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Original Research

Potential Biodiversity Disruptions Caused by Changes in Water Body Coverage. A Case of Lake Taldykol, Kazakhstan

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Abstract

The incorporation of water bodies into city surroundings is gaining popularity as metropolitan areas expand rapidly. Maintaining the ecological health of these lakes poses challenges for ecologists and local government officials, given the influence of human activity on hydrological and hydrochemical properties and the resident organisms. Lake Taldykol serves as an illustrative example of how substantial human involvement disrupts the natural equilibrium of water bodies. This disruption offers a valuable model for studying ecological succession patterns amid fluctuating hydrological conditions. The primary objective of this study was to understand how the decreasing water supply in Astana's lake system affects the biodiversity of aquatic fauna. Studies on the fauna in the vicinity of Taldykol Lake were conducted from 2020 to 2022. The research classified species and quantitatively evaluated the fauna of the lake and its adjacent coasts. The quantitative data was then utilized to calculate the Shannon index for each unique biome. Results indicated a significant impact on the quantity and distribution of species due to a 65% reduction in the lake's area. Several species emerged as particularly sensitive environmental indicators. Notably, the Shannon index decreased by 0.8 points (30%) from an initial value of 2.7 to 1.9 as the water area decreased by 2,800,000 square meters (65%), and the water volume decreased by 3,098,000 cubic meters (71%). This reduction highlights the ecological implications of the changing lake conditions on biodiversity and overall water quality.

Keywords: biocenosis, species diversity, Shannon index, urban lakes, ecological health

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Introduction

Lakes have long been associated with particular feelings in our minds about the environment because they are dynamic ecosystems that support a diverse range of living forms and significantly increase biodiversity worldwide. However, in the modern world, the idealized vision of immaculate lakes frequently collides with the harsh environmental realities they must contend with [1]. These aquatic ecosystems have been irrevocably impacted by the combination of urban growth and human involvement, which has changed their ecological dynamics and presented them with significant problems [2]. Within the quickly changing urban landscape of Kazakhstan's capital, Astana, the Taldykol Lake system offers an insightful setting for investigating the intricate interactions between human activity and the delicate balance of the local fauna [3]. The entire ecosystem is affected by the effects of this intervention, which include pollution, modifications to habitat structure, and adjustments to hydrological patterns.

Urbanization is a prominent phenomenon in human civilization that presents a range of benefits and problems to cities that thrive on innovation, culture, economic expansion, and population growth [4]. However, as metropolitan areas grow, they take a toll on the environment, and this often affects the lakes themselves, which have historically served a variety of purposes, including recreation, water supply, ecosystem support, and aesthetic and cultural significance [5]. The natural environment that coexists with urban landscapes is increasingly affected by human activity as these landscapes expand [6]. Water bodies, especially lakes, play a crucial role in this coexistence by providing both aesthetic attractiveness and essential homes for a wide range of creatures, making them essential for maintaining biodiversity [7].

But as urbanization increases anthropogenic stresses on lakes, which show up as pollution, habitat loss, and disruptions in water regimes, this peaceful cohabitation is always in jeopardy [8]. Pollutants from industry, sewage, and runoff are created by urban expansion and have a significant effect on water quality. Additionally, changes in land use and shoreline structures further degrade important habitats. Beyond the Taldykol Lake system, human activity has an impact on lake ecosystems globally as lakes deal with the fallout from urbanization, industrialization, and intensive agriculture—all of which contribute to environmental changes [9]. Urbanization poses a potent threat to lakes and their surroundings [10, 11]. The spatial expansion of human settlements and growing resource demands place overwhelming pressure on these ecosystems, resulting in compromised water quality and diminished biodiversity [12–14]. Certain lakes face threats from drainage projects for urban development, and their shorelines are altered, further destabilizing the ecosystems within. An illuminating paradigm for examining the intricate connections between human intervention and the dynamics of lake fauna is the Taldy-Kol Lake system [15]. Significant changes to this system have drawn the interest of ecologists, environmentalists, and local government officials, sparking discussions on how to handle the problems brought about by urbanization and human intervention in the environment.

Nestled within the rapidly evolving city of Astana, the Taldykol Lake system bears a rich natural and anthropogenic history that dates back thousands of years [16]. This system's origins lie in climatic shifts during the postglacial and Holocene periods, with the lakes forming in temporary channels of the Nura River [17]. Presently, the Taldykol System 100 includes Big Taldykol Lake and a group of smaller lakes known as Small Taldykol. These lakes have historically combined into a continuous body of water during times of high water, demonstrating their biological interdependence. However, the system has seen significant alterations due to active urban expansion, which has caused some lakes to infiltrate and shift from cohesive water bodies into isolated water islands. The largest lake in the system, Big Taldykol Lake, is particularly notable for its unique human impact history, having been used for almost fifty years as a storage area for sewage water released from Astana. The ecosystem as a whole underwent a total alteration as a result of this practice, which dramatically changed its characteristics.

Presently, Lake Taldykol is grappling with severe shallowing, primarily due to anthropogenic activities that aim to further urbanize the lake's surrounding areas [18]. The Taldykol Lake system offers a chance to investigate the processes of destructive succession within the biocenosis of lake ecosystems, bringing both theoretical relevance and practical insights. Additionally, it clarifies the ecological effects of urban growth and human intervention, which is crucial information for ecological management strategies, conservation efforts, and sustainable urban development [19]. Moreover, in the face of rapid urbanization and widespread anthropogenic interference in natural ecosystems, it is crucial to understand how these activities impact aquatic ecosystems' fauna [20]. An exemplary model that provides insights into the far-reaching effects of urban expansion on biodiversity, water quality, and habitat modification is the Taldykol Lake system. In order to lessen the negative consequences of anthropogenic involvement, conservation initiatives, sustainable urban development techniques, and ecological management strategies might be informed by the research findings. In a day of rising urbanization and environmental difficulties, it emphasizes the critical need to strike a balance between urban expansion and the preservation of natural habitats and biodiversity. It also emphasizes the significance of responsible care for our common natural heritage.

The purpose of this study is to evaluate how the biodiversity of the local fauna is affected by the decreased water availability in the Taldykol Lake system. Examining changing patterns in the local fauna, it explores the ecological ramifications of these changes and adds to the continuing conversation on managing and protecting urban lakes in the face of increasing urbanization. A call to action, supporting responsible care of our common natural heritage in the face of urban expansion, is also made by the study, which attests to the resilience of the Taldykol Lake system. This study is unusual because it is the first to thoroughly examine how human activities – especially those related to urbanization – affect the complex dynamics of the fauna that live in the Taldykol Lake System. This research offers a unique chance to examine the ecological ramifications of significant changes brought about by human intervention. It also looks into how modifications to the lake's hydrological regime, brought about by reduced water availability as a result of human activity, can cause changes in the species composition of the ecosystem, which in turn can have an impact on the ecological integrity of the whole system. Consequently, it adds to the expanding corpus of knowledge regarding the complex effects of urbanization on aquatic ecosystems, especially the role lakes play in influencing biodiversity, and offers crucial insights to guide conservation initiatives and sustainable urban development in the face of continuous urban growth and environmental difficulties.

Materials and Methods

Description of the Case Study

In the interfluve zone of Nury and Yesil, the lake land is located in the southwest of Astana. A mildly sloping plain with a slight northwest slope characterizes the terrain. The northwest has an elevation of 335–340 meters above sea level, whereas the southeast has an elevation of 450-480 meters above sea level. Since there are no prominent elevations in the northwest portion of the interfluve, the amount of surface runoff entering the watershed is lower, and the frequency of waterlogging processes is higher. The Taldykol lake system comprises both Big Taldykol and Small Taldykol lakes, situated in the southwestern region of Astana city. Prior to 2017, Small Taldykol consisted of six individual lakes, three of which have since dried up. During years of high water, particularly during spring floods, these separate lakes merge to form a unified water body, only to revert to distinct bodies of water during the low-water period in summer and autumn. The formation of these lakes can be traced back to increased humidity in the climate of the region during the post-glacial and Holocene periods, approximately 13 thousand years ago. Shallow and without drainage, the lakes possess a natural origin and sustain established ecosystems.

The sequence of processes leading to the formation of the lake group during the historical period can be discerned through the development of coastal deformations and the hydrographic network's direction. The Taldykol lakes originated as arms within the ancient channel of the Nura River in Sarkromy. The water flow of the Nura River facilitated the redistribution of water resources in three directions. The widest and deepest depressions formed along the Taldykol and Small Taldykol lakes, serving as conduits for the primary outflow of water masses into the Yesil River during flood phases. Parts of the temporary channels formed by the flow subsequently evolved into the hollows that comprise the present-day lakes.

The climate of the city exhibits characteristics of continental and arid nature, characterized by prolonged winters typically blanketed in snowfall and marked by intense frosts, contrasted with relatively brief yet sweltering summers. This region falls within the classification of inadequately moist climates. The Taldykol lakes, integral to this ecosystem, maintain an average depth of 1.5 meters with a maximum depth reaching 3 meters, rendering them relatively shallow water bodies within the area. The total amount of precipitation that falls each year and the rate at which water evaporates from the lake's surface in the sweltering summer months determine how much these lakes fill up. These lakes usually reach their maximum water levels in April, which is also the month when the active snowmelt phase occurs. On the other hand, the months preceding the lake's total freezing point experienced the lowest water levels. The lakes show low amplitude changes in their water level, which has helped them survive over a long historical period and prevent desiccation during dry years. Local catchment regions help refill the water levels throughout the year. The spring rise in water levels, which is followed by a steady fall that lasts through the summer and fall, is an important part of the lakes' hydrological regime. There are no rare or Red Book-listed species in the study region, and the majority of the vegetative cover is made up of weed species. Though they are scattered, the therapeutic plants do not grow into large thickets. The dominant vegetation is mostly classified as ruderal vegetation, with xerophytic species predominating. These plants include *Field Thistle, Cirsium arvense (L.) Scop., Sisymbrium loeselii L., Melilotus officinalis (L.) Pall., Medicago falcata L., Artemisia absinthium L., and Achillea nobilis L.*

The tributaries feeding into Lake Taldykol include small streams such as the Nura River and the Ishim River, which originate from the surrounding areas of Astana. These tributaries contribute to the lake's water volume and quality, bringing in sediments, nutrients, and other materials from the watershed.

The morphometric parameters of Lake Taldykol include a surface area of approximately 1,200 square kilometers, a maximum depth of 15 meters, and a shoreline length of 90 kilometers. These parameters influence the lake's ecological processes, including nutrient cycling, habitat availability, and water circulation patterns. Historical data from previous years provides important context for understanding the long-term trends and changes in Lake Taldykol's ecosystem. These data include records of water quality parameters such as pH, dissolved oxygen levels, and nutrient concentrations, as well as observations of ecological indicators such as species diversity and abundance. Catchment management efforts aimed at preserving Lake Taldykol's ecological integrity encompass land-use planning, erosion control measures, and pollution prevention strategies. The primary sources of water supply to Lake Taldykol include surface runoff from urbanized and agricultural areas, groundwater inflow from underlying aquifers, and precipitation. Inflowing pollutants, particularly sewage discharge, pose a threat to Lake Taldykol's water quality and ecological health. Efforts to monitor and mitigate pollution sources include the implementation of wastewater treatment systems, stormwater management practices, and public education campaigns to promote environmental stewardship.

Generally, the study employed various methods to assess the impact of urban expansion on the aquatic ecosystem of Lake Taldykol. As part of the analysis, typical water quality parameters were monitored to evaluate the health and condition of the lake. Water samples were collected from multiple locations within Lake Taldykol during the study period. pH levels were measured using a calibrated pH meter, and the results showed a range between 7 and 9. These values indicate slightly alkaline to alkaline conditions, which are generally favorable for the aquatic ecosystem. Dissolved oxygen (DO) levels in the water samples were assessed using a dissolved oxygen probe. The measurements revealed concentrations ranging from 6 to 10 milligrams per liter (mg/L). These values indicate sufficient levels of dissolved oxygen to support a diverse range of aquatic life within the lake. Nutrient concentrations, including nitrogen and phosphorus, were analyzed using standardized laboratory methods. The results indicated that nutrient concentrations generally fell within acceptable limits for a healthy lake ecosystem. This suggests that the lake's water quality was not significantly impacted by excessive nutrient loading during the study period. The monitoring of these typical water quality parameters provided valuable insights into the overall health and condition of Lake Taldykol. The pH values indicated the alkaline nature of the lake, while the dissolved oxygen levels suggested sufficient oxygen availability to support aquatic organisms. Furthermore, the nutrient concentrations within acceptable limits indicated a healthy nutrient balance in the lake. It is important to note that these methods and parameters are commonly used in water quality assessments and provide a baseline understanding of the ecosystem's health. However, it is advisable to complement these findings with additional analyses and monitoring of other relevant parameters to obtain a more comprehensive picture of the lake's ecological state.

The research utilized satellite imagery to generate a detailed water body map of the urban region, outlining the boundaries of the lake for both August 2020 and August 2022 (Fig. 1). The assessment of both the lake area and its catchment area involved the utilization of data sourced from the Sentinel-2 series satellites, processed through the SNAP software provided by the European Space Agency. These processed satellite images were made accessible through the Copernicus Open Access Hub. To ascertain the water surface area, SNAP v7.0 software was utilized, employing the Modified Normalized Difference Water Index (MNDWI). Introduced by Hanqiu Xu in 2006, this index utilizes pixel values from the green and mid-wave infrared ranges to determine water presence, calculated using the formula (Green – MIR) / (Green + MIR), yielding values between -1 and +1, where -1 indicates land and +1 signifies water. Subsequently, water bodies were identified by binarizing the raster based on a threshold value of the MNDWI index. The estimation of water volume in the lakes was facilitated by utilizing depth and area data in the calculations. This comprehensive approach enabled a thorough examination of changes in the lake's size and shape over a span of two years.

Collection and Recording of Animal Species (Data Collection and Biodiversity)

In the vicinity of Big Taldykol Lake, biodiversity assessments were carried out in August and September of 2020 and 2022, with an emphasis on describing species diversity and abundance across different animal groups. Standard techniques were used to do this. Entomological nets were used to catch the insects, allowing for a detailed investigation of the many insect species that were there. Following collection, the specimens were fixed with formalin or alcohol or submerged in ethyl acetate to preserve them. Moreover, ocular surveys using the route technique at designated monitoring sites were used to quantify insect species. This approach comprised a thorough count of all insects spotted, with a 500 m2 area being monitored for 30 minutes every 2-3 hours. The invertebrates found in the soil were carefully collected and counted using an excavation method. Four test pits totaling 0.25 m2 each had 0.25 m2 of excavation sites set up at predetermined places. Excavations were done methodically, working 200 down to deeper strata (5–10 cm, for example) after removing the top layer (5 cm) of soil. Barber's soil traps were also used to collect and measure animals that lived in the soil. A variety of techniques were used to evaluate the aquatic fauna, including the use of water nets, Apstein nets, and strategically positioned water traps baited with pet food or food waste inside aquatic plant thickets.

Species Diversity Index

As an indicator of the species structure of the community, we chose the Shannon species diversity

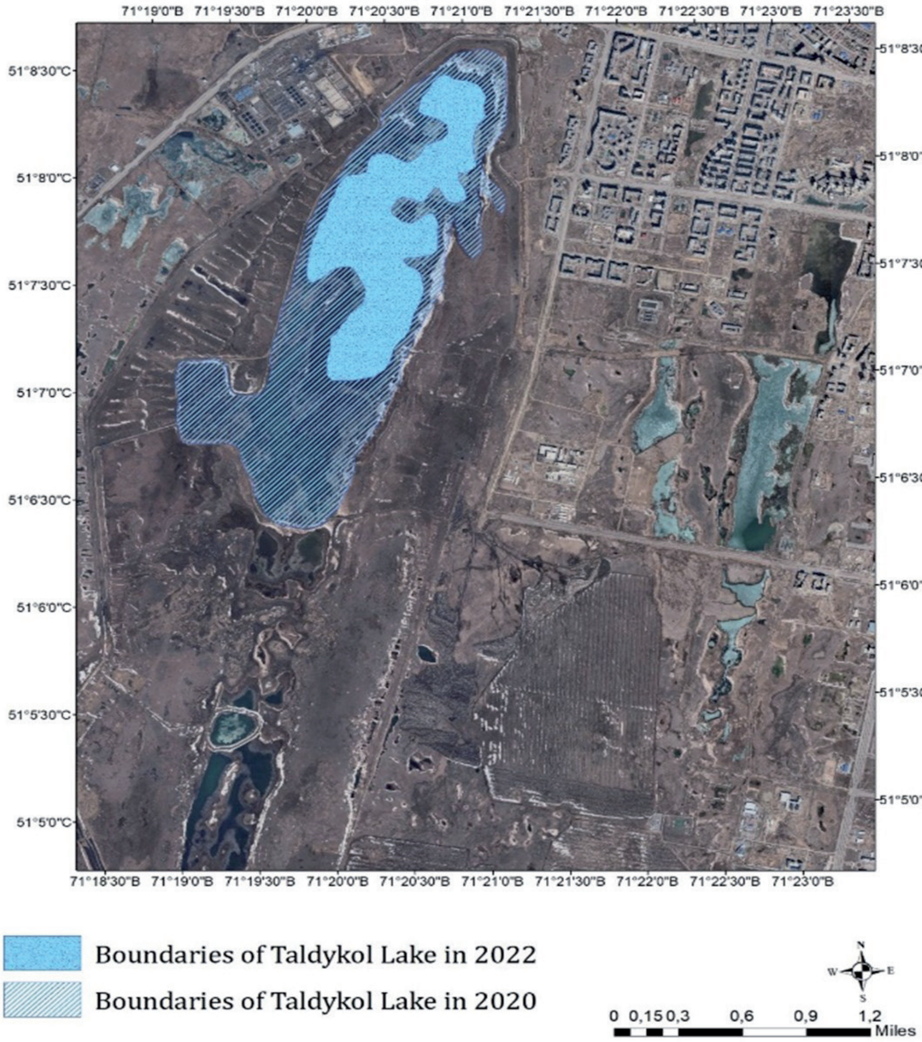

Fig. 1. Boundaries of Taldykol Lake in Astana in 2020 and in 2022.

index, which is informative for assessing the degree of structuring of biocenoses [21].

$$H = -\sum_{i=1}^{k} P_i \times \ln P_i \quad (1)$$

Whereby:

$$P_i = \frac{N_i}{N} \; or \; \frac{B_i}{B} \quad (2)$$

When calculating the Shannon index, the numbers Ni, N, and Bi stand for the number of individuals in the i^{th} species, the total number of individuals, and the biomass of individuals in the i^{-h} species, respectively. The Shannon index is a statistic that evaluates the evenness of the distribution of relative species abundance in addition to the diversity of species within a community. A greater index value is said to indicate a better state of the community.

Results

Parametric Data of Taldykol Lake

Fig. 2 shows significant changes in the Taldykol Lake system's characteristics between 2020 and 2022. First of all, the lake area shrank significantly, with its surface area falling by an astounding 65% from 4,290,000 square meters in 2020 to 1,490,000 square meters in 2022. There was also a shift towards shallower water as the lake's average depth dropped from 1 meter in 2020 to 0.8 meters in 2022. This decline, along with the area reduction, resulted in a significant fall in the lake's volume. The volume dropped significantly, by 72%, from 4,290,000 cubic meters in 2020 to 1,192,000 cubic meters in 2022. All of these results point to a significant decline in the Taldykol Lake system's size and water volume over the past two years. This decrease can be linked to the location of the Taldykol system within the interfluve of the Nury and Yesil rivers, characterized by numerous oval relief depressions conducive to the formation of shallow lake groups.

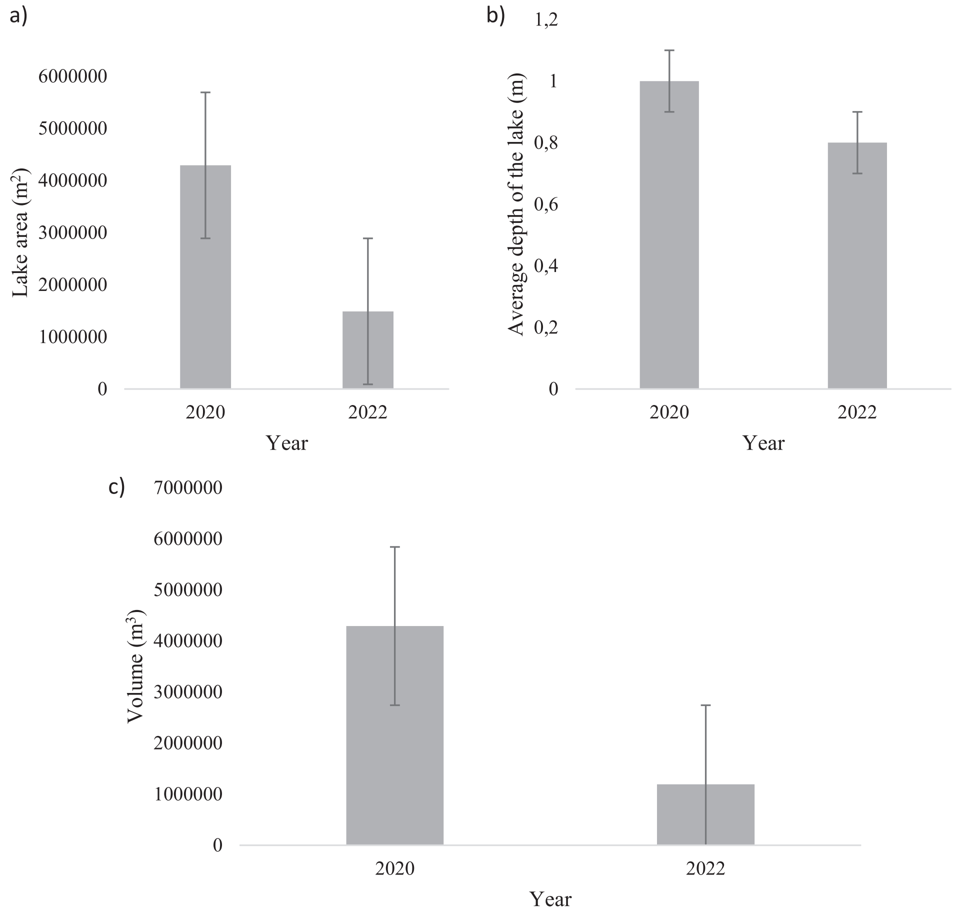

Fig. 2. Parameters of Taldykol Lake in 2020 and in 2022.

However, efforts by city authorities to mitigate flooding during high-water periods led to the construction of numerous hydraulic structures in the area. Additionally, alterations to the channel of the Yesil River were made repeatedly by city planners to prevent flooding. Presently, the completion of construction and drainage works on the Small Taldykol lakes has resulted in a gradual decline in groundwater levels within the drained area, attributed to the interception of precipitation by buildings, paved roads, lawns, and green spaces. However, the primary cause of the significant reduction in water volumes within the Taldykol Lake system can be attributed to the cessation of wastewater discharge and drainage activities, as well as construction and installation works since 2016. As seen in Fig. 1, such a decrease in lake volume and size can have a significant impact on the aquatic ecosystem, potentially affecting biodiversity and the general well-being of the species that call it home.

Hydrochemical Data

The hydrochemical analysis of the water samples from the Taldykol Lake system offers a thorough understanding of the water's chemical makeup (Table 1). Significantly, the pH level is within the typical range, suggesting some stability. But a host of other factors give cause for alarm. A significant excess of contaminants is indicated by the dry residue, which significantly exceeds the Maximum Permissible Concentrations (MPC) by a factor of 2.5. Elevated levels of calcium, magnesium, potassium, sodium, chlorides, and overall hardness underscore the departure of the water from acceptable standards. Similarly, sulfates fall within the upper threshold of the norm, but heightened levels of iron, manganese, and COD surpass the norm significantly, suggesting potential sources of contamination. Encouragingly, the Maximum Allowable Concentrations (MAC) for nitrogen, copper, APAV, polyphase, petroleum products, dissolved oxygen, BOD_5, boron, and molybdenum remain within acceptable limits. However, the Water Purity Index (WPI) classifies the water quality as highly polluted (Class III), with the study attributing the principal source of pollution to the urban area. This underscores the urgent imperative for comprehensive environmental management and rehabilitation efforts in the vicinity.

The hydrochemical studies were conducted on Lake Big Taldykol at the Analytical Laboratory of the Astana Su Arnasy Sewer Treatment Plant. The analyses revealed a significant increase in overall mineralization and concentrations of oxidizability pollutants, chlorides, sulfates, and general hardness in the lake, as indicated in Table 1.

Table 1. Hydro-chemical characteristics of the investigated parameters.

Parameter	Measurement 2020	Measurement 2022	MPC Exceedance Factor
pH Level	8.37	7.14	Within Norm
Oxidizability	19.2 mg O_2/dm³	14.3 mg O_2/dm³	-
Alkalinity	2.95 mg-eq/dm³	4.9 mg-eq/dm³	-
Total Hardness	26.25 mg-eq/dm³	96 mg-eq/dm³	-
Dry Residue	2545.99	19044.0	2.5 times
Calcium Concentration	290.58 mg/dm³	-	1.6 times
Magnesium Levels	142.88 mg/dm³	-	3.6 times
Potassium + Sodium Concentration	402 mg/dm³	-	2 times
Chlorides	1023 mg/dm³	4839.0 mg/dm³	2.92 times
Sulfate Levels	507.58 mg/dm³	3992.0 mg/dm³	Within Upper Limit
Nitrogen	5,64 mg/dm³	5.04 mg/dm³	Within Norm
Copper	0.007 mg/dm³	-	Within Norm
APAV	-	-	Within Norm
Polyphosphates	-	-	Within Norm
Petroleum Products	0.259 mg/dm³	0,302 mg/dm³	Within Norm
Dissolved Oxygen	5.62 mg/dm³	4.03 mg/dm³	Within Norm
BOD5	30.0 mg/dm³	26.0 mg/dm³	Within Norm
Boron	-	-	Within Norm
Molybdenum	-	-	Within Norm
Iron	1.63 mg/dm³	3.09 mg/dm³	5.43 times
Manganese	0.29 mg/dm³	0.040 mg/dm³	2.9 times
COD	61.3 mgO2/dm³	72 mgO2/dm³	2.04 times
Water Purity Index (WPI)	1.39	1.74	Class III (Moderately Polluted)
Pollution Source	Predominantly Urban Side	Predominantly Urban Side	-

Biodiversity of Lake Taldykol

The species diversity assessment, conducted in August and September of both 2022 and 2020, affirmed a notable alteration in the ecosystem's composition. In the course of these two epochs, the ecosystem's total animal species diversity was represented by four kinds and nine different animal classes (Table 2). A wide variety of animal classes were represented in the 2557 total animals that were identified in 2020. Notably, the *Arthropoda* type dominated with 291 species, while the *Insecta* type had the highest number of species (246), consisting of 11 orders and 66 families. The *Insecta* class *Coleoptera* was very abundant, with eight families and an astounding 89 specimens in the *Carabidae* family alone. Additionally, with 14 species and 182 specimens for the *Orthoptera* class (*Acrididae*) and 13 species and 98 specimens for the *Hemiptera* class (*Miridae*), respectively, these two classes demonstrated significant numbers. By comparison, the *Plathelminthes* type has the least diversity of species, with only one species (*Schistocephalus solidus Müller*) and only ten specimens. The ecosystem's diversity of animal species, which still includes four types and nine classes (Table 2), saw a notable decline in species diversity in 2022 when compared to 2020. With a total of 966 recognized animals in 2022, there was a significant drop in species diversity, with each class seeing a dip. The total number of species across all classifications decreased to 153, indicating an astounding 62% decrease in the diversity of animal species.

The taxonomic classification and population sizes of three different animal groups – *Plathelminthes, Annelida, and Mollusca* – are summarized in Table 3. The only species in the *Plathelminthes* type that was represented was *Schistocephalus solidus Müller*, which showed a 90% decline in population size. The type *Annelida*, which includes two classes, saw a significant

Table 2. Biodiversity of fauna of Big Taldykol Lake.

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Plathelminthes	*Cestoda*	*Pseudophyllidea*	*Ligulidae*	*Schistocephalus solidus Müller, 1776*	10	1
Annelida	*Clitellata*	*Oligochaeta*	*Haplotaxida*	*Lumbricidae*	11	5
				Allolobophora parva Eisen,1874 -	4	2
				Eisenia fetida (Savigny, 1826)	3	0
				Eisenia nordenskioldi (Eisen, 1879)	4	3
	Hirudinea	*Rhynchobdellae*	*Glossiphonidae*	*Glossiphonia complanata (Linnaeus, 1758)*	3	2
			Piscicolidae	*Piscicola geometra*	1	0
		Arhynchobdellida	*Erpobdellidae*	*Erpobdella octoculata (Linnaeus, 1758)*	2	0
Mollusca	*Gastropoda*	*Mesogastropoda*	*Bithyniidae*	*Bithynia tentaculata (Linnaeus, 1758)*	3	0
		Pulmonata	*Lymnaeidae*	*Lymnaea stagnalis (Linnaeus, 1758)*	5	0
				Galba truncatula (O. F. Muller, 1774)	8	0
				Ampullaceana balthica (Linnaeus, 1758)	8	0
				Radix auricularia (Linnaeus, 1758)	7	0
			Physidae	*Physa fontinalis (Linnaeus, 1758)*	14	7
			Planorbidae	*Gyraulus acronicus (J.B. Férussac, 1807)*	13	5
				Bathyomphalus contortus (Linnaeus, 1758)	12	5
			Succineidae	*Succinea putris (Linnaeus, 1758)*	5	0
			Agriolimacidae	*Deroceras agreste (Linnaeus, 1758)*	2	0

59% decline in population size. In the meantime, the *Mollusca* type included only one class, *Gastropoda*, for which there was a significant 76% decrease in the total number of individuals detected. In particular, the most negatively impacted species by these changes in population sizes were those belonging to the *Gastropoda* class, including *Ampullaceana balthica, Radix auricularia, Lymnaea stagnalis,* and *Succinea putris* from the *Pulmonata* order. This decrease highlights how vulnerable some of these animal species are.

The diversity of the *Arthropoda* type, which happens to be the most prevalent among the given categories, is shown in Table 4. The three classes that comprise this type are *Malacostraca, Arachnida,* and *Insecta*. With two orders, three families, and only three species, the class *Malacostraca* is the least abundant in this classification. There has been a concerning 90% decrease in the number of people in this class. In contrast, the class *Arachnida*, which consists of 34 species total, 10 families, and one order, is the second largest in terms of individual numbers, despite a 60% decline in population. However, with 2137 individuals recorded in 2020, the Insecta class emerges as the most abundant of all. The species diversity within the class *Insecta* is further described in Tables 4, 5, 6, and 7, which emphasize the class's importance in the animal population of this ecosystem.

As the most abundant class, the *Insecta* class saw a significant decline of about 60%, going from 246 species in 2020 to 117 species in 2022, with 10 orders and 70 families (Table 5). Table 4 lists the four orders that make up this class: *Hemiptera, Homoptera, Odonata,* and *Ephemeroptera.* In 2020, there was only one species in the *Ephemeroptera* order, which was a very fragile group. Odonata comprised four families in 2020; however, in 2022, the numbers drastically dropped by 100% for the families *Lestidae* and *Coenagrionidae*. There were nine families in the *Homoptera* order, with two of the families being absent in 2022. Sadly, the most susceptible species were found to be Lepyronia coleoptrata of the *Aphrophoridae* family and *Gargara genistae* of the *Membracidae* family.

Table 3. Biodiversity of Arthropoda types inhabiting Big Taldykol Lake.

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Arthropoda	*Malacostraca*	*Amphipoda*	*Gammaridae*	*Gammarus lacustris G.O.Sars, 1863*	5	0
		Isopoda	*Porcellionidae*	*Porcellio scaber Latreille, 1804*	5	1
			Agnaridae	*Hemilepistus sp.*	1	0
	Arachnida	*Aranei*	*Thomisidae*	*Diaea suspiciosa O. P.- Cambridge, 1885*	3	0
				Ozyptila scabricula (Westring, 1851)	3	0
				Thomisus onustus Walckenaer, 1805	6	0
				Misumena vatia (Clerck, 1757)	2	0
				Spiracme striatipes (L. Koch, 1870)	13	3
				cristatus (Clerck, 1758)	11	4
				Xysticus ninnii Thorell, 1872	5	0
				Heriaeus melloteei Simon, 1886	1	0
			Oxyopidae	*Oxyopes ramosus (Martini et Goeze, 1778)*	21	16
				Oxyopes heterophthalmus (Latreille, 1804)	11	3
			Pisauridae	*Pisaura mirabilis (Clerck, 1757)*	6	2
			Gnaphosidae	Micaria pygmaea Kroneberg, 1875	4	2
				Zelotes clivicola (L. Koch, 1870)	5	3
			Lycosidae	*Alopecosa solitaria (Herman, 1876)*	9	5
				Pardosa agrestis (Westring, 1861)	12	9
				Pardosa paludicola (Clerck, 1757)	13	3
				Pardosa hortensis (Thorell, 1872)	8	3
				P. riparia (C. L. Koch, 1847)	9	4
				Lycosa singoriensis (Laxmann, 1770)	5	2
				Trochosa ruricola (De Geer, 1778)	10	3
				Trochosa terricola (Thorell, 1856)	5	2
			Philodromidae	*Tibellus oblongus (Walckenaer, 1802)*	11	5
				Paratibellus oblongiusculus (Lucas, 1846)	3	0
				Philodromus cespitum (Walckenaer, 1802)	8	0
				Philodromus histrio (Latreille, 1819)	7	5
			Dyctinidae	*Dictyna arundinacea (Linnaeus, 1758)*	12	4
			Araneidae	*Larinioides patagiatus (Clerck, 1757)*	9	4
				Araneus diadematus (Clerck, 1758)	2	0
				Aculepeira ceropegia (Walckenaer, 1802)	13	3
				Hypsosinga sanguinea (C.L. Koch, 1844)	3	2
			Theridiidae	*Enoplognatha mordax (Thorell, 1875)*	3	2
				Neottiura bimaculata (Linnaeus, 1767)	6	4
				Steatoda albomaculata (De Geer, 1778)	4	3
			Salticidae	*Evarcha arcuata (Clerck, 1757)*	1	0

Table 4. Biodiversity of Insecta class of Arthropoda type inhabiting Big Taldykol Lake.

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Arthropoda	*Insecta*	*Ephemeroptera*	*Caenidae*	*Caenis robusta Eaton, 1884*	12	0
		Odonata	*Aeschnidae*	*Aeshna mixta (Latreille, 1805)*	6	1
				A. serrata Hagen, 1856	7	1
				A. juncea Linnaeus, 1758	3	1
				Anax imperator Leach, 1815	2	0
				A. parthenope Selys, 1839	3	0
			Libellulidae	*Sympetrum danae Sulzer, 1776*	9	2
				Sympetrum flaveolum (Linnaeus, 1758)	17	5
				Sympetrum vulgatum (Linnaeus, 1758)	10	0
				Orthetrum cancellatum Linnaeus, 1758	3	0
			Lestidae	*Lestes barbarus (Fabricius, 1798)*	14	0
				Lestes dryas	11	0
				Sympycna paedisca Brauer, 1877	12	0
			Coenagrionidae	*Enallagma cyathigerum (Charpentier, 1840)*	14	0
				Ischnura pumilio (Charpentier, 1825)	7	0
				I. elegans (Vander Linden, 1820)	5	0
		Homoptera	*Cicadellidae*	*Cicadella viridis (Linnaeus, 1758)*	11	4
				Kyboasca vittata (Lethierry, 1884)	14	7
				Pinumius areatus (Stal, 1858	12	4
				Empoasca solani (Curtis, 1846)	10	4
			Delphacidae	*Delphacodes albifrons (Fieber, 1879)*	3	0
				Stenocranus minutus (Fabricius, 1787)	27	18
				Laodelphax striatellus (Fallén, 1826)	15	6
				Muirodelphax aubei (Perris, 1857)	9	3
			Caliscelidae	*Ommatidiotus dissimilis (Fallen, 1806)*	7	2
			Aphrophoridae	Lepyronia coleoptrata (Linnaeus, 1758)	4	0
				Paraphilaenus notatus (Mulsant & Rey, 1855)	1	0
			Membracidae	*Gargara genistae (Fabricius, 1775)*	2	0
			Psyllidae	*Cyamophila glycyrrhizae (Becker, 1864)*	12	5
				Psylla intacta Loginova, 1964	8	3
			Dictyopharidae	*Dictyophara pannonica (Germar, 1830)*	3	0
				Scirtophaca tianshanskyi (Oshanin, 1913)	4	0
				Mesorgerius rysakovi Kusnezov, 1933	6	5
			Cixiidae	*Pentastiridius leporinus (Linnaeus, 1761)*	2	0
				Tachycixius desertorum (Fieber, 1876)	8	2
			Aphididae	*Aphis fabae Scopoli, 1763*	63	51
				Aphis arundinis Fabricius, 1775	112	85

Table 5. Biodiversity of Insecta class of Arthropoda type inhabiting Big Taldykol Lake (continuation).

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Arthropoda	*Insecta*	*Hemiptera*	*Corixidae*	*Callicorixa praeusta Fieber, 1848*	2	0
				Corixa dentipes Thomson, 1869 - 5/0	5	0
				Sigara lateralis (Leach, 1817)	8	0
				Micronecta pusilla (Horváth, 1895)	6	0
			Pleidae	*Plea minutissima Leach, 1817*	7	0
			Nepidae	*Ranatra linearis (Linnaeus, 1758)*	1	0
			Naucoridae	*Ilyocoris cimicoides (Linnaeus, 1758)*	2	0
			Notonectidae	*Notonecta glauca (Linnaeus, 1758)*	2	0
			Saldidae	*Salda littoralis (Linnaeus, 1758)*	9	5
				Saldula pallipes (Fabricius, 1794)	14	3
			Miridae	*Trigonotylus ruficornis (Geoffroy, 1785)*	3	0
				Adelphocoris lineolatus (Goeze, 1778)	2	0
				Deraeocoris punctulatus (Fallen, 1807)	14	7
				Deraeocoris annulipes (Herrich Schaffer, 1842)	13	5
				Deraeocoris ventralis Reuter, 1904	12	3
				Lygus pratensis (Linnaeus, 1758)	4	0
				Phytocoris incanus Fieber, 1864	7	0
				Plagiognathus chrysanthemi (Wolff, 1804)	5	0
				P. arbustorum (Fabricius, 1794)	9	4
				Polymerus cognatus Fieber, 1858	7	3
				Stenodema calcaratum (Fallen, 1807)	3	0
				Globiceps fulvicollis Jakovlev, 1877	8	5
				Psallus anticus (Reuter, 1876)	11	5
			Anthocoridae	*Orius niger (Wolff, 1811)*	17	5
				Orius minutus (Linnaeus, 1758)	11	4
				Orius horvathi (Reuter, 1884	11	3
			Nabidae	*Nabis ferus (Linnaeus, 1758)*	9	0
				Nabis sareptanus (Dohrn, 1862)	6	0
				Nabicula nigrovittata (Sahlberg, 1878)	11	5
			Reduviidae	*Vachiria deserta (Becker, 1867)*	2	0
				Coranus contrarius Reuter, 1881	3	0
			Rhopalidae	*Chorosoma schillingii (Schilling, 1829)*	7	3
				Corizus hyoscyami Linnaeus, 1758	2	0
				Brachycarenus tigrinus (Schilling, 1829)	13	10
			Lygaeidae	*Lygaeus equestris (Linnaeus, 1758)*	3	0
			Geocoridae	*Engistus salinus (Jakovlev, 1874)*	5	0
				Geocoris dispar (Waga, 1839)	4	0
				G. pubescens (Jakovlev, 1871)	11	9

Table 5. Continued.

Arthropoda	*Insecta*	*Hemiptera*	*Pentatomidae*	*Aelia acuminata (Linnaeus, 1758)*	5	2
				Holcostethus vernalis (Fabricius, 1803)	6	2
				Peribalus inclusus (Dohrn, 1860)	5	0
				Carpocoris fuscispinus (Boheman, 1851)	3	0
				Eurydema ornata (Linnaeus, 1758)	4	2
				E. oleracea (Linnaeus, 1758)	3	0
				Zicrona coerulea (Linnaeus, 1758)	2	0

Table 6 shows that the number of individuals in one order of *Hemiptera* decreased by 70% from 14 families in 2020 to 7 families in 2022. *Lygaeus equestris* of the *Lygaeidae* family, *Lepyronia coleoptrata, Vachiria deserta,* and *Coranus contrarius* from the *Reduviidae* family, *Notonecta glauca, Ilyocoris cimicoides, Ranatra linearis*, and *Plea minutissima* from their respective families were among the vulnerable species in this order. The *Corixidae* family included *Callicorixa praeusta, Corixa dentipes, Sigara lateralis,* and *Micronecta pusilla* as additional vulnerable species. These alterations demonstrate how the insect population in the ecosystem is dynamic, with a number of species experiencing declines and fragility.

Table 7 offers information on the four orders of the class *Insecta*: *Coleoptera, Neuroptera, Dermatoptera,* and *Orthoptera*. There has been a discernible decline in species diversity in each of these orders. There has been a 66% decline in the order *Orthoptera*, a significant 86% fall in *Dermatoptera*, a 63% decrease in *Coleoptera*, and a 43% loss in *Neuroptera*. Remarkably, a number of species from these orders have disappeared: *Chrysolina sanguinolenta, C. marginata, Cryptocephalus sericeus, Sper-mophagus sericeus, Brachidius unicolor* from the *Crysomelidae* family, and *Pseudaplemonus artemisiae* from the *Apionidae* family are among them. Furthermore, species belonging to the families *Dermestidae, Gryllotalpidae,* and *Tettigoniidae* – *Dermestes coronatus, Dermestes lardarius, Trogoderma glabrum, Gryllotalpa gryllotalpa, Tettigonia viridissima,* and *Platycleis intermedia* – have either perished or seen a decline in population. These modifications highlight the way that the species composition of these insect orders has changed, which has a big effect on the diversity and abundance of these insects in the ecosystem.

Table 7 provides information on the *Insecta* class's *Lepidoptera, Hymenoptera*, and *Diptera* orders. The order *Lepidoptera*, which consists of 11 families, has decreased by a significant 70%. The species that are most susceptible to these modifications are Satyrus briseis and Coenonym-pha pamphilus from the *Satyridae* family, *Acleris scabrana Denis & Schiffermuller* from the *Tortricidae* family, and *Loxostege* sticticalis *Linnaeus* from the *Crambidae* family. The eight families that make up the *Hymenoptera* order have likewise declined by 57%. The *Calliphoridae* family's *Lucilia sericata*, *Ch. cin-gulatus*, and *Lucilia illustris Meigen, the Muscidae* family's *Musca domestica*, and *the Tabanidae* family's *Hybomitra ciureai, H. montana Meigen*, and *Haematopota turkestanica* have all vanished from the *Diptera* order. The decline in animal populations in the lake region highlights the danger to biodiversity. The principal factors contributing to this reduction are the decreasing area of the lake and modifications made to animal habitats. The fast expansion of the region around the Taldykol Lake system is one example of how human activity also plays a role in the decline in animal populations. All of these elements work together to highlight the complex issues that the local ecology is facing.

Shannon Index

Owing to the varied ecological circumstances in the research region, the Shannon Index was calculated for every unique biome, offering a thorough evaluation of animal biodiversity (Table 8). Eleven primary biomes were identified, all of which denote different habitats: watery settings, wetlands, regions with a tree and shrub population, open areas, soil-covered areas, arid desert regions, widespread or ubiquitous zones, arid meadows, cultivated garden phytocenoses, omnipresent vegetation, and areas with cereal plants. A detailed understanding of biodiversity within the many ecological niches found in the research area is made possible by this careful categorization.

The Shannon Diversity Index was chosen because it is a good fit for representing data on the diversity of animal species. 2020 saw a range of 0.6 to 3.6 for the diversity index among the various biomes. With a value of 3.6 and 245 people counted, the "plots with cereal plants" biome had the highest Shannon index among the 11 categorized biomes. Furthermore, the biome known as "ubiquitous vegetation" demonstrated a high degree of species variety, with 620 species and a Shannon score of 3.5. With Shannon index values of 3.0 and 2.9, respectively, "wet meadow areas" (258 individuals) and "dry meadow areas" (263 individuals) likewise showed a significant species abundance. With an index of 0.6, the "soil" biome displayed the lowest value.

When the Shannon index was calculated as the arithmetic mean of all biomes, the result was 2.7±0.27.

Table 6. Biodiversity of Orthoptera of class Insecta inhabiting Big Taldykol Lake (continuation).

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Arthropoda	*Insecta*	*Orthoptera*	*Tettigoniidae*	*Tettigonia viridissima (Linnaeus, 1758)*	3	0
				Platycleis intermedia (Serville, 1838)	3	0
			Gryllidae	*Melanogryllus desertus (Pallas, 1771)*	11	5
				Modicogryllus frontalis Fieber, 1844	4	0
			Gryllotalpidae	*Gryllotalpa gryllotalpa (Linnaeus, 1758)*	7	0
			Acrididae	*Eremippus simplex Eversmann, 1859*	9	3
				Calliptamus italicus (Linnaeus, 1758)	17	14
				Locusta migratoria (Linnaeus, 1758)	35	28
				Oedipoda miniata L.	9	0
				O. coerulescens (L.)	17	3
				Chorthippus albomarginatus (De Geer, 1773)	7	0
				Ch. brunneus Thunberg, 1815	12	2
				Ch. biguttulus (Linnaeus, 1758)	16	13
				Omocestus haemorrhoidalis (Charpentier, 1825)	13	0
				Stenobothrus fischeri (Ev.)	12	2
				Epacromius pulverulentus (Fischer von Waldheim, 1846)	5	0
				Euchorthippus pulvinatus (Fischer von Waldheim, 1846)	15	0
				Dociostaurus kraussi (Ingenitskii, 1897)	8	0
				D. brevicollis (Eversmann, 1848)	7	0
		Dermatoptera	*Forficulidae*	*Anechura bipunctata (Fabricius, 1781)*	2	0
			Labiduridae	*Labidura riparia (Pallas, 1773)*	5	1
		Coleoptera	*Carabidae*	*Poecilus cupreus (Linnaeus, 1758)*	6	0
				Agonum sexpunctatum (Linnaeus, 1758)	7	1
				Amara aenea (De Geer, 1774)	4	0
				A. equestris (Duftschmid, 1812)	3	0
				Bembidion fumigatum (Duftschmid, 1812)	8	6
				B. lampros (Herbst, 1784)	7	6
				Clivina fossor (Linnaeus, 1758)	11	9
				Anisodactylus poeciloides (Stephens, 1828)	5	0
				Harpalus distinguendus (Duftschmid, 1812)	9	0
				H. smaragdinus (Duftschmid, 1812)	8	0
				Cicindela littoralis conjunctaepustulata Dokht.	3	0
				C. campestris Linnaeus, 1758	2	0
				Brachinus brevicollis Motschulsky, 1844	9	0
				Calosoma auropunctatum (Herbst, 1784)	3	0
				Carabus clathratus Linnaeus, 1760	2	0
				Pterostichus niger (Schaller, 1783)	2	0

Table 6. Continued.

Arthropoda	Insecta	Coleoptera	Silphidae	*Silpha obscura Linnaeus, 1758*	1	0
			Staphylinidae	*Philonthus tenuicornis Mulsant & Rey, 1853*	7	2
				Ph. binotatus (Gravenhorst, 1806)	9	6
				Paederus riparius (Linnaeus, 1758)	6	4
			Dermestidae	*Dermestes coronatus Steven, 1808*	4	0
				D. lardarius Linnaeus, 1758	2	0
				Trogoderma glabrum (Herbst, 1783)	5	0
			Coccinellidae	*Hippodamia variegata (Goeze, 1777)*	27	21
				H. tredecimpunctata (Linnaeus, 1758)	8	0
				Adalia bipunctata (Linnaeus, 1758)	21	18
				A. decimpunctata (Linnaeus, 1758)	17	13
				Coccinula quatuordecimpustulata (Linnaeus, 1758)	10	0
				Coccinella undecimpunctata menetriesi Mulsant, 1850	19	7
				Oenopia conglobata (Linnaeus, 1758)	9	2
				Anisosticta novemdecimpunctata (Linnaeus, 1758)	5	2
				Coccinella septempunctata (Linnaeus, 1758)	7	2
				Bulaea lichatschovi (Hummel, 1827)	17	0
			Crysomelidae	*Chrysolina sanguinolenta (Linnaeus, 1758)*	5	0
				C. marginata (Linnaeus, 1758)	4	0
				Gastrophysa polygoni (Linnaeus, 1758)	7	0
				Phyllotreta vittula (Redtenbacher, 1849)	32	28
				Chaetocnema breviuscula (Faldermann, 1837)	17	5
				Cryptocephalus sericeus (Linnaeus, 1758)	2	0
				Spermophagus sericeus (Geoffroy, 1785)	3	0
				Brachidius unicolor (Olivier, 1775)	4	0
				Entomoscelis adonidis Pallas, 1771	9	1
			Apionidae	*Pseudaplemonus artemisiae (Moravitz, 1861)*	4	0
			Curculionidae	*Cyphocleonus dealbatus (Gmelin, 1790)*	3	0
				Eusomus acuminatus (Bohemann, 1840)	6	0
				Hypera meles (Fabricius, 1792)	11	4
		Neuroptera	Chrysopidae	*Chrysoperla carnea Stephens, 1836*	12	11
				Chrysoperla viridana Schneider, 1845	7	0

This number, which usually falls between 1.5 and 4.5, indicates that the community is under considerable stress. However, the coefficient of variance, which varied according to the kind of biome, was 33.7%.

The diversity index was revised in 2022, but the number of biomes stayed the same. Biomes with notable index values included "water" (128 individuals), "plots with cereal plants" (89 individuals), and "ubiquitous vegetation" (284 individuals) with values of 2.5 and 2.1, respectively. Conversely, the biome known as "wet meadow plots" had the lowest index value, with 56 individuals at 0.8. In 2022, the Shannon index's arithmetic mean was 1.9±0.16. According to the Student's coefficient t = 2.6, equivalent to $p<0.05$, this indicated an increase in community stress levels of 0.8 when compared to 2020. Interestingly, the index's coefficient of variation dropped to 26.9% in 2020 – a fall of 6.8% (Fig. 3). The main cause of this change in the

Table 7. Biodiversity of Orthoptera of class Insecta inhabiting Big Taldykol Lake (continuation).

Taxonomic affiliation, number of individuals of the species (2020/2022)					Number of copies	
Type	Class	Squad	Family	Appearance	2020 year	2022 year
Arthropoda	*Insecta*	*Lepidoptera*	*Crambidae*	*Loxostege sticticalis Linnaeus, 1761*	3	0
			Tortricida	*Acleris scabrana Denis & Schiffermuller, 1776*	3	0
			Hesperiidae	*Hesperia comma (Linnaeus, 1758)*	4	3
				Thymelicus lineola Ochsenheimer, 1808	2	2
			Nymphalidae	*Vanessa atalanta Linnaeus, 1758*	2	0
				Cynthia cardui (Linnaeus, 1758)	3	3
				Aglais urticae (Linnaeus, 1758)	3	2
				Melitaea didyma Staudinger, 1895	4	2
				Melitaea cinxia (Linnaeus, 1758)	3	0
			Satyridae	*Satyrus briseis (Linnaeus, 1758)*	4	0
				Coenonympha pamphilus (Linnaeus, 1758)	5	0
			Pieridae	*Pieris rapae Linnaeus, 1758 - 6/4,*		
				Pontia daplidicae (Hübner, 1813)	11	3
				P. chloridice (Hübner, 1813)	10	2
				Leptidea sinapis (Linnaeus, 1758)	4	0
				Colias erate (Esper, 1805)	9	3
				C. hyale (Linnaeus, 1758)	4	0
			Lycaenidae	*Polyommatus icarus (Rottemburg, 1775)*	4	0
				Plebejus argus (Linnaeus, 1758)	5	0
			Noctuidae	*Noctua fimbriata (Schreber, 1759)*	7	4
				Hecatera bicolorata Hufnagel, 1766	8	5
				M. suasa (Denis & Schiffermuller, 1775)	9	7
				Autographa gamma (Linnaeus, 1758)	4	0
				Cucullia argentina (Fabricius, 1787)	9	8
				Cucullia biornata (Fischer de Waldheim, 1840)	7	0
			Erebidae	*Arctia caja Linnaeus, 1758*	3	0
				Lacydes spectabilis (Tauscher, 1806)	5	0
			Lasiocampidae	*Lasiocampa trifolii (Denis & Schiffermuller, 1775)*	2	0
			Sphingidae	*Macroglossum stellatarum Linnaeus, 1758*	5	0
		Hymenoptera	*Braconidae*	*Agathis montana Shestakov, 1932*	7	0
				Apanteles appellator Telenga, 1949	28	9
				Glyptomorpha pectoralis (Brullé, 1832)	8	2
				Diospilus capito (Nees, 1834)	4	0
				Rogas bicolor (Schrottky, 1915)	6	5
			Sphecidae	*Pemphredon lethifer (Shuckard, 1837)*	5	2
				Tachytes panzeri Dufour, 1841 -	2	0
				Oxybelus latro Olivier, 1812	3	0
			Crabronidae	*Ectemnius rubicola (Dufour & Perris, 1840)*	5	3
				Bembix rostrata Linnaeus, 1758	3	0

Table 7. Continued.

Arthropoda	Insecta	Hymenoptera	Chrysididae	*Chrysis indigotea Dufour & Perris, 1840*	2	0
				Hedychrum nobile Scopoli, 1763	3	1
			Apidae	*Apis mellifera Linnaeus, 1758*	8	4
				Bombus pascuorum Scopoli, 1763	7	4
				Bombus lucorum Linnaeus, 1761	9	5
				Bombus laesus Morawitz, 1875	3	0
				Eucera longicornis Linnaeus, 1758	3	0
				Nomiapis diversipes (Latreille, 1806)	3	0
			Halictidae	*Halictus eurygnathus Blüthgen, 1931*	12	7
				H. sexcinctus Fabricius, 1775	7	5
				Lasioglossum calceatum (Scopoli, 1763)	6	0
				Rophites canus (Eversmann, 1852)	2	0
			Megachilidae	*Megachile leachella Curtis, 1828*	11	3
				M. centuncularis (Linnaeus, 1758)	6	4
				Osmia coerulescens (Linnaeus, 1758)	8	7
				Anthidium cingulatum Latreille, 1809	3	0
				Anthidiellum strigatum (Panzer, 1805)	1	0
			Formicidae	*Cataglyphis aenescens (Nylander, 1849)*	17	9
				Formica cunicularia Latreille, 1798	48	24
				Lasius alienus (Foerster, 1850)	35	19
				Tetramorium caespitum Linnaeus, 1758	27	13
		Diptera	Muscidae	*Musca domestica*	2	0
			Sarcophagidae	*S. pernix Harris, 1780*	3	0
				Sarcophaga carnaria (Linnaeus, 1758)	4	2
			Calliphoridae	*Calliphora uralensis Villeneuve, 1922*	2	0
				Lucilia sericata (Meigen, 1826)	4	0
				Lucilia illustris Meigen, 1826	3	0
				Protophormia terraenovae (Robineau-Desvoidy, 1830)	5	3
			Chironomidae	*Chironomus plumosus (Linnaeus, 1758)*	29	17
				Chironomus cingulatus Meigen, 1930	19	6
				Chironomus thummi Kieffer -	27	17
				Chironomus riparius (Meigen, 1804)	49	35
				Microchironomus cojugens Lenz, 1926	18	4
				M. tener (Kieffer, 1819)	21	16
			Culicidae	*Culex pipiens Linnaeus, 1758*	17	2
				C. modestus Ficalbi, 1889	27	2
				Aedes caspius (Pallas, 1771) -	39	8
				Aedes cinereus Meigen, 1818 -	11	1
				Culiseta alaskaensis (Ludlow. 1906)	3	0
			Tabanidae	*Hybomitra ciureai (Séguy, 1937)*	2	0
				H. montana Meigen, 1820	3	0
				Haematopota turkestanica (Krober, 1922)	3	0

Table 7. Continued.

Arthropoda	*Insecta*	*Diptera*	*Syrphidae*	*Syrphus ribesii (Linnaeus, 1758)*	11	9
				Spherophoria sp.	19	9
				Episyrphus balteatus (De Geer, 1776)	7	3
				Eupeodes corollae (Fabricius, 1794)	8	7
				Chrysotoxum cautum Harris, 1776	2	0
				Scaeva pyrastri (Linnaeus, 1758)	3	0
				Eristalis tenax (Linnaeus, 1758)	5	1
				Eristalis arbustorum (Linnaeus, 1758)	7	0
				Helophilus trivittatus (Fabricius, 1805)	6	2
				Volucella bombylans (Linnaeus, 1758)	2	0
			Tachinidae	*Exorista larvarum (Linnaeus, 1758)*	9	3
				Ectophasia crassipennis Fabricius, 1794	5	0
				Gymnosoma nudifrons Herting, 1966	2	0
				Tachina fera (Linnaeus, 1761)	9	1

Table 8. Shannon index (H) value in selected biomes in 2020 and in 2022.

№	Biome	Number of individuals in 2020	H 2020	Number of individuals in 2022	H 2022
1.	Water	394	3.3	128	2.1
2.	Wet meadow areas	258	3.0	56	0.8
3.	Plots with trees and shrubs	122	2.5	25	1.6
4.	Open areas	163	3.0	56	2.0
5.	Desert areas	132	2.4	80	2.0
6.	Dry meadow areas	263	2.9	91	1.6
7.	Pervasive vegetation	620	3.5	284	2.6
8.	Garden phytocenoses	137	3.0	60	2.4
9.	Plots with cereal plants	245	3.6	89	2.5
10.	Everywhere	71	1.5	19	1.6
11.	Soil	152	0.6	79	1.8
	Arithmetic mean and error (M±m)		2.7±0.27		1.9±0.16
	Standard deviation (δ)		0.90		0.51
	Coefficient of variation *Cv*		33.7%		26.9%

Shannon index was the extinction of species in biomes such as “water,” “wet meadow plots,” and “plots with trees and shrubs.”

There were notable changes in index values in the Wet Meadows biome, where there was a roughly threefold decline in the Shannon Index and a corresponding loss in species diversity. On the other hand, even if the diversity of species decreased, this index increased in the “soil” and “ubiquitous” biomes as compared to 2020. This is an interesting phenomenon that can be explained by the two years of drying that the area experienced, which altered the quality of the soil. As a result, this started a process of community transformation that resulted in an increase in the numbers of previously uncommon species and a shift in the population sizes of already-existing species. Compared to 2020, when this biome contained 506 individuals from 38 species, the “water” biome in 2022 was represented by 128 individuals from 10 species. Notable species that were no longer observed included *Piscicola geometry, Erpobdella octoculata*

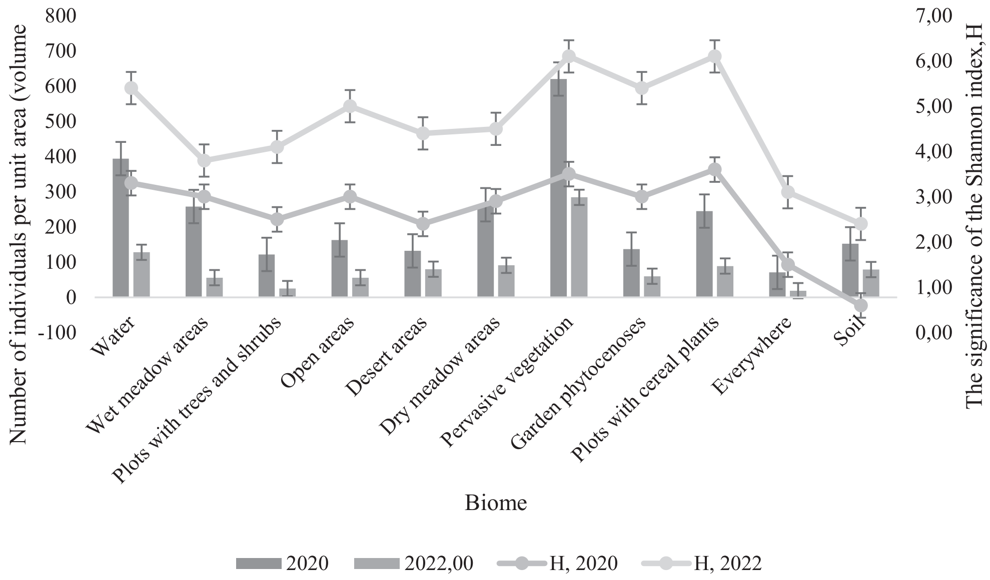

Fig. 3. Distribution of species diversity in biomes and Shannon index (H) in 2020 and in 2022.

(Linnaeus, 1758), *Bithynia tentaculata* (Linnaeus, 1758), *Notonecta glauca (*Linnaeus, 1758*), Lymnaea stagnali, Lymnaea truncatula, L. ovata,* and *Radix auricularia*. The 2020 "wet meadow areas" contained 258 individuals belonging to 28 different species. By 2022, there were just 56 individuals, belonging to 22 different species. Among the species that could no longer be identified were *Delphacodes albifrons, Trigonotylus ruficornis, Carabus clathratus, Pterostichus niger, Culiseta alaskaensis Ludlow*, and *Gymnosoma nudifrons Herting*. In 2020, there were 620 individuals from 62 species in the "ubiquitous vegetation" biome. By 2022, there were fewer inhabitants and species in this biome (284 persons from 31 species). Among the extinct species were *Succinea putris, Thomisus onustus, Philodromus cespitum, Nabis ferus, and N. sareptanus*.

Discussion

The study, conducted from 2020 to 2022, aimed to assess the impact of urban expansion on the aquatic ecosystem, with a focus on Lake Taldykol. The comparison of area coverage was made based on data collected at the beginning and end of the study period, with most values presented as averages. These findings provide important insights into the changes occurring within the study area. The results indicate a significant reduction in the area and volume of Lake Taldykol over the study period. This suggests that urbanization and associated human activities have had a tangible impact on the lake's physical characteristics. The decrease in area coverage raises concerns about the potential loss of valuable aquatic habitats and the subsequent implications for biodiversity. In the context of urban expansion, preserving the natural balance of aquatic ecosystems presents a formidable and intricate challenge. The inexorable growth of human populations, escalating consumption, and the rapid pace of globalization have inflicted widespread degradation and disruption upon natural systems, with freshwater environments bearing the brunt of the damage. Freshwater ecosystems have suffered a more severe loss of species and habitats compared to their terrestrial counterparts, and it is within aquatic environments, encompassing lakes, rivers, and wetlands, that species communities face their most acute threats [22]. However, the urbanization process, though unstoppable, inevitably influences alterations in land use, subsequently impacting water bodies. As land use expansion is one of the causes of biodiversity loss, with increasing urbanization involving more and more areas, a concomitant determination of species diversity is required. In this regard, the results of the monitoring of Lake Taldykol demonstrate how animal biodiversity in a lake ecosystem can change under rapid urbanization. For instance, McDonaldi et al. [23], who surveyed 825 ecoregions, including 29 that had become urbanized, revealed that one-third of these areas were home to 213 endemic terrestrial vertebrates.

In addition to tackling numerous important hydrological and hydro-chemical issues related to maintaining water availability and preventing lake pollution, monitoring the biotic component is essential to reducing the negative effects of human activity on aquatic ecosystems. The introduction of invasive species, overexploitation, and habitat degradation are the main causes of biodiversity loss that are commonly mentioned [24]. The community of various plants, animals, and microorganisms that make up these ecosystems is essential to maintaining the self-regulation, homeostasis, and natural material cycles of the ecosystem. However, population abundance and species composition are sensitive and dynamic indices that are influenced by human factors. Integrated metrics, like the Shannon Index, are useful for quantifying these changes in biodiversity. Because of its widespread use, the Shannon Index is a priceless tool for comparing and categorizing the biodiversity of distinct aquatic and coastal ecosystems in diverse parts of the world with a range of environmental circumstances. Under this framework, the computation of the ecosystem's primary ecotopes' Shannon Index based on animal communities provides a nuanced viewpoint [25]. Over the course of two years, the Shannon Index has shown changes that are responsive to changes in abiotic conditions. As such, it is a sensitive indicator of the health of animal populations that are subject to anthropogenic interference.

In the case of Lake Taldykol, the Shannon index, along with its various adaptations, serves as a valuable tool for appraising species diversity across diverse levels of the animal and plant kingdoms. This index provides insights into the relative or objective aspects of overall biodiversity. For instance, Kalneniece et al. [26] harnessed this index to scrutinize cultured microorganisms. Their investigation centered on sediments tainted by hydrocarbon contamination, seeking to gauge the impacts of biostimulation and bioaugmentation on hydrocarbon biodegradation and the resultant shifts in the microbial community structure.

Huiqun Sun et al. [27] harnessed the Shannon index to assess the diversity of plant communities in their research. Their study delved into the ramifications of heavy metal presence on species diversity within wetlands. Through a rigorous analysis of heavy metal sources in the soil and correlation assessments, they aimed to elucidate the connection between heavy metal concentrations and biodiversity indices. The findings underscored that heavy metals exert differential effects on plant species diversity within the study area.

In the Lake Tana region, a study focused on the influence of human activities on wetland biodiversity. Shannon-Wiener diversity index values were instrumental in evaluating the status of both plants and macroinvertebrates [28]. Furthermore, the Shannon-Wiener index has proven to be instrumental in quantifying biodiversity among fish, birds, and other fauna, as evidenced by the work of scientists from Bangladesh [29].

By using this methodology, we were able to provide an objective and thorough measurement of the wide fluctuations in species composition and abundance within the ecosystem under study, especially in response to the decreasing availability of lake water. We first discovered that it was more feasible to compute the Shannon Index for individual biomes. From these biome-specific indices, we then calculated an average index for the entire wide ecosystem.

The analysis of the reduction in water availability within the Taldykol Lake system in correlation with the Shannon index reveals the notable sensitivity of the lake and its coastal biocenosis's biodiversity to alterations in water levels [30]. As the water area diminished by 2,800,000 square meters and the water volume decreased by 3,098,000 cubic meters, the Shannon index exhibited a decrease of 0.71. It is worth noting that the study of biodiversity changes should consider that, beyond a certain threshold of water level reduction, the initial biocenosis composition becomes unstable and gradually gives way to new species [31]. This suggests that the Shannon index may eventually exhibit an increase. Such a trend has begun to emerge in select biomes within our study, primarily within the desiccated soil layer.

Essentially, the Shannon index's quantification of biodiversity functions as a highly responsive indicator, providing insightful information on how to effectively mitigate biodiversity loss and address various environmental issues, such as the complex relationships between ecosystem services and biodiversity.

Conclusions

The study found significant consequences for the fauna living in the Taldykol Lake ecological system in Astana city, which is rapidly losing water due to human disturbances. This is because we conducted a thorough analysis of the species diversity in this ecosystem. These effects are observable in the form of discernible changes in the total number of species and individual organisms, as well as a decrease in the Shannon index that is seen throughout the research region and in a variety of biomes. Some species belonging to the classes *Gastropoda, Malacos-traca, Insecta*, and *Hirudinea* have been found to be extremely sensitive to moisture shortages, to the point where these species have become extinct. The Shannon index drop is inextricably related to declines in particular populations and animal species within biomes like wet meadows, water, and ubiquitous vegetation. Notably, soil communities exhibit swift changes in biocenotic traits in response to abrupt decreases in moisture, in contrast to patterns observed in other biomes. This phenomenon results in a rise in the Shannon index. The significant decrease of 72% in water volume and 65% in water surface area has resulted in a notable 30% drop in the Shannon Index, highlighting the critical role that water availability plays in determining the biodiversity of the Taldykol Lake environment. These results highlight the critical role that water availability plays in maintaining the ecological balance of the Taldykol Lake system and highlight the need for prompt and efficient strategies to protect this ecosystem's biodiversity in the face of ongoing urbanization and environmental issues.

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Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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