

## ••• ЗООЛОГІЯ ТА ЕКОЛОГІЯ ••• ZOOLOGY AND ECOLOGY •••

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### Види-двійники мишей роду *Sylvaemus* Ognev, 1924 (Mammalia, Rodentia) в Українських Карпатах Золтан Баркасі

У регіоні Українських Карпат трапляються три види роду *Sylvaemus*: мишак жовтогрудий (*S. tauricus*), мишак лісовий (*S. sylvaticus*) та мишак уральський (*S. uralensis*). Питання таксономії роду та ідентифікації видів у деяких частинах ареалу залишаються дискусійними, а у регіоні Українських Карпат взагалі є недостатньо вивченими. Нами досліджено понад 250 зразків мишей роду *Sylvaemus*, здобутих у регіоні Українських Карпат, з них морфометрично проаналізовано 216 зразків за 4 екстер'єрними та 11 краніальними ознаками. Показано, що за лінійними розмірами тіла лише *S. uralensis* ідентифікується з високою вірогідністю. Для пари видів *tauricus*–*sylvaticus* найменш мінливою серед лінійних розмірів тіла є довжина задньої стопи, що можна розглядати діагностичною ознакою, хоча для неї також характерне деяке перекривання значень. Для правильної ідентифікації видів необхідно застосувати краніометричні ознаки. Серед вивчених нами 11 краніометричних ознак найменш мінливими для пари *tauricus*–*sylvaticus* є довжина верхнього ряду молярів (M13), ширина (CRB) та висота (CRH) мозкової капсули. Змішані вибірки дорослих особин трьох видів можна розділити з мінімальним або практично без перекриття значень за відношенням довжини верхнього ряду молярів до ширини мозкової капсули, конділобазальної довжини черепа та довжини слухового барабану. Аналіз ступеню перекривання значень окремих ознак у дорослих особин показав, що пара видів *S. tauricus*–*S. sylvaticus* найбільше розходяться за такими ознаками, як довжина верхнього ряду молярів (M13), ширина (CRB) та висота (CRH) мозкової капсули, конділобазальна довжина черепа (CBL) і довжина слухового барабану (BUL). Подібна тенденція була виявлена і для пари *S. sylvaticus*–*S. uralensis*. Розроблено регіональний діагностичний ключ для ідентифікації дорослих особин, який дозволяє вірогідно ідентифікувати 93,5% зразків. Завдяки перевизначенню зразків показано, що *S. tauricus* має найбільш широку висотну та біотопну преференції, *S. sylvaticus* трапляється переважно у вологих заплавах біотопів (ліси, чагарники), майже виключно уздовж річкових долин, по яким проникає далеко в гори, а *S. uralensis* представлений нечисленними знахідками з рівнинних заплавах біотопів.

**Ключові слова:** морфологічна мінливість, *Sylvaemus*, видова діагностика, поширення, Карпати.

### Sibling mice species of the genus *Sylvaemus* Ognev, 1924 (Mammalia, Rodentia) in the Ukrainian Carpathians Zoltán Barkaszi

Three species of the genus *Sylvaemus* occur in the region of the Ukrainian Carpathians: the yellow-necked field mouse (*S. tauricus*), the long-tailed field mouse (*S. sylvaticus*) and the pygmy field mouse (*S. uralensis*). Issues of the genus's taxonomy and identification of species have remained controversial in some parts of the geographic range, while in the Ukrainian Carpathians they have been studied scarcely at all. We studied about 250 mice specimens from the Ukrainian Carpathians belonging to the genus *Sylvaemus*, among which 216 were analysed morphometrically based on 4 external and 11 cranial characters. Results indicate that by linear body dimension only *S. uralensis* can be differentiated with high probability. For the pair of species *tauricus*–*sylvaticus*, the hind foot length is the least variable among linear body characters, which might be considered diagnostic, although values of this character also tend to overlap. To identify species correctly, it is necessary to use craniometrical characters. For the pair of *tauricus*–*sylvaticus*, the least variable among the 11 studied characters are the upper molars length (M13), braincase width (CRB), and braincase height (CRH). Mixed samples of adult specimens of the three species can be differentiated with minimal or practically no overlap by using the relation of the upper molars length to braincase width, condylobasal length, and auditory bulla length. Analysis of characters' uniformity in adult specimens showed that *S. tauricus* and *S. sylvaticus* differ from one another the most by the upper molars length (M13), braincase width (CRB), braincase height (CRH), condylobasal length (CBL), and auditory bulla length (BUL). A similar tendency was revealed for the pair of *S. sylvaticus* and *S. uralensis*. A regional identification key was developed for differentiation of adult mice, which allows identifying reliably 93.5% of specimens. Results of the revision of samples suggest that *S. tauricus* has the widest altitudinal and habitat preferences, *S. sylvaticus* occurs mainly in humid floodplain biotopes (shrubs,

woods) entering far into the mountains along river valleys, while *S. uralensis* is represented only by few records from lowland floodplain habitats.

**Key words:** *morphological variation, Sylvaemus, species identification, distribution, Carpathians.*

## Виды-двойники мышей рода *Sylvaemus* Ognev, 1924 (Mammalia, Rodentia) в Украинских Карпатах Золтан Баркаси

В регионе Украинских Карпат встречаются три вида рода *Sylvaemus*: мышь желтогорлая (*S. tauricus*), мышь европейская (*S. sylvaticus*) и мышь лесная (*S. uralensis*). Вопросы таксономии рода та идентификации видов в некоторых частях ареала остаются дискуссионными, а в регионе Украинских Карпат вообще недостаточно изучены. Нами исследовано более 250 экземпляров мышей рода *Sylvaemus*, добытых в регионе Украинских Карпат, из них морфометрически проанализировано 216 образцов по 4 экстерьерным и 11 краниальным признакам. Показано, что по линейным размерам тела лишь *S. uralensis* идентифицируется с высокой вероятностью. Для пары видов *tauricus*–*sylvaticus* наименее изменчивой среди линейных размеров тела является длина задней ступни, хотя для нее тоже характерно некоторое перекрытие значений. Для корректной идентификации видов необходимо использовать краниометрические признаки. Среди изученных нами 11 краниометрических признаков наименее изменчивыми для пары *tauricus*–*sylvaticus* являются длина верхнего ряда моляров (M13), ширина (CRB) и высота (CRH) мозговой капсулы. Смешанные выборки взрослых особей трех видов можно разделить с минимальным или практически без перекрытия значений, используя отношение длины верхнего ряда моляров к ширине мозговой капсулы, кондилобазальной длины черепа и длины слухового барабана. Анализ степени перекрытия значений отдельных признаков у взрослых особей показал, что пара видов *S. tauricus*–*S. sylvaticus* наиболее расходятся по таким признакам, как длина верхнего ряда моляров (M13), ширина (CRB) и высота (CRH) мозговой капсулы (CRH), кондилобазальная длина черепа (CBL) и длина слухового барабана (BUL). Похожая тенденция была выявлена и для пары *S. sylvaticus*–*S. uralensis*. Разработан региональный диагностический ключ для идентификации взрослых особей, который позволяет идентифицировать 93,5% образцов. Благодаря переопределению образцов показано, что *S. tauricus* имеет наиболее широкую высотную и биотопическую преференции, *S. sylvaticus* встречается в основном во влажных пойменных биотопах (леса, кустарники), почти исключительно вдоль речных долин, по которым проникает далеко в горы, а *S. uralensis* представлен немногочисленными находками из равнинных пойменных биотопов.

**Ключевые слова:** *морфологическая изменчивость, Sylvaemus, видовая диагностика, распространение, Карпаты.*

### Introduction

Field mice of the genus *Sylvaemus* are common species in the mammal fauna of Europe. The species richness of the genus increases in Europe eastward: in Western Europe sympatrically occur *S. tauricus* and *S. sylvaticus*, in Central Europe there is a third species – *S. uralensis*, while in Eastern Europe a fourth one – *S. witherbyi* – appears (Orlov et al., 1996). Accordingly, in the region of the Ukrainian Carpathians three species co-occur (Barkaszi, Zagorodniuk, 2016), namely the yellow-necked field mouse *S. tauricus*, the long-tailed field mouse *S. sylvaticus*, and the pygmy field mouse *S. uralensis*. Moreover, the Carpathian region represents the south-western range edge of the latter (Kryštufek et al., 2008). Due to the exceptionally high morphological similarity between the three species, their differentiation and thus the genus's taxonomy is rather a complex issue, which in many parts of the geographic range have yet remained debatable (Chelomina et al., 2007). Zimmermann (1962) first proposed to divide the Palearctic genus *Apodemus* into three subgenera: *Apodemus*, *Sylvaemus*, and *Alsomys*. Among them, *Apodemus* is sympatric with the two other subgenera, but it co-occurs in Eastern Europe only with *Sylvaemus*.

Morphological similarity between the field mouse species is related to the specifics of their evolution. Earlier it was suggested that the common ancestor of *S. tauricus* and *S. sylvaticus* appeared in Europe in the late Pliocene, most likely from eastern regions, and diverged rapidly due to allopatric speciation (Michaux et al., 2003). During the Quaternary, *S. sylvaticus* survived the glaciations in the Iberian Peninsula, wherefrom it recolonized almost the whole rest of Europe in the end of the last glaciation, while *S. tauricus* recolonized Europe, including northern Spain, during the Holocene from an Italo-Balkan refugium, where in this time *S. sylvaticus* suffered a serious "bottleneck effect" (Michaux et al., 2005). Further studies showed that *S. tauricus* likely survived the last glacial maximum in at least two refugia

located on different banks of the Danube (Bugarski-Stanojević et al., 2008), while *S. sylvaticus* also could recolonize Europe from a second (northern) refugium as well possibly located in the Dordogne or Carpathian region (Herman et al., 2017). The third species, *S. uralensis*, is represented by two races, a European and an Asian, respectively (Chelomina et al., 2007). Paleontological data confirm the results of molecular phylogeographic research, although indicate sufficient differences between the species by the dynamics of colonization of their range (Knitlová, Horáček, 2017).

The existing phenotypic similarity between field mouse species is presumably the result of a long evolutionary process under similar ecological conditions (Jojić et al., 2014). Dzeverin and Lashkova (2012) estimating the tempo of divergence in species of the genus *Sylvaemus* concluded that the group is in the state of an evolutionary stasis and its divergence, which occurred by both the size and form of the skull, has been slowed down by stabilizing selection.

According to Zagorodniuk and Kavun (2000), the increase of general dimensions, i.e. phylogenetic growth, can be considered the main vector of changes in the evolutionary line of *Sylvaemus*. Therefore, age-related variation and fixation of different stages of ontogenetic development in adults are the basis for the emergence of differences between closely related species. The growth of the group in general is repeated in the postnatal ontogenesis of the large species meaning that on early stages of ontogenesis such species will represent an ontogenetic equivalent (morphological copy) of older age stages of its smaller sibling.

Views of researchers of the fauna of Ukraine and of the Ukrainian Carpathians on the identification of *Sylvaemus* species based on morphological characters – both external and cranial – remain controversial. Due to the absence of a clear scheme of species diagnostics, each researcher prefers using different “key characters” (e.g., presence/absence and form of the chest spot, hind foot length, tooth row length, etc.). However, such approach often led to the amassment of mixed samples and distorted conclusions on distribution, habitat preferences and other ecological features of field mice in the region.

A plenty of studies were conducted into the morphological variation of field mouse species in order to shed light on the taxonomic structure of the genus *Sylvaemus*, and many attempts were made to develop a convenient scheme for species identification. Such research become more complicated by the fact that typical “*tauricus*-related” characters can appear in populations of *S. sylvaticus* as well due to low species divergence (Tchernov, 1979). Odontological characters, which are relatively convenient and useful in species diagnostics of voles, are rather polymorphic within the genus *Sylvaemus* and each variant can appear in any of the species, thus this criterion is usually unreliable (Tchernov, 1979).

Morphometric differences between the field mouse species were studied in details mainly for taxonomic and diagnostic purposes. In particular, several attempts were made to find diagnostic criteria by odontometric characters (e.g., Haitlinger, Ruprecht, 1967; Demeter, Lázár, 1984; Panzironi et al., 1993) and morphometric characters of the lower jaw (e.g., Demeter, Lázár, 1984; Lashkova et al., 2006). Yet most research were devoted to the study of variation of craniometrical characters using traditional and geometric morphometry and multivariate analyses (e.g., Cranbrook, 1957; Fielding, 1966; Niethammer, 1969; Balčiauskienė et al., 2002; Vohralík, 2002; Janžekovič, Kryštufek, 2004; Cserkés, 2005; Chassovnikarova, Markov, 2007; Barčiová, Macholán, 2009; Jojić et al., 2014; Čanády, Mošanský, 2015). Such studies were conducted on field mice of Eastern Europe as well (e.g., Mezhzherin, Zagorodniuk, 1989; Vorontsov et al., 1992; Popov, 1993; Zagorodniuk, 1996; Lashkova, Dzeverin, 2002; Mezhzherin et al., 2002; Lashkova et al., 2005).

Relatively sufficient regional craniometric differences were shown for distinct populations of both *S. sylvaticus* (Čanády, Mošanský, 2015) and *S. uralensis* (Čanády et al., 2014), particularly in relation to the elevation and even on short geographic distances (within 1°). Therefore, development of regional identification keys is crucial, as it was concluded earlier (e.g., Demeter, Lázár, 1984; Barčiová, Macholán, 2009). Special studies on the diagnostics of field mice of the Ukrainian Carpathians have not been conducted before, and researchers of the local fauna usually used identification criteria developed on geographically mixed samples.

Controversial or incorrect species identification of *Sylvaemus* specimens in the past certainly distorted the real picture of distribution of field mice in the region. We can be convinced of this if analyse the works of authors of the mid-20th century (subsequent authors often cited these works without critical analysis or revision of data). Some of them considered that *S. sylvaticus* has low abundance in the region (Sokur, 1952; Kolyushev, 1953; Tatarinov, 1956) and occurs only in lowland and piedmont areas (Sokur, 1952; Kolyushev, 1953). Another view, according to Shnarevich (1959), is that the long-tailed field mouse

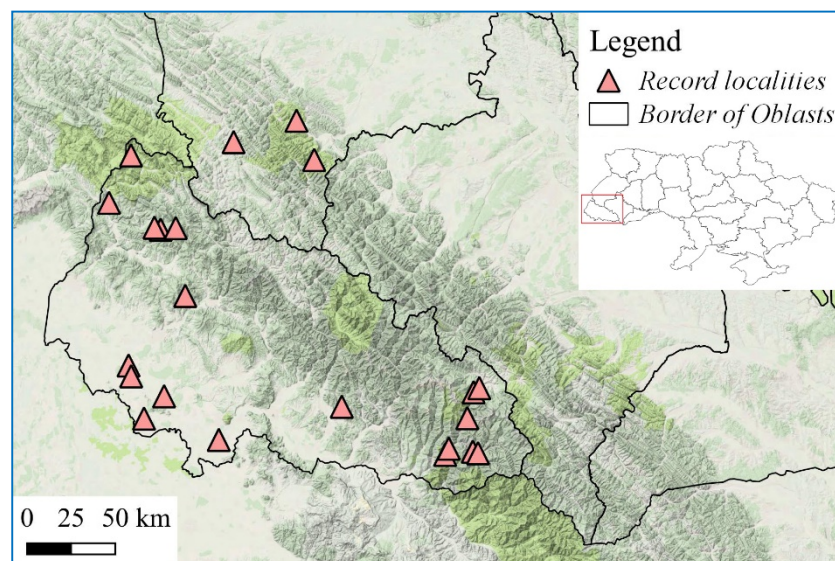
in Bukovina occurs mainly in piedmont and mountain areas. Other zoologists (Tatarinov, 1956; Turyanin, 1959) considered *S. sylvaticus* as one of the most common and widely distributed rodents in the region. Obviously, each of these researchers were using different diagnostic characters and approaches to species identification, which eventually led to controversial conclusions on the distribution of field mouse species in the Ukrainian Carpathians.

The distribution of *S. uralensis* in the region is the least explored. This species is known from practically all parts of Ukraine, yet it is considered more common for the eastern regions (Naglov, 1995; Mezhzherin et al., 2002). In the Ukrainian Carpathians, the presence of *S. uralensis* had been long denied, although Turyanin (1959) was practically the first who draw attention on the occurrence of “large and small forms of *S. sylvaticus*” in the fauna of Transcarpathia (i.e. Zakarpattia Oblast). However, the first record of *S. uralensis* in the Ukrainian Carpathians was reported only in 1980 (Polushina, Voznyuk, 1980), and later the existence of an isolated highland population of the species on Sheshurska polonina of the Chornohora range was reported as well (Kyselyuk, 1993). Few records of *S. uralensis* are known from the region of the Ukrainian Carpathians, although the pygmy field mouse is a common species in adjacent lowland regions of neighbouring countries (Cserkés, 2005; Cichocki et al., 2011; Čanádý et al., 2014).

The aim of the present research was to analyse the morphological features of field mice of the Ukrainian Carpathians and to develop a regional key for species identification. Based on the revision of samples, we also aimed to clarify the distribution and habitat preferences of field mice in the region.

### Material and methods

About 250 specimens of field mice of the genus *Sylvaemus* collected in the region of the Ukrainian Carpathians were analysed from the mammal collection of the National Museum of Natural History, NAS of Ukraine (Kyiv) and from the author's working collection. Data on linear body dimensions and measurements of cranial structures were obtained from 216 specimens, among which 164 were identified eventually as *S. tauricus*, 32 as *S. sylvaticus*, and 6 as *S. uralensis*. Record localities of specimens are shown on Fig. 1.



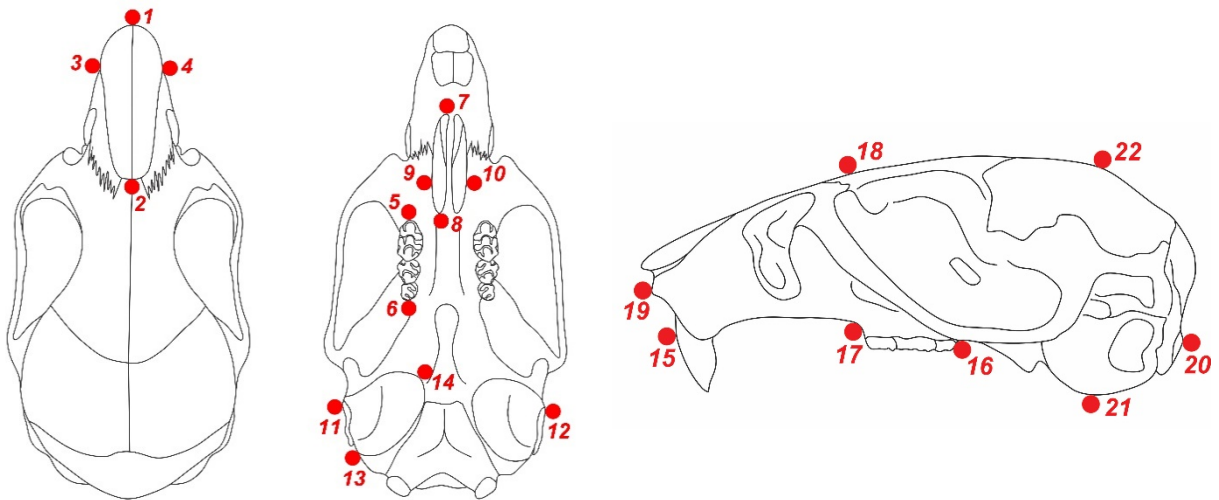
**Fig. 1. Record localities of the studied mice specimens of the genus *Sylvaemus***

The relative age of specimens was determined according to the scheme “juvenilis–subadultus–adultus” based on a set of characters including general body and skull dimensions, skull sculpture and level of tooth crown wear (Delany, Davis, 1961; Adamczewska-Andrzejewska, 1967).

Morphological variation of specimens was studied using study skins, linear body dimensions (body length L, tail length Ca, hind foot length Pl, and auricle length Au) and 11 cranial characters. The latter were selected after an extensive survey of former publications in which these characters turned out to be the most promising for species diagnostics. The analysed cranial characters are as follows: IM3, upper tooth

row coronal length; M13, upper molars coronal length; FIL, incisive foramina length; FIB, incisive foramina width; NAL, nasal bones length; NAB, nasal bones width; ROH, rostral height of the skull; CBL, condylobasal length of the skull; CRB, braincase width measured between ectotympanic bones; CRH, braincase height; BUL, auditory bulla length.

The scheme of cranial measurements is shown on Fig. 2.



**Fig. 2. Scheme of cranial measurements.** 1–2 NAL, 3–4 NAB, 5–6 M13, 7–8 FIL, 9–10 FIB, 11–12 CRB, 13–14 BUL, 15–16 IM3, 17–18 ROH, 19–20 CBL, 21–22 CRH

Metric data were processed statistically using electronic spreadsheets and analysed by the following parameters: minimal value (Min), maximal value (Max), arithmetic mean value (Mean), standard deviation (SD), and coefficient of variation (CV). The uniformity of different datasets was estimated using Mayr's coefficient of divergence (CD).

Maps were created by QGIS software using Google, personal and public domain layers.

## Results and discussion

### **Variation of external morphological characters**

As siblings, field mice have a highly similar external look by both colouration and details of body structure. In addition, different age groups of one species morphologically often resemble other age groups of another species (e.g., see Cserkés, 2005; Stetsula, 2012).

Practically there are no non-metric external characters, which allow reliable identification of field mice specimens. During species identification, the attention is usually paid first to the presence and outlines of the chest spot, which is, according to the "traditional" view, similar to a collar in *S. tauricus* or to a tie or a blurred drop in *S. sylvaticus*, while *S. uralensis* has no chest spot at all (Fig. 3). Yet in case of field mice from the Ukrainian Carpathians this character seems to be highly variable and the chest spot can be very alike in *S. tauricus* and *S. sylvaticus* (Fig. 4).

Species identification based on linear body dimensions is also problematic. Most of the external metric characters is relatively highly variable (Table 1) and in case of correct preliminary age determination body dimensions allow to reliably differentiate only specimens of *S. uralensis* (Fig. 5). For the pair of species *tauricus*–*sylvaticus*, the hind foot length is the least variable among linear body characters, which might be considered diagnostic, although values of this character also tend to overlap.

Thus, using only external characters for species identification in field mice leads to unreliable results hence it is necessary to involve craniometric characters as well (see further). For instance, using the hind foot length in combination with upper molars length decreases the overlap of values and increases the diagnostic weight of the hind foot length (Fig. 6).

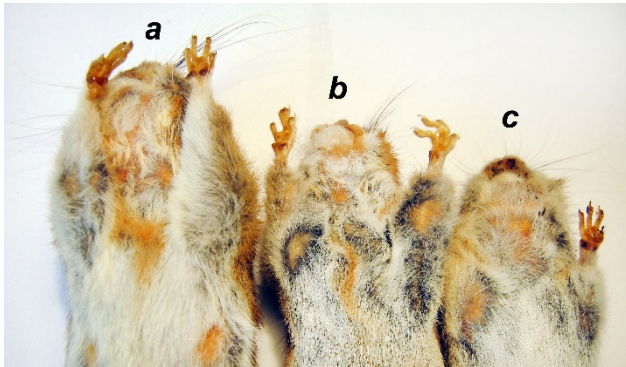


Fig. 3. Form of the chest spot in *Sylvaemus* species: collar in *S. tauricus* (a); tie in *S. sylvaticus* (b) and no spot in *S. uralensis* (c)



Fig. 4. Similar drop-like chest spots in *S. tauricus* (a) and *S. sylvaticus* (b), a character that may lead to incorrect species identification

Table 1.

Variation of external metric characters in adult mice of the genus *Sylvaemus* from the Ukrainian Carpathians

Species	Character	N	Min mm	Max mm	Mean mm	SD	CV %
<i>S. tauricus</i>	L	139	85.0	124.0	102.7	7.69	7.49
	Ca	133	80.0	127.0	102.1	8.80	8.63
	PI	140	<b>23.0</b>	<b>26.2</b>	24.1	0.79	<b>3.27</b>
	Au	136	15.0	21.0	17.7	1.09	6.18
<i>S. sylvaticus</i>	L	8	91.9	108.7	98.4	6.47	6.58
	Ca	8	91.0	113.0	99.5	8.57	8.61
	PI	8	<b>22.3</b>	<b>23.9</b>	23.0	0.67	<b>2.92</b>
	Au	8	15.5	18.3	16.8	0.97	5.77
<i>S. uralensis</i>	L	4	83.5	88.5	87.0	2.33	2.68
	Ca	4	76.0	89.0	83.5	5.57	6.67
	PI	4	<b>18.0</b>	<b>19.3</b>	18.8	0.57	3.02
	Au	4	13.1	14.0	13.7	0.40	2.95

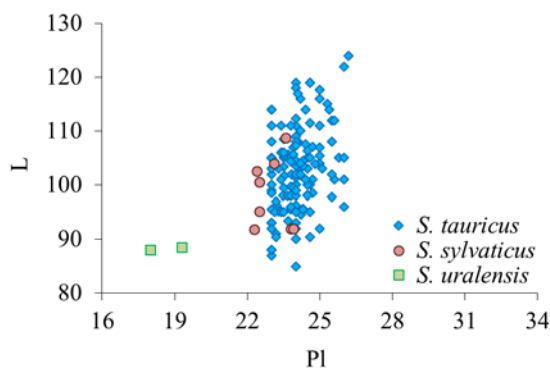


Fig. 5. The relation between the hind foot length (PI) and body length (L)

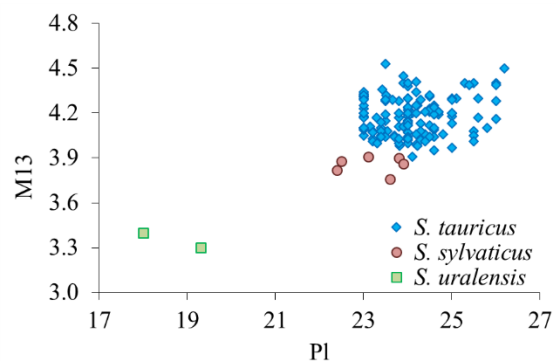


Fig. 6. The relation between the hind foot length (PI) and upper molars length (M13)

#### Variation of craniometric characters

Among the 11 studied craniometric characters, the least variable for the pair of species *tauricus*–*sylvaticus* are the upper molars length (M13), braincase width (CRB), braincase height (CRH) (Table 2). In

case of *S. uralensis*, comparison of coefficients of variation with those in other species would be incorrect due to the small number of specimens in the pygmy field mouse sample.

Some other characters with relatively higher levels of variation also can be used for species identification as additional criteria, and their diagnostic value is higher when used in combination with the least variable characters. In particular, mixed samples of adult specimens of the three field mouse species can be discriminated with minimal or practically without overlap of values using the relation of upper molars length to braincase width (Fig. 7), condylobasal length (Fig. 8), and auditory bulla length (Fig. 9). The probability that values would overlap in the pair of *tauricus-sylvaticus* increases in the space of such characters as M13/NAL (Fig. 10), M13/ROH (Fig. 11) and M13/FIL (Fig. 12).

Data analysis showed that combinations of some other craniometric characters (i.e. not in comparison to M13) can also be used in species identification as additional criteria, particularly in cases when skulls are damaged, especially their diagnostically relevant structures. However, these characters show a greater overlap of values, for example, CRB/FIL and CRH/CRB in the pair of *tauricus-sylvaticus*, while in case of CRH/BUL, NAL/CRB and CRB/ROH extreme values overlap in all three species.

**Table 2.**  
**Variation of craniometric characters in adult mice of the genus *Sylvaemus* from the Ukrainian Carpathians**

Species	Character	N	Min mm	Max mm	Mean mm	SD	CV %
<i>S. tauricus</i>	IM3	149	11.9	14.9	13.3	0.67	5.04
	M13	150	3.9	4.5	4.2	0.13	<b>3.07</b>
	FIL	150	4.9	6.2	5.5	0.28	5.08
	FIB	149	1.7	2.3	2.0	0.14	6.88
	NAL	137	9.2	11.9	10.5	0.55	5.27
	NAB	142	2.8	3.9	3.3	0.23	7.04
	ROH	149	5.7	7.1	6.4	0.31	4.75
	CBL	130	24.3	28.6	26.2	1.12	4.27
	CRB	124	10.7	12.6	11.6	0.41	<b>3.53</b>
	CRH	123	8.5	10.5	9.5	0.39	<b>4.11</b>
BUL	132	4.6	5.6	5.1	0.21	4.16	
<i>S. sylvaticus</i>	IM3	29	10.6	13.4	11.6	0.62	5.36
	M13	30	3.6	3.9	3.8	0.04	<b>2.21</b>
	FIL	30	4.7	5.8	5.2	0.33	6.30
	FIB	29	1.8	2.3	2.0	0.17	8.46
	NAL	24	8.3	10.6	9.2	0.61	6.68
	NAB	25	2.5	3.4	2.9	0.22	7.62
	ROH	29	4.9	6.5	5.6	0.36	6.35
	CBL	15	20.4	24.4	22.5	1.21	5.35
CRB	10	10.3	10.8	10.5	0.16	<b>1.47</b>	
CRH	11	8.2	8.9	8.6	0.25	<b>2.93</b>	
BUL	20	3.9	4.8	4.4	0.24	5.48	
<i>S. uralensis</i>	IM3	3	10.9	11.1	10.0	0.13	1.15
	M13	4	3.2	3.4	3.3	0.07	2.22
	FIL	4	4.3	4.8	4.5	0.21	4.62
	FIB	3	1.4	1.6	1.5	0.10	6.86
	NAL	1	8.7	8.7	8.7	—	—
	NAB	1	2.6	2.6	2.6	—	—
	ROH	3	5.4	5.6	5.5	0.12	2.19
	CBL	3	20.9	21.4	21.1	0.27	1.27
	CRB	3	9.9	10.2	10.0	0.15	1.48
CRH	3	8.0	8.1	8.1	0.05	0.62	
BUL	4	4.0	4.2	4.1	0.08	1.85	

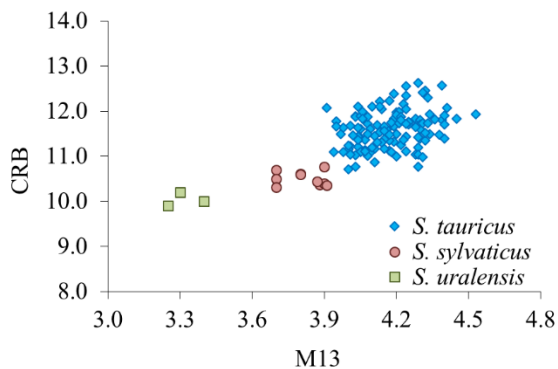


Fig. 7. The relation between the upper molars length (M13) and braincase width (CRB)

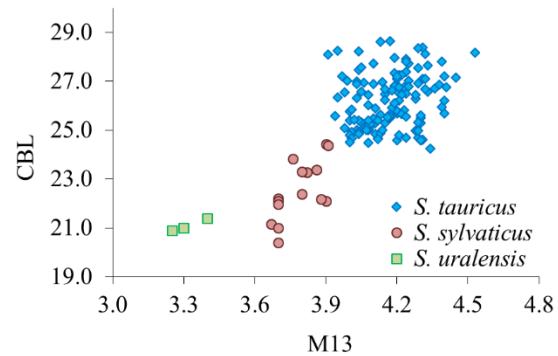


Fig. 8. The relation between the upper molars length (M13) and condylobasal length (CBL)

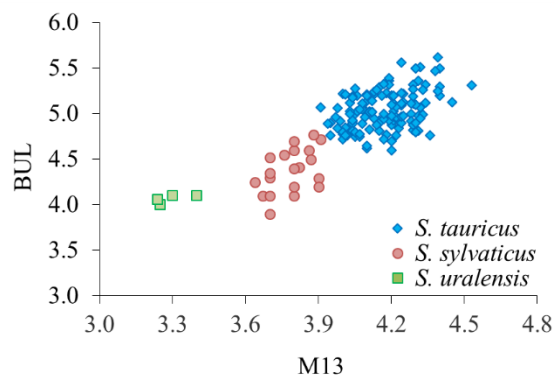


Fig. 9. The relation between the upper molars length (M13) and auditory bulla length (BUL)

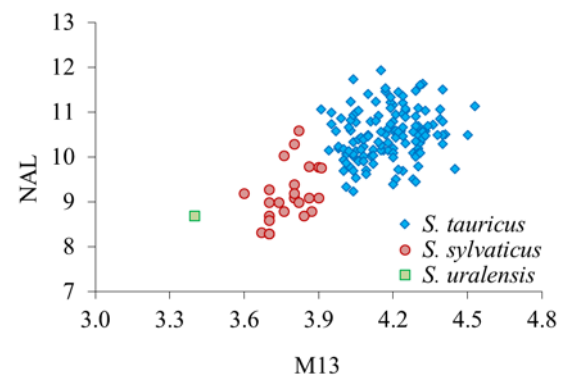


Fig. 10. The relation between the upper molars length (M13) and nasal bones length (NAL)

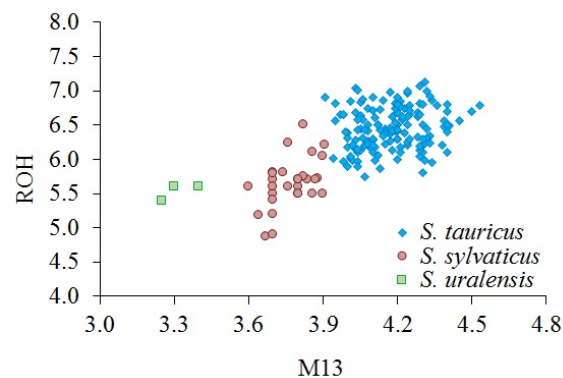


Fig. 11. The relation between the upper molars length (M13) and rostral height (ROH)

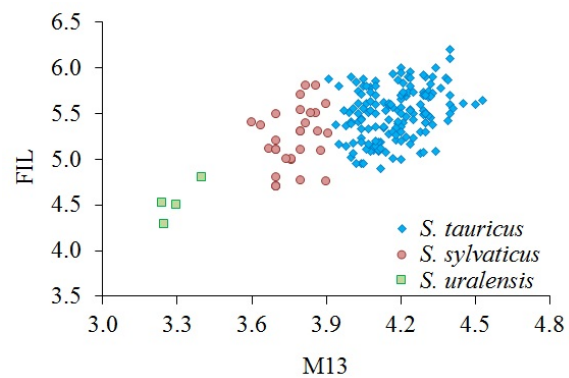


Fig. 12. The relation between the upper molars length (M13) and incisive foramina length (FIL)

Total overlapping of values was observed when analysing the relation of nasal bones length to rostral height (NAL/ROH) and to incisive foramina length (NAL/FIL) thus such combinations of characters are unsuitable in species diagnostics.

#### **General trends of variation and approaches to species diagnostics**

Previous research into the geographical variation of species of the genus *Sylvaemus* showed that general body dimensions of *S. sylvaticus* in Europe increase westward, while in *S. uralensis* and *S. tauricus* body size increases eastward (Zagorodniuk, 1996). The geographic range of all three species overlap in Central Europe, thus in the Carpathian region we can observe an overlap in the species' morphological



characters as well, which complicates species identification. Considering the relatively sufficient variation of field mice even on small geographic distances, the development of regional identification keys is extremely important for reliable species diagnostics.

According to our results, external (both metric and non-metric) characters allow to discriminate reliably only *S. uralensis* from the other two species, while craniometric characters with the lowest coefficients of variation can be used for identification of adult specimens of all three species. Analysis of characters uniformity in adult specimens showed that *S. tauricus* and *S. sylvaticus* differ from one another the most in upper molars length (M13), braincase width (CRB), braincase height (CRH), condylobasal length (CBL), and auditory bulla length (BUL). A similar tendency was revealed for the pair of species *S. sylvaticus*–*S. uralensis*, although we draw attention again to the small number of *S. uralensis* specimens in the studied sample (Table 3). Besides, there is also a tendency that characters of length are reliable for diagnostics more often than characters of width and height.

**Table 3.**  
**Mayr's coefficients of divergence (CD) for craniometric characters of adult mice of the genus *Sylvaemus* from the Ukrainian Carpathians**

Species	IM3	M13	FIL	FIB	NAL	NAB	ROH	CBL	CRB	CRH	BUL
<i>tau-syl</i>	2.49	<b>3.73</b>	0.97	0.04	2.27	1.78	2.38	<b>3.12</b>	<b>3.54</b>	2.58	<b>2.97</b>
<i>syl-ura</i>	1.05	<b>4.85</b>	1.90	2.52	—	—	0.33	1.18	2.52	2.27	1.19

Note: characters having the least uniformity are given in **bold**.

Considering all of the revealed differences between the field mouse species, we propose a regional diagnostic key for their identification. Using this key, we could reliably identify 202 of the 216 examined in details mice, i.e. 93.5% of specimens. In particular, 12 of 164 specimens (7.3%) of *S. tauricus* were re-identified from the sample of *S. sylvaticus*, 5 of 32 specimens (15.6%) of *S. sylvaticus* were re-identified from the sample of *S. tauricus*, while all 6 specimens (100%) of *S. uralensis* were re-identified from the sample of *S. sylvaticus*. The absence of field mice originally identified as *S. uralensis* in the collections is might be related to the fact that the species status of the pygmy field mouse had not been long accepted in the region, and detailed revision of the Carpathian field mice samples was not conducted before.

Problematic specimens, which we could not reliably identify, were those with highly damaged skulls in which, respectively, we could not examine diagnostically important characters. Thus, the proposed scheme works the best for specimens with the fullest set of characters, especially craniometric characters.

**Key for the identification of mice of the genus *Sylvaemus***

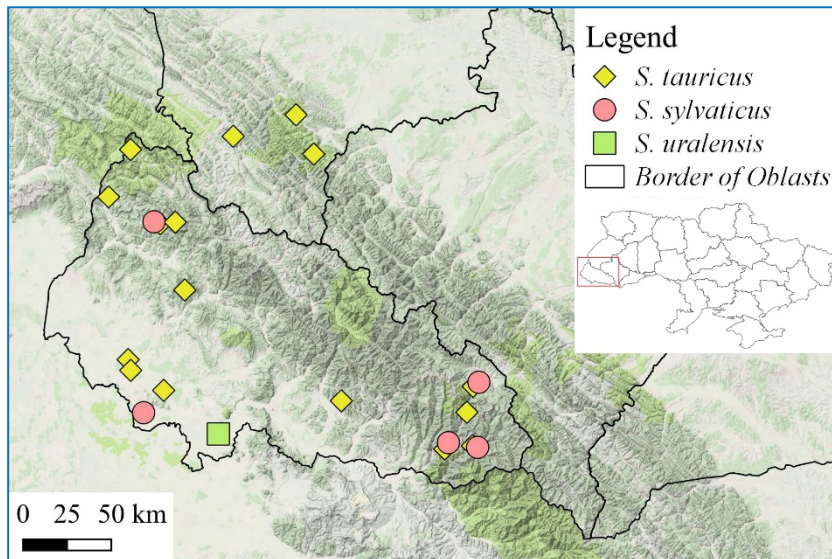
The proposed here diagnostic key was developed for identification of field mouse species of the genus *Sylvaemus* collected in the region of the Ukrainian Carpathians. The probability of correct identification is the highest when the material being diagnosed is fully represented, i.e. the skin and linear body dimensions are available, and, more importantly, cranial material is intact or minimally damaged. However, the key can be also applied for specimens from adjacent regions, although with the increase of distance the key's effectiveness will decrease, respectively.

- 1 Chest spot absent. Body length to 90 mm. Hind foot length less than 20 mm.
- Chest spot present. Body length to 125 mm. Hind foot length more than 20 mm. 3
- 2 Upper molars length 3.2–3.4 mm. Incisive foramina width 1.4–1.6 mm. ***S. uralensis***
- 3 Upper molars length 3.6–3.9 mm. Braincase width less than 10.5 mm. Condylobasal length 20–25 mm. ***S. sylvaticus***
- Upper molars length 3.9–4.5 mm. Braincase width more than 10.5 mm. Condylobasal length 24–28 mm. ***S. tauricus***

In case of identification of damaged and problematic specimens, when some of the characters proposed in the key are unavailable, and in order to increase the reliability of identification it is worth considering the studied specimen in a space of two characters, particularly of those shown on Figs 7–12.

#### **Distribution of field mice in the region**

Analysis of specimens from personal and museum collections showed that the general distribution (Fig. 13) and habitat preferences of field mice in the region of the Ukrainian Carpathians do not differ substantially from those in other parts of the geographic range (Marsh, Harris, 2000; Kuncová, Frynta, 2009), including Ukraine (Mezhzherin et al., 2002; Hooper et al., 2007).



**Fig. 13. Distribution of three species of *Sylvaemus* in the region of the Ukrainian Carpathian based on re-identification of specimens**

Data suggest that *S. tauricus* has the widest altitudinal and habitat preferences among field mice of the studied region and occurs from the lowlands up to poloninas (i.e. subalpine meadows). The yellow-necked field mouse is a common and abundant species of forest habitats including deciduous, coniferous, and mixed forests, but also occurring in shrubs, clear cuttings, timberline habitats, etc. On the contrary, *S. sylvaticus* mainly occurs in humid floodplain habitats entering far into the mountains along river valleys. The pygmy field mouse, *S. uralensis*, is represented by few records from lowland floodplain habitats (banks of the Tisza river), and its occurrence in highland biotopes of the Ukrainian Carpathians (Kyselyuk, 1993), in our opinion, requires a revision.

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