Conchological variation of widely common species of terrestrial mollusks of Uzbekistan

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Abstract. This article presents current research on the variability of widespread common species of terrestrial mollusks of the family Buliminidae of Uzbekistan. The study of features of the population structure of species - indicators of changes in biocenoses under the influence of various factors, including anthropogenic ones, is an important component of environmental monitoring of various territories. These species, in particular, include terrestrial mollusks Pseudonapaeus albiplicatus, Psendonapaeus sogdianus, Pseudonapaeus secalina, Psendonapaeus miser, Chondrulopsina fedtschenkoi. A number of studies have been devoted to the analysis of intrapopulation variability of these species. In the course of these studies, it has been shown that these species are sensitive to successional processes with the morphology of their shell, as well as the frequency ratio of polymorphic characters. In this work, biotopic variability of morphometric characters, conchological variability of the shell, variability of morphometric characters of different habitats of Pseudonapaeus albiplicatus, Pseudonapaeus sogdianus, Pseudonapaeus secalina, Pseudonapaeus miser, Chondrulopsina fedtschenkoi were studied. Which, living in arid conditions, adapt to sharp changes in temperature and humidity, while acquiring a number of additional characteristics, such as: parietal callus, mouth lips and teeth, which play one or another role in reducing the loss of moisture from the body of mollusks. The indicator ability of these species is enhanced by the relative inactivity of individuals and at the same time by the large number of populations and wide distribution throughout Europe. It seems that the study of populations of these mollusks living in various landscapes will provide a clearer picture of the state of the environment, and, in addition, will add to the range of data on microevolutionary processes currently occurring. Goal of the work. Comparison of intrapopulation variability molluscs of the family Buliminidae living on the territory Uzbekistan.

1 Introduction

The nature of variability of Central Asian mollusks was partially analyzed in the work of A.A. Shileiko [1], K.K. Uvalieva[2], A. Pazilov[3-4], A. Pazilov, D.R. Daminova [5], P.V

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Matekin [6], however, in most cases, researchers limited themselves to stating the facts of variability and describing the adaptation of each specific form to the conditions of specific biotopes.

In this context, it seems relevant to us to study the variability of widespread common species of terrestrial mollusks of the family Buliminidae of Uzbekistan.

2 Materials and methods

The material for the study was shell collections Pseudonapaeus albiplicatus, Pseudonapaeus sogdianus, Pseudonapaeus secalina, Pseudonapaeus miser, Chondrulopsina fedtschenkoi from various territories.

The factual basis of the article is compiled based on materials from our collections carried out in the mountain ranges: Karzhantau, Ugam, Pskem, Chatkal, Talas, Kuramin, Fergana, Alai, Turkestan, Zarafshan, Gissar, Nurata, Kugitangtau, Baysuntau, Babatag and in Fergana, Chirchik-Akhangaran, Zarafshan, Kashkadarya and Surkhan-Sherabad valleys, as well as extensive collections of the Zoological Institute of the Russian Academy of Sciences, the Zoological Museum of Moscow University. In addition, the collections of Samarkand University and the Institute of Zoology and Parasitology of the Academy of Sciences of the Republic of Tajikistan were partially used.

3 Results

Conchological variability is considered using the example of the following species, widespread in the studied area.

Pseudonapaeus albiplicatus. An extremely variable species both biotopically and geographically. Living in two biotopes, not far from each other, they differ extremely sharply. For example, on the Chatkal ridge, the Piyazdy-sai gorge is at a height1000 m above sea level. among bushes, on the lower parts of thickets of grasses, mollusks have a large, thick-walled shell, the shape of the shell is almost pool-shaped. 8 turns, not convex, almost flat. The color consists of a dark brown background and developed radial streaks. The aperture is truncated-oval, the place of its attachment is close, but not connected (Figure 1.A).

Living in the same gorge at a height1600 m above sea level, among subshrubs, mollusks have oval-cylindrical shells. Whorls 7, slightly convex. Sculpture in the form of rough wrinkles. Coloration: light radial streaks are so strongly developed that one can most likely talk about a white shell. The aperture is truncated-oval, the attachment points are widely spaced, its edges are moderately turned away (Figure 1.B).

On the left bank of the river. Ugam, vicinity of the village. Khumsan, on the southern slopes of the hills, on various screees, basal areas of grasses, mollusks have a conical-cylindrical shell shape, thick-walled. 7 turns, well convex. The last whorl towards the mouth is raised very weakly. The height of the last whorl is 2 times less than the height of the shell. The color consists of a horny background and light radial streaks, developed to varying degrees. The sculpture consists of sharp, blunt, massive ribs. The aperture is slightly oblique, truncated-oval, the places of its attachment are connected by a well-developed callos, its edges are equipped with a wide lip and are moderately turned away (Fig. 1.B).
Fig. 1. Pseudonapeus albiplicatus. A, B-ug. Piyazdy-sai (Chatkal ridge).

In-from the vicinity of the village. Khumsana (on the left bank of the Ugam River); G-surroundings of the village. Hazratishah (Chartak district, Namangan region).

Mollusks living on the southern slopes of hills, the lower parts of semi-shrub plants, in the vicinity the village of Khazratishah (Chartak district, Namangan region) have the following differences from other populations: the shape of the shell is oval-conical, shiny; the color consists of a light brown background and light radial streaks developed to varying degrees; the places of attachment of the mouth are not connected; on the palatal wall there is a weak development of the tubercle, a tooth is visible, which is clearly visible when the shell is turned to the left (Figure 1 D).

In addition to the above mentioned quality characteristics, biotopic variability is well expressed in shell size (Table 1).

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>VR</th>
<th>DB</th>
<th>VU</th>
<th>HPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 biotope Piyazdy-sai gorge at altitude 1000 m above sea level, among subshubs (Chatkal ranges)</td>
<td>14.99±0.10 CV% 3.06</td>
<td>4.85±0.3 CV% 3.31</td>
<td>4.37±0.3 CV% 3.07</td>
<td>7.66±0.2 CV% 1.78</td>
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<tr>
<td>2</td>
<td>2 biotope On high 1600 m above sea level, among bushes, on the lower parts of grass thickets</td>
<td>9.92±0.10 CV% 4.83</td>
<td>3.99±0.7 CV% 8.40</td>
<td>3.42±0.4 CV% 5.75</td>
<td>6.39±0.3 CV% 2.58</td>
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</table>

Analysis biotopic variability of morphometric characters (Table 1) shows that shell height varies greatly among biotopes. In mollusks of the second biotope, the large diameter and height of the mouth turned out to be highly variable, the coefficient of variation of which is 8.40-5.75%, respectively. Of the morphometric characters in both biotopes, the coefficient of variation before the last whorl is low, ranging from 1.78-2.58%.

Pseudonapeus sogdianus. They are found in foothill and mountain zones, at an altitude of 1300-1800 m. They live among herbaceous and semi-shrub vegetation.

The shell is very variable like that of Ps. albiplicatus. For example, in mollusks that live in coarse rocky screes, on the northern slopes of the Urta-Chukki tracts (Nurata Range), the shape of the shell is oval-cylindrical, shiny, 6 whorls, convex, the last whorl is raised towards the mouth, its height is 1.5 times more than half the height shells. The color of the shell is horny (three embryonic whorls are light brown). Sculpture – embryonic whorls are
smooth, the rest with irregular radial wrinkles. The aperture is slightly beveled, the places of its attachment are close together and connected by a thin callus, the edges are strongly turned away (Figure 2, A).

![A](image1.png) ![B](image2.png) ![C](image3.png)

**Fig. 2.** Shell variability Psedonapaeus sogdianus: A-Urta-chukki tract, (Nurata Range); B, C - surroundings of the village. Vodul (Fergana region).

In the vicinity of the village. Vodul (Fergana region), on the southern and northern slopes, lower parts of subshrub stems and among subshrubs under stones, two forms of Ps live. sogdianus. The first, living on the southern slopes, has a large shell (Figure 2 B), with a conical-cylindrical shape, 7 whorls. Color: the upper 3 whorls are brown, the remaining whorls have radial streaks on a white background. The aperture is slightly slanted, the place of its attachment is moderately close but not connected. And mollusks living on the northern slopes have a small shell (Fig. 5. 2, B), thin-walled, with an elongated oval shape. There are 5 whorls, the color is light horny, the places of attachment of the aperture are not close together.

As can be seen from the translated data, variability is manifested in the shape, color, aperture structure, as well as in the size of the shell (Table 2).

Study of the variability of morphometric characteristics of the shell *P. sogdianus* different habitats (Table 2) shows that the height of the shell turned out to be more variable (the values of the coefficients of variation are in the range of 2.60-5.04%), the variability of other characteristics is low (about 2%).

**Table 2.** Biotopic variability of morphometric characters of the terrestrial mollusk Pseudonapaeus sogdianus.

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
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<th>DB</th>
<th>VU</th>
<th>HPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urta-chukki tract, (Nurata Range)</td>
<td>12.85±0.7</td>
<td>5.92±0.2</td>
<td>4.97±0.1</td>
<td>8.44±0.3</td>
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<td></td>
<td></td>
<td>CV% 2.60</td>
<td>CV% 2.16</td>
<td>CV% 1.47</td>
<td>CV% 1.85</td>
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<td>2</td>
<td>Neighborhood of Vodul village, southern slope of the hills (Fergana region)</td>
<td>16.29±0.14</td>
<td>5.96±0.27</td>
<td>5.36±0.3</td>
<td>8.87±0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CV% 2.74</td>
<td>CV% 0.43</td>
<td>CV% 0.56</td>
<td>CV% 0.71</td>
</tr>
<tr>
<td>3</td>
<td>Neighborhood of Vodul village, northern slope of the hills (Fergana region)</td>
<td>9.83±0.11</td>
<td>4.00±0.2</td>
<td>3.46±0.2</td>
<td>5.98±0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CV% 5.04</td>
<td>CV% 2.43</td>
<td>CV% 3.02</td>
<td>CV% 2.27</td>
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</tbody>
</table>
Pseudonapaeus secalina. The variability of conchological characters of this species is expressed in the color of the shell and the structure of the mouth fittings. The variability of conchological characters has been studied in the following populations. Karzhantau ridge, gorge. Azadbashsay, at an altitude of 2300–2500 m above sea level, on bushy slopes the mollusks have tower-shaped shells. Whorls 6, well convex, the last whorl towards the mouth is very slightly raised.

![Image](image1)

**Fig. 3.** Shell variations *Pseudonahaeus secalina* A – Azadbashsay gorge (Karzhantau Range); B – uzh. Dardar (Turkestan Range). In the vicinity of the village of Khumsan (Ugam Ranges).

The color of the upper 5 whorls is reddish-horny, and the last whorl is covered with light streaks. Sculpture in the form of radial striations. The edges of the mouth are not close together, slightly turned away and connected by a callus (Figure 3 A).

On the southern slopes of the Turkestan ridge, gorge. Dardar, at an altitude of 1500–1700 m above sea level, in coarse debris, shells of mollusks are shiny to varying degrees. Whorls 6, moderately convex. The color of the upper 3 whorls is dark brown, the rest with light radial streaks. The mouth is broadly oval, its edges are not close together and are connected by a very weak callus. There is a small tubercle on the parietal wall (Figure 3 B).

OnIn the Ugam ridge, on the northern outskirts of the village of Khumsan, on the left bank of the Ugam River valley, there are mollusks with a conical-cylindrical, non-shiny shell. Whorls 7, slightly convex, last whorl not raised towards the aperture. The color is white, in places with dark radial streaks. The aperture is almost round, the edges are close and connected to a rough callus, there is no tubercle on the parietal wall (Figure 3 B).

*Pseudonapaeus miser* lives in different types of biotopes, distributed in the mountainous zones of Central Asia. The variability of this species, like other species, is manifested in shell shape, color and size.

In the Tashkent region of the Bostanlyk district, in the floodplain of the Pskem River, under stones, mollusks have a conical-cylindrical shell. There are 6 whorls, moderately convex, separated by a deep suture, the last whorl towards the mouth is very slightly raised, its height is less than half the height of the shell. The aperture is oval, slightly beveled, the edges are well turned back (Figure 4 A).

In mollusks living west of Lake Iskandar-Kul, the right bank of the river valley. Kara-Kul (Fan Mountains), shell elongated-oval, 5 whorls, well convex. The last whorl towards the mouth is not raised, its height is slightly greater than the height of the shell. The color is light brown. Sculpture in the form of rare radial wrinkles. The mouth is wide - oval (Figure 4 B).
In mollusks living in the eastern Kazakhstan region (Ulba Range), the shell is short-oval, 5 whorls are slightly convex, and the color is dark brown. The sculpture consists of radial striations, the edges and mouths are well turned away (Figure 4 B).

Chondrulopsina fedtschenkoi. In this species, biotopic and population (geographic) variability of conchological characters is well expressed in the structure of the wellhead structure.

Biotopic variability of conchological characters of Ch. fedtschenkoi was studied in 3 biotopes on the northern slopes of the Alai Range in the vicinity of Shakhimardan.

1 biotope Left bank of the Koksu River, vicinity of the village. Shakhimardan, southern slopes of the hills, under small stones. Here the mollusks have almost tower-shaped, high, moderately hard-walled shells. 8 whorls, well convex, separated by a deep seam. The last whorl towards the mouth is vigorously raised, its height is almost half the height of the shell. The color is horny, the upper whorls (embryonic) are light brown. The aperture is oval, the place of its attachment is slightly closer, but connected to a thick callus. At the mouth there are three teeth, parietal, columellar (very poorly developed) and palatal (Figure 5 A).

2 biotope Right bank of the Koksu River, vicinity of the village. Shakhimardan, northern slopes of the hills among semi-shrub plants. Umollusks living in this biotope have the following differences, among mollusks of the first biotope: the shell is elongated-oval; shiny; translucent; 7 whorls, slightly convex; color light brown; the mouth is rounded-triangular, the place of its attachment is not close, widely spaced; at the mouth there are two teeth, parietal and palatal (Figure 5 B).
Fig. 5. Biotopic variability of the shell *Ch. fedtschenkoi*. A-1 biotope; B-2 biotope; B-3 biotope.

3 biotope Southern slopes of the hills, among thickets of grass. The mollusks living here have the following differences: chestnut color, upper whorls are usually darker than lower ones; the mouth is triangular; ostial teeth are absent; the edges of the mouth are sharp (Figure 5 B).

Population (geographic) variability *Ch. fedtschenkoi* The following populations have been studied, variability is expressed in shape, color and wellhead fittings.

Population 1. Northern slope Zarafshan ridge, gorge Kizilbosh, near the village. Kizilbash (Urgut district) at an altitude of 1400–1500 m above sea level, under stones, among semi-shrubs. Here you can find mollusks with a conical-cylindrical shell, hard-walled, large, the height of which is 9 mm. 7 whorls, well convex, separated by a fine seam. The color is light brown. The sculpture is in the form of thin radial striations. The aperture is triangular, the places of its attachment are spaced and connected by a very callus. The edges of the mouth are turned away and thickened with a blurred but powerful lip. At the mouth, the parietal and palatal teeth are well developed, and the collumellar one is poorly developed in the form of a barely noticeable swelling (Figure 6 A).

Population 2. Pass Takhtakaracha (Zarafshan Range) at altitude 1700 m above sea level, under stones, among shrubs. The mollusks living here differ from the first population below in the following: the shape of the shell is cylindrical; small, the height of which is 6.5-7 mm; chestnut color; all ostial teeth (parietal, collumellar and palatal) are very well developed (Figure 6 B).

Thus, after studying the variability of 5 common species, it was revealed that the variability of conchological characters is expressed in the shape and size of the shell, its color, surface sculpture and the degree of development of the elements of the wellhead fittings.
As noted A.A. Shileiko [1], specialization in size and shape of representatives of the family Buliminidae occurs in four main directions: 1- preservation of the archaic appearance with the appearance of various small adaptations; 2- increase in size (in height) and acquisition of a spindle-shaped or tower-shaped shell; 3- reduction in size with parallel acquisition of an oval shape; 4- decrease in the number of revolutions and the appearance of microhelicoid shells. This enumeration of specialization in size and shape is manifested in adaptation to specific habitats.

For example, at *P. albiplicatus* living in the Piyazdy-sai gorge (Chatkal range) at a height 1000 m above sea level, in less humid and arid conditions, the shell is large, the height of which is 14.99 ± 0.10 (mm). Whereas in mollusks living at altitude 1600 m above sea level, the shell is small, only 9.92 ± 0.10 (mm). *P. Sogdianus*, living on the southern slopes of the hills (surroundings of the village of Vodul, Fergana region), has a large shell compared to the northern slopes.

At *Ch. fedtschenkoi*, depending on the altitude of the area and the nature of the biotopes, the shell size ratio varies. For example, individuals live at an altitude of 1400–1500 m above sea level, the Kizilbosh gorge (Zarafshan Range) in comparison with the Takhtakaracha pass (Zarafshan Range), at an altitude 1700 m above sea level, larger sizes.

Many examples can be given confirming that the size of the shell varies depending on the specific conditions of the area.

Thus, the study shows that the drier the habitat conditions, the larger the shell.

As we know, large shells allow mollusks to accumulate large reserves of moisture, which give animals the opportunity to survive longer in an inactive state, which is essential for life in arid conditions.

An increase or decrease in shell size is apparently also associated with the living conditions and ecology of the mollusks. For example, at *P. sogdianus* living in 2 biotopes (the vicinity of the village of Vodul, Fergana region) located close to each other and having almost the same altitude and climatic conditions, they differ sharply in shell sizes. Those living on the southern slopes mollusks have a very large shell, the height of which is 16.29 ± 0.14 (mm), while in individuals living on the northern slopes, the shell is small - 9.83 ± 0.11 (mm).
Study showed that mollusks living on southern slopes (with large shells) remain on the soil surface during drought, sticking their mouths to the stems of bushes and stones. And the special ones that live on the northern slopes (small in size) are usually buried in the soil.

Apparently, mollusks that have minimal connection with the ground have large shells. And mollusks (burrowing species) that have a constant connection with the soil have a small shell.

In many cases, variability in the size of the shell entails changes in the overall shape of the shell, for example, swelling of the shellshell turnover. Swelling of whorls is associated with living in open places or with a gradual decrease in humidity.

The gradual development of shell swelling is observed in species Ps. sogdianus (Urta-Chukki tract, Nurata Ranges), P. maydanica (Darasay gorges, Kugitang ridge) These species live in drier biotopes on loose soils; when unfavorable conditions occur, they burrow into the ground.

As we know, when burrowing the main role is played by the leg, and it is natural that in burrowing species the leg is powerful and muscular. The increase in the last turnover in this case is precisely due to the need to place voluminous legs when retracting the animal.

Thus, species that actively burrow into the soil (at the onset of a dry period) formed a life form with a characteristic shell appearance: swellinglast turn.

As noted above, in the species studied, variability also manifests itself inshell color. Depending on the habitat, the color develops from light streaks, radial streaks on a dark background to completely white shells.

For example, in the Piyazdy-sai gorge (Chatkal range) among bushes, on the lower parts of grass thickets in P. albiplicatus, light radial streaks are developed to varying degrees. Whereas in the mollusks living in the same gorge in the open space, the light radial streaks are so strongly developed that we can most likely talk about a white shell.

4 Discussion

Another example, having an extensive range of Ps. sogdianus inhabiting a large set of biotopes, the color of the shell is very variable. In mollusks living in the vicinity of the village. Vodul (Fergana region), on the southern slopes of the hills, the upper 3 whorls of the shell are brown, the remaining whorls have white radial streaks. And mollusks living on the northern slopes have a light horny color.

The study showed that in mollusks living in open dry spaces, light radial streaks are highly developed on the shell.

Thus, the more solar energy in nature, the more populations with light-colored shells. Depending on the ecology, the most characteristic of the studied species is adaptivetype of surface sculpture - from fine striations to coarse wrinkles, and sometimes blunt massive ribs.

For example, at P. albiplicatus, living in the Piyazdy-sai gorge (Chatkal range), the sculpture consists of fine striations, and in mollusks living in the vicinity of the village of Khazratishah (Chartak district, Namangan region) it consists of coarse wrinkles, while in mollusks common in the vicinity of the village. Khumsan (on the left bank of the Ugam River) the sculpture consists of blunt massive ribs.

It should be noted that such a strong variability of sculpture led to the description of subspecies and even new species for science by a number of foreign researchers.

In this regard, first, we studied the intraspecific variability of P. albiplicatus using molecular genetic methods.

Using polymerase chain reaction (PCR) using primers, the 18S region of DNA was amplified, and the variability of P. albiplicatus from two populations was studied (1 population in the vicinity of the village of Khumsan, Tashkent region; 2 populations in the
vicinity of the village of Hazratshah, Namangan region) (Figure 7). The size of the amplifications was analyzed using gel electrophoresis in a 1.5% agarose gel.

The results obtained show that the nucleotide sequences of partial sections of 18S rDNA in the two populations of mollusks were identical.

And using molecular genetic methods, we studied the variability of P. albiplicatus and the variety of P. sogdiana.

When comparing the nucleotide sequences of these regions (18S region of DNA), differences in two nucleotide positions were found in these forms.

<table>
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</table>

Fig. 7. Comparison of nucleotide sequences P. albiplicatus from two populations and two forms of P. albiplicatus f. albiplicata and P. Albiplicatus f sogdiana (direction from 5’ to 3’ end, dots indicate nucleotide bases).

In percentage terms, the differences between the studied areas of these mollusks were 2.0%. When comparing sequence differences between P. albiplicatus and P. sogdiana, 2 nucleotide positions are marked, which are represented by the transition between pyrimidines (C+T) (Figure 7 at positions 382 and 400). It can be noted that, given the detected characteristics, the indicated species are clearly distinguished.
The data obtained show that these species differ from each other both at the morphological and genetic levels and are true species of both P. albiplicatus and P. sogdianus.

We also carried out phylogenetic analysis using the nearest neighbor method (Neighbor-joining, NJ) obtained on the basis of 18S sequences of two varieties of mollusks and their intraspecific forms (Figure 8). In the phylogenetic tree, two well-separated species ps.albiplicatus and ps. sogdianus.

Fig. 8. Phylogenetic tree depicting the sequence-derived 18S region of two Psendonapeus species based on our own research and the GenBank database (AY 145373).

5 Conclusion

Thus, mollusks living in arid conditions, adapting to sharp changes in temperature and humidity, acquire a number of additional features, such as: parietal callus, mouth lips and teeth, which play one or another role in reducing the loss of moisture from the body of mollusks.

Having studied variability conchological signs, we have identified a certain pattern. Consequently, all the signs of the shell arose in connection with general climate aridization, depending on the characteristics of the habitat.

The variability of shell color is directly related to the environmental factors in which they live:

- Light brown or light the horny color of the shell is characteristic of mollusks living on the southern slopes of more open areas of the southern slopes.
- A reddish-brown or dark brown shell is characteristic of biotopes with mesophytic and moisture-loving plant associations.
- Radially striped strokes, white streaks on a dark background are characteristic of species living among shrubs on open slopes.

The variability of the shell shape is in a certain way related to the surface of the substrate on which the animal is located:

- Populations of open rocky-gravelly slopes are characterized by a short-cylindrical shell.
- Shrub populations are characterized by a more slender shell.
- Populations of rocks and screes are characterized by a short or oval-cylindrical shell.

In the development of the surface sculpture and aperture structures of the shell, certain patterns associated with living conditions are also observed:

- Mollusks living on the southern slopes in fine and coarse talus, the sculpture consists of coarse radial rugosity.
- Mollusks living among bushes. the sculpture consists of rough radial striations.
- In mollusks living among thickets of grasses, the sculpture consists of thin radial striations.
- The drier and higher the temperature of the habitat, the better developed the mouth lip.
- Superficial teeth are characteristic of forms that are buried in the soil during the dry season.
- As aridization of conditions increases, a strengthening of the surface teeth is observed. This trend applies to forms that live openly and survive drought by sticking their mouths to the surface of the substrate.
- Depending on the altitude of the area and the nature of the biotopes, the shell size ratio varies:
  - As you move from north to south, in all cases there is a shift in shell size. This trend persists when comparing the malacofauna of the mountains of the north and south.
  - When comparing the size of mollusks living in the mountains with the plains, an increase in size is noted in some cases, and a decrease in size in others.

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