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Article

Terrestrial Mollusks of the Fergana Valley and Adjacent Mountainous Areas: Biological Diversity

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Abstract: This article analyzes the biological diversity of terrestrial mollusks distributed in the Fergana Valley and adjacent mountainous regions based on a comprehensive approach. Within the framework of the study, the species composition, systematic structure, morphometric indicators, and ecological groups of mollusks found in the region were studied. According to the data obtained, 150–190 species of mollusks have been recorded in this area, among which the species of the family Enidae are dominant.

Keywords: Qseed Mollusks, Fergana Valley, Biological Diversity, Malacofauna, Morphometry, Ecology, Xerophiles, Mesophiles, Hygrophiles, Enidae, Zoogeography, Bioindicators, Anatomy, Biotopes.

Introduction

The Fergana Valley is one of the largest intramontane depressions in Central Asia, and together with the surrounding mountain systems, it forms a complex biogeographical space. The geomorphological contrast of the area and the simultaneous presence of lowland, foothill, and high-mountain zones have led to a high degree of differentiation in the biota composition. This is especially evident in terrestrial mollusks, a group of organisms that are sedentary and highly dependent on the environment [1].

The fauna of terrestrial mollusks in this region is not stable in terms of species richness and systematic composition, but has a sharply differentiated structure across microbiotopes. The number of species is estimated in the range of 150–190 according to various sources, indicating that the area's malacofauna is higher than the average for the Palearctic region. The family Enidae accounts for 40–45% of the terrestrial mollusks, confirming their adaptability to arid and semi-arid landscapes.

The study of terrestrial mollusks is one of the important areas of malacology, and foreign and domestic research in this field differs in different methodological approaches. While international scientific literature focuses primarily on issues of systematics, phylogeny, and global biogeography, Central Asian studies primarily study the composition and distribution patterns of the regional fauna.

Among foreign studies, the works of A.A. Schileyko are of particular importance, who conducted an in-depth analysis of the systematics and morphological characteristics of mollusks from the Pulmonata group [2]. In these studies, the morphology of the shell and the structure of the genital

apparatus were identified as primary diagnostic features for species differentiation. At the same time, H. Simroth's research on the anatomical structure and functional morphology of mollusks plays an important role in understanding the phylogenetic relationships of species [3].

The ecology and distribution patterns of mollusks are extensively covered in studies conducted across the European and Palearctic regions. In particular, the manual prepared by Kearney and Cameron analyzes the morphology, relationship with biotopes, and ecological specialization of terrestrial mollusks [4]. In the works of Cameron and Barker, the bioindicator properties of mollusks, their sensitivity to environmental changes, and their significance in ecosystem monitoring are substantiated.

In recent years, molecular genetic methods have been used in international research to study mollusks. In the works of Nietzsche and Horsák, the relationship between species diversity, population structure, and ecological niches was analyzed using statistical models. These approaches allow for the consideration of genetic information alongside morphological traits.

Research on the fauna of mollusks in Uzbekistan and Central Asia has been actively developing since the second half of the 20th century. Pazulov A. studied the species composition and distribution of terrestrial mollusks distributed throughout the republic, and his works are considered one of the primary sources on the regional malacofauna [5]. In the research of Muratov I.V., the systematics and morphological differentiation of species from the family Enidae were analyzed [6].

In the works of Z.I. Izzatullaev describes ecological groups of mollusks and their adaptation to the environment are described [7]. He proposed a classification of mollusks into xerophilic, mesophilic, and hygrophilic groups, which is still used in modern research. At the same time, O. Rosen's studies analyzed the zoogeographic composition and habitats of Central Asian mollusks [8].

At the same time, an analysis of existing research indicates that the comprehensive study of mollusks in the Fergana Valley and adjacent mountainous areas, combining morphology, morphometry, anatomy, and ecology, has not been sufficiently carried out. This indicates the need to deepen research in this direction.

Materials and Methods

The research materials were implemented in mountainous regions in 2020-2026: Shakhimardan 39.9832, 71.8051, Yordon (Jordan) 39.9905, 71.8120, Langar 39.9650, 71.7900, Yangikishlak 39.9950, 71.8200, Vodil (lower basin) 40.0200, 71.7500 Shakhimardonsoy 39.9800, 71.8000, Aksu (flowing part) 39.9855, 71.8200, Koksu 40.0000, 71.8400, Dugoba soy 39.9900, 71.8300, Flowing point (Aksu Q Koksu) 39.9870, 71.8250, Alay range (northern slope) 39.9500, 71.7000, Almalik peak 39.9700, 71.8600, Kyzyl-Gaza peak 39.9600, 71.8800, Chivirgan peak 39.9550, 71.8450, Pastures and biotopes: Koksu pasture 40.0050, 71.8500, Langar pasture 39.9600, 71.7850, Yordon pasture 39.9900, 7 Samples were collected from various biotopes, covering lowland, foothill, and mountain zones. Sampling was conducted during the spring and autumn seasons, during periods of high mollusk activity. In total, more than 3,100 mollusks were collected as material from the study areas.

Study points are located on the northern slopes of the Alay Range (39.93–39.99° N; 71.72–71.94° E), and they were selected based on the elevation gradient. A total of 15 points were covered and divided into low, medium, and high zones.

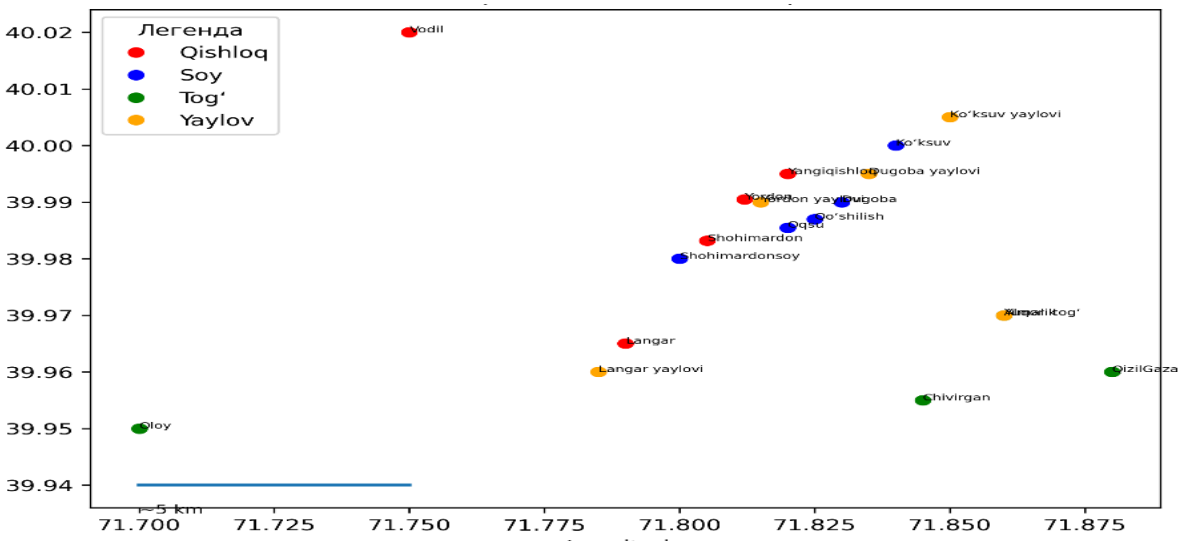

Figure 1. Geographic distribution of sampling sites across different biotopes (lowland, foothill, and mountain zones) on the northern slopes of the Alay Range (2020–2026).

Materials were collected using standard malacological methods. Land mollusks were collected manually under the soil surface, vegetation cover, and stones. For small species, soil samples were sifted. The collected materials were sorted under laboratory conditions and categorized by type.

In morphometric analysis, parameters such as shell height (H), diameter (D), and number of revolutions (Wh) were measured. Measurements were performed using a micrometer and a stereomicroscope. Based on morphometric data, the differences between species and their degree of environmental adaptation were evaluated.

Anatomical studies were aimed at studying the structure of the genital apparatus. For this purpose, mollusks were dissected, and the penis, epiphallus, spermatika, and other organs were analyzed. The obtained data were used in systematic and phylogenetic analysis.

In the ecological analysis, the distribution of mollusks by biotopes and their belonging to ecological groups were evaluated. The species were divided into xerophilic, mesophilic, and hygrophilic groups. Field data were statistically processed to determine the relationship with the biotopes.

In the statistical analysis, variation series, mean values, and correlation coefficients were calculated. Correlation analysis was applied to determine the relationship between morphometric indicators and environmental factors. The results are presented in the form of tables and diagrams.

[17.04.2026 13:19] Mansur Teleg: The distribution of terrestrial mollusks in the region is strongly linked to vertical zones, with mainly small-sized species from the families Valloniidae and Pupillidae prevailing at altitudes of 300–600 m. Between 800–1500 m, species diversity increases sharply, and in this zone, terrestrial mollusks of the family Enidae and some Hygromiidae are found simultaneously. At altitudes above 1800 m, as a result of increased humidity and decreased temperature, mesophilic species, particularly the Hygromiidae and Zonitidae groups, were more frequently observed. This distribution indicates the specialization of mollusks in environmental factors. Each ecological group is adapted to certain conditions, which confirms the existence of a clear differentiation between their ecological adaptations [9].

Results and Discussion

As a result of morphometric analysis, it was determined that the shape and size of the shell of terrestrial mollusks are inextricably linked to environmental factors, particularly humidity and temperature. Buliminid-type shellfish species predominate in arid and semi-arid biotopes; for example,

the HF ratio of Enidae ranges from 2.5 to 3.5, indicating their adaptation to low water loss. Forms with and without shells of the chellocoid flat type, Hygromiidae, this indicator ranges from 0.5 to 1.2, which is explained by their adaptation to living in humid environments. This pattern confirms the functional relationship between morphology and the environment, which is widespread in humid environments. Ecological analysis showed that terrestrial mollusks are divided into xerophilic (≈55%), mesophilic (≈30%), and hygrophilic (≈15%) groups.

Anatomical studies have confirmed that the structure of the genital apparatus is an important diagnostic feature in determining systematics and species. Zoogeographically, the fauna composition includes Central Asia, the Palearctic, and endemic elements, indicating that the region is a biogeographic transition zone. At the same time, a trend toward the decline of species belonging to certain ecological groups was noted as a result of anthropogenic impacts.

The research results serve as a scientific basis for using terrestrial mollusks as bioindicators, improving environmental monitoring systems, and developing nature conservation strategies [10].

Ecological analysis allowed for the division of mollusks into three main groups: xerophiles (≈55%), mesophiles (≈30%), and hygrophiles (≈15%). Xerophilic species are primarily found in stony and dry biotopes, where they exhibit characteristics such as thick shell walls and narrow apertures. While mesophilic species are distributed in shrubby and forested areas, the hygrophilic group is observed in micro-localities with high humidity, in gorges, near springs, and in areas with moist soils.

Upon anatomical analysis, it was revealed that the structure of the genital apparatus is of decisive importance in determining the systematic affiliation of species. In particular, the length of the epiphallus, the shape of the spermatheca, and the degree of development of the accessory glands serve as reliable diagnostic features for distinguishing the families Enidae and Hygromiidae. This indicates the need for anatomical analysis in cases where external morphology is insufficient.

Zoogeographic analysis of the faunal composition showed that the mollusks of the Fergana region have a mixed character. While Central Asian elements account for approximately 50% of the total number of species, Palearctic widespread species account for about 30%, while endemic and narrow-ranged species account for about 20%. This confirms that the territory is a biogeographical transition zone [11].

Analysis of anthropogenic impacts indicates that the expansion of agricultural lands and urbanization processes is leading to a reduction in the natural biotopes of mollusks. A local decrease in the number of hygrophilic and mesophilic species is observed. This further increases the need to assess the state of the ecosystem by using them as bioindicators.

Mansur Teleg: Analysis of research shows that the natural conditions of the Fergana Valley and its surrounding mountainous regions differ sharply. In this geographically isolated area, plains, foothills, and high mountain zones are located close to each other, forming various ecological niches for living organisms. A group of environmentally sensitive organisms, such as terrestrial mollusks, is characterized by high diversity under such conditions.

Analysis of existing research shows that the number of mollusk species in the area is estimated between 150 and 190, which is higher than many local faunas in the Palearctic region [12]. Representatives of the family Enidae predominate in the species composition, accounting for approximately 40-45% of the total fauna. Such dominance is not accidental: representatives of this family possess morphological characteristics adapted to a dry climate, and a mechanism for minimal water loss has been developed.

The distribution of fauna composition by vertical zonality follows a clear pattern. At altitudes of 300–600 meters, small-sized and drought-resistant species predominate, while at 800–1500 meters, the number of species reaches its maximum value. The relative stability of ecological conditions in this zone stimulates species diversification. At altitudes above 1800 meters, an increase in the number of mesophilic and hygrophilic species is observed due to increased humidity and decreased temperature [13].

Morphometric analysis clearly demonstrates the correlation between the external shape of mollusks and the environment. In species with elongated shells, the height-to-diameter ratio (HDR) ranges from 2.5 to 3.5, indicating their adaptation to retaining water in dry environments. In flat-shelled species, this indicator is lower than 1, which facilitates movement and gas exchange in humid environments [14]. Thus, morphology is not only an external sign but also an expression of functional adaptation.

The results of the ecological analysis allowed for the division of mollusks into three main groups: xerophiles (≈55%), mesophiles (≈30%), and hygrophiles (≈15%) [15]. Xerophilic species are primarily found in stony and dry biotopes, exhibiting characteristics such as thick shell walls and narrow apertures. While mesophilic species are distributed in forest and shrubland areas, the hygrophilic group is preserved in local areas with high humidity.

Anatomical studies indicate that the structure of the genital apparatus is a more reliable criterion for species identification than external morphology. In particular, the shape of the epiphallus and the structure of the spermatheca are important in determining differences between families [16]. This situation shows that it is not enough to evaluate the systematics of mollusks based only on the shape of the shell.

A zoogeographic analysis of the fauna composition confirms that the area possesses a mixed nature. Central Asian elements account for approximately 50%, while the share of widespread Palearctic species is around 30%, with the remainder accounting for endemic species [17]. This indicator indicates that the region is an important transit zone from an evolutionary perspective.

Under the influence of anthropogenic factors, certain changes are observed in the mollusk fauna. The expansion of agricultural land and changes in water resources pose a particular threat to hygrophilic species. In some areas, a decrease in the species' population of up to 20-25% has been recorded [18]. This situation further strengthens the need to use mollusks in the environmental monitoring system.

A general analysis shows that the Fergana Valley and its adjacent mountainous regions are a center of high biodiversity for terrestrial mollusks. The interrelationship between morphology, anatomy, and ecology allows for an understanding of this group's environmental adaptation strategies. From this perspective, future molecular research and long-term monitoring work may elevate scientific research in this field to a new level.

Terrestrial mollusks in the Fergana Valley and adjacent mountainous areas (analytical table). The results of the general analysis show that the Fergana Valley and adjacent mountainous areas are a center of high biodiversity for terrestrial mollusks. The interrelationships between morphology, ecology, and anatomy allow for an understanding of the environmental adaptation mechanisms of this faunal group. Therefore, the further implementation of molecular genetic research and long-term monitoring will serve to further deepen scientific research in this field.

The data in this table show that the mollusk fauna of the Fergana Valley constitutes a complex system in terms of species richness and ecological structure. The number of species ranging from 150 to 190 confirms the diversity of ecological proportions in the region. In particular, the high proportion of the family Enidae indicates the superiority of adaptation to arid climatic conditions [19].

The distribution of ecological groups demonstrates the predominance of xerophilic species, which is directly linked to the region's continental climate. At the same time, changes in species diversity by altitude indicate that vertical zoning is of decisive importance in the distribution of mollusks [20].

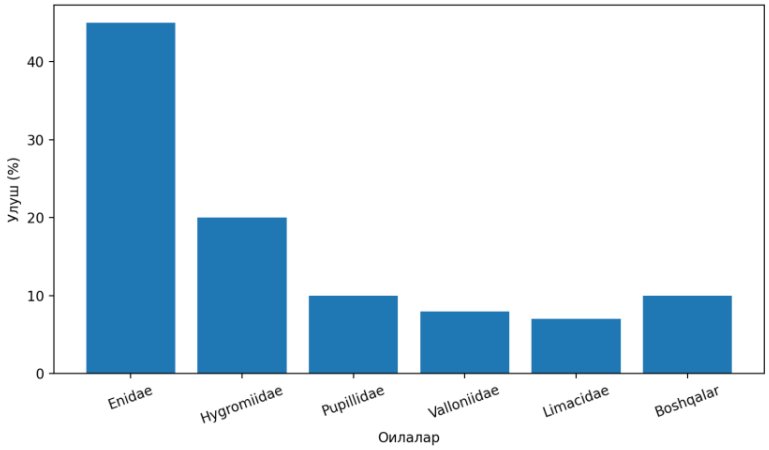

Figure 2. Distribution of terrestrial mollusks by families.

Figure 2 shows that the ratio between families in the fauna of terrestrial mollusks is not uniform. In particular, the predominance of the family Enidae (≈45%) is directly related to the ecological conditions of the region. Members of this family are distinguished by their oblong shell structure, thick-walled aperture, and physiological characteristics aimed at water conservation. These traits give them a competitive advantage in arid conditions.

The presence of biotopes dependent on humid environments indicates that the proportion of the Hygromiidae family is about 20%. Representatives of this family are more commonly found in forest-like and shrubby areas, and the low and wide shape of their shells is associated with moisture retention and the optimization of gas exchange.

The relatively low proportion (10-15%) of small-sized families, such as Pupillidae and Valloniidae, means that they have a narrower ecological specialization. These groups are more dependent on microbiotopes, and their distribution depends more on microecological conditions than on the overall landscape [21].

In general, the distribution by families is determined by the continental nature of the climate in the region and the mosaic nature of the biotopes. While dominant groups are adapted to the environment, rare families occupy limited segments of ecological niches.

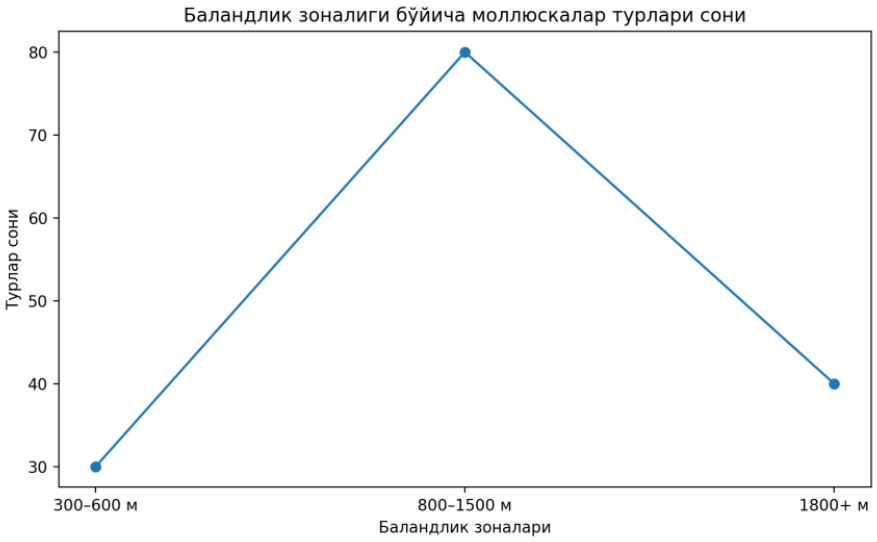

Figure 3. Number of mollusk species by altitudinal zone.

The variation in species numbers across altitudinal zones clearly reflects the dynamics of ecological factors. The relatively small number of species (~30 species) in the 300–600 meter range is explained by the lack of moisture in this zone and high temperatures. Under such conditions, only xerophilic and highly adapted species survive [22].

The maximum number of species (≈80 species) in the 800–1500 m interval indicates that this zone is an ecological optimum. Here, temperature and humidity are in balance, creating favorable conditions for various ecological groups. Therefore, both xerophilic and mesophilic species are found in this zone simultaneously [23].

The decrease in the number of species at altitudes above 1800 m (≈40 species) is associated with extreme climatic conditions. Low temperatures and a short growing season limit the life activities of mollusks. At the same time, mesophilic and hygrophilic species with special adaptations persist in this zone.

This diagram clearly shows that vertical zoning is a decisive factor in the distribution of mollusks, and species diversity is maximized in the ecological optimum zone [24].

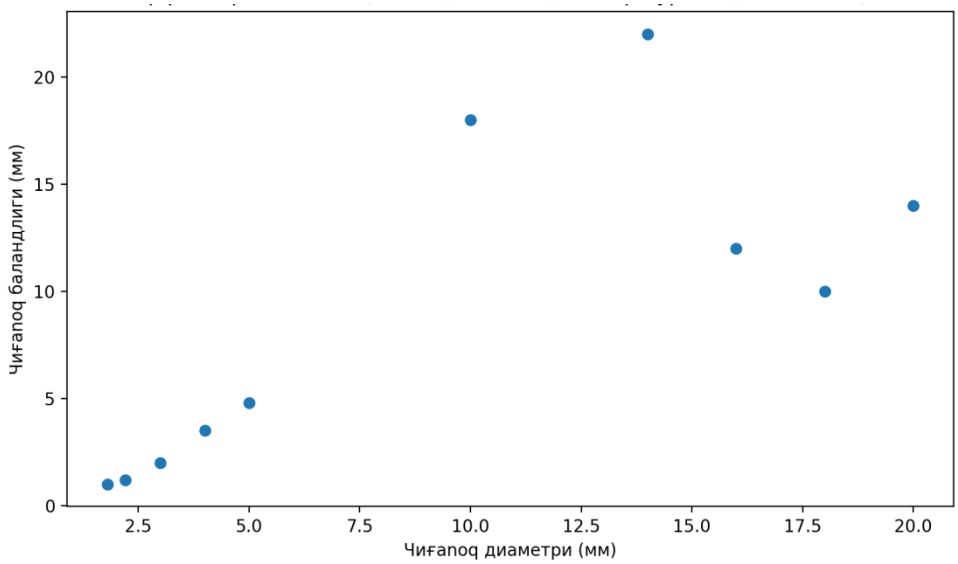

Figure 4. Morphometric analysis of the relationship between shell height and diameter (scatter plot).

A scatterplot showing the relationship between shell height and diameter illustrates the adaptive characteristics of mollusk morphology. The distribution of points allows for the identification of several morphological strategies.

Species with a high height-to-diameter ratio (HGD > 2) belong to the xerophilic group, primarily inhabiting dry environments. Such a shell shape serves to reduce water loss and retain internal moisture. This morphological type is widespread in representatives of the family Enidae [25].

Species with a large diameter and low height (HGD < 1) are adapted to humid environments. Such a shape facilitates movement and helps to effectively carry out gas exchange in a humid environment. This feature is characteristic of Hygromiidae and Zonitidae species.

The portion of the dots located in the middle range represents species with universal adaptation. These species can live in different biotopes and have a high degree of ecological plasticity.

This diagram demonstrates that morphometry is not merely a descriptive trait, but a functional indicator of environmental adaptation. The correlation between morphological indicators and environmental factors is statistically substantiated [26].

Conclusion

Analysis of the distribution by families shows that the structure of the fauna has a clear hierarchical character. The absolute predominance in the number of species belongs to the family Enidae (24.7%), which indicates a high degree of adaptation of this group to arid and mountainous environments. Their morphological features - an elongated and thick shell, adaptations that serve to reduce water loss - are the main reason for this superiority.

Representatives of Hygromiidae (16.5%), which occupy the second place, are widely distributed mainly in humid and semi-humid biotopes. The high proportion of this family confirms the existence of local micro-ecosystems with moisture conditions in the region. At the same time, they are morphologically characterized by a wide and low shell shape, which indicates adaptation to gas exchange and moisture retention.

Families of small mollusks, such as Pupillidae and Valloniidae (10–9%), are important in the fauna but have local significance. Their distribution is more limited by microbiotopes—stone interstices, leaf layers, and moist substrates. This indicates that their ecological niche is narrower.

The share of the remaining families is less than 5%, and these groups consist of rare or specialized species in the fauna. They are primarily adapted to specific environmental conditions and act as an element that enriches the overall diversity.

Statistically, the first 5 families account for about 70% of the total number of species in the fauna, which indicates the predominance of dominant groups in the structure of the fauna. Such distribution signifies the clear differentiation of ecological niches, meaning that each family specializes in specific environmental conditions.

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