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Diversity of gastropods (Mollusca: Gastropoda) in different altitude regions of the Zarafshan Mountains and adjacent areas, Uzbekistan

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Abstract. *Uralov U, Kudratov J, Pazilov A, Izzatullaev Z, Khalimov F, Otakulov B, Jabbarov A, Fundukchiev S, Orziyeva Y, Suyunov G, Abduxamidovich BM, Boymurodov K, Gulboev D, Urinova X. 2025. Diversity of gastropods (Mollusca: Gastropoda) in different altitude regions of the Zarafshan Mountains and adjacent areas, Uzbekistan. Biodiversitas 26: 5012-5022.* As an important part of the food chain in nature, it is of great importance to determine the systematic structure and diversity of mollusks. This study presents data obtained by assessing the current state of the taxonomic structure of gastropod mollusks in biogeographical regions with different vertical heights in the study area. The study area includes 15 locations in the Zarafshan Mountains of Uzbekistan and adjacent areas. The study sites were formed based on more than 3,000 samples collected in 2018-2025. It was found that the gastropod fauna of the region consists of 80 species belonging to 21 families and 35 genera. Using modern morphological and anatomical methods of species identification, *Archaica haziratishaxika* was identified for science; the following species were recorded for the first time as new species for the region, adding to the region's biodiversity: *Sogdamnicola shadini*, *Lymnaea fragilis*, *Galba truncatula*, *Radix bactriana*, *Candaharia rozeni*, *Macrochlamys turanica*, *Macrochlamys kasnakowi*, *Vertigo antivertigo*, and *Chondrina intumescens*. The results obtained will serve as a primary source for supplementing the data on the gastropod fauna of mountain ranges in Uzbekistan with the missing data on the Zarafshan Mountains and adjacent areas, and will provide specialists with the first information on this area.

Keywords: Correlation, distribution, mollusks, mountains, similarity

INTRODUCTION

Gastropods are the largest class of mollusks, accounting for 80% of the phylum, and are the second most diverse animals in the fauna, occurring in all major environments except air (Strong et al. 2008). Gastropods, despite being categorized into relatively few taxonomic groups, have successfully colonized a wide range of environments from an ecological perspective (Hamli et al. 2024). Gastropods are among the few groups of animals that have successfully adapted to three habitats (ocean, freshwater, and terrestrial) (Amarasinghe et al. 2021; Isroni et al. 2023). Their role characterizes the importance of gastropods as a food source, pest, and bird food (Islamy and Hasan 2020). In this way, they participate in the maintenance of trophic chains and serve as one of the important levels (Nge et al. 2023).

The distribution of animals, with its unique characteristics along the vertical altitudinal gradient, is a fascinating area of study (Medetov et al. 2025). Researchers play a crucial role in uncovering the influence of climatic parameters and environmental factors in these regions. Their efforts have revealed how animals develop structures, behaviors, and functional abilities to survive in the changing environment, thereby maintaining species diversity within populations (Susintowati et al. 2019; Zokirova et al. 2025). In Central Asia, Kudratov et al. (2024) studied gastropod land mollusks in the Gissar Mountain Range and adjacent areas along the vertical altitudinal zones. As a result, they noted differences in the composition and abundance of species in four vertical

altitudinal zones in this region. A number of other similar studies, conducted on the example of aquatic gastropods, have shown that the systematic diversity of malacofauna varies in areas with different depths (Strong et al. 2007; de Mendoza et al. 2023; Krepski et al. 2025).

Globally, as a result of the widespread impact of anthropogenic factors, there is a trend towards a decrease in biological diversity and a change in natural resources, including faunal diversity (Shivanna 2022). In particular, the widespread use of mountains and adjacent areas by the population as pastures is negatively affecting the existing flora and fauna (Jakobsson et al. 2024). Assessment of the modern taxonomic composition of gastropod mollusks in the areas of natural ecosystems under the influence of the anthropogenic factor, and determining the factors influencing it, is of great scientific importance. One such area is the Zarafshan Mountain Range and adjacent areas (Uzbekistan). The peculiarity of the area is the presence of several zones along the vertical elevation gradient.

The Zarafshan Range stretches for 370 km from east to west. The eastern part of the range (up to the Fandarya) is strongly dissected, with some peaks rising to 4,500-5,000 meters above sea level (m asl). The highest point is Chimtarga (5,494 m asl) in the central part. From the Magyandarya to the west, the range decreases in height and consists of the Chakilkalon (2,388 m asl) and Qoratepa (2,209 m asl) ranges. They separate the Zarafshan and Kashkadarya valleys (Soliev 2014). Experts note that the difference in the biogeography and climate of the highland regions of the Zarafshan Mountains and the adjacent plains has led to a high diversity of fauna (Alimova et al. 2024), flora (Khojakulov et al. 2024), and microorganisms (Mukhtorova et al. 2024).

Information on the composition of the gastropod malacofauna of the Zarafshan Mountains and adjacent plains is found in the records of Izzatullyaev (2019) and Makhmudjonov et al. (2023). However, these studies were conducted on separate groups of mollusks, and the records given in them do not provide accurate information on the species composition of gastropod mollusks of the Uzbekistan part of the Zarafshan Range. Therefore, this study aimed to identify the species composition of gastropod mollusks across different altitude zones of the Zarafshan Mountains and nearby plains, compare the similarity of malacofauna between regions, and determine factors influencing changes in species diversity.

MATERIALS AND METHODS

Study area

The selection of sampling stations took into account the differences in altitude, annual precipitation, and temperature of the area. The study area includes 15 locations in the Zarafshan Mountains of Uzbekistan and adjacent areas (Table 1). A full description of the sampling stations is provided in Figure 1 and Table 2. The study sites were formed based on more than 3,000 samples collected in 2018-2025.

Table 1. Sampling site of mollusks (gastropods) in the Zarafshan Mountains and adjacent areas, Uzbekistan

Location	Name of location	Coordinate	Height, meters above sea level (m asl)
ZMR-1	Langar	39°44'02.0"N 65°54'08.0"E	843
ZMR-2	Ingichka	39°43'01.0"N 66°01'01.0"E	642
ZMR-3	Korateri	39°48'01.0"N 66°54'01.0"E	626
ZMR-4	Zarafshan National Park	39°40'02.0"N 67°05'03.0"E	712
ZMR-5	Ravotkhuja	39°32'04.0"N 67°24'04.0"E	888
ZMR-6	Oksay	39°29'02.0"N 66°37'01.0"E	1,415
ZMR-7	Tepakul	39°28'01.0"N 66°45'04.0"E	1,604
ZMR-8	Kumkutan	39°27'05.0"N 66°51'02.0"E	1,960
ZMR-9	Bulbulsay	39°26'07.0"N 66°59'02.0"E	1,059
ZMR-10	Yulsay	39°18'07.0"N 66°53'02.0"E	1,794
ZMR-11	Kamangaron	39°22'06.0"N 67°11'05.0"E	1,455
ZMR-12	Saygus	39°19'03.0"N 67°17'02.0"E	2,383
ZMR-13	Amankutan	39°19'03.0"N 67°17'02.0"E	2,333
ZMR-14	Kalkama	39°18'45.5"N 66°38'30.5"E	666
ZMR-15	Lolabulak	39°20'09.2"N 66°30'20.0"E	977

Table 2. Biogeographical characteristics of the collection sites

Research area (m asl)	Locations	Climate	Annual average temperature (°C)	Precipitation (mm/year)	Number of samples collected
≤ 900	ZMR-1, ZMR-2, ZMR-3, ZMR-4, ZMR-5, ZMR-14	Arid, semi-arid, relatively dry	19	380	980
900-1500	ZMR-6, ZMR-9, ZMR-11, ZMR-15	Semi-arid, moderate	17	620	825
1500-2200	ZMR-7, ZMR-8, ZMR-10	Mountainous, with sharp temperature changes	15	850	910
≥2200	ZMR-12, ZMR-13	Mountainous, high humidity	12	1010	230

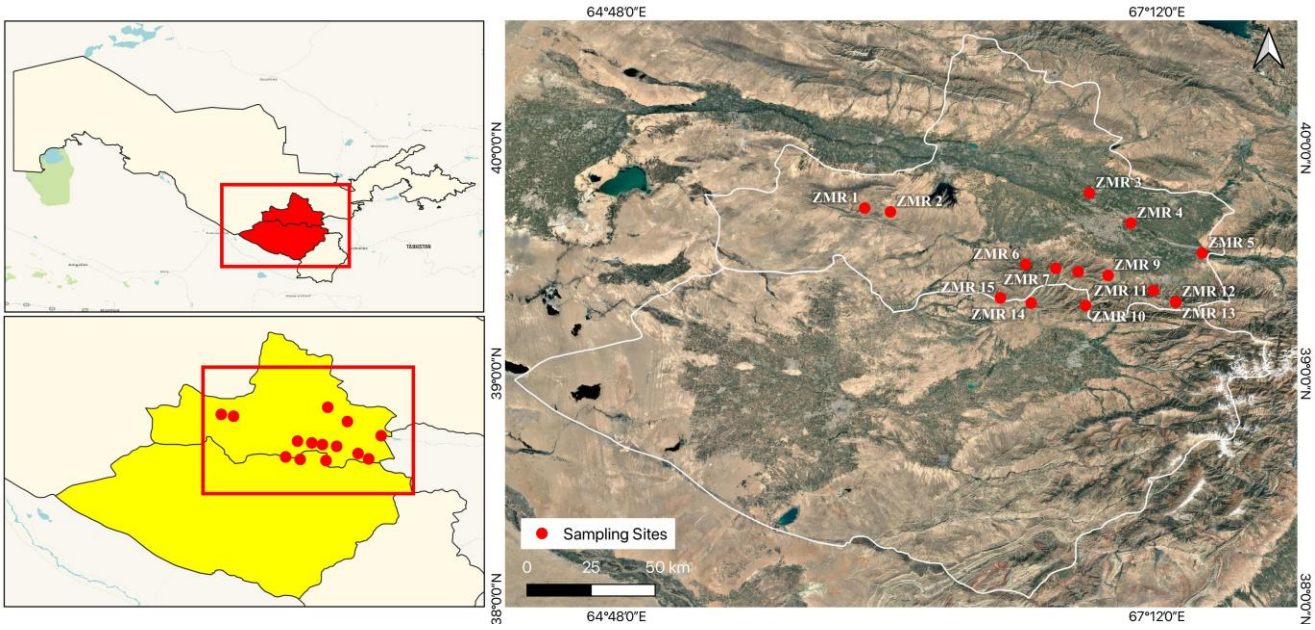

Figure 1. Map of research areas in the Zarafshan Mountains and adjacent areas, Uzbekistan

Procedures

Collection of samples.

Collection and initial processing of aquatic mollusks. The material selection and processing were carried out using the method of Izzatullyaev (2019) and Pazilov and Umarov (2021). The material was mainly collected from waters up to 1.5 meters deep with a hydrobiological boat or a net. Samples were also collected manually under and around aquatic weeds. Plant branches and aquatic weeds were collected in polyethylene bags, and mollusks were separated by washing in a sieve in laboratory conditions. Mollusks were collected from springs, lakes, rivers, and reservoirs deeper than 2 meters with a dredge. Regardless of where and when the mollusks were collected, their habitat was taken into account: soil characteristics, depth, biotope (deep, among plants) where the mollusks were collected, and water temperature. This information was recorded in the field notebook, indicating the month, date, and year in the appropriate order. The collected mollusk samples were labeled. The fixation of mollusks is carried out with 70-75% alcohol. If it was impossible to fix with alcohol, it was fixed in 2% formalin, and soda ($NaHCO_3$) was added to the mixture to prevent the shell from dissolving (Izzatullyaev 2019). This adaptability in preservation techniques ensures the robustness of the methods. All the shells were kept dry in cardboard boxes of different sizes.

Collection and initial processing of land mollusks. Land mollusks were studied using the method of Schilkeyko et al. (2017, 2020). The material was mainly collected by hand because hand collection allows for a more thorough examination of various biotopes in natural landscapes. The collection was typically done in the morning during damp weather, when dew had not yet dried and many mollusks were active, making them easier to find. During hot weather (summer months), many terrestrial mollusks were collected from fallen trees and bark, under stones, and beneath various embankments. Additionally, some species can burrow into the soil up to 20-25 cm deep. Therefore, if the species had shells but no living specimens, samples were gathered by digging under large stones to a few centimeters. The collected samples were placed in boxes labeled with details such as the collection site, biotope, collector's name, and date. Live mollusks were kept in jars filled with cold water, sealed with lids fitted with leather gaskets. Clams in these jars died after 17-18 hours. Afterward, they were removed from water and preserved in 40-45% alcohol, then transferred to 70% alcohol after 5-6 days, and finally stored in 75% alcohol after two weeks.

Identification of mollusks. The cases of Starobogatov et al. (2004) and Izzatullyaev (2019) were used to identify mollusks. After being photographed and identified, the sample is stored in the collection bottle. The methods used to identify mollusks species consisted of morphological, anatomical, and taxonomic analysis. Identification of mollusks samples was carried out based on the morphology of mollusk shells and the structure of genital organs.

Data analysis

Assessment of the degree of similarity of species

The Chekanovsky-Sørensen coefficient was calculated using the following formula (Mirzaev et al. 2024):

$$S_N = \frac{2jN}{(aN + bN)}$$

Where, aN+bN: The total number of individuals in plots A and B, jN: The number of species in both plots having a small value.

The Jacquard coefficient was calculated using the following formula (Narzullayev and Subbotin 2025):

$$S_j = \frac{j}{(a+b-j)}$$

Where: j: The number of species common to both areas, a and b: The number of species in each area.

The similarity dendrogram according to the Jacquard and Chekanovsky-Sørensen coefficients was constructed using the PAST 4.0.7z program (Ergasheva et al. 2024; Kudratov et al. 2024; Rayimova et al. 2024).

Determination of correlation

The correlation (r) between the number of species and some factors in the cross-section of areas was calculated using the Statistics Kingdom (https://www.statskingdom.com/correlation-calculator.html) online program based and graphs were formed (Akramov et al. 2025; Ergashev et al. 2025).

RESULTS AND DISCUSSION

Gastropod species composition and their distribution by altitudinal zones

During our research in the region from 2018 to 2025, more than 3,000 specimens of gastropods were collected and identified. As a result of the identification of materials collected from the Zarafshan Mountains and adjacent areas, 80 species of gastropods belonging to 21 families and 34 genera were recorded in the study area (Table 3).

When studying the distribution of these species across altitudinal zones, it was found that 46 species were distributed at an altitude of ≤900 m asl, 68 species were found between 900-1,500 m asl, 58 species were found between 1,500-2,200 m asl, and 30 species were found at an altitude of ≥2,200 m asl. It was also observed that 46.25% (37 species) of the 80 species recorded in the study area were distributed in two altitudinal zones, and 52.5% (42 species) were distributed in three altitudinal zones. It was found that only one species, *Odontotrema diplodon*, was found in all studied altitudinal zones. Among the identified species, 9 species (species marked * in Table 3) were recorded for the regions of Uzbekistan for the first time (Figure 2). Research and analysis allowed us to identify a species new to science in the region, *Archaica haziratishaxika* (Figure 3).

Archaica haziratishakhika, the shell is small, compressed to various degrees, relatively thin-walled, slightly transparent, and domed-conical in shape. 4-4.5 convex whorls gradually increase in size. The last whorl is rounded in profile, tapering to a flat shape towards the mouth. The color of the embryonic part is always brownish; the rest is hornlike, and the part below the periphery is grayish-hornlike, transparent in appearance. The embryonic shell is shiny, strongly flattened with radial stripes. The shape of the subsequent whorls consists of uneven radial ribs, which are noticeably weakened on the lower surface.

The species was collected only from the typical habitat, where it lives on gravelly slopes among semi-shrubs. The shell of this species is smaller than that of other members of the family, relatively thin-walled, slightly transparent, with at most 4.5 convex, expanding folds on the shell, and anatomically, the stylophores (upper and inner) are always spherical in shape. According to Figure 2, the mucous glands of the species are 2x2 in size.

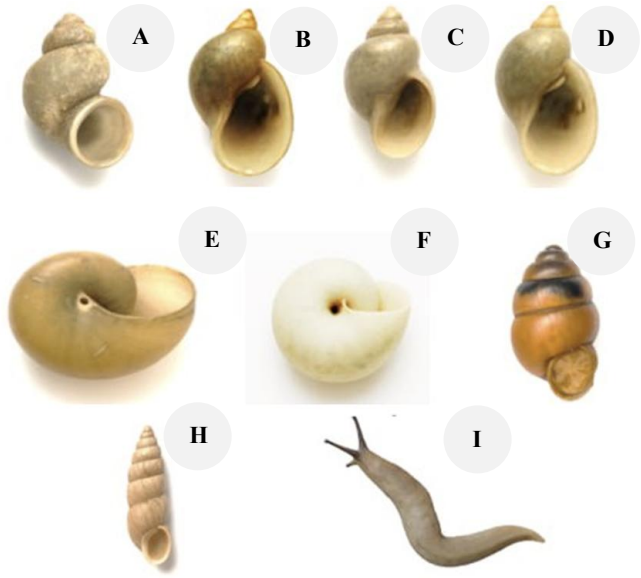

Figure 2. Species were recorded for the regions of Uzbekistan for the first time. A. *Sogdamnicola shadini*, B. *Lymnaea fragilis*, C. *Galba truncatula*, D. *Radix bactriana*, E. *Macrochlamys turanica*, F. *Macrochlamys kasnakowi*, G. *Vertigo antivertigo*, H. *Chondrina intumescens*, I. *Candaharia rozeni*

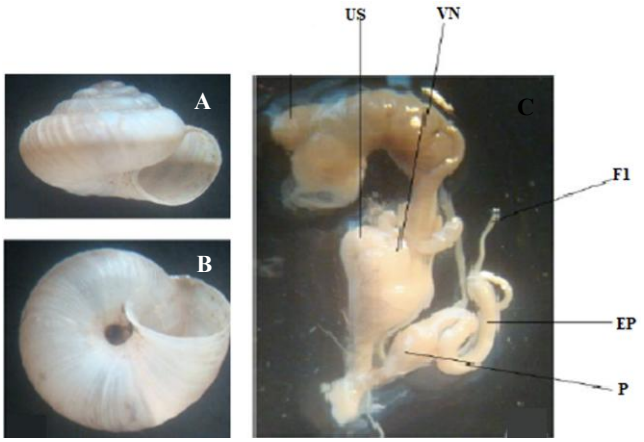

Figure 3. A new species for science: *Archaica haziratishaxika* (A-B: scrotum; C: Genital apparatus; P: Penis; US: Superior Stylophore; VN: Middle stylophore; F1: Phallus; EP: Epiphallus)

Table 3. The species composition of gastropods of the Zarafshan Mountains and adjacent areas, Uzbekistan

Names of the species	Research area (Height above sea level, meters)			
	≤ 900	900-1500	1500-2200	≥2200
Hydrobiidae (Stimpson, 1865)				
Sogdamnicola pallida (von Martens, 1874)	+	+		
**S. shadini* (Izzatullaev, 1984)	+	+		
Valvatamnicola archangelskii (Zhadin, 1952)	+	+		
V. schahimardanica (Izzatullaev, 1984)	+	+		
Acroloxidae (Thiele, 1931)				
Acroloxus lacustris (Linnaeus, 1758)	+	+		
Lymnaeidae (Rafinesque, 1815)				
Lymnaea stagnalis (Linnaeus, 1758)	+	+		
L. subangulata (Roffiaen, 1868)		+	+	+
L. rectilabrum (Annandale et Prashad, 1919)	+	+		
**L. fragilis* (Linnaeus, 1758)	+	+		
L. intercisa (Lindholm, 1909)	+	+		
L. persica (G.B.Sowerby II, 1872)	+	+	+	
**Galba truncatula* (O.F. Müller, 1774)	+	+	+	
G. bowelli (Preston, 1909)	+	+		
Radix auricularia (Linnaeus, 1758)	+	+		
**R. bactriana* (T. Hutton, 1849)	+	+		
R. narziculovi (Izzatullaev, Kruglov va Starobogatov, 1983)	+	+		
Ampullaceana fontinalis (S.Studer, 1820)		+	+	+
A. lagotis (Schrank, 1803)		+	+	+
Physidae (Fitzinger, 1833)				
Physella acuta (Draparnaud, 1805)		+	+	+
P. integra (Haldeman, 1841)		+	+	
Planorbis duryi (Wetherby, 1879)	+	+	+	
P. planorbis (Linnaeus, 1758)	+	+		
P. tangitarensis (Germain, 1918)	+	+		
Gyraulus acronicus (Férussac, 1807)	+	+	+	
G. albus (O. F. Müller, 1774)	+	+		
G. convexiusculus (T. Hutton, 1849)	+	+		
G. ladacensis (Nevill, 1878)	+	+		
Melanopsidae (H.Adams et A.Adams, 1854)				
Melanopsis transcaspica (Izzat. et Star., 1984)			+	+
M. turkmenica (Izzat. et Star., 1984)			+	+
M. zarudny (Izzat. et Star., 1984)			+	+
M. roseni (Izzat. va Star., 1984)			+	+
M. parvarishi (Izzat. et Star., 1984)			+	+
M. ashgabatensis (Izzat. et Star., 1984)			+	+
***Hygromiidae* (Tryon, 1866)**				
Nanaja cumulata (Schileyko, 1978)			+	+
N. chatkalica (Kuznetsov, 1996)			+	+
Odontotrema diplodon (Lindholm, 1927)	+	+	+	+
Leucozonella rufispira (Rosen,1897)		+	+	
L. rubens (E. von Martens, 1874)				+
*L. angulata (*Westerlund, 1896)		+	+	
L. retteri (Rosen, 1897)	+	+	+	
Archaica heptapotamica (Lindholm, 1927)				+
A. apollinis (E.von Martens, 1882)	+	+	+	
A. eleorika (Schileyko et Pazilov, 2003)		+	+	+
***A. haziratishaxika* (Pazilov, Kudratov & Makhmudzhonov, 2019)		+	+	
A. labianix (Schileyko, 1978)		+	+	+
Agriolimacidae (Wagner, 1975)				
Deroceras laeve (O.F.Müller, 1774)	+	+	+	
D. agreste (Linnaeus, 1758)	+	+	+	
Parmacellidae (Gray, 1860)				
Candaharia rutellum (Hutton, 1849)		+	+	+
C. aethiops (Westerlund, 1896)	+	+	+	
C. levanderi (Simroth, 1901)	+	+	+	
C. izzatullaevi (Likharev et Wiktor, 1980)	+	+	+	
**C. rozeni* (Simroth, 1912)	+	+	+	
C. langarica izzatullaevi (Likharev et Wiktor, 1980)	+	+	+	
Ariophantidae (Benson, 1832)				
**Macrochlamys turanica* (Ye.von Martens, 1874)		+	+	+

***M. kasnakowi* (Westerlund, 1898)**		+	+	+
Gastrodontidae (Benson, 1832)				
Zonitoides nitidus (Miiller, 1774)	+	+	+	
Buliminidae (Woodward, 1903)				
Pseudonapaeus miser (E.von Martens, 1874)		+	+	+
P. kasnakowi (Westerlund, 1898)		+	+	+
P. sogdianus (E.von Martens, 1874)		+	+	
Cochlicopidae (Pilsbry, 1900)				
Cochlicopa nitens (Gallenstein, 1852)	+	+	+	
C. lubrica (O.F.Müller, 1774)	+	+	+	
Orculidae (Steenberg, 1925)				
Sphyradium doliolum (Brugieri, 1792)	+	+	+	
Lauria cylindracea (Da Costa, 1778)	+	+	+	
Valloniidae (Morse, 1864)				
Acanthinula aculata (Muller, 1774)		+	+	+
Vallonia costata (Muller, 1774)		+	+	+
V. pulchella (O.F.Müller, 1774)		+	+	+
V. ladacensis (G.Nevill, 1878)		+	+	+
Pupillidae (Turton, 1831)				
Gibbulinopsis signata (Mousson, 1873)			+	+
G. nanosignata (Schileyko et Izzatullaev, 1980)			+	+
Pupilla triplisata (Studer, 1820)	+	+	+	
P. muscorum (Linnaeus, 1758)	+	+	+	
P. turcmenica (O. Boettger, 1889)	+	+	+	
Vertiginidae (Pilsbry, 1918)				
***Vertigo antivertigo* (Draparnaud, 1801)**		+	+	+
Truncatellininae (Steenberg, 1925)				
Columella columella (G. Martens, 1830)		+	+	+
Chondrinidae (Steenberg, 1925)				
***Chondrina intumescens* (E. von Martens, 1874)**	+	+		
Bradybaenidae (Pilsbry, 1939)				
Kugitangia hatagica (Shileyko, Pazilov et Abdulazizova, 2019)	+	+	+	
Ferussaciidae (Tryon, 1886)				
Cecilioides acicula (Férussac, 1814)	+	+		
Succineidae (Beck, 1837)				
Novisuccinea evoluta (Martens, 1879)	+	+	+	
Pamirsuccinea eximia (Schileyko et Likharev, 1986)	+	+	+	
Oxyloma elegans (Risso, 1826).	+	+	+	
Total	46	68	58	30

Note: *: Recorded for the first time in Uzbekistan, **: New species for science

The stylophores are developed to varying degrees: the outer stylophore is relatively large, with a spherical tip, and the inner stylophore slightly compresses the wall of the anal opening with the spherical outer stylophore, but retains its spherical shape. The genital organ is small and spherical. The cylindrical epiphallus is folded twice. The flagellum is 1.5 times larger than the epiphallus. The seminal duct is absent, and there is no membrane between the epiphallus and the genital organ. The seminal duct is short and ends in a spherical reservoir. These characteristics distinguish this species from other species and confirm that it is a new species.

Analysis of taxon composition of gastropod mollusks

According to the distribution indicators of gastropod species in the Zarafshan Mountains and adjacent plains by family, the families Lymnaeidae and Hygromiidae are the most species-rich families in the region, with 31.25% of the species in the region (a total of 25 species) belonging to these families. The families Physidae (9 species), Melanopsidae, and Parmacellidae (6 species each) are also distinguished by their relatively high number of species. In addition, 5 species of the Pupillidae family, 4 species of the Hydrobiidae and Valloniidae families, 3 species of the Buliminidae and Succineidae families, 2 species of the Agriolimacidae, Ariophantidae, Cochlicopidae, and Orculidae families, and one species each of the Acroloxidae, Gastrodontidae, Bradybaenidae, and Ferussaciidae families are found in this microregion. According to the distribution of species within families, the families Lymnaeidae (4 genera) and Succineidae (3 genera) are dominant in the study area (Figure 4).

Analysis of the distribution of gastropod mollusk species of the Zarafshan Mountains and adjacent plains by genera showed a decrease in species abundance by genera: *Lymnaea*, *Melanopsis*, *Candaharia* (6 species each), *Archaica* (5 species), *Anisus*, *Leucozonella* (4 species each), *Planorbis*, *Radix*, *Pupilla*, *Vallonia*, *Pseudonapaeus* (3 species each), *Sogdamnicola*, *Valvatamnicola*, *Galba*, *Ampullaceana*, *Physella*, *Nanaja*, *Deroceras*, *Macrochlamys*, *Cochlicopa*, *Gibbulinopsis* (2 species each). It was also noted that 15 more genera had one species each (Figure 5).

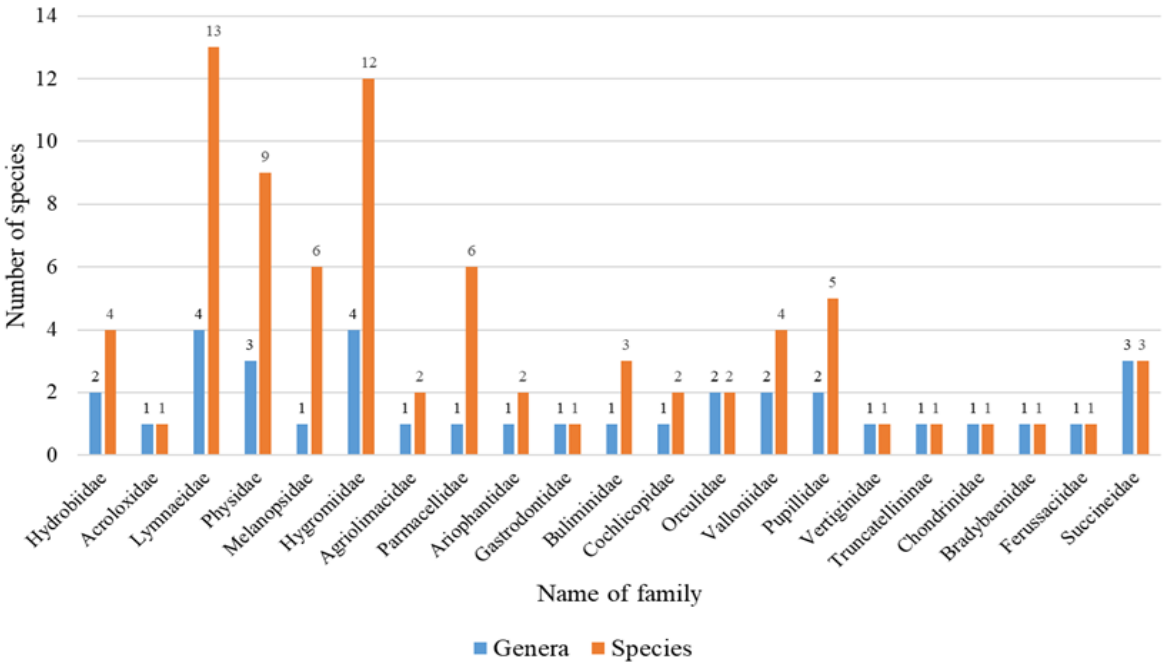

Figure 4. Distribution of genera and species of gastropod mollusks in the Zarafshan Mountains and adjacent areas (Uzbekistan) into families

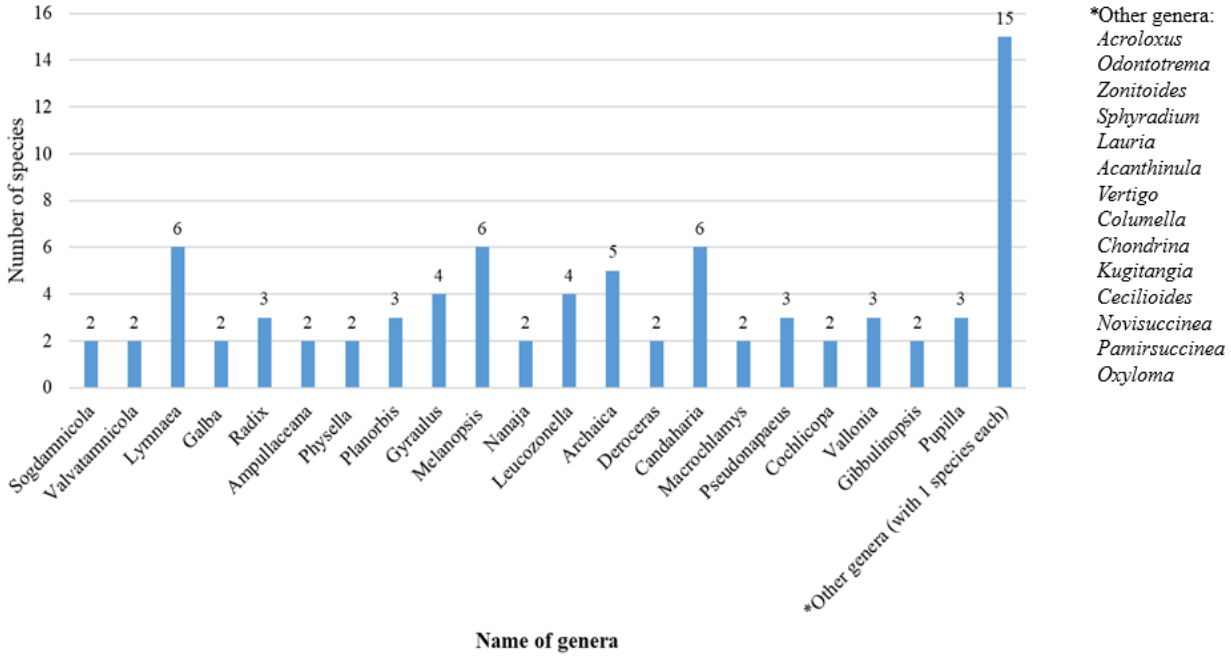

Figure 5. Distribution of species of gastropod mollusks in the Zarafshan Mountains and adjacent areas (Uzbekistan) into genera

Similarity of species composition of gastropod mollusks in the Zarafshan Mountains and adjacent areas

Analyses of the similarity of the species composition of gastropods in the Zarafshan Mountains and adjacent areas showed that the gastropod malacofauna at altitudes ≤900 m asl in the study area has the highest similarity with the gastropod malacofauna at altitudes between 900 and 1,500 m asl (Chekanovsky-Sørensen: 0.68; Jacquard: 0.81). The lowest values were recorded in the data on the species composition of gastropods at altitudes ≤900 m asl and ≥2,200 m asl (Chekanovsky-Sørensen: 0.01; Jacquard: 0.03). It was also found that the species composition of the gastropod malacofauna distributed at an altitude of 900-1,500 m asl is closer to the species composition of

gastropod mollusks distributed at an altitude of 1,500-2,200 masl (Chekanovsky-Sørensen: 0.62; Jacquard: 0.76) (Table 4).

The Similarity dendrogram created based on the identified data is shown in Figure 6. Figure 6 shows that according to Jaccard, the species composition of gastropod mollusks in the Zarafshan Mountains and adjacent areas is more diverse in areas with an altitude of ≥2,200 m asl compared to other areas. According to Chekanovsky-Sørensen, the species composition of samples collected from locations at altitudes of ≤900 m asl and between 900-1,500 m asl, and between 900 to 1,500 m asl and ≥2,200 m asl is more similar to each other (Figure 6).

The number of gastropod mollusks species in the Zarafshan Mountains and adjacent areas, and correlations between some factors

The above data revealed a fascinating insight: the number and composition of gastropod species vary depending on the altitude of the studied areas. This finding, along with the understanding that other environmental factors also shape species diversity, led us to investigate the effect of the composition and number of species of the fauna. Based on this, our study determined the effect of annual average temperature and precipitation on the number of species in the gastropod malacofauna. The data in Tables 2 and 3 were instrumental in our analysis. We found a strong correlation (r: 0.53) between the annual average temperature and the number of species in the gastropod malacofauna (Figure 7.A), and there is no correlation (r: -0.38) between the annual average precipitation and species number (Figure 7.B). These findings have significant implications for our understanding of gastropod malacofauna and the role of environmental factors in species diversity.

Discussion

This study is the first to comprehensively study the gastropod mollusks of the Zarafshan Mountains and adjacent areas (Uzbekistan) by dividing them into vertical altitudinal zones. Another important feature of this study is that both terrestrial and aquatic mollusks were studied. Local specialists in the Nurota Mountains and Gissar Mountains have carried out similar studies. Kudratov et al. (2023) identified 15 species of gastropod mollusks belonging to 4 families (Belgrandiellidae, Lymnaeidae, Physidae, and Planorbidae) and 5 genera in this area by identifying materials collected from 11 streams in the Nurota Mountains. When analyzing the species composition, it was noted that representatives of the Lymnaeidae family predominated in the gastropod mollusk fauna of the Nurota Mountains. Compared with the Nurota mountain range, the species of the Lymnaeidae family (9 species) were found to be dominant in the Zarafshan mountains and adjacent areas. Studies conducted in 13 biotopes in the Hissar mountain range and adjacent areas revealed that 46 species of terrestrial gastropod mollusks were found in this area, and the number and density of species in the steppe and arid regions were lower than in the mountain zone, where the vertical elevation gradient was relatively high (Kudratov et al. 2024). Considering that the current study also included the mountain zone of the regions with an altitude of 900-1,500 m asl (68 species) and 1,500-2,200 m asl (58 species), it is reasonable to assume that the species composition and distribution trends of gastropod mollusks in Uzbekistan are relatively similar.

Data on the taxonomic diversity of gastropods and the factors affecting it have been reported in the works of several foreign authors. Studies conducted in the Euphrates River in northern Iraq revealed that 7 species of gastropods belonging to 6 families and 6 genera were present in this river. That water temperature, pH, and water chemistry affected the density of individuals in the species population (Ali et al. 2022). Gumuş et al. (2022) in Turkey and Bidat et al. (2023) in Malaysia noted that the species composition and density of gastropods in the respective regions are directly related to the depth at which samples were taken and the height of the vertical gradient of the region, as well as anthropogenic factors.

The analysis of scientific sources showed that the data on the species composition and diversity of terrestrial gastropods do not provide a significant opportunity to compare the results obtained. Belhiouani et al. (2019) showed that 11 species of terrestrial gastropods belonging to 6 families and 9 genera occur in Northeast Algeria, based on samples collected from different altitudes in 5 locations. The data obtained in the current study confirm that the gastropod malacofauna of the mountainous and neighboring regions of Uzbekistan is quite diverse.

The composition and number of species of animals, including gastropods, and their dynamics of change are influenced by a number of biotic and abiotic factors (Dong et al. 2022). In this regard, the temperature of the environment in which animals live is of particular importance. Floyd et al. (2020) noted that temperature moderation increases the survival of mollusks by optimizing their physiological processes, leading to increased species composition and population density. Biogeographical location, soil and water composition, and other factors can also affect biological diversity in mollusks (Zaidi et al. 2021; Avila et al. 2024). These observations serve as the basis for the results obtained on the number of gastropod species in the Zarafshan Mountains and adjacent areas and the correlations between some factors.

Table 4. Similarity coefficients of the malacofauna of the Zarafshan Mountains and adjacent microregions in Uzbekistan (Chekanovsky-Sørensen\Jacquard)

Research areas	≤ 900	900-1500	1500-2200	≥2200
≤ 900	1	0.68	0.33	0.01
900-1500	0.81	1	0.62	0.23
1500-2200	0.5	0.76	1	0.47
≥2200	0.03	0.37	0.64	1

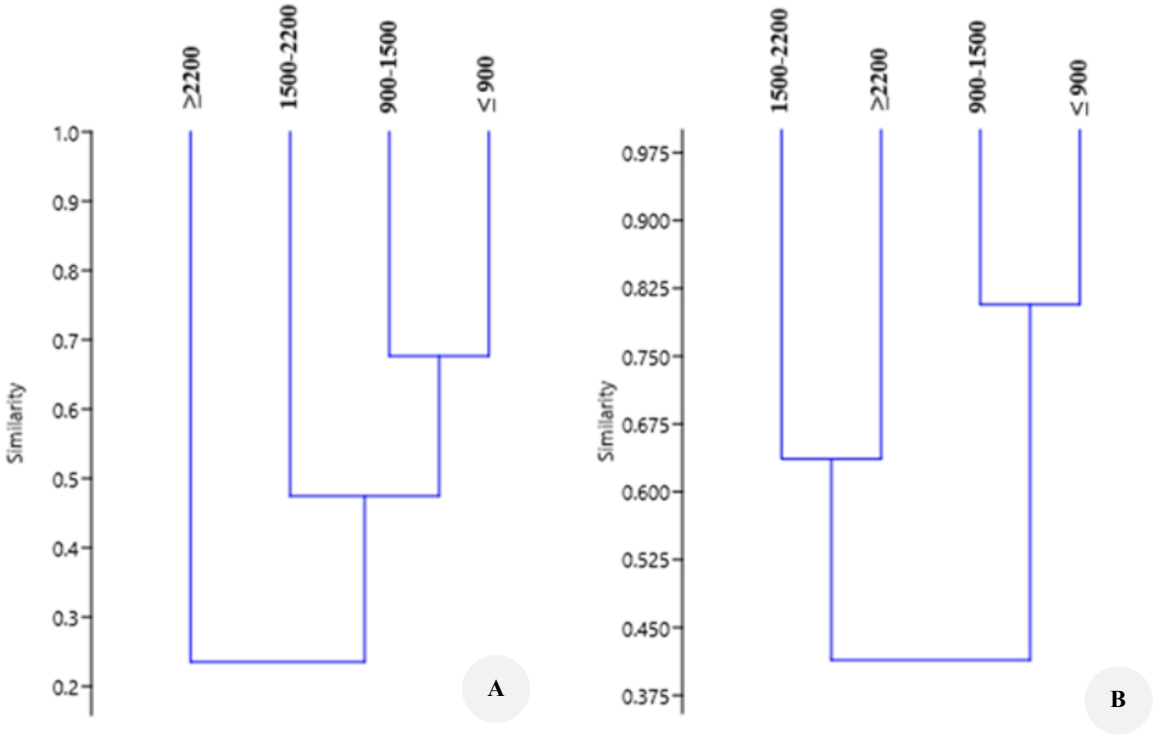

Figure 6. Similarity dendrogram of the malacofauna of the Zarafshan Mountains and adjacent microregions in Uzbekistan, based on Jaccard (A) and Chekanovsky-Sørensen (B) coefficients

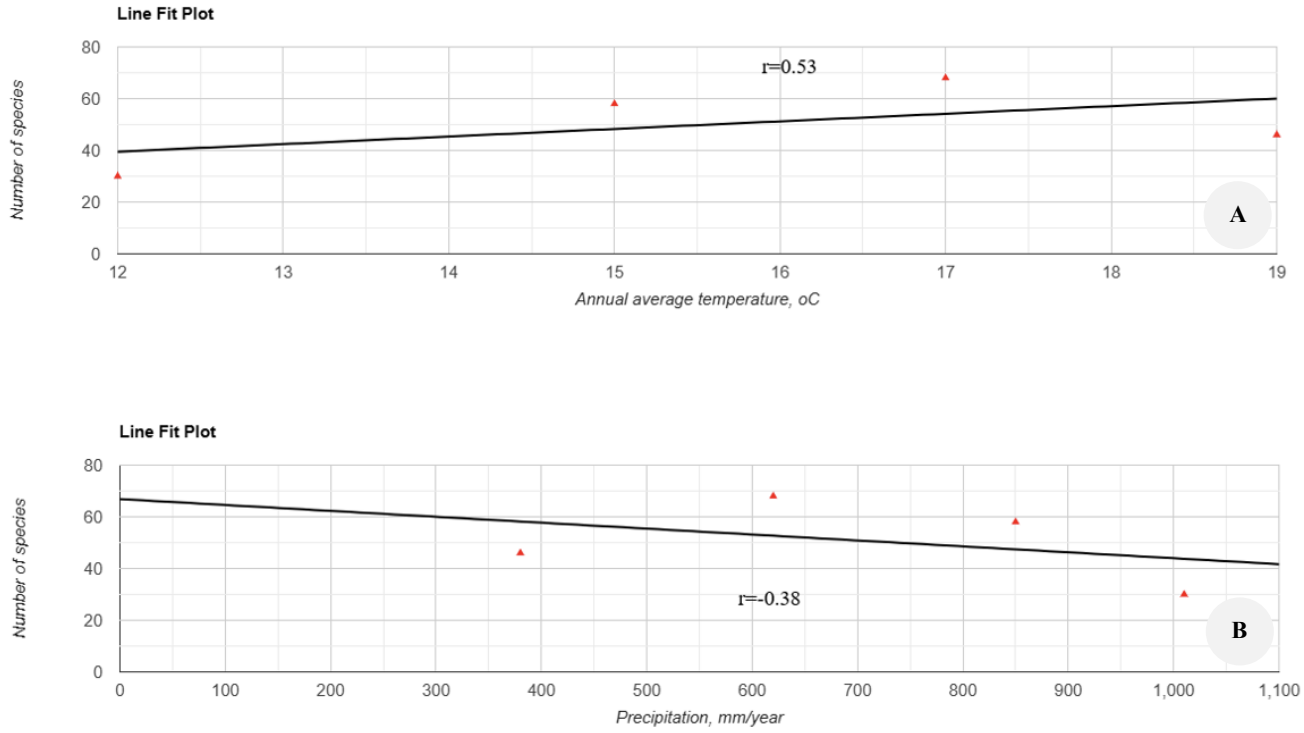

Figure 7. Correlation of the number of gastropod mollusk species with various factors (A: Temperature, B: Precipitation) in the Zarafshan Mountains and adjacent areas (Uzbekistan)

In conclusion, it can be stated that 80 species of gastropod mollusks belonging to 21 families and 34 genera (including 1 species described for science and 9 species recorded for the first time in Uzbekistan) are found in the Zarafshan Mountains and surrounding areas. These species are distributed in varying numbers across different altitudinal zones. In terms of species richness, the families Lymnaeidae and Hygromiidae are dominant, with representatives of the genera *Lymnaea* and *Melanopsis* being especially prevalent. The data presented here represent the first comprehensive results that contribute to the knowledge base needed by specialists to study the malacofauna of the Zarafshan Mountains. Additionally, these findings can inform the development of recommendations aimed at maintaining biological diversity.

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