Biotopic variability of Myodes rutilus mandibula shape in the taiga-woodland zone of the south of Western Siberia

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Abstract The method of geometric morphometry was used to study the variability of the shape of the red vole’s (Myodes rutilus Pallas, 1779) mandibula in the taiga-woodland zone in the south of Western Siberia. A discrepancy in the morphospace of the mandibula shape of animals from the territory of three local biotopes was revealed. The red voles of the extrazonal floodplain biotope differ in both configuration and larger mandibula size in relation to the animals of the taiga and subtaiga subzones.

1. Introduction
A relatively new method of studying the morphological variability of biological objects is the method of geometric morphometry which allows analyzing the variability of the form of organisms and individual biological structures. One of the advantages of this method is the ability to visualize transformations of the objects’ shape that occur as a result of various environmental factors’ influence on it [1-4]. Visualization of morphological variability significantly assists in biological interpretation of research results. The addition of intra- and interpopulation comparisons to the possibility of analyzing the morphogenetic reactions of the objects of research and their groups to changes and the specifics of environmental conditions allows us to significantly expand the methodological potential of population ecology. Thus, geometric morphometry can be a very effective and versatile approach to solving problems of population ecology [5, 6].

The red vole (Myodes rutilus Pallas, 1779) was chosen as the object of the study. Possessing a wide range, covering the forest, forest-steppe, forest-tundra zones of Eurasia and the western part of North America [7], and forming many intraspecific forms, the red vole is one of the model types of evolutionary, genetic, morphological and ecological studies.

The aim of the study is to explore the variability of the shape of the red vole’s (Myodes rutilus Pallas, 1779) mandibula in the environment of taiga-woodland zone of southern Western Siberia based on the method of geometric morphometry.

2. Materials and Methods
The material was collected in three local biotopes of the taiga-woodland area of the West Siberian province [8].
Biotope 1 (N57.409359 degrees, E84.075854 degrees) – refers to the southern taiga subzone. It is represented by a flat rolling plain with low dissection. Vegetation is represented by dark coniferous and birch small grass, reed grass and sedge forests.

Biotope 2 (N56.808746 degrees, E87.273522 degrees) – is a subzone of subtaiga. Wavy hills with birch-aspen and pine-birch grass forests.

Biotope 3 (N56.409359 degrees, E84.075854 degrees) – is an extrazonal area, representing a bar plain with flat ground-in weakly drained areas.

The work is based on the analysis of the shape of the right and left sides of the mandibula of 60 mature (subadultus and adultus) specimens.

Animals’ capturing was carried out in summer (June-July) according to standard methods using Gero’ break-back trap [9].

Digital images of the mandibula (lingual side) were obtained using a Canon PowerShot A610 camera. On digitized images, the shape of the mandibula is contoured using the tpsUtil and tpsDig2 software [10, 11]. 11 landmarks are arranged: 1 – posterior dorsal edge of the alveoli of the mandibula incisor; 2 – anterior edge of the alveoli m1; 3 – intersection point of the projection of the edge of the crown m3 with the front edge of the base of the coronoid process; 4 – posterior edge of the alveoli m3; 5 – the deepest point of the coronoid articulation; 6 – anterior edge of the condyle of the articular process; 7 – posterior edge of the condyle of the articular process; 8 – the deepest point of articulate angular process; 9 – a point on the top of a convex curve formed by the body of the mandibula and the angular process; 10 – point on the lower edge of the symphazial tubercle; 11 – posterior ventral edge (Figure 1). The alignment of landmarks on the images of the right side of the mandibula was carried out after their mirror reversal. The position of the landmarks is determined by the following principle – the tags are as descriptive of the configuration of the mandibula as possible.

![Figure 1. Layout of landmarks (1-11) on the lingual side of the red vole mandibula (descriptions mentioned above in the text)](image)

To reduce the possible error, the alignment of the landmarks was carried out in triplicate; the calculations were carried out using the average value. The superposition procedure was performed by means of Procrustean analysis. The calculation of the centroid size (CS) was calculated as the square root of the sum of square distances from the center of the image to each landmark [12]. During the statistical processing canonical analysis of Procrustean coordinates describing the variability of the shape of the mandibula was used. For statistical analysis software packages PAST 2.17, Statistica Trial 13.3 were used.

3. Results and Discussion
A preliminary analysis of the shape of the mandibula of the studied groups of animals did not reveal statistically significant differences by gender, and therefore, during the subsequent analysis, the samples of males and females were combined.

Initially it was assumed that a more isolated group would be a sample of animals from the southern taiga subzone. The assumption was based on the fact that this biotope is located north of the other two. In addition, in contrast to the biotopes of the subtaiga and extrazonal areas, the southern taiga biotope is located on the left bank of the r. Ob, which can serve as a barrier.
The canonical analysis (MANOVA/CVA) of the mandibula configurations constructed using Procrustean coordinates revealed some differences (p < 0.01) in the shape of representatives of all the animal groups under study (Figure 2). The proportion of intergroup dispersion along the first canonical variable (CV1) was 60.0%. On this axis, the group of animals of extrazonal flood plain biotope is shifted towards negative values.

![Canonical variable 1 (CV1)](image)

**Figure 2.** The results of the canonical analysis of Procrustean coordinates characterizing the variability of the shape of the red vole mandibula from the territory of three biotopes in the taiga-woodland region of south of Western Siberia: 1. – southern taiga, 2. – sub-taiga, 3. – extrazonal floodplain. Spread ellipsoids combine 95% of the ordinates dispersion. The projections of the mandibula configurations on the deformation lattices demonstrate the most significant changes in its shape along the corresponding canonical axes.

Along with the analysis of the mandibula shape, the variability of the centroid sizes centroid (CS) was analyzed. The largest values of the centroid size (p < 0.05) are animals from the territory of the extrazonal flood plain biotope (Figure 3).

![Figure 3](image)

**Figure 3.** Comparison of centroid size (CS ± SECS) of the red vole mandibula from the territory of the three biotopes of the taiga-woodland region of the south of Western Siberia: 1. – South taiga, 2. – sub-taiga, 3. – extrazonal floodplain.

The method of cluster analysis of the shape of the mandibula revealed the separation of the analyzed animals into two groups. The first group included males and females from the extrazonal floodplain biotope, the second group included animals from the territories of the southern taiga and sub-taiga biotope (Figure 4).
Figure 4. The results of cluster analysis of red vole mandibula shape from the territory of the three biotopes of the taiga-woodland region of the south of Western Suberia: 1. – South taiga, 2. – subtaiga, 3. – extrazonal floodplain.

4. Conclusion
The analysis of the configurations of the red vole mandibula shape from the territory of the three biotopes of the taiga-woodland region of the West Siberian province revealed their divergence in morphospace, most pronounced in animals from the territory of the extrazonal floodplain biotope. The animals of the taiga and subtaiga biotopes are characterized by fewer differences. Red voles of the extrazonal floodplain biotope are distinguished by larger mandibula size relative to the animals of the taiga and subtaiga subzones. No differences in the mandibula shape and size of the animals of different sexes were identified.

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