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IDENTIFICATION OF SPECIES OF THE GENUS *SYLVAEMUS* OF NORTH-EASTERN UKRAINE BY METRIC CHARACTERS

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Abstract

The reliable identification of representatives of the genus *Sylvaemus* is complicated by the huge coincidence of external and metrical characters, as well as by the fact that in most of their range, mice are in conditions of sympatry or even syntopy Moreover, identification is complicated by opposite clinal variability in size and geographic variability in fur colouration. The species are also similar in karyotypes, so their reliable identification is usually possible only based on biochemical or molecular analysis. The craniological collection of small mammals of O. V. Zorya and collection specimens of the Museum of Nature of V. N. Karazin Kharkiv National University were studied. In total, 436 specimens of three species of the genus *Sylvaemus* were analysed: *Sylvaemus uralensis*, *Sylvaemus sylvaticus*, and *Sylvaemus tauricus*. Analysed were 14 odontometric and 23 craniological characters. Among the metric characters, three odontometrical—width of first upper molar (WM^1), length of second lower molar (LM_2), length of lower molar row (LM_{123})—and seven craniometrical characters—length of first upper molar (LM1), length of *foramen incisivum* (LFI), length of upper molar row (LUM), width of choana (WCH), height of skull including *bulla tympanica* (HBCB), length of lower molar row (LLM), length of mandible (LM)—made the greatest contribution to the differentiation of mice of the genus *Sylvaemus*. Width of first upper molar (WM^1), length of first lower molar (LM_1), length of second lower molar (LM_2), length of braincase (LBC), least interorbital constriction (LIOC), width of braincase (WBC), distance between incisor and M^3 (LIM3), length of upper molar row (LUM), condylobasal length of skull (CBL), palatal length (LPP), greatest length of skull (GLS), and length of lower molar row (LLM) are the least variable metric characters. Scatterplots linking LLM/CBL, LUM/CBL, and LUM/GLS appeared to be the most suitable for differentiating the specimens, with minimal overlap of species in the morphospace. In north-eastern Ukraine, the best distribution of mice of the genus *Sylvaemus* was obtained as a result of the analysis based on both odontometrical and craniological characters, when the correctness of the classification was 100%.

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Ідентифікація видів роду *Sylvaemus* північного сходу України за метричними ознаками

Оксана Марковська

Резюме. Надійна ідентифікація представників роду *Sylvaemus* ускладнена величезним збігом екстер'єрних та метричних ознак, а також тим, що на більшій частині свого ареалу, мишаки перебувають в умовах симпатрії або навіть синтопії. Більш того, ідентифікація ускладнена протилежною клинальною мінливістю розмірів та географічною мінливістю забарвлення хутра. Види також схожі за каріотипами, тому їх надійна ідентифікація зазвичай можлива тільки за допомогою біохімічного чи молекулярного аналізу. Досліджено краніологічну колекцію дрібних ссавців О. В. Зорі та колекційні зразки Музею природи Харківського національного університету В. Н. Каразіна. Проаналізовано 436 екземплярів трьох видів роду *Sylvaemus*: *Sylvaemus uralensis*, *Sylvaemus sylvaticus*, *Sylvaemus tauricus*. Для аналізу використано 14 одонтометричних та 23 краніологічні ознаки. Серед метричних ознак найбільший вклад в розподіл мишаків роду *Sylvaemus* вносили три одонтометричні ознаки—ширина першого верхнього моляру (WM^1), довжина другого нижнього моляру (LM_2), довжина нижнього молярного ряду (LM_{123}) та сім краніологічних ознак—довжина першого верхнього моляру (LM1), довжина піднебінного отвору (LFI), довжина верхнього молярного ряду (LUM), ширина хоан (WCH), висота черепної коробки, включаючи *bulla tympanica* (HBCB), довжина нижнього молярного ряду (LLM), довжина нижньої щелепи (LM). До найменш мінливих метричних ознак належать ширина першого верхнього моляру (WM^1), довжина першого нижнього моляру (LM_1), довжина другого нижнього моляру (LM_2), довжина черепної коробки (LBC), міжочноямкова ширина (LIOC), ширина мозкової коробки (WBC), довжина верхнього зубного ряду (LIM3), довжина верхнього молярного ряду (LUM), кондилобазальна довжина (CBL), довжина піднебіння (LPP), найбільша довжина черепу (GLS), довжина нижнього молярного ряду (LLM). Графіки розсіювання, які пов'язують LLM/CBL, LUM/CBL, LUM/GLS виявилися найбільш придатним для диференціації зразків, з мінімальним перекриванням видів у морфопросторі. В північно-східній Україні, найкращий розподіл мишаків роду *Sylvaemus* отримано в результаті аналізу відразу за одонтометричними та краніологічними ознаками, коректність класифікації склала 100%.

Ключові слова: *Sylvaemus*, географічна мінливість, одонтометрія, краніометрія.

Introduction

Despite the wide distribution and high abundance of the western Palearctic group of species of the genus *Sylvaemus*, the problem of species differentiation according to morphological criteria still remains unresolved [Michaux *et al.* 2005]. This is primarily due to diagnostic problems arising from the geographic variability and karyotypic uniformity of *Sylvaemus* [Zagorodniuk & Mezhzherin 1992]. The main zone of spatial interaction of species is the territory of Eastern Europe, mainly the interfluve of the Dnieper and Don rivers, as well as the Crimea and Ciscaucasia. The wood mice group has long been considered a taxon with very low levels of population divergence and extensive hybridisation between all known forms [Reutter *et al.* 1999]. Genetic studies have shown the presence of several discrete forms and provoked significant changes in the taxonomy of the genus. Currently, four species of *Sylvaemus* are distinguished in the fauna of Eastern Europe: *S. uralensis*, *S. sylvaticus*, *S. arianus*, and *S. tauricus* [Lashkova & Dzeverin 2002; Zagorodniuk 2005*a*].

The aim of this work is to analyse the variability of odontometrical and craniometrical characters of mice of the genus *Sylvaemus* from north-eastern Ukraine in order to develop reliable diagnostic methods.

Review of previous studies

The problem of identification of species of the genus *Sylvaemus* is often discussed in the taxonomy of mammals and is primarily related to the large overlap of taxonomic characteristics [Canady *et al.* 2014; Sozio *et al.* 2018]. Species of wood mice are phylogenetically and taxonomically close, their ecological characters are somewhat different, but still overlap, they are sympatric and even syntopic throughout most of their range, and their phenotypes are often so similar that it is very difficult to distinguish them in the field [Michaux *et al.* 2005; Ancillotto *et al.* 2017]. In addition, the lack of a reliable morphological approach led to frequent misidentification of specimens, causing further confusion and misinterpretation of their taxonomy and distribution [Jojic *et al.* 2014; Sozio *et al.* 2018].

Often due to the huge overlap in size and colouration in many areas of their sympatry, reliable identification is only possible with the help of molecular markers [Reutter *et al.* 1999; Barciova & Macholan 2006]. Allozyme data suggest that individual species of *Sylvaemus* are genetically well differentiated and retain their genetic identity throughout their geographic range [Frynta *et al.* 2006]. The species are also similar in karyotypes, so their reliable identification is usually possible only with the help of biochemical or molecular analysis [Bellinvia 2004; Barciova & Macholan 2009].

Sylvaemus sylvaticus and *Sylvaemus tauricus* have similar karyotypes with 48 acrocentric chromosomes and similar G-banding patterns. Nevertheless, differences in the amount and distribution of constitutive heterochromatin (C-band) were found. While in *S. tauricus* it is located exclusively in the centromeric region, in *S. sylvaticus*, in addition to a variable number of centromeric bands, several chromosomes have additional telomeric and/or interstitial bands. Thus, the Q/C-banding method is recommended as a reliable method for differentiating between these two species. Successful identification of *S. sylvaticus* and *S. tauricus* is also possible using protein electrophoresis [Zagorodniuk & Mezhzherin 1992; Colak *et al.* 2005], standard PCR with species-specific primers [Michaux *et al.* 2001], real-time PCR using *TaqMan* probes [Sozio *et al.* 2018], sequencing of the mitochondrial region of cytochrome *b*, multilocus DNA profiles and microsatellite analysis [Jojic *et al.* 2014].

There are often difficulties in identifying the skulls of mice of the genus *Sylvaemus* obtained from pellets of owls and other birds of prey. These difficulties increase with the identification of young individuals, which differ little morphologically [Haitlinger & Ruprecht 1967]. In addition, non-geographic and geographic variability of wood mice have become the subject of many studies [Demeter & Lazar 1984]. The authors have created many identification keys, although they emphasize their local efficiency and warn against extrapolating results to other parts of the geogrpahic range [Jojic *et al.* 2014].

Many authors point out that the problem of species identification of wood mice is more typical for the southern regions of Europe and Asia [Popov 1993; Frynta *et al.* 2006]. In particular, the similarity of *Sylvaemus sylvaticus* and *Sylvaemus tauricus* in terms of morphological and morphometrical characters has been reported in southern Italy [Panzironi *et al.* 1993], in France [Michaux *et al.* 1996], in Bulgaria [Popov 1993; Chassovnikarova & Markov 2007] and in Iran [Siahsarvie & Darvish 2008]. Reports from central Europe indicate that most adult wood mice can be identified there by the exterior, the shape of the skull and its individual structures [Ancillotto *et al.* 2017], but difficult to identify based on skull fragments commonly found in owl pellets [Demeter & Lazar 1984]. *S. sylvaticus* and *S. tauricus* can easily be identified in northern areas, but their morphological identification is complicated by the opposite clinal variation of body size from north to south, as well as other *Sylvaemus* species occurring in central, southern and south-eastern Europe [Barciova & Macholan 2009].

In southern Europe, *Sylvaemus sylvaticus* and *Sylvaemus tauricus* are characterised by opposite clinal size variability [Filippucci *et al.* 1989]. Moreover, in *S. tauricus*, there is a reduction of the collar to a chest spot, similar to *S. sylvaticus*. *S. tauricus* decreases to the south in body size and chest spot size, also expanding the ecological niche to the southeast. Whereas the body size of *S. sylvaticus* increases towards the south. The coincidence of body size and chest spot does not always allow to correctly identify the species, especially in those areas where these two species are in sympatry. Thus, there is a significant overlap in the size of the chest spot between *S. sylvaticus* and *S. tauricus* and this character cannot be used as an absolute diagnostic criterion [Popov 1993; Barciova & Macholan 2006].

Significant geographical variability of fur colouration was also revealed. The following fur characteristics are usually recorded in wood mice: back colour (usually brown or dark brown in *S. sylvaticus*, reddish-brown in *S. tauricus*), belly colour (greyish-white in *S. sylvaticus*, white in *S. tauricus*), the border between the dorsal and ventral parts of the body (not expressed in *S. sylvaticus*, expressed in *S. tauricus*), the presence and width of the chest spot (full or almost complete collar and wide spot in *S. tauricus*, elongated, reduced or completely absent spot in *S. sylvaticus*) [Filippucci *et al.* 1989]. In general, *S. tauricus* has a brighter and more contrasting colouration. However, it is worth noting that these differences are not absolute [Popov 1993].

With the help of three-colour calorimetry, the difference between the species was revealed by the brightness coefficient, that is, by the degree of lightness of the fur. However, this difference cannot be seen with the naked eye [Demeter & Lazar 1984].

Tail and hind foot length, as well as eye diameter, have traditionally been used in the field to identify sibling species of the genus *Sylvaemus*. The shorter tail and hind foot, as well as the small diameter of the eye of *Sylvaemus uralensis*, are considered to be related to the high burrowing activity of this species. Also, it was noted that the length of vibrissae is functionally related to the diameter of the studied space. Thus, underground species usually have short vibrissae, and those living in rocky terrain have long ones. The vibrissae of some species were examined and found to increase in length in the following order: *Apodemus agrarius*, *S. uralensis*, *S. sylvaticus*, *S. tauricus*, and *Apodemus mystacinus* [Kuncova & Frynta 2009].

In a similar way, sibling species can be distinguished in central and northern Europe by morphological characters and ecological parameters: *S. tauricus*—large size, with yellow-red solid colour and a wide spot on the chest, inhabits exclusively coniferous and broad-leaved forests; *S. sylvaticus*—smaller in size, with an elongated chest spot that never forms a collar, eurytopic [Popov 1993]. One of the exterior indicators—the length of the hind foot—is of the utmost importance for the differentiation of wood mice, and of the craniometrical characters, it is first of all the length of the upper and lower rows of molar teeth and the length of auditory bullae [Lashkova 2003]. Usually, in *S. sylvaticus*, the length of the head and body is greater than the length of the tail, and in *S. tauricus*, on the contrary, it is shorter [Filippucci *et al.* 1989].

At the same time, Lashkova *et al.* [2005] proposed the use of classification functions and discriminant analysis for species diagnosis, which requires accounting for a large number of variable quantitative or discrete traits. Thus, the results of the discriminant analysis of the differences between adult mice showed that it is more convenient to use three external characters for building classification functions: tail length, foot length and ear length. 93% of adults can be identified by the combination of these characters.

Other researchers proposed to identify species by the number of tail vertebrae, because this character is stable throughout the life of individuals and, unlike tail length, does not depend on measurement error [Stepankova & Vohralik 2008]. The number of vertebrae increases in the order *S. uralensis*, *S. sylvaticus*, and *S. tauricus*. However, a significant coincidence in the number of tail vertebrae does not allow reliable identification of species [Steiner 1968; Niethammer 1969; Filippucci *et al.* 1996]. Previously, relative tail length, expressed as the ratio of the sum of head and body length to tail length, was also used for identification [Heinrich 1951]. However, this relation is often affected by various circumstances, such as rigor mortis and spine injury. Therefore, some zoologists tried to express the length of the tail using the number of skin rings on the surface of the tail [Wedemeyer 1936; Heinrich 1951] and, as it turned out, this character has a large intraspecific variability and is not suitable for reliable species identification.

A bioacoustic approach that does not require killing the animals and classifies the animals based on the alarm signals they produce when they are handled has also been developed to identify the sibling species of the genus *Sylvaemus* [Ancillotto *et al.* 2017].

A morphological approach is usually insufficient for species identification, since morphological intraspecific variability can hide real patterns of variability. However, when using multidimensional craniometric methods, the samples can be successfully distinguished in most cases. These methods require a control group—a sufficient number of individuals that are previously determined by both molecular and morphometric methods. Without a control group, unknown samples cannot be determined using these methods. Moreover, the ranges of specific measurements show more or less overlap, and no single character can be a diagnostic criterion on its own. Also, there are always specimens that can be considered intermediate between species [Bugarski-Stanojevic *et al.* 2012].

Of cranial measurements, condylobasal length of skull (CBL) and length of upper molar row (LUM) [Demeter & Lazar 1984] have the greatest influence on the distribution of species of the genus *Sylvaemus* and belong to the least variable characters [Canady & Mosansky 2015]. Length of diastema (LD) and length of *bulla tympanica* (LBUL) were also most significant for species differentiation in Switzerland, Austria, Italy, France, and Germany [Reutter *et al.* 1999]. Although Steiner & Raczyski [1976] did not include the length of *bulla tympanica* in the analysis due to the inaccuracy of measuring this cranial character.

Other important measurements that influence the distribution of specimens include greatest length of skull (GLS), length of *foramen incisivum* (LFI), width of braincase (WBC), least interorbital constriction (LIOC), depth of incisor (DI) (in samples from Hungary) [Demeter & Lazar 1984], height of rostrum (HR), width of rostrum (WR), distance between incisor and M^3 (LIM3), length of lower molar row (LLM) (in samples from Slovakia) [Canady *et al.* 2014], length of first upper molar (LM1), length of mandible (LM), height of skull including *bulla tympanica* (HBCB) (in samples from Slovakia) [Canady & Mosansky 2015], length of braincase (LBC), length of rostral part (LF), palatal length (LPP), length of condyle (LCP), length of nasals (LN) (in samples from Switzerland, Austria, Italy, France, and Germany) [Reutter *et al.* 1999], width of choana (WCH), width between *bulla tympanica* (WBB) (in samples from eastern Turkey and Iran) [Frynta *et al.* 2001].

The dependence of length of hind foot on the length of upper molar row, the thickness of incisor on length of *foramen incisivum* is also used to differentiate species (in samples from southern Italy) [Gemmeke & Niethammer 1980]. The dependences of depth of incisor on length of upper molar row, width of first upper molar on length of upper molar row, length of diastema on length of *foramen incisivum* were used in studies of wood mice remains from owl pellets (in samples from Hungary) [Demeter & Lazar 1984].

Other potentially useful scatterplots relating length of upper molar row to greatest length of skull [Amtmann 1965], length of upper molar row and length of *bulla tympanica* [Filippucci *et al.* 1996], length of upper molar row and condylobasal length of skull [Storch & Lutt 1989], thickness of incisor and condylobasal length of skull, length of *foramen incisivum* and distance between incisor and M^3 [Gemmeke & Niethammer 1980], length of upper molar row and length of lower molar row [Panzironi *et al.* 1993], length of *bulla tympanica* and condylobasal length of skull [Mezhzherin & Lashkova 1992], as well as indices such as [thickness of incisor + length of upper molar row] versus length of diastema [Storch & Lutt 1989] or [length of upper molar row × width of third molar], versus [condylobasal length of skull × width of zygomatic bone] [Steiner 1968] have been proposed based on the study of samples from various parts of the genus's geographic range. A scatterplot relating length of upper molar row to length of *bulla tympanica* was the most suitable for differentiating the specimens, but there was still overlap between species [Barciova & Macholan 2009].

Using the correlation between length of *foramen incisivum* and condylobasal length of skull, Niethammer [1969] and Storch & Lutt [1989] found that in all European populations the *foramen incisivum* is longer in *S. sylvaticus* than in *S. tauricus*. Tvrtkovic [1976] and Krystufek & Stojanovski [1996] used two-dimensional plots of the distance from the incisor to third upper molar as a function of length of *foramen incisivum* to differentiate these two sibling species in different European and south-western Balkan populations. Barciova & Macholan [2009] proposed an identification key that differentiates *S. sylvaticus* and *S. tauricus* with an accuracy of 98.3%. This identification key includes three cranial measurements—length of lower molar row, condylobasal length of skull, and length of *bulla tympanica* [Jojic *et al.* 2014]. Demeter & Lazar [1984] concluded that it is sufficient to examine and measure only the lower mandible to identify specimens, but emphasized that this is sufficient only for mice of the Carpathian Basin, because the characters are subject to geographic variability. Amori & Contoli [1994] note that the morphometric diversity in *S. tauricus* was greater than in the *S. sylvaticus* population and increased in the order: allopatric < partially allopatric < sympatric.

On the other hand, Filippucci *et al.* [1984] proposed a morphometric index (MI) for the identification of *S. sylvaticus* and *S. tauricus*: MI = (LUM + LPP + LIOC) – LFI (length of upper molar row (LUM), palatal length (LPP), least interorbital constriction (LIOC), length of *foramen incisivum* (LFI)). Values lower than 6.9 are common for *S. sylvaticus*, values higher than 8.0 are characteristic of *S. tauricus* [Filippucci *et al.* 1989].

Using landmark-based geometric morphometry, some differences in the shape of the lower mandible between *S. sylvaticus* and *S. tauricus* were revealed at border between the body of the lower mandible and the upper part of the ascending branch [Barciova & Macholan 2009]. The ventral skulls of *S. tauricus*, in contrast to *S. sylvaticus*, are somewhat narrower in the temporal region, with a shorter *foramen incisivum* and a narrower *foramen magnum*. In addition, the posterior foramen palatine and foramen ovale are located anteriorly in *S. tauricus* and posteriorly in *S. sylvaticus* [Jojic *et al.* 2014]. Additionally, *S. sylvaticus* has a longer incisive foramen, wider foramen magnum and larger *os parietale* and *os interparietale* than *S. tauricus* [Barciova & Macholan 2006].

In addition to cranial measurements, many researchers have studied the differentiation of wood mice species exclusively by dental measurements. Most often, length of molar row and distance between incisor and M^3 were significant. Some studies concerned the classification of species by molar tubercles and crests. The difference was found in the morphology of the tubercles on the molars: *t9* on the second upper molar (usually present in *S. sylvaticus* and absent in *S. tauricus*), *t4* and *t7* on the first upper molar (usually fused in *S. sylvaticus* and separated in *S. tauricus*) [Filippucci *et al.* 1989]. Storch & Lutt [1989] note that the average length of M^3 of *S. sylvaticus* is relatively shorter than that of *S. tauricus*.

Traditionally, molar morphometry is limited to measuring the length and width of molars, sometimes their height [Lashkova & Dzeverin 2002; Janzekovic & Krystufek 2004], in particular, length of upper molar row, length of first upper molar, length of first lower molar, width of first lower molar [Frynta *et al.* 2001], thickness of upper incisor [Haitlinger & Ruprecht 1967], distance between incisor and M^3 [Demeter & Lazar 1984], and length of lower molar row [Barciova & Macholan 2009] turned out to be significant for the distribution of species. It should be noted that the state of these measurements is not significantly affected by molar wear [Knitlova & Horacek 2017].

In order to reveal the geographical variability of characters, which does not depend on the size of the specimen, it is necessary to take into account the sex and age of the individuals [Sara & Casamento 1995]. Also, to avoid unwanted deviations due to potential asymmetry, it is necessary to measure the same side of each specimen [Canady *et al.* 2014].

For craniometrical and odontometrical analysis, individuals are usually selected from the age of five months, when they can be considered adults [Kuncova & Frynta 2009]. Jojic *et al.* [2011] included in the analysis all individuals with complete eruption of the third upper molar, because the most intensive growth occurs during the first four weeks after birth and then gradually slows down [Niethammer 1969]. In their research, Barciova & Macholan [2009] also excluded individuals without well-developed third upper molars from the morphometric analysis.

Materials and Methods

The craniological collection of small mammals of O. V. Zorya, collected in the territory of Kharkiv Oblast, Ukraine, which is deposited at the Department of Zoology and Animal Ecology of V. N. Karazin Kharkiv National University, was studied. In total, 272 specimens of three species of the genus *Sylvaemus* were selected: pygmy wood mouse (*Sylvaemus uralensis* Pallas, 1811), European wood mouse (*Sylvaemus sylvaticus* Linnaeus, 1758), and yellow-necked wood mouse (*Sylvaemus tauricus* Pallas, 1811). Only 198 specimens were suitable for odontometric analysis: *Sylvaemus uralensis*—123, *Sylvaemus sylvaticus*—68, and *Sylvaemus tauricus*—7. In total, 120 intact skulls were selected for craniological analysis: *Sylvaemus uralensis*—74, *Sylvaemus sylvaticus*—42, and *Sylvaemus tauricus*—4.

The collection was collected in 7 districts (raions) and 52 settlements of Kharkiv Oblast, Ukraine (Table 1). The specimens are dated to the periods of 1989–1996 and 1999–2012. A considerable number of specimens are dated to 1990, 2004, 2008, and 2011.

The collection of small mammals of the Museum of Nature of V. N. Karazin Kharkiv National University was also studied. In total, 238 specimens were selected for craniological analysis: *Sylvaemus uralensis*—37, *Sylvaemus sylvaticus*—109, *Sylvaemus tauricus*—92. The specimens were collected in 8 regions and 22 settlements (Table 2). The specimens are dated to 1932, 1935–1938, 1945, 1947, 1949–1959, and 1967–1968. A significant number of specimens are dated to 1936, 1952, 1957, and 1958.

The age of the selected specimens was determined using binoculars according to the method of Adamczewska-Andrzejewska [1967], which is based on the degree of molar wear. The degree of wear was determined on the left upper row of molars. It should be mentioned that the degree of wear of the occlusal surface was found to be different between the left and right upper rows of molars. Usually, the degree of wear on the right upper row is an order of magnitude lower than on the left. That is why the left upper row of molar teeth was chosen for analysis. All individuals with complete eruption of third upper molar (II, III, and IV age classes) were selected for further analysis (Table 3).

For further measurements of odontometrical characters in the collection specimens, photos of tooth rows were taken using electronic binoculars. Measurements were made in the Toup View program. The left lower and upper rows of molars were selected for taking measurements. Odontometrical characters were measured according to Lashkova & Dzeverin [2002].

Table 1. The number of specimens of mice of the genus *Sylvaemus* collected in the territory of Kharkiv Oblast from different areas

Таблиця 1. Кількість екземплярів мишаків роду *Sylvaemus*, зібраних на території Харківської області з різних місцезнаходжень*

Species/District	Kp	Kr	Khr	Bh	Iz	Chh	Lz	Total
Sylvaemus uralensis	23	58	11	18	22	37	3	172
Sylvaemus sylvaticus	1	7	24	23	23	11	1	90
Sylvaemus tauricus	0	2	0	2	0	4	2	10
Total	24	67	35	43	45	52	6	272

* *Bohodukhiv* (Bh): Volodymyrivka, Dovzhik, Kobzarivka, Kolomak, Moyka, Oleksandrivka, Oleksiyivka, Pokrovka, Stepanivka, Tetyushchine, Fesky, Sharivka; *Izium* (Iz): Andriivka, Barvinkove, Donets, Kapytolivka, Oskil, Pidlyman, Snizhkivka, Topolske; *Krasnohrad* (Kr): Vlasivka, Druzhba, Zarichne, Zachepylivka, Novopavlivka, Natalyne, Khrestyshche; *Kupiansk* (Kp): Arkadivka, Dvorichna, Kamianka, Shyshkivka; *Lozova* (Lz): Bratolyubivka, Bulatselivka, Yakovivka; *Kharkiv* (Khr): Bezlyudivka, Bobrivka, Nove, Pytomnyk, Podvirky, Prosyane, Ruska Lozova, Stara Vodolaga, Cherkaski Tyshky, Kharkiv; *Chuhuiv* (Chh): Vvedenka, Verkhniy Saltiv, Gaidary, Gontarivka, Zamulivka, Martove, Staryy Saltiv, Khotimlya.

Table 2. The number of specimens of mice of the genus *Sylvaemus* from the collection of small mammals of the Museum of Nature from different areas

Таблиця 2. Кількість екземплярів мишаків роду *Sylvaemus* з колекції дрібних ссавців Музею природи з різних місцезнаходжень*

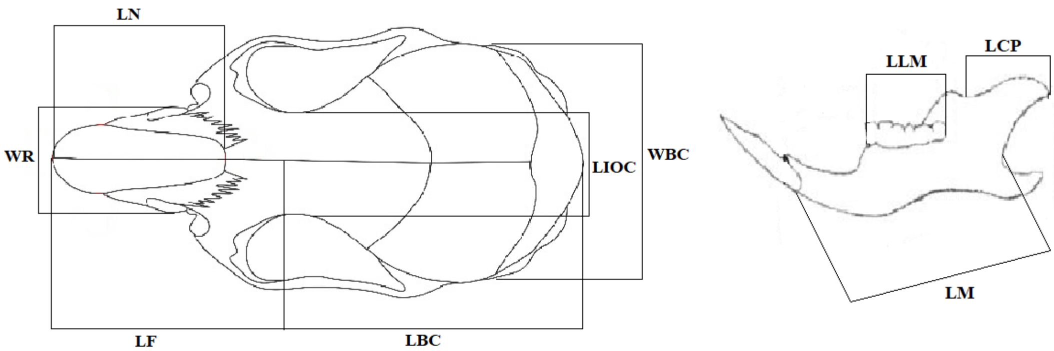
Species/Oblast	ARCr	Dts	Zp	Lh	Od	Sm	Khr	Khs	Total
Sylvaemus uralensis	–	7	14	2	–	–	14	–	37
Sylvaemus sylvaticus	–	10	46	2	13	–	37	1	109
Sylvaemus tauricus	14	–	–	3	1	1	73	–	92
Total	14	17	60	7	14	1	124	1	238

* *Autonomous Republic of Crimea* (ARCr): Alushta, Dzhankoi, Novostepove, Yalta; *Donetsk* (Dts): Volnovakha, Mariupol; *Zaporizka* (Zp): Berdiansk, Voznesenka, Melitopol, Novopylypivka, Tykhonivka; *Luhansk* (Lh): Dovzhansk, Svatove; *Odesa* (Od): Volodymyrivka; *Sumy* (Sm): Lebedyn; *Kharkiv* (Khr): Gaidary, Huty, Pechenihy, Staryy Saltiv, Cherkas′ka Lozova, Kharkiv; *Kherson* (Khs): Partyzany.

Table 3. Age groups of collection specimens of *Sylvaemus* determined by the degree of molar wear

Таблиця 3. Вікові групи колекційних зразків *Sylvaemus*, визначені за ступенем стирання кутніх зубів

Species/Age group	II	III	IV	Total
Sylvaemus uralensis	0	17	106	123
Sylvaemus sylvaticus	5	17	46	68
Sylvaemus tauricus	1	2	4	7
Total	6	36	156	198



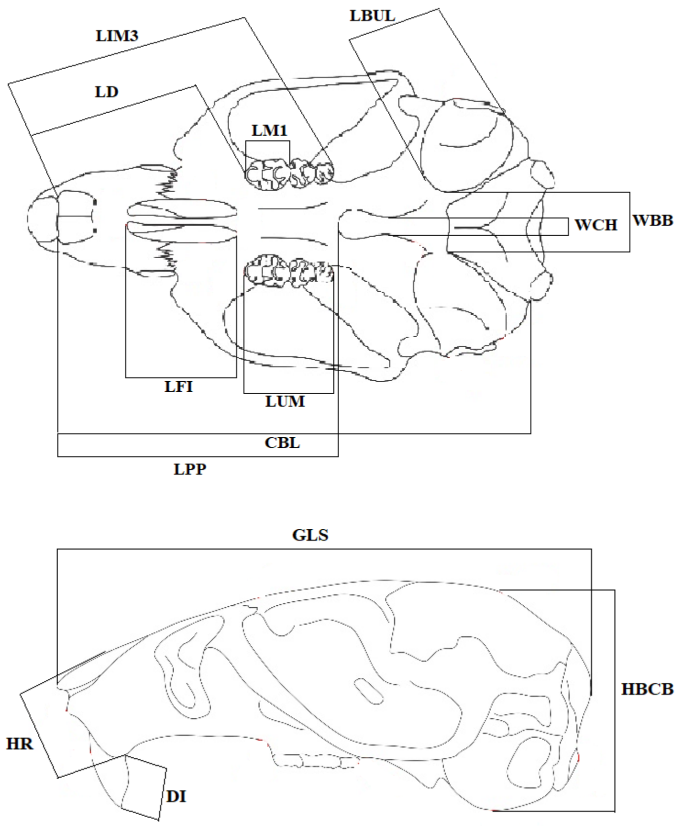


Fig. 1. Craniometrical characters analysed: LN, length of nasals; WR, width of rostrum; LF, length of rostral part; LBC, length of braincase; LIOC, least interorbital constriction; WBC, width of braincase; LIM3, distance between incisor and M^3; LD, length of diastema; LM1, length of first upper molar; LBUL, length of *bulla tympanica*; LFI, length of *foramen incisivum*; LUM, length of upper molar row; CBL, condylobasal length of skull; LPP, palatal length; WCH, width of choana; WBB, width between *bulla tympanica*; GLS, greatest length of skull; HBCB, height of skull including *bulla tympanica*; HR, height of rostrum; DI, depth of incisor; LLM, length of lower molar row; LCP, length of condyle; LM, length of mandible. Scheme of measurements after Barkaszi [2019] with modifications.

Рис. 1. Ознаки для краніометричного аналізу: LN, довжина носових кісток; WR, ширина рострому; LF, довжина лицьового відділу; LBC, довжина черепної коробки; LIOC, міжочноямкова ширина; WBC, ширина мозкової коробки; LIM3, довжина верхнього зубного ряду; LD, довжина діастеми; LM1, довжина першого верхнього моляру; LBUL, довжина *bulla tympanica*; LFI, довжина піднебінного отвору; LUM, довжина верхнього молярного ряду; CBL, кондилобазальна довжина; LPP, довжина піднебіння; WCH, ширина хоан; WBB, ширина між *bulla tympanica*; GLS, найбільша довжина черепу; HBCB, висота черепної коробки, включаючи *bulla tympanica*; HR, висота роструму; DI, глибина різця; LLM, довжина нижнього молярного ряду; LCP, довжина виростку; LM, довжина нижньої щелепи. Схема промірів за Barkaszi [2019] зі змінами.

Thus, the following odontometrical measurements were taken for analysis: LM^1, LM^2, and LM^3—length of first, second, and third upper molars; WM^1, WM^2, and WM^3—width of first, second, and third upper molars; LM^{123}—length of upper molar row; LM_1, LM_2, and LM_3—length of first, second, and third lower molars; WM_1, WM_2, and WM_3—width of first, second, and third lower molars; LM_{123}—length of lower molar row. The largest width and length of the molars were measured. For collection specimens from the Museum of Nature, age determination by the degree of molar wear and odontometric analysis were not performed.

Based on literature data, 23 characters were selected for craniometrical analysis (Fig. 1). Cranial characters were measured using an electronic calliper (0.01 mm). Discriminant and canonical analyses were used for data analysis.

Results

Usually, a number of exterior and metric characters are used to determine the species of mice of the genus *Sylvaemus* in the field. To clarify the identification, a number of analyses are carried out, which are based on measurements of craniological and odontometric characters.

Differentiation of species by odontometrical characters

The distribution of mice of the genus *Sylvaemus* according to odontometrical characters (Fig. 2) does not have a clear character, the morphospaces of the species overlap. The correctness of the classification of specimens according to the odontometrical characters selected in the analysis is 98%. All odontometrical characters contribute almost equally to the distribution, but width of first upper molar (WM^1), length of second lower molar (LM_2), and length of lower molar row (LM_{123}) make the largest contribution (Table 4). The ranges of variability of absolute values of odontometrical characters of different species also overlap (Table 5).

The least variable odontometrical characters were width of first upper molar (WM^1), length of upper molar row (LM^{123}), length of first lower molar (LM_1), length of second lower molar (LM_2) and length of lower molar row (LM_{123}). According to the χ^2 criterion, no statistically significant difference was found between the variability of the absolute values of odontometrical characters compared to the same values in Lashkova & Dzeverin [2002].

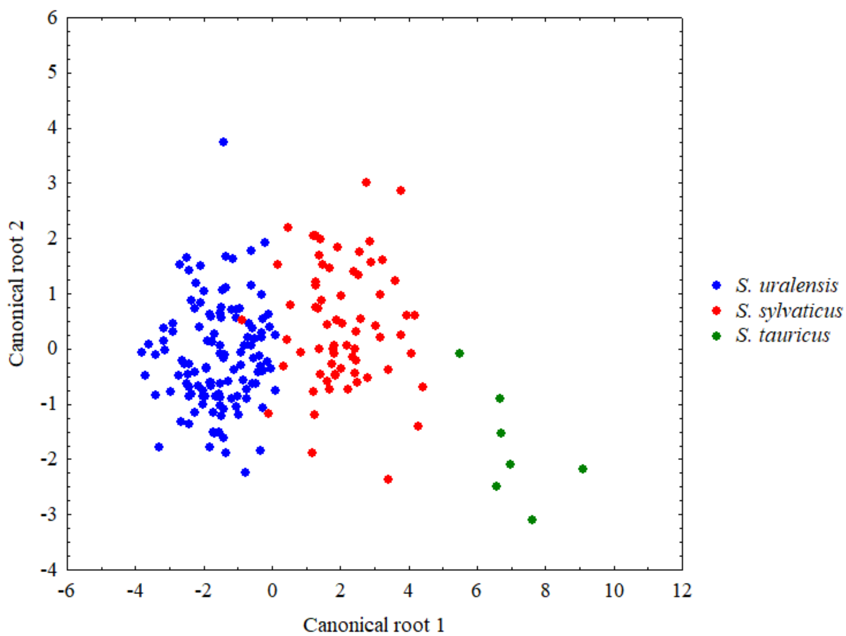


Fig. 2. Distribution of wood mice of the genus *Sylvaemus* based on odontometrical characters in the space of the first two canonical roots.

Рис. 2. Розподіл мишаків роду *Sylvaemus* за одонтометричними ознаками у просторі значень першої і другої канонічних змінних.

Table 4. Values of Wilks' lambda and factor loadings of odontometrical characters on the canonical variables

Таблиця 4. Значення лямбди Уілкса та факторні навантаження одонтометричних ознак на канонічні змінні

Character	Wilks' Lambda	Root 1	Root 2
Length of first upper molar (LM^1)	0.146	**0.612**	-0.066
Length of second upper molar (LM^2)	0.150	0.321	-0.343
Length of third upper molar (LM^3)	0.148	0.234	-0.294
Width of first upper molar (WM^1)	**0.156**	0.575	0.368
Width of second upper molar (WM^2)	0.149	0.458	-0.112
Width of third upper molar (WM^3)	0.147	0.359	-0.301
Length of upper molar row (LM^{123})	0.148	**0.696**	-0.163
Length of first lower molar (LM_1)	0.147	**0.716**	0.059
Length of second lower molar (LM_2)	**0.151**	**0.645**	-0.301
Length of third lower molar (LM_3)	0.148	0.487	-0.234
Width of first lower molar (WM_1)	0.146	0.435	0.204
Width of second lower molar (WM_2)	0.147	0.524	0.286
Width of third lower molar (WM_3)	0.148	0.433	0.108
Length of lower molar row (LM_{123})	**0.151**	**0.889**	-0.054

Table 5. Variability of absolute values of odontometrical characters of mice of the genus *Sylvaemus* (min–max, ave, c.v.)

Таблиця 5. Мінливість абсолютних значень одонтометричних ознак мишаків роду *Sylvaemus* (min–max, ave, c.v.)

Character	*S. uralensis*	*S. sylvaticus*	*S. tauricus*
Length of first upper molar (LM^1)	1.26–1.81 1.62 (6.12%)	1.52–2.06 1.83 (5.28%)	2.07–2.23 2.14 (2.98%)
Length of second upper molar (LM^2)	0.88–1.26 1.10 (6.89%)	1.01–1.40 1.18 (6.83%)	1.04–1.48 1.37 (11.13%)
Length of third upper molar (LM^3)	0.67–1.03 0.84 (7.96%)	0.63–1.06 0.88 (8.88%)	0.94–1.07 1.01 (4.12%)
Width of first upper molar (WM^1)	0.70–0.96 0.86 (4.76%)	0.84–1.06 0.96 (4.69%)	1.00–1.07 1.04 (2.44%)
Width of second upper molar (WM^2)	0.63–0.91 0.81 (5.57%)	0.73–0.98 0.88 (5.34%)	0.93–1.04 0.99 (3.71%)
Width of third upper molar (WM^3)	0.45–0.71 0.59 (8.18%)	0.52–0.78 0.64 (7.25%)	0.68–0.83 0.76 (6.62%)
Length of upper molar row (LM^{123})	2.93–3.70 3.36 (4.68%)	3.23–4.09 3.74 (4.21%)	4.03–4.47 4.33 (3.36%)
Length of first lower molar (LM_1)	1.42–1.72 1.58 (4.20%)	1.54–1.92 1.77 (4.43%)	1.95–2.20 2.01 (4.18%)
Length of second lower molar (LM_2)	0.90–1.19 1.07 (4.45%)	1.02–1.29 1.18 (4.51%)	1.33–1.45 1.37 (3.07%)
Length of third lower molar (LM_3)	0.79–1.05 0.88 (5.96%)	0.83–1.09 0.97 (5.59%)	1.02–1.21 1.13 (6.13%)
Width of first lower molar (WM_1)	0.70–0.89 0.76 (4.57%)	0.70–1.01 0.83 (5.67%)	0.81–0.96 0.90 (5.28%)
Width of second lower molar (WM_2)	0.69–0.88 0.76 (4.89%)	0.70–0.93 0.85 (5.38%)	0.87–0.97 0.92 (3.30%)
Width of third lower molar (WM_3)	0.56–0.79 0.64 (6.70%)	0.59–0.82 0.71 (7.21%)	0.71–0.86 0.80 (5.83%)
Length of lower molar row (LM_{123})	3.14–3.69 3.46 (3.25%)	3.50–4.13 3.85 (3.55%)	4.18–4.72 4.41 (3.83%)

Identification of species by craniological characters

For craniometrical analysis, specimens from the collection of O. V. Zorya and specimens from the Museum of Nature, which were collected in the territory of Kharkiv Oblast, were combined. In total, 244 intact skulls were selected: *Sylvaemus uralensis*—88, *Sylvaemus sylvaticus*—79, *Sylvaemus tauricus*—77. The morphospaces of the samples, according to the distribution by craniological characters, overlap (Fig. 3), especially in the *uralensis*—*sylvaticus* pair. The correctness of the classification of specimens according to the craniological characters selected in the analysis is 93%. All craniological characters contribute almost equally to the distribution, but the largest contribution is made by length of first upper molar (LM1), length of *foramen incisivum* (LFI), length of upper molar row (LUM), width of choana (WCH), height of skull including *bulla tympanica* (HBCB), length of lower molar row (LLM), and length of mandible (LM) (Table 6).

The variability of absolute values of craniological characters was calculated for each species (Table 7). The least variable of the craniological characters were length of braincase (LBC), least interorbital constriction (LIOC), width of braincase (WBC), distance between incisor and M^3 (LIM3), length of upper molar row (LUM), condylobasal length of skull (CBL), palatal length (LPP), greatest length of skull (GLS), and length of lower molar row (LLM).

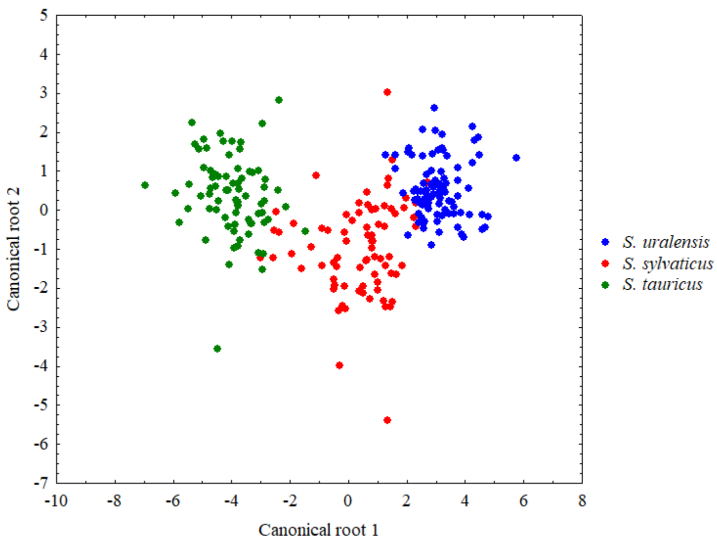


Fig. 3. Distribution of wood mice of the genus *Sylvaemus* based on all selected craniometrical characters in the space of the first two canonical roots.

Рис. 3. Розподіл мишаків роду *Sylvaemus* за всіма обраними краніологічними ознаками у просторі значень першої і другої канонічних змінних.

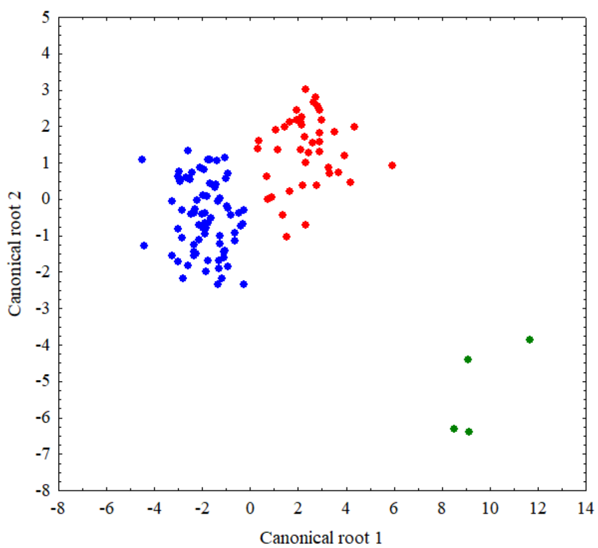


Fig. 4. Distribution of wood mice of the genus *Sylvaemus* based on odontometrical and craniometrical characters in the space of the first two canonical roots.

Рис. 4. Розподіл мишаків роду *Sylvaemus* за одонтометричними та краніологічними ознаками у просторі значень першої і другої канонічних змінних.

For specimens from the craniological collection of small mammals of O. V. Zorya, analysis was carried out according to both odontometrical and craniological characters. In total, 120 intact skulls were selected: *Sylvaemus uralensis*—74, *Sylvaemus sylvaticus*—42, *Sylvaemus tauricus*—4. The clearest distribution of species ranges was obtained, no overlap between species was observed (Fig. 4). The correctness of the classification of specimens according to the odontometrical and craniological characters selected in the analysis is 100%. The characters that make the greatest contribution to the distribution were length of *foramen incisivum* (LFI), width of choana (WCH), and length of mandible (LM) (Table 8).

Potentially useful scatterplots that can be used to differentiate specimens were also tested—dependence of depth of incisor (DI) on length of upper molar row (LUM), length of diastema (LD) on length of *foramen incisivum* (LFI) [Demeter & Lazar 1984], length of upper molar row (LUM) on greatest length of skull (GLS) [Amtmann 1965], length of upper molar row (LUM) on length of *bulla tympanica* (LBUL)[Filippucci *et al.* 1996], length of upper molar row (LUM) on condylobasal length of skull (CBL) [Storch & Lutt 1989], length of *foramen incisivum* (LFI) on distance between incisor and M^3 (LIM3) [Gemmeke & Niethammer 1980], length of upper molar row (LUM) on length of lower molar row (LLM) [Panzironi *et al.* 1993], length of *bulla tympanica* (LBUL) on condylobasal length of skull (CBL) [Mezhzherin & Lashkova 1992], length of *foramen incisivum* (LFI) on condylobasal length of skull (CBL) [Niethammer 1969], length of lower molar row (LLM) on condylobasal length of skull (CBL) [Barciova & Macholan 2009], length of upper molar row (LUM) on width of braincase (WBC), length of upper molar row (LUM) on length of nasals (LN), length of upper molar row (LUM) on height of rostrum (HR) [Barkaszi 2018].

Table 6. Values of Wilks' lambda and factor loadings of craniometrical characters on the canonical variables

Таблиця 6. Значення лямбди Уілкса та факторні навантаження краніологічних ознак на канонічні змінні

Character	Wilks' Lambda	Root 1	Root 2
Length of nasals (LN)	0.072	-0.353	0.206
Width of rostrum (WR)	0.071	-0.413	0.048
Length of rostral part (LF)	0.071	-0.418	0.126
Length of braincase (LBC)	0.072	-0.460	0.224
Least interorbital constriction (LIOC)	0.071	-0.320	0.069
Width of braincase (WBC)	0.071	-0.456	0.101
Distance between incisor and M^3 (LIM3)	0.071	-0.570	0.211
Length of diastema (LD)	0.072	-0.348	0.261
Length of first upper molar (LM1)	**0.073**	-0.547	-0.305
Length of *bulla tympanica* (LBUL)	0.072	-0.541	0.272
Length of *foramen incisivum* (LFI)	**0.080**	-0.350	-0.313
Length of upper molar row (LUM)	**0.073**	**-0.795**	-0.078
Condylobasal length of skull (CBL)	0.071	-0.549	0.236
Palatal length (LPP)	0.071	-0.541	0.191
Width of choana (WCH)	**0.074**	-0.153	0.206
Width between *bulla tympanica* (WBB)	0.071	-0.087	-0.049
Greatest length of skull (GLS)	0.071	-0.525	0.191
Height of skull including *bulla tympanica* (HBCB)	**0.074**	-0.474	-0.233
Height of rostrum (HR)	0.072	-0.441	0.192
Depth of incisor (DI)	0.072	-0.179	0.232
Length of lower molar row (LLM)	**0.077**	**-0.780**	-0.072
Length of condyle (LCP)	0.071	-0.287	0.185
Length of mandible (LM)	**0.075**	-0.408	0.439

Table 7. Variability of absolute values of craniometrical characters of mice of the genus *Sylvaemus* (min–max, ave, c.v.)

Таблиця 7. Мінливість абсолютних значень краніометричних ознак мишаків роду *Sylvaemus* (min–max, ave, c.v.)

Character	*S. uralensis*	*S. sylvaticus*	*S. tauricus*
Length of nasals (LN)	6.87–9.97 8.41 (6.52%)	7.79–11.41 8.87 (6.88%)	7.71–11.95 10.16 (9.15%)
Width of rostrum (WR)	3.35–4.55 3.92 (5.98%)	3.55–5.05 4.21 (5.74%)	4.08–5.74 4.71 (7.10%)
Length of rostral part (LF)	3.85–10.58 9.23 (8.31%)	8.59–12.20 9.97 (6.44%)	8.80–13.74 11.53 (8.02%)
Length of braincase (LBC)	13.23–16.59 15.07 (3.69%)	14.00–17.28 15.71 (3.87%)	15.24–19.58 17.34 (5.31%)
Least interorbital constriction (LIOC)	3.62–4.37 3.92 (3.83%)	3.25–4.73 4.07 (4.83%)	3.86–5.28 4.36 (5.26%)
Width of braincase (WBC)	10.20–11.63 10.95 (2.67%)	10.51–12.34 11.34 (3.31%)	11.04–13.48 12.12 (3.47%)
Distance between incisor and M^3 (LIM3)	9.61–11.96 11.31 (3.53%)	11.09–13.21 11.97 (4.07%)	11.81–15.52 13.47 (5.29%)
Length of diastema (LD)	6.33–8.44 7.72 (4.92%)	7.11–9.09 8.00 (5.23%)	7.68–10.90 8.97 (7.88%)
Length of first upper molar (LM1)	1.24–1.63 1.47 (5.49%)	1.43–2.20 1.69 (8.62%)	1.60–2.15 1.91 (5.12%)
Length of *bulla tympanica* (LBUL)	3.59–4.52 4.06 (5.20%)	3.78–5.28 4.33 (6.76%)	4.45–5.49 5.03 (5.31%)
Length of *foramen incisivum* (LFI)	3.19–4.75 4.09 (6.98%)	3.49–5.48 4.63 (9.24%)	3.85–5.78 5.03 (7.96%)
Length of upper molar row (LUM)	2.96–3.70 3.39 (4.08%)	3.35–4.40 3.77 (5.51%)	3.98–4.72 4.33 (3.54%)
Condylobasal length of skull (CBL)	17.70–21.86 20.41 (3.54%)	19.76–24.40 21.55 (3.78%)	21.12–28.52 24.29 (5.77%)
Palatal length (LPP)	10.00–12.38 11.59 (3.57%)	10.86–13.79 12.34 (4.22%)	12.02–16.46 14.01 (6.46%)
Width of choana (WCH)	0.52–1.26 0.99 (13.13%)	0.66–1.42 1.01 (18.06%)	0.80–1.77 1.15 (13.20%)
Width between *bulla tympanica* (WBB)	1.52–2.48 1.93 (10.29%)	1.55–2.50 2.00 (10.20%)	1.50–2.87 2.08 (14.74%)
Greatest length of skull (GLS)	19.90–25.14 23.30 (3.46%)	22.56–28.59 24.59 (3.88%)	22.40–31.01 27.50 (5.72%)
Height of skull including *bulla tympanica* (HBCB)	6.96–8.78 8.06 (3.73%)	7.57–10.11 8.79 (5.34%)	8.31–12.15 9.56 (5.68%)
Height of rostrum (HR)	3.18–4.14 3.69 (4.97%)	2.98–4.58 3.93 (6.67%)	3.52–5.19 4.50 (7.38%)
Depth of incisor (DI)	1.72–3.01 2.24 (9.93%)	1.84–3.01 2.28 (11.68%)	1.86–4.83 2.62 (16.40%)
Length of lower molar row (LLM)	2.32–3.61 3.34 (4.54%)	3.35–4.44 3.75 (6.25%)	3.85–4.74 4.34 (3.38%)
Length of condyle (LCP)	2.64–4.02 3.47 (7.47%)	2.84–4.39 3.62 (8.38%)	3.28–5.24 4.09 (9.05%)
Length of mandible (LM)	7.88–9.67 9.00 (3.77%)	3.81–11.66 9.26 (8.94%)	9.33–11.96 10.73 (5.62%)

Table 8. Values of Wilks' lambda and factor loadings of studied characters on the canonical variables
Таблиця 8. Значення лямбди Уілкса та факторні навантаження досліджених ознак на канонічні змінні

Character	Wilks' Lambda	Root 1	Root 2
Length of first upper molar (LM^1)	0.044	0.505	0.032
Length of second upper molar (LM^2)	0.046	0.262	-0.166
Length of third upper molar (LM^3)	0.044	0.185	-0.154
Width of first upper molar (WM^1)	0.046	0.450	0.169
Width of second upper molar (WM^2)	0.045	0.426	0.044
Width of third upper molar (WM^3)	0.045	0.321	-0.072
Length of upper molar row (LM^{123})	0.044	0.563	-0.028
Length of first lower molar (LM_1)	0.045	0.552	0.088
Length of second lower molar (LM_2)	0.046	0.560	-0.051
Length of third lower molar (LM_3)	0.045	0.440	-0.111
Width of first lower molar (WM_1)	0.044	0.350	0.067
Width of second lower molar (WM_2)	0.045	0.420	0.128
Width of third lower molar (WM_3)	0.046	0.378	-0.003
Length of lower molar row (LM_{123})	0.046	**0.759**	0.016
Length of nasals (LN)	0.046	0.252	-0.178
Width of rostrum (WR)	0.045	0.252	0.022
Length of rostral part (LF)	0.044	0.316	-0.163
Length of braincase (LBC)	0.044	0.332	-0.117
Least interorbital constriction (LIOC)	0.044	0.138	-0.029
Width of braincase (WBC)	0.044	0.257	-0.045
Distance between incisor and M^3 (LIM3)	0.045	0.385	-0.133
Length of diastema (LD)	0.046	0.214	-0.173
Length of first upper molar (LM1)	0.044	0.426	-0.003
Length of *bulla tympanica* (LBUL)	0.045	0.284	-0.179
Length of *foramen incisivum* (LFI)	**0.051**	0.361	0.232
Length of upper molar row (LUM)	0.044	**0.610**	-0.042
Condylobasal length of skull (CBL)	0.044	0.395	-0.151
Palatal length (LPP)	0.046	0.433	-0.106
Width of choana (WCH)	**0.048**	0.005	-0.228
Width between *bulla tympanica* (WBB)	0.044	0.066	0.101
Greatest length of skull (GLS)	0.044	0.423	-0.147
Height of skull including *bulla tympanica* (HBCB)	0.044	0.469	-0.026
Height of rostrum (HR)	0.044	0.282	-0.104
Depth of incisor (DI)	0.044	0.125	-0.177
Length of lower molar row (LLM)	0.044	0.569	-0.059
Length of condyle (LCP)	0.044	0.216	-0.052
Length of mandible (LM)	**0.050**	0.296	-0.355

Among the selected odontometrical and craniological characters, length of upper (LUM) and lower (LLM) molar rows has the largest factor loading on the canonical variables (Table 8). The scatterplot linking these two craniological characters does not give a clear distribution, the morphospaces of the species overlap to a large extent. Scatterplots relating length of lower molar row (LLM) and condylobasal length of skull (CBL) (Fig. 5), length of upper molar row (LUM) and condylobasal length of skull (CBL), length of upper molar row (LUM) and greatest length of skull (GLS) appeared to be the most suitable for differentiating specimens, but overlap between species morphospaces was still present. Scatterplots combined with length of *foramen incisivum* (LFI) and length of *bulla tympanica* (LBUL) turned out to be the least suitable for differentiating the samples.

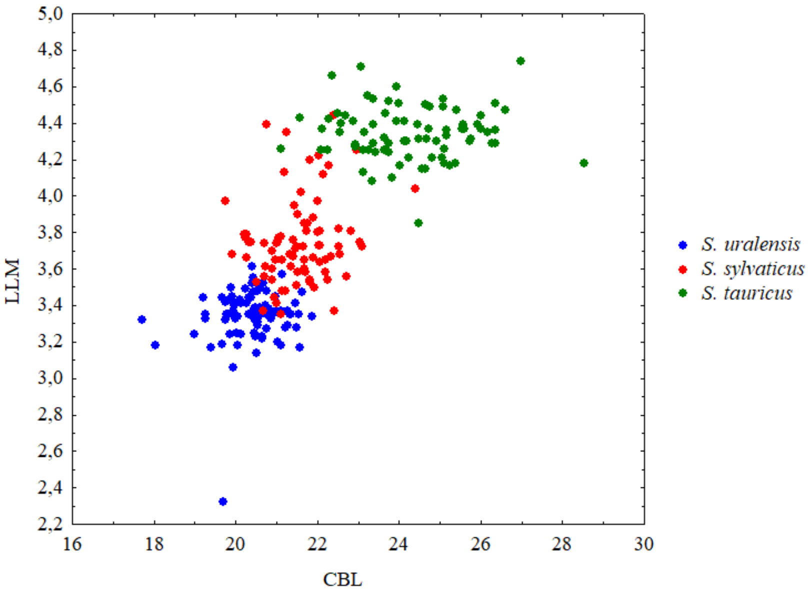


Fig. 5. The relation between the length of lower molar row (LLM) and condylobasal length of skull (CBL).

Рис. 5. Залежність довжини нижнього молярного ряду (LLM) від кондилобазальної довжини (CBL).

Demonstrations of geographic variability in mice of the genus Sylvaemus

The distribution of all studied craniological specimens of mice of the genus *Sylvaemus* from the Museum of Nature according to craniological characters is presented in Fig. 6. Specimens from eight, mostly eastern and southern, regions of Ukraine were selected for analysis (see: Table 2). The morphospaces of the samples strongly overlap, especially in the pair *uralensis—sylvaticus*. The correctness of the classification of specimens according to the craniological characters selected in the analysis is only 83%. However, if craniometrical analysis is performed only for specimens from Kharkiv Oblast, the distribution improves, the level of overlap decreases (Fig. 7), and the correctness of classification of the specimens increases to 92%.

When considering the variation of specimens from specific regions on the example of a single species—*Sylvaemus sylvaticus* (Fig. 8), it can be seen that within the morphospace of the samples, the specimens form separate clusters, which, of course, overlap. For example, the specimens of *S. sylvaticus* that overlap the most with *S. uralensis* were collected in Odesa and Donetsk oblasts. This is rather interesting, because according to opposite clinal variability, *S. sylvaticus* should have larger body size in the south and be closer in variation *S. tauricus*.

Discussion

During the revision of the craniological collection of small mammals by O. V. Zorya, 8% of the specimens were re-identified, confusion generally arose due to the disorganisation of the collection and incomplete data on the labels. In the collection from the Museum of Nature, 13% of specimens were re-identified. Problems with species identification generally occurred in *uralensis–sylvaticus* pairs, between large *uralensis* specimens and small *sylvaticus* specimens with a weak chest spot, and in the *sylvaticus–tauricus* pair, between large *sylvaticus* specimens and *tauricus* specimens with a small chest spot or incomplete collar. It should be noted that the dimensional characters of the species increase in the row of *uralensis* < *sylvaticus* < *tauricus* [Zagorodniuk & Fedorchenko 1993]. Therefore, often the main metric diagnostic characters, especially the length of hind foot, overlap and should be used in conjunction with other external characters such as fur colouration and presence, size, and shape of the chest spot.

Erroneous identification also depends on the syntopy and the level of sympatry between the species. In the Kharkiv samples, confusion occurred more often in the *sylvaticus–tauricus* pair caught in terrestrial and floodplain oak forests, where quite large specimens of *sylvaticus* occur. In the steppe part, there are more doubts about the *uralensis–sylvaticus* pair, where large specimens of *uralensis* and small specimens of *sylvaticus* with a weakly expressed chest spot are found.

In the case of the odontometrical and craniometrical analyses, the problems of identification based on craniological material occur more often in the pair *uralensis–sylvaticus*, the values of the craniological characters of these two species overlap more than in the pair *sylvaticus–tauricus*.

Another significant factor affecting the reliability of species identification is the geographical variability of wood mice. Due to the coincidence of body size and chest spot, as well as the overlap of ecological niches, there is confusion in the identification of species [Zagorodniuk 2005*b*]. Therefore, most authors emphasise the importance to study local populations and warn against extrapolating the results to other parts of the range.

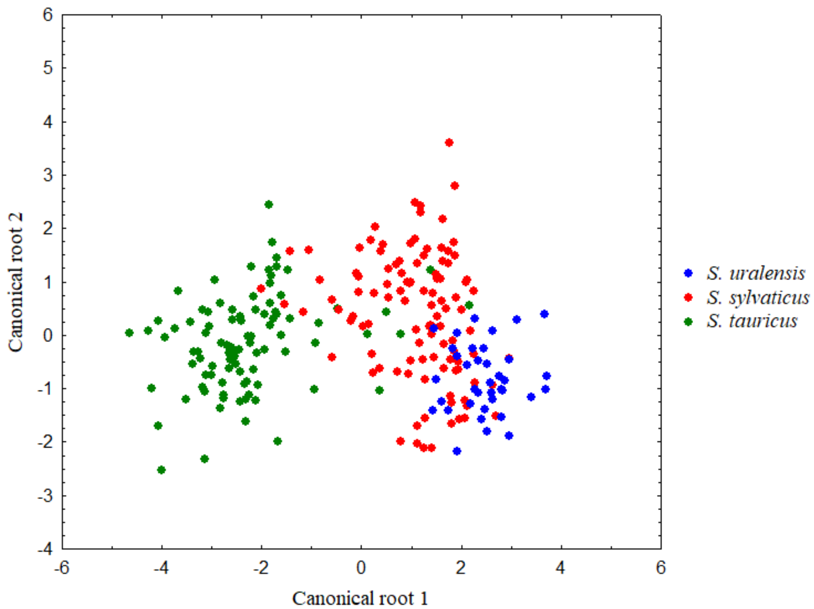


Fig. 6. Distribution of all collection specimens of mice of the genus *Sylvaemus* from the Museum of Nature based on craniometrical characters in the space of the first two canonical roots.

Рис. 6. Розподіл всіх колекційних зразків мишаків роду *Sylvaemus* з Музею природи за краніологічними ознаками у просторі значень першої і другої канонічних змінних.

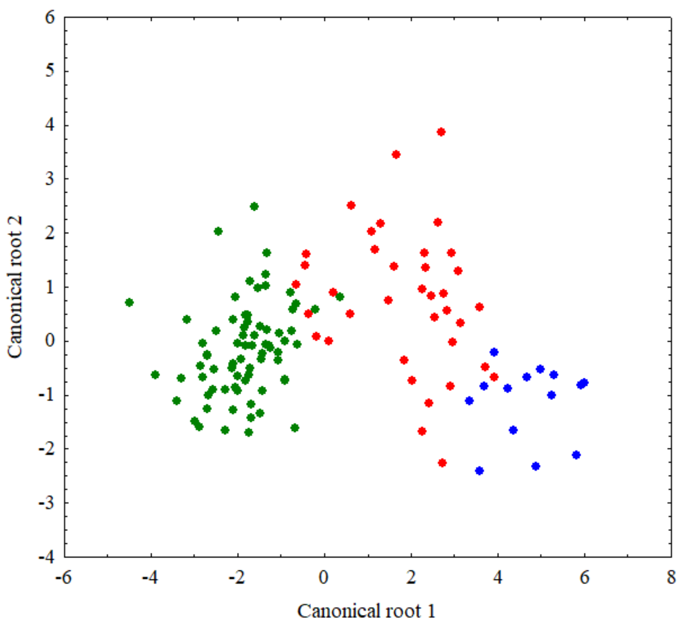


Fig. 7. Distribution of mice of the genus *Sylvaemus* from the Museum of Nature, collected in the territory of Kharkiv Oblast based on craniometrical characters in the space of the first two canonical roots.

Рис. 7. Розподіл мишаків роду *Sylvaemus* з Музею природи, зібраних на території Харківської області, за краніологічними ознаками у просторі значень першої і другої канонічних змінних.

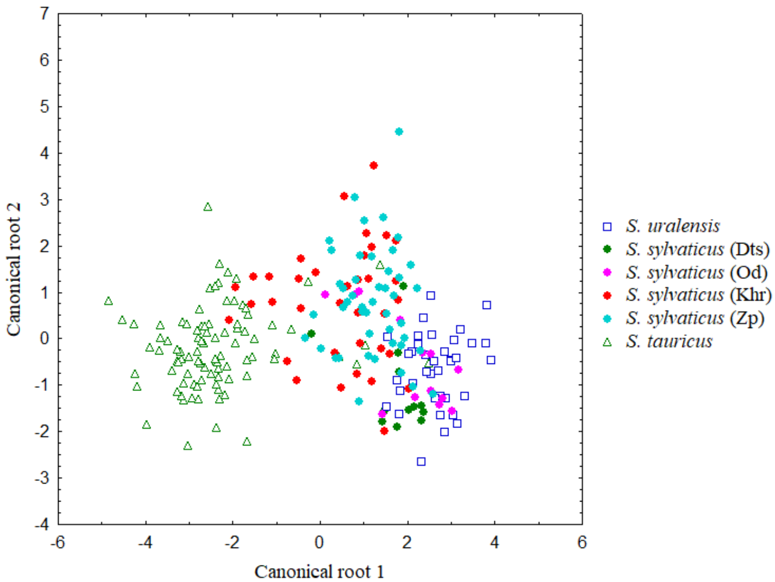


Fig. 8. Distribution of all collection specimens of mice of the genus *Sylvaemus* from the Museum of Nature based on craniometrical characters in the space of the first two canonical roots. *S. sylvaticus* specimens were divided into geographical samples: Donetsk (Dts), Odesa (Od), Kharkiv (Khr), and Zaporizhzhya (Zp).

Рис. 8. Розподіл всіх колекційних зразків мишаків роду *Sylvaemus* з Музею природи за краніологічними ознаками у просторі значень першої і другої канонічних змінних. Зразки *S. sylvaticus* поділено на географічні вибірки: Донецька (Dts), Одеська (Od), Харківська (Khr), Запорізька (Zp).

Conclusions

1. Among the metric characters, three odontometrical—width of first upper molar (WM^1), length of second lower molar (LM_2), length of lower molar row (LM_{123})—and seven craniometrical characters—length of first upper molar (LM1), length of *foramen incisivum* (LFI), length of upper molar row (LUM), width of choana (WCH), height of skull including *bulla tympanica* (HBCB), length of lower molar row (LLM), and length of mandible (LM)—made the greatest contribution to the differentiation of mice of the genus *Sylvaemus*.

2. Width of first upper molar (WM^1), length of first lower molar (LM_1), length of second lower molar (LM_2), length of braincase (LBC), least interorbital constriction (LIOC), width of braincase (WBC), distance between incisor and M^3 (LIM3), length of upper molar row (LUM), condylobasal length of skull (CBL), palatal length (LPP), greatest length of skull (GLS), and length of lower molar row (LLM) are the least variable metric characters.

3. Scatterplots relating length of lower molar row (LLM) and condylobasal length of skull (CBL), length of upper molar row (LUM) and condylobasal length of skull (CBL), length of upper molar row (LUM), and greatest length of skull (GLS) appeared to be the most suitable for the discrimination of specimens, with minimal overlap of species in the morphospace.

4. The best distribution of mice of the genus *Sylvaemus* was obtained as a result of the analysis based on both odontometrical and craniological characters, the correctness of the classification was 100%.

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