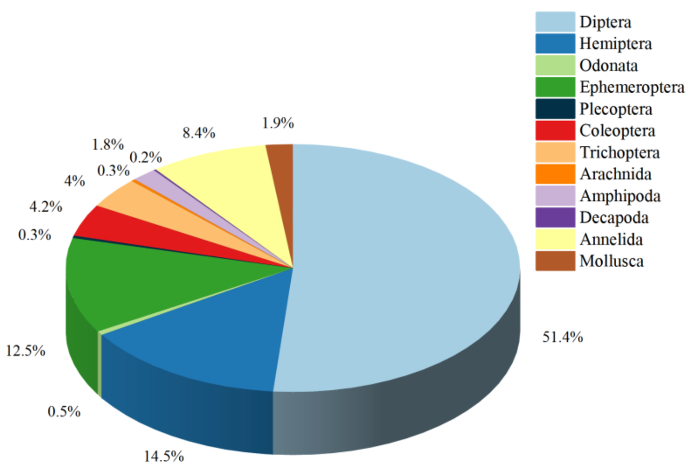

Figure 2. Proportions of individual numbers of different taxa of macrobenthos.

In May, the density of macrobenthos ranged from 52 to 1120 ind/m^2, with the lowest point occurring in Qiakultu Town (S7) and the highest point occurring in Agashi Aobao Township (S3). The average value was 283 ind/m^2. The biomass range was 0.056~5.897 g/m^2, with the lowest point occurring at Fuhai Bridge (S11) and the highest point occurring at Ertai Bridge (S6). The average value was 2.17 g/m^2 (Figure 3).

In August, the density of macrobenthos ranged from 36 to 8448 ind/m^2, with the lowest point occurring at Fuhai Bridge (S11) and the highest point occurring at Tucker Shiken Town (S4). The average value was 1426 ind/m^2. The biomass range was 0.6404~14.5832 g/m^2, with the lowest point occurring at Ertai Bridge (S6) and the highest point occurring at Fuhai Bridge (S11). The average value was 4.39 g/m^2.

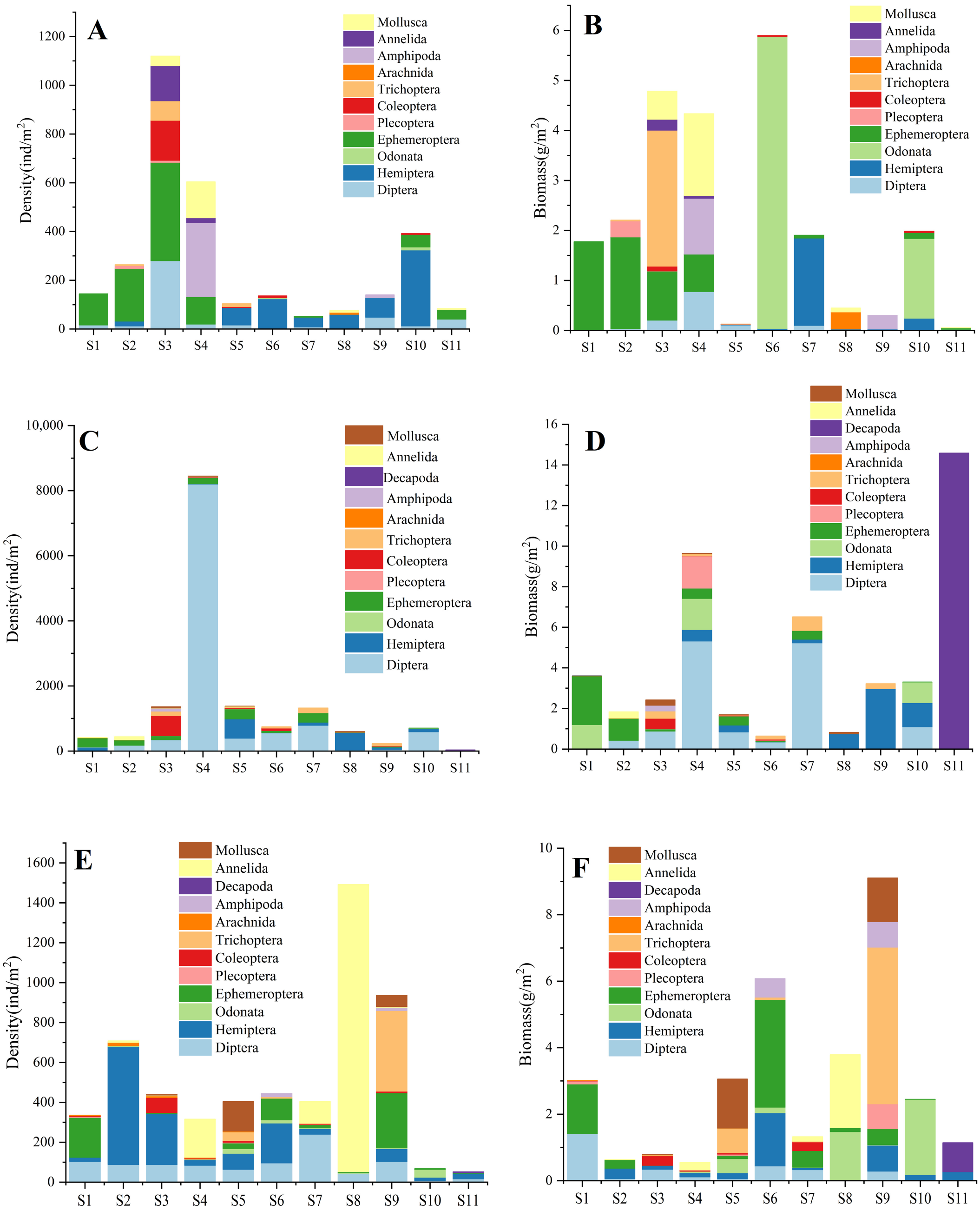

Figure 3. Density and biomass of macrobenthos. (**A**) Macrobenthic density in May, (**B**) macrobenthic biomass in May, (**C**) macrobenthic density in August, (**D**) macrobenthic biomass in August, (**E**) macrobenthic density in October, and (**F**) macrobenthic biomass in October.

In October, the density of macrobenthos ranged from 52 to 1492 ind/m^2, with the lowest point occurring at Fuhai Bridge (S11) and the highest point occurring at Yerk Kala (S8). The average value was 509 ind/m^2. The biomass ranged from 0.5504 to 9.1056 g/m^2, with the lowest point occurring in Tucker Shiken Town (S4) and the highest point occurring in Dure Town (S9). The average value was 2.90 g/m^2.

The average density and biomass of macrobenthos in the Ulungu River were in the order of August > October > May at the temporal level; at the spatial level, the average density was greater in the tributaries than in the main stream, and the average biomass was greater in the main stream than in the tributaries (Table 3). After nonparametric testing, there was a significant difference in macrobenthic density between seasons (p = 0.038), but there was no significant difference in biomass between seasons (p = 0.234). The changes in macrobenthic density and biomass at various points in the Ulungu River Basin are shown in Figure 3.

Table 3. The average value of spatial horizontal density and biomass of macrobenthos.

Site		Density (ind/m^2)			Biomass (g/m^2)		
		May	August	October	May	August	October
tributaries	S1	144	416	336	1.77	3.60	3.02
	S2	264	440	708	2.21	1.84	0.64
	S3	1120	1360	440	4.78	2.42	0.79
	S4	604	8448	316	4.33	9.64	0.55
	S5	104	1380	404	0.13	1.69	3.06
	Mean		1099			2.70	
main stream	S6	136	748	444	5.90	0.64	6.08
	S7	52	1324	404	1.90	6.52	1.32
	S8	76	600	1492	0.45	0.82	3.79
	S9	140	228	936	0.30	3.22	9.11
	S10	392	708	68	1.98	3.30	2.45
	S11	84	36	52	0.06	14.58	1.14
	Mean		440			3.53	

The Shannon—Wiener index (H′) of the Ulungu River in May ranged from 0.57 to 3.25, with an average of 1.91; the Margalef richness index (d) ranged from 0.47 to 2.46, with an average of 1.35; and the Pielou evenness index (J) ranged between 0.29 and 0.83, with an average value of 0.63. The maximum values of H′ and d both occurred in Agashi Aobao Township (S3), and the maximum value of J occurred at the Fuhai Bridge (S11). The minimum values of H′ and J both occurred at Ertai Bridge (S6), and the minimum value of d occurred at Yerk Kala (S8) (Figure 4).

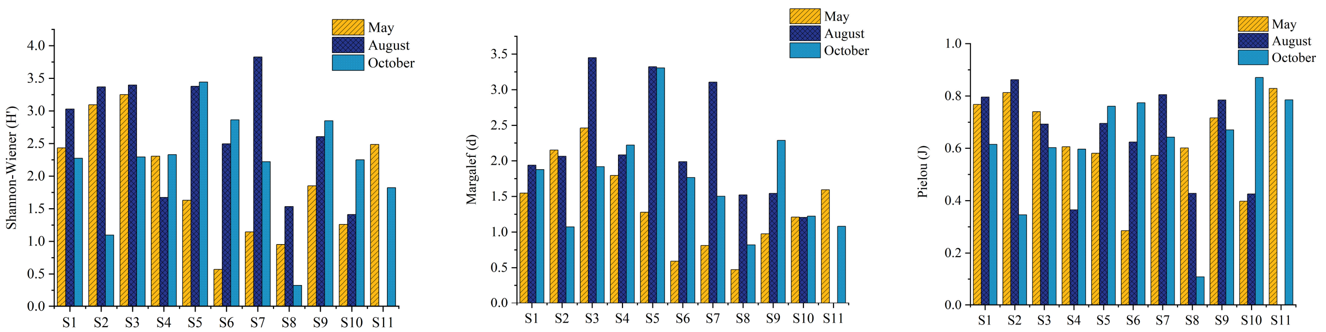

Figure 4. Spatial changes in the macrobenthic diversity index.

In August, the Shannon—Wiener index ranged from 0 to 3.83, with an average value of 2.43; the Margalef richness index ranged from 0 to 3.45, with an average value of 2.02; and the Pielou evenness index ranged from 0 to 0.86, with an average value of 0.59. The maximum values of H′, d, and J occurred in Qiakultu Town (S7), Agashi Aobao Township (S3), and Qinggri River Twin Bridge (S2), respectively. During the investigation of Fuhai Bridge (S11), only species of Palaemonidae were found at this site, and all diversity indices were zero.

In October, the Shannon—Wiener index ranged from 0.33 to 3.44, with an average value of 2.16; the Margalef richness index ranged from 0.82 to 3.30, with an average value of 1.73; and the Pielou evenness index ranged from 0.11 to 0.87, with an average value of 0.62. The maximum values of H′ and d both occurred in Ihigen Village (S5), and the maximum value of J occurred in Kalamagai Town (S10). The minimum values of H′, d, and J were all in Yerk Kala (S8).

The mean values of the Shannon—Wiener index and Margalef richness index followed the order August > October > May at the temporal level, and the mean values of the Pielou evenness index followed the order May > October > August at the temporal level. At the spatial level, the overall mean value of each diversity index indicated that the tributaries had larger diversity indices than the main stream. The specific changes in the diversity indices are shown in Figure 4.

3.3. Water Quality Evaluation Results

The Shannon—Wiener index water quality evaluation results show (Table 4) that the Ulungu River Basin was experiencing light pollution overall, with the largest proportion of clean sites occurring in August. The water quality conditions were better in August than in October, followed by May. The water quality of the Qinggri River Twin Bridge (S2) and Agashi Aobao Township (S3) was clean in May and August, and the water quality of Ihigen Village (S5) was clean in August and October. The water quality of the Daqing River Bridge (S1) was poor in August. According to the average value of the Shannon–Wiener index at different sites, all the tributaries had light pollution, and the water quality was better than that of the main stream, and Yerk Kala (S8) had heavy pollution in the main stream.

Table 4. Results of the Shannon–Wiener index for evaluating water quality.

Site	May		August		October		Mean	Level
	H′	**Level**	**H′**	**Level**	**H′**	**Level**		
S1	2.43	Light pollution	3.03	Clean	2.28	Light pollution	2.58	Light pollution
S2	3.09	Clean	3.37	Clean	1.10	Moderate pollution	2.52	Light pollution
S3	3.25	Clean	3.40	Clean	2.29	Light pollution	2.98	Light pollution
S4	2.31	Light pollution	1.68	Moderate pollution	2.33	Light pollution	2.11	Light pollution
S5	1.63	Moderate pollution	3.38	Clean	3.44	Clean	2.82	Light pollution
S6	0.57	Heavy pollution	2.51	Light pollution	2.86	Light pollution	1.98	Moderate pollution
S7	1.15	Moderate pollution	3.83	Clean	2.22	Light pollution	2.40	Light pollution
S8	0.95	Heavy pollution	1.53	Moderate pollution	0.33	Heavy pollution	0.94	Heavy pollution
S9	1.85	Moderate pollution	2.61	Light pollution	2.85	Light pollution	2.44	Light pollution
S10	1.26	Moderate pollution	1.41	Moderate pollution	2.25	Light pollution	1.64	Moderate pollution
S11	2.49	Light pollution	0	Heavy pollution	1.82	Moderate pollution	1.44	Moderate pollution
Mean	1.91	Moderate pollution	2.43	Light pollution	2.16	Light pollution	2.17	Light pollution

The average FBI index shows (Table 5) that the water quality grade of the Ulungu River Basin was poor, with the water quality conditions in May being better than those in August, followed by those in October. In May, the water quality in Qiakultu Town (S7) was healthy, and the water quality at Daqing River Bridge (S1) and Qinggri River Twin Bridge (S2) was good; in August, the water quality in Dure Town (S9) was good; and in October, the water quality levels at the Daqing River Bridge (S1) and Dure Town (S9) were good. During the investigation period, the remaining sites were polluted to varying degrees, and the water quality level of Yerk Kala (S8) was very poor in May, August, and October. According to the average value of the FBI index at different sites, the water quality of Daqing River Bridge (S1) was good, and Yerk Kala (S8) was very poor. The water quality of the tributaries and the main stream was similar.

The average BMWP index shows (Table 6) that the water quality level of the Ulungu River Basin was moderate, with the water quality conditions in August being better than those in October, and May being the worst. In May, the water quality levels of the Qinggri River Twin Bridge (S2), Agashi Aobao Township (S3), and Tucker Shiken Town (S4) were good; in August, the water quality levels of Agashi Aobao Township (S3) and Ihigen Village (S5) were healthy, and the water quality levels of Tucker Shiken Town (S4), Ertai Bridge (S6), and Qiakultu Town (S7) were good; in October, the water quality level of the Daqing River Bridge (S1) was good. According to the average value of BMWP scores at different sites, the water quality of Agashi Aobao Township (S3) and Tucker Shiken Town (S4) and

Ihigen Village (S5) in the tributary was good, Fuhai Bridge (S11) was poor, and the other sites were general. The water quality of tributaries was better than that of the main stream.

Table 5. FBI results for water quality evaluation.

Site	May		August		October		Mean	Level
	FBI	Level	FBI	Level	FBI	Level		
S1	4.03	Good	5.24	General	4.29	Good	4.52	Good
S2	4.76	Good	6.83	Poor	7.62	Very poor	6.40	Poor
S3	6.80	Poor	6.53	Poor	6.95	Poor	6.76	Poor
S4	6.38	Poor	6.98	Poor	8.28	Very poor	7.21	Poor
S5	6.77	Poor	6.83	Poor	5.78	Poor	6.46	Poor
S6	7.31	Very poor	6.94	Poor	6.27	Poor	6.84	Poor
S7	2.01	Healthy	6.30	Poor	7.53	Very poor	5.28	General
S8	7.52	Very poor	7.47	Very poor	9.08	Very poor	8.02	Very poor
S9	7.57	Very poor	4.32	Good	4.83	Good	5.57	General
S10	7.19	Poor	6.26	Poor	5.29	General	6.25	Poor
S11	6.58	Poor	6.00	Poor	7.42	Very poor	6.67	Poor
Mean	6.08	Poor	6.34	Poor	6.67	Poor	6.36	Poor

Table 6. BMWP water quality evaluation results.

Site	May		August		October		Mean	Level
	BMWP	Level	BMWP	Level	BMWP	Level		
S1	25.1	General	35.9	General	57.0	Good	39.3	General
S2	54.7	Good	34.2	General	17.0	Poor	35.3	General
S3	71.4	Good	87.7	Healthy	33.0	General	64.0	Good
S4	55.2	Good	77.7	Good	32.5	General	55.1	Good
S5	34.9	General	95.1	Healthy	93.4	Healthy	74.5	Good
S6	22.6	Poor	54.8	Good	39.0	General	38.8	General
S7	22.9	Poor	77.1	Good	40.2	General	46.7	General
S8	6.1	Very poor	38.1	General	30.1	General	24.8	General
S9	7.5	Very poor	29.0	General	102.8	Healthy	46.4	General
S10	44.5	General	38.3	General	20.5	Poor	34.4	General
S11	18.0	Poor	4.0	Very poor	12.0	Poor	11.3	Poor
Mean	33.0	General	52.0	Good	43.4	General	42.8	General

Taken together, according to the respective overall average values of H′, FBI, and BMWP indices, overall, the water quality of the Ulungu River Basin ranged from light pollution to poor. The water quality of the tributary was better than that of the main stream (Table 7).

Table 7. Water quality assessment results of the average values of Shannon–Wiener, FBI, and BMWP indexes in tributaries and main streams.

River Basin	H′		FBI		BMWP	
	Mean	Level	Mean	Level	Mean	Level
tributaries	2.6	Light pollution	6.27	Poor	53.65	Good
main stream	1.81	Moderate pollution	6.44	Poor	33.75	General

4. Discussion

4.1. Environmental Factors

Aquatic ecological factors are potential indicators for predicting changes in aquatic biological communities. The water temperature of natural water bodies will experience seasonal and diurnal changes [27]. The highest water temperature monitored during the survey was at Fuhai Bridge (S11) in August. This may be due to the basin's proximity to towns and human activity areas, coupled with the nearby terrain being flat, and the absence of tall trees blocking light. The average pH value of the three surveys (7.61 $\pm$ 0.65) indicated that the water body was weakly alkaline, which is consistent with the pH range of most natural water bodies in the range of 5–9 [28]. This weak alkalinity may be related to the alkaline wastewater discharged into the water and human activities occurring around the riverbanks. DO was at a low level in August, and DO could cause changes in community structure by affecting the respiration and diffusion of macrobenthos [29–31]. DO is often related to water temperature, with generally higher water temperatures causing DO levels to decrease. The results of this study found that the trend of water temperature and dissolved oxygen in the Ulungu River Basin was opposite at the temporal level. The low DO level in August was accompanied by an increase in the abundance of Chironomidae species, which is similar to previous findings [32].

4.2. Macrobenthos

The survey results of the macrobenthos in the Ulungu River Basin showed that aquatic insects accounted for the largest proportion of the population in the region. These findings are similar to the results of previous studies in the Irtysh River Basin, which has a similar geographical location. The number of dominant species is less than that in the Irtysh River Basin [33], though the species are similar. The density survey results are higher than those in the Irtysh River Basin, indicating that the average density of macrobenthos in the Ulungu River is greater than that in the Irtysh River Basin. A possible reason is that the water environmental factors in the Ulungu River Basin are more favorable than those in the Irtysh River [19]. The Ulungu River Basin accounts for the largest proportion of arthropod species, especially Diptera, and this is similar to the results of studies on macrobenthos in lakes in the southern Ob-Irtysh basin [34]. However, the Chinese urban rivers with similar latitudes also have the largest number of arthropods, but the proportion is lower than that of the Ulungu River Basin [35]. Compared with the African Ganges with a similar longitude, the Ganges has the largest proportion of mollusks, and there are only a few species of Ephemeroptera, which is significantly different from the macrobenthos community structure in the Ulungu River Basin [36]. The density and biomass of macrobenthos in the Ulungu River Basin are much greater than those in the Tarim River Basin, which is also an inland river, and the dominant species are quite different from those in the Tarim River Basin [37]. This may be because Ulungu River is close to the Altai Mountains, and Tarim River is close to the edge of the Taklimakan Desert. There are obvious differences in the ecological environment between the two regions. The habitats of the Ulungu River Basin and the Ili River Basin are complex. The dominant species all include Ephemeroptera and Chironomid species, and the average density and biomass are not much different [38].

At the spatial level, the overall density of tributaries is higher than that of the main stream, but the biomass is lower than that of the main stream. This is mainly because the main stream is mostly distributed with some large-bodied but small-number macrobenthic animals, such as Amphipoda, Decapoda, Odonata, etc. The average diversity index showed that the diversity in the tributaries was greater than that in the main stream, indicating that the overall macrobenthic diversity in the tributary reaches was greater than that in the main stream. This is similar to the results of the study on the Jarama River in Madrid, Europe, where tributaries close to mountains and at high altitudes will have higher diversity of macrobenthic animals [39]. A possible reason is that the main stream is close to the downstream reaches, and less runoff will reduce the benthos diversity [40]. Because the tributaries are close to the Altai Mountains and receive a large amount of rainfall, the downstream reaches of the main stream are close to the Junggar Basin and receive less rainfall. In addition, the overexploitation and utilization of land in tributary reaches and the increase in new industrial water use have resulted in the runoff of the downstream reaches of the main stream being much smaller than that of the tributaries [41]. In addition, during the investigation, it was found that the substrate in the tributary river sections consisted mostly of pebbles and gravel, which are more suitable for the survival of macrobenthos [42,43]. The diversity indices of the Fuhai Bridge (S11), located in the main stream of the Ulungu River in August, were all zero. The main reason may be the impact of the flow interruption in the Fuhai section of Ulungu River's lower reaches of the main stream during the August survey. Since the 1990s, due to the overexploitation of land in the tributaries of the Ulungu River and a surge in industrial water use, the number of days without flow in the Fuhai section of the downstream main stream has increased annually. As a result, the habitats and breeding grounds of aquatic life in this section have almost disappeared, and the aquatic ecological environment has been severely damaged.

4.3. Water Quality Evaluation

In the Ulungu River Basin, the biological evaluation of the water quality of each index had different results due to differences in evaluation standards. The Shannon–Wiener index and BMWP evaluation results were relatively similar, and the water quality of the tributaries was better than that of the main stream. The water quality evaluation results of the FBI of Yerk Kala (S8) in the three surveys were all very poor, which is consistent with the conditions observed during the survey. The water body at this site was turbid during the survey, the surrounding water body was mostly rocky, the vegetation was sparse, and the biodiversity was low. Most of the species were pollution-resistant species, such as oligochaetes, and the water quality was poor. Overall, the water quality of the Ulungu River Basin ranges from light pollution to poor quality. The possible reason is that the Ulungu River Basin is dominated by agriculture and animal husbandry, and rainfall and snowmelt will bring a large amount of harmful substances produced by agriculture and animal husbandry into the river. In addition, a large amount of human interference, such as an increase in organic matter and an increase in chironomid larvae and oligochaetes in the water body [44], has also impacted the water quality of the basin. Chironomidae taxa found in tropical rivers may be pollution-resistant taxa. Compared with tropical rivers, the proportion of Chironomidae taxa in the Ulungu River Basin is larger, which is consistent with the results of the presence of pollution in water bodies in this study. In areas where organic pollution is present, the proportion of chironomid taxa is associated with a higher abundance of chironomid larvae [45]. At the spatial level, there are many types of EPTs in tributaries, and the water quality is better than that in the main stream. The main reason may be that the tributaries are more rural and group farms and receive more rainfall. The vegetation coverage near the basin is high, the water flow rate is fast, and the self-purification ability is strong. The discharge of industrial and domestic wastewater and pollution caused by livestock farming flow into the main stream with the water flow. However, the downstream reaches of the main rivers are prone to flow interruptions, the discharged wastewater cannot be diluted, the erosion and siltation capacity of the river sections is reduced, the self-purification ability is lost, and the water quality is deteriorating annually.

As a tributary of the Irtysh River, the Ulungu River's polluted water may have a negative impact on the water quality of the Irtysh River and even the Ob River along with runoff. However, previous studies have found [46] that the pollution level of the upper reaches of the Irtysh River is low, and the cross-border runoff does not have the characteristics of serious pollution. This may be due to increased rainfall and reduced permafrost volume, coupled with the effective operation of large dams and reservoirs in the Irtysh River Basin in China and the implementation of water-saving technologies, which ensured the water level in the basin [47] and weakened the impact of polluted water in the Ulungu River, ensuring the health of the river. However, the water quality of the Irtysh River in East Kazakhstan is poor, which may be mainly due to heavy metal and nuclear pollution caused by previous industries in the area [48]. There is no obvious pollution in the water quality of the Irtysh River downstream after Pavlodar in Kazakhstan, which may be due to its high self-purification ability downstream. The Irtysh River eventually merges into the Ob River. Some studies have found that the Ob River leech diversity in Russia is relatively large [49], which may mean that the water quality of the river is good. This may be due to the flat nature of the branch water system, and many tributaries carry nutrients from the vast territory, combined with the Atlantic Multidecadal Variability (AMV), inducing an increase in normal rainfall in the Ob River [50], giving the river a high level of self-purification capacity. But, in fact, the Ob River is also suffering from some radionuclides and heavy metal pollution that may come from European nuclear power plants and some human factors [51,52]. In contrast, the impact of pollution from the Ulungu River may be diluted during the long runoff process, but after long-term accumulation, it is speculated that it may also have a potentially deeper impact on the Ob River Basin ecosystem. In addition, compared with the Shuya River in northern Russia, due to its lower degree of eutrophication, the water quality is better than that of the Ulungu River Basin. There are many residents and farms along the Ulungu River Basin, so it is speculated that the water body already has a certain degree of eutrophication [53].

5. Conclusions

As the second largest river in the Altay region of Xinjiang, China, the water quality of the Ulungu River is closely related to the ecological health of the basin and the lives of surrounding residents. The macrobenthos in the basin are mainly aquatic insect species with high density and biomass. According to the respective overall average values of H′, FBI, and BMWP indices, overall, the water quality level of the Ulungu River Basin ranges from light pollution to poor quality, and human interference activities such as basin development and livestock husbandry have a greater impact on the water quality of the basin. The water ecology of the Ulungu River Basin is relatively fragile and has little ability to withstand pollution. To protect and restore basin ecology, it is necessary to strengthen the management and governance of pollution sources, strengthen the management of the harm of livestock, irrigation, and other activities to basin ecology, and rationally plan the scale of basin development without harming the ecological environment.

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