

Studies on the morphology and karyology on the genus *Apodemus* from Turkey, with some notes on the bioecology

Tarkan YORULMAZ*

İrfan ALBAYRAK

University of Kırıkkale, Faculty of Sciences and Arts, Department of Biology, 71451, Yahşihan, Kırıkkale, Turkey

*Corresponding Author

E- mail: tyorulmaz@kku.edu.tr, iralbayrak@hotmail.com

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Abstract

This study is based on 99 specimens of the genus *Apodemus* collected from Kırıkkale, Kastamonu, Kırşehir, Ankara and Mersin Provinces in Turkey, between 1992 and 2006. It was determined that, *Apodemus sylvaticus*, *A. hermonensis* and *A. mystacinus*, were found in these provinces. Diagnostic characters, habitat, fur color, reproduction, feeding and karyological features of each species are given in this study. To carry out karyological analysis and observe some feeding behaviors, nine specimens were kept in captivity. Karyological data showed that the diploid chromosome number (2n) for *Apodemus sylvaticus*, *A. hermonensis* and *A. mystacinus* was 48. Three statistical analyses, that are discriminant function analysis (DFA), principal component analysis (PCA) and unweighted pair-group average (UPGMA), were applied between this three *Apodemus* species showed clear discrimination between *A. mystacinus* and the other two species, but *A. sylvaticus* have not been showed clear discrimination of the *A. hermonensis* as morphometric in Anatolia. This study represents the first record of *A. sylvaticus* from Central Anatolia and second record from the Black Sea coast and the first report of *A. hermonensis*, including descriptions of cranial, dentition, some biological and ecological features in Turkey.

Key words: *Apodemus* spp., morphology, karyology, bioecology, Turkey

INTRODUCTION

In Turkey, the Order Rodentia is represented by 51 species, including 5 genera and 11 species in the family Muridae [1, 2]. Six species in the genus *Apodemus* - *Apodemus agrarius*, *A. flavicollis*, *A. mystacinus*, *A. sylvaticus*, *A. uralensis*, and *A. hermonensis* - have been recorded from Turkey [1, 3-11].

Studies about on genus *Apodemus* using electrophoretic analyses of allozyme have been increasing in East Europe since 1980s [7, 9, 12, 13]. According to some researchers, recently studies on genus *Apodemus* in Turkey showed that *A. sylvaticus* is virtually absent from Anatolia [7, 9, 14], while distribution of *A. hermonensis* is wide, newly described by Filippucci, Simson and Nevo [12] from Mt. Hermon in Israel.

Many studies relevant mammals distinguished sibling species using discriminant function analysis of external and cranial measurements [10, 15-17]. The purpose of this study is to characterize distributional, bioecological and karyological features and to determine distinguishability using some statistical analysis of external and cranial measurements of the species of *Apodemus* that occur in some provinces, Kırıkkale, Kastamonu, Kırşehir, Ankara and Mersin in Turkey.

MATERIALS and METHODS

Field work was carried out between September 2001 and January 2006 in some provinces, Kırıkkale, Kastamonu, Kırşehir, Ankara and Mersin in Turkey. Ninety-nine specimens of the genus *Apodemus* were caught using kill traps and live traps. Four standard external measurements and body weights

were recorded. The animals were prepared as conventional museum type according to Mursaloğlu [18]. The samples were deposited at the University of Kırıkkale, Faculty of Sciences and Arts, Department of Biology. Standard statistics including mean, minimum, maximum and standard deviation are given in Table 1.

The specimens were divided into three age groups - infant, juvenile and adult - based on their degree of tooth wear and fur color, as determined from field notes. Species identifications were made according to original descriptions, [7, 12, 19-21]. Morphometric and karyological attributes of each species were evaluated by comparing them to the relevant literature. Definitions of fur color were made according to Ridgway [22], bacula were characterized according to Lidicker [23] and karyology was based on Patton [24].

For the statistical tests was used programme of SPSS for Windows (Release 10.0.5-27 Nov 1999). The variables are: Total length (TL), tail length (T), hind foot length (HF), ear (E), weight (W), condylobasal length (Cbl), condylobasillar length (CblI), occipitonasal length (Ocn), diastema (Dia), nasal length (Nasl), upper molar length (Uppm), bullae length (Bull), inter orbital breadth (Int), palatal length (Plt), lower molar length (Lml), mandible length (Mnl).

RESULTS

Three species of the genus *Apodemus* - *Apodemus sylvaticus*, *A. hermonensis* and *A. mystacinus* - were found in Kırıkkale, Kastamonu, Kırşehir, Ankara and Mersin Provinces in Turkey.

Apodemus sylvaticus (Linnaeus 1758)

Mus sylvaticus Linnaeus 1758. Syst. Nat. I., 10th ed., p. 62.

Type locality: Upsala, Sweden

Apodemus sylvaticus Miller 1912. Ann. Mag. Nat. Hist., 8th sr. VI. p. 460.

Diagnostic characters: Incisive foramina are long, exceeding posteriorly the line connecting the anterior margins of first upper molar (M^1) alveoli in all of the specimens. There is usually a triangle-shaped yellowish pectoral spot in 86% of the specimens. From a ventral view, the passage of the posterior palatal margin into the medial pterygoid plates is rounded or near straight in 52% of the specimens (Figure 1).

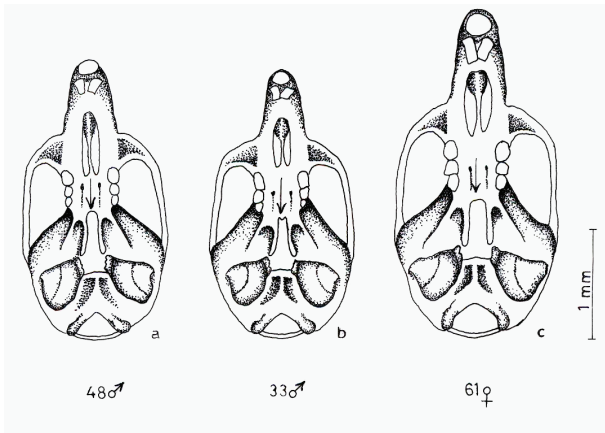


Figure 1. Skulls of three *Apodemus* species: *A. sylvaticus* (a), *A. hermonensis* (b) and *A. mystacinus* (c) in ventral view (The arrows indicate posterior palatal margin; each specimen number is given just below the figure).

On M^1 , cusps t1 and t5 or cusps t3 and t5 are connected by a ridge in 26 % of the specimens. The t12 cusp on M^1 is small in about 96% of the specimen (Figure 2), total length is 177-210 mm, and upper molar length with alveoli is 3.6-4.4 mm (Table 1).

Bioecological features: *A. sylvaticus* is found near woods, brooks, and rivers, in rocky and steep thickets, rocky areas amongst oak and pine forests, near lakes, dry lake beds, and amongst oleaster, willow, poplar and reed beds. It is found at altitudes from 710 to 1200 m.

The dorsal color of juvenile males and females is slightly yellowish grey and the ventral color is slightly grayish white.

Dorsal color of adult males and females varies from brownish-yellowish grey to light brownish grey. Ventral color varies from very slightly yellowish to gray-white. The dorsal color of the tail is brownish yellow-grey and the ventral color is yellowish white.

A pregnant female containing 5 embryos was collected in July. There are black spots at posterior end of the scrotum of adult male *A. sylvaticus*. Karyological analysis of three

specimens revealed that the diploid chromosome number ($2n$) is 48, the fundamental number (FN) is 50 and number of autosome arms (FN_a) is 46. All of the 23 pairs of autosomes are acrocentric, but occur in a range of sizes. The X chromosome is a large acrocentric and the Y chromosome is a medium-sized acrocentric.

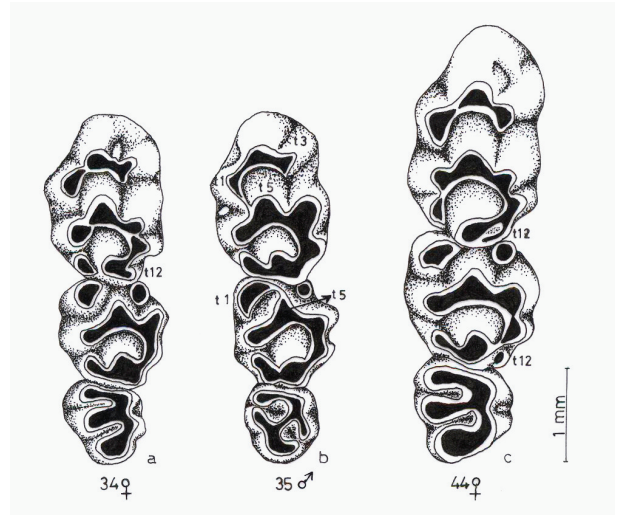


Figure 2. Maxillary tooth rows of *Apodemus* species: *A. sylvaticus* (a), *A. hermonensis* (b) and *A. mystacinus* (c) (Each specimen number is given just below the figure).

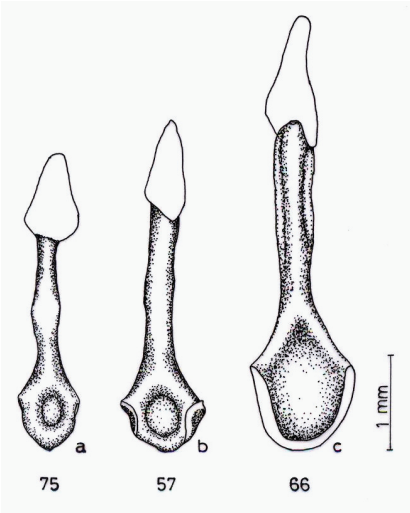


Figure 3. Ventral views of bacula of *Apodemus sylvaticus* (a), *A. hermonensis* (b) and *A. mystacinus* (c) (Each specimen number is given just below the figure).

Apodemus hermonensis Filippucci, Storch and Nevo 1989
Apodemus hermonensis Filippucci et al. 1989. Boll. Zool., 56:361-376

Type locality: Mount Hermon (Israel).

Diagnostic characters: Posterior margins of incisive foramina lie mainly anterior margins of first upper molar (M^1) alveoli in all of the specimen. There is usually a triangle-shaped yellowish pectoral spot in 86% of the specimens. The posterior margin of the palatine has a medial protrusion (Figure 1) in 70% of the specimens. On M^1 , cusps t1 and t5 or cusps t3 and t5 are connected by a bridge in 84 % of the specimens. On second

upper molar (M^2), the large and crescent-shaped t1 cusp has a posterior or anterior connection with the t5 cusp (Figure 2). Total length is 162-220 mm, condylobasal length is 23.1-24.5 mm, the upper molar length with alveoli is 3.8-4.4 mm (Table 1), and baculum length is 2.2-3.2 mm (Figure 3). There is a cartilaginous process that is 0.7-1.0 mm long that is attached to

Kırşehir, Kaman, 3 (3 ♂♂, 16 Sep 2004) (Figure 4).

Bioecological features: The habitat features are same as those of the previous species. *Apodemus hermonensis* appears to live sympatrically with *A. sylvaticus* in this study area.

Table 1. Standard statistics for 17 morphological measurements (in mm) of *Apodemus sylvaticus*, *A. hermonensis* and *A. mystacinus*. Statistics given are mean (m), minimum (min), maximum (max) and standard deviation (\pm sd).

Variables	<i>A. sylvaticus</i>					<i>A. hermonensis</i>					<i>A. mystacinus</i>				
	n	m	min	max	\pm sd	n	m	Min	max	\pm sd	n	M	min	max	\pm sd
TL	8	190.13	177.00	210.00	11.640	58	192.03	145.00	230.00	15.37	18	214.61	170.00	252.00	22.060
T	8	97.62	81.00	111.00	8.805	58	97.78	65.00	110.00	8.946	18	111.22	83.00	130.00	13.270
HF	8	22.67	22.00	24.00	0.690	58	22.29	12.00	25.00	1.921	18	23.98	21.00	29.00	2.285
E	8	15.66	14.00	18.00	1.418	58	15.50	10.00	22.00	2.062	18	18.34	15.00	27.00	2.695
W	8	22.99	18.00	26.00	2.862	58	23.62	11.50	32.00	4.447	18	33.82	14.00	45.00	8.066
Cbl	8	23.69	22.10	24.30	0.918	58	23.80	20.60	25.44	0.970	18	26.22	24.30	29.32	1.642
Cbll	8	23.00	21.50	23.59	0.867	58	23.01	20.00	24.70	0.957	18	25.50	23.59	28.14	1.560
Ocn	8	25.98	23.50	26.70	1.172	58	26.10	22.80	27.76	1.055	18	28.95	26.50	32.40	1.926
Dia	8	6.31	5.80	6.90	0.313	58	6.52	5.60	7.48	0.375	18	7.40	6.10	8.26	0.576
Nasl	8	9.34	8.60	10.70	0.636	58	9.27	7.50	10.60	0.582	18	11.16	9.00	12.50	0.890
Uppm	8	3.78	3.60	4.40	0.271	58	3.72	3.40	4.50	0.185	18	4.54	3.80	4.98	0.366
Bull	8	4.56	4.20	4.80	0.187	58	4.50	3.90	5.16	0.255	18	5.15	4.65	5.90	0.398
Int	8	4.29	4.10	4.50	0.135	58	4.23	3.74	4.96	0.182	18	4.66	4.30	5.00	0.198
Plt	8	11.85	11.10	13.30	0.713	58	11.79	10.07	12.92	0.619	18	13.98	12.26	15.14	0.817
Lml	8	4.13	3.50	4.60	0.373	58	3.93	3.22	4.90	0.272	18	4.90	4.00	5.20	0.292
Mnl	8	13.26	12.20	14.30	0.803	58	13.23	11.10	15.40	0.753	18	15.50	13.90	16.92	1.006

Baculum length is 2.0-3.4 mm (Figure 3) and there is a cartilaginous process 0.8 –1.1 mm in length that is attached to distal end of the baculum.

Specimens examined (8) and localities: Kastamonu; Taşköprü, Köçekli village 1 (1 ♂, 5 July 1992); Kırıkkale; Bahşılı, Çeşme, 2 (1 ♂, 1 ♀, 18 July 2003); Delice, Kaleönü, Tatlıcak village, 1 (1 ♀, 10 June 2003); Kırıkkale Province, Hasandede, 2 (1 ♀, 1 ♂, 25 Nov 2002); Sulakyurt, Kayalidere, 1 (1 ♀, 16 Sep 2001); Yahşihan, Kırıkkale University campus, 1 (1 ♂, 15 Nov 2002) (Figure 4).

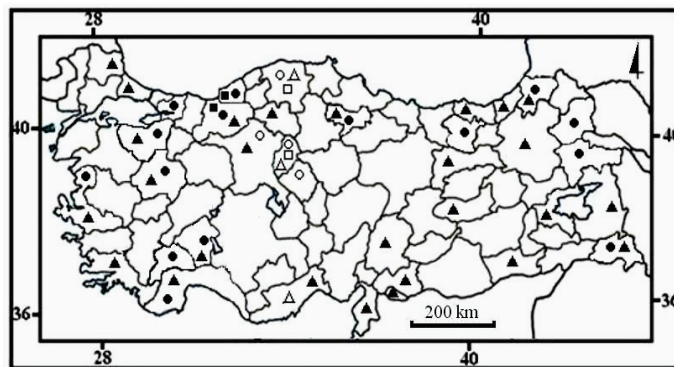


Figure 4. Map of Turkey showing the collection localities of *Apodemus sylvaticus* (■, □), *A. hermonensis* (●, ○) and *A. mystacinus* (▲, △). (Solid symbols : Previous records, open symbols: our records).

Specimens examined (64) and localities: Ankara, Akyurt, 1 (1 ♂, 10 June 2004); Kastamonu, Taşköprü, Köçekli village, 5 (2 ♂♂, 29 June 1992, 1 ♂, 1 ♀, 3 July 1992, 1 ♀, 5 July 1992); Tosya, Kışla, 1 (1 ♀, 8 July 1992), Hasanorgı, Ortayol mevki, 4 (2 ♂♂, 1 ♀, 9 July 1992, 1 ♂, 10 July 1992); Araç, Soğanlı Çayı Mevkii, 6 (1 ♂, 1 ♀, 13 July 1992, 2 ♂♂, 2 ♀♀, 14 July 1992); Doday, Göç village, 4 (2 ♂♂, 21 July 1992, 2 ♂♂, 23 July 1992); Azdavay, 3 (1 ♂, 25 July 1992, 1 ♂, 26 July 1992, 1 ♂, 27 July 1992), Cide, 1 (1 ♂, 30 July 1992); Kırıkkale Bahşılı, Çeşme, 4 (1 ♂, 8 July 2003); Balışeyh, Kulaksız, Gölpinarı, 3 (2 ♀♀, 1 ♂, 14 July 2003); Çelebi, 1 (1 ♂, 20 July 2003); Karakeçeli, Sulubük village, Tebrüş, 3 (1 ♂, 4 June 2003; 2 ♀♀, 5 June 2003), Sazlık, 3 (1 ♀, 2 ♂♂, 5 June 2003); Keskin, Dağsolaklısı village, Yediler, 1 (1 ♂, 30 July 2002), Kırıkkale Province, Hasandede, Eskimez, 1 (1 ♂, 15 July 2001), Hasandede, near

The dorsal color of adult males and females varies from brownish yellow-grey to light brownish grey and the ventral color is very slightly yellow-grayish white. The dorsal color of the tail is brownish yellowish grey and the ventral color of the tail is yellowish white. A pregnant female containing six embryos was collected in April and three pregnant females containing 8, 5 and 4 embryos were collected in June. There are black spots at the posterior end of the scrotum of adult male *A. hermonensis*.

An adult female captured on 5 June was kept in captivity and, after four days, it gave birth to five blind and naked young. After one day, we noticed that one of the young had been eaten by its mother. The remainder of the litter weighed 1.398 g, 1.554 g, 1.368 g and 1.208 g. During the next few days we observed that the pups were covered with fleas and, therefore, the mother and young were transferred to another cage. After three days,

two additional pups had been eaten by their mother and the remainders were found dead. The karyology of *A. hermonensis* is identical to that of *A. sylvaticus* (Figure 5).

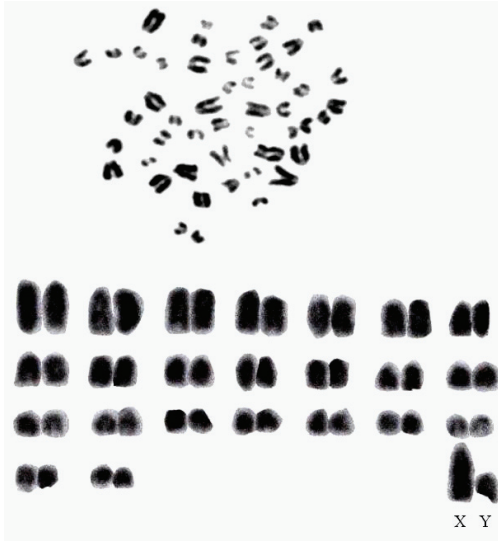


Figure 5. Metaphase spread (above) and karyogram (below) of the Turkish *A. hermonensis*

Apodemus mystacinus (Danford and Alston 1877)

Mus sylvaticus Danford and Alston 1877. Proc. Zool. Soc. p. 279.

Type locality: Zebil, Bolkar Mountain, Mersin.

Apodemus mystacinus Allen 1915. Bull. Mus. Comp. Zool. Harvard, 59:10.

Diagnostic characters: There is no pectoral spot and the posterior margin of the palatine is nearly straight (Figure 1). Cusp t12 is distinct on both first and second upper molar (M1 and M2) (Figure 2). Total length is 170-240 mm, condylobasal length is 25.4-27.8 mm, and upper molar length with alveoli is 4.2-5.4 mm (Table 1). The baculum length is 4.2-5.3 mm and there is a cartilaginous process measuring 1.1-1.4 mm that is attached to distal end of the bone (Figure 3).

Specimens examined (27) and localities: Kastamonu, Abana, Manavra Deresi, 1 (♀, 28 July 1992); Tosya, Ortalica Beldesi, Ortaboğaz, 1 (♀, 16 Jun 1993); Kırkkale, Sulakyurt, Kayalidere, 14 (2 ♀♀, 2 ♂♂, 16 September 2001, 3 ♂♂, 12 July 2002, 2 ♀♀, 22 May 2003, 2 ♀♀, 1 ♂, 11 July 2003, 1 ♂, 14 Jul 2003, 1 ♂, 16 July 2003); Mersin, Silifke, Akkum, 2 (1 ♂, 1 ♀, 17 Jan 2006) (Figure 4).

Bioecological features: *A. mystacinus* was found in rocky places in evergreen oak woodlands and in areas characterized by grasses and bushes at an altitude of 850 m.

The dorsal color of juvenile males and females is a slightly yellowish, smoky pale grey and the ventral color is slightly yellowishwhite. The dorsal color of the tail is yellowish grey and the ventral color is light yellowish. The dorsal color and the ventral color is relatively dirty white with a slightly yellowish shade. A pregnant female containing four embryos was collected in May. There are pinkish spots at the posterior end of the scrotum of adult male *A. mystacinus*.

An adult male with a tick (*Ixodes* sp.) on its ear and with ten worms (*Ascaris* sp.) in its stomach and intestines was collected in July.

Karyological analysis of *A. mystacinus* revealed that the diploid chromosome number (2n) is 48, the fundamental nu-

ber (FN) is 54 and the number of autosomal arms (FNa) is 50. Twenty-one of the autosome pairs are acrocentrics of different sizes, two pairs are small metacentrics and the sex chromosomes are small acrocentrics (Figure 6).



Figure 6. Metaphase spread (above) and karyogram (below) of the Turkish *A. mystacinus*

Morphometric Analysis: Three statistical analysis, that are discriminant function analysis (DFA), principal component analysis (PCA) and unweighted pair-group average (UPGMA) were used to showed differentiation between this three *Apodemus* species *A. mystacinus*, *A. sylvaticus* and *A. hermonensis*.

Discriminant functions analysis based on 11 cranial and 6 external measurements. A scatter plot of function 1 and function 2 showed clear discrimination between *A. mystacinus* and the other two species *A. sylvaticus*, *A. hermonensis*. but *A. sylvaticus* have not been showed clear discrimination of the *A. hermonensis* (Figure 7).

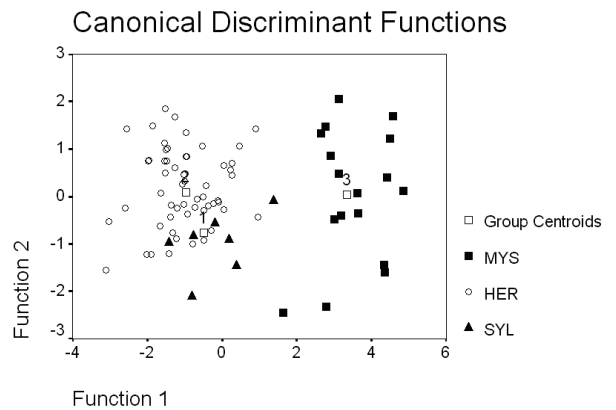


Figure 7. Scatter plot of Canonical DFA based on measurements of *Apodemus sylvaticus* (SYL), *A. hermonensis* (HER) and *A. mystacinus* (MYS).

Principal component analysis (PCA), the first three principal components explain 77.099 % of variation. The first factor (PC 1) accounted for 62.919 % of the overall variance, the second factor (PC 2) accounted for 8.214 %, whereas the third factor (PC 3) accounted for only 5.966 % (Figure 8). A plots showing the relationships between these first three components (Figure 8) clustered the 99 specimens in the three *Apodemus* species. According to PCA analysis, *A. mystacinus* was clearly separated from other *Apodemus* species, but *A. sylvaticus* was

the Kızılırmak, 4 (3 ♀♀, 1 ♂ 25 Nov 2002); Sulakyurt,

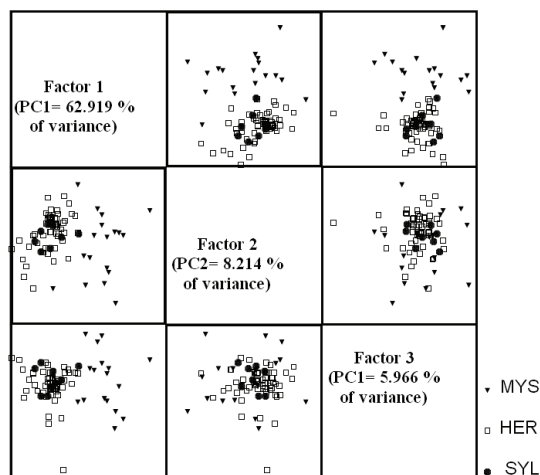


Figure 8. Scatter plots of PCA based on morphological relationship between *Apodemus sylvaticus* (SYL), *A. hermonensis* (HER) and *A. mystacinus* (MYS).

Unweighted Pair-Group Average (UPGMA) tree diagram (Figure 9) and Euclidean distance matrix (Table 2) based on 17 cranial and external measurements of three *Apodemus* species *A. sylvaticus*, *A. hermonensis* and *A. mystacinus*. According to UPGMA test diagram *Apodemus mystacinus* clearly separate from the other two species and *A. sylvaticus* fairly close with *A. hermonensis*.

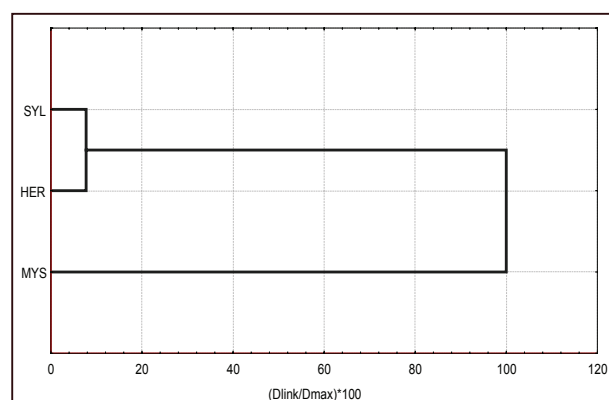


Figure 9. Tree diagram of UPGMA for three *Apodemus* species, *Apodemus sylvaticus* (SYL), *A. hermonensis* (HER) and *A. mystacinus* (MYS).

Table 2. Euclidean Distances between three *Apodemus* species, *A. sylvaticus*, *A. hermonensis* and *A. mystacinus*

	1. <i>A. sylvaticus</i>	2. <i>A. hermonensis</i>	3. <i>A. mystacinus</i>
1. <i>A. sylvaticus</i>	0.000	2.449	32.678
2. <i>A. hermonensis</i>	2.449	0.000	30.591
3. <i>A. mystacinus</i>	32.678	30.591	0.000

Table 3. Compared karyotypic characteristics of *A. sylvaticus* and *A. mystacinus* from Yugoslavia, Greece, Germany and Turkey.

Countries	<i>A. sylvaticus</i>							<i>A. mystacinus</i>									
	2n	FN	N	Fa	A	M	X	Y	2n	F	N	NFa	A	M	X	Y	
Yugoslavia (Saldotović et al. 1969, 1975)	48	48	-	4	6	-	A	A	48	5	2	-	42	4	A	A	
Greece (Niethammer 1974)									48	5	2	-	4	2	4	A	A
Germany (Engel et al. 1973)	48	48	-	4	6	-	A	A									
Yugoslavia (Zima and Král, 1984)	48	48	-	4	6	-	A	A									
Turkey (Doğramacı and Kefelioğlu 1991)	48	48	-	4	6	-	A	A	48	52	5	0	42	4	A	A	
Turkey (Our study)	48	48	46	46	46	-	A	A	48	52	5	0	42	4	A	A	

DISCUSSION

Filippucci et al. [12] reported the existence of a new *Apodemus* species, *A. hermonensis*, which is regarded as a synonym of *A. sylvaticus* from Israel. According to Filippucci et al. [7], Macholán et al. [9], revealed that the distribution of *A. sylvaticus* seemed to be limited to a small area in northwestern Asia Minor along the southern coast of the Black Sea (Figure 4). In our study, *A. sylvaticus* was recorded for the first time in central Anatolia.

Kryštufek [21] reported that *A. sylvaticus creticus* Miller, 1910 is certainly *A. sylvaticus*, which is evident from features of incisive foramina, palato-pterygoid region and dentition. In our study, we found for the first time eight *A. sylvaticus* specimens, according to these features (Figure 1, 2) in Central Anatolia.

Our karyological data for *A. sylvaticus* were compared with those obtained from Yugoslavia [25, 26], Germany [27] and Turkey, according to Doğramacı and Kefelioğlu [28] (Table 3). Our specimens are consistent with data from Yugoslavia, Germany and previous studies in Turkey. Doğramacı and Kefelioğlu [28] determined that the Y chromosome of the Mersin specimen was an acrocentric and the Y chromosome of the Amasya specimens was smaller than those of four *A. sylvaticus* specimens obtained from Amasya and Mersin. Filippucci et al. [12] defined *A. hermonensis* based on a holotype and three paratypes using the following diagnostic characters: “hindfoot length less than 21.5 mm, lower molar length at the alveoli less than 3.85 mm, zygomatic breadth less than 13.06 mm, condylobasal length less than 23.50 mm, tail usually longer than the head and body, dorsal pelage light brown and ventral pelage snow-white with a sharp dorsal/ventral boundary, tubercle t9 on second upper molar M² present, and t4 and t7 generally separated on the first upper molar”. Filippucci et al. [7], which consider the subgenus *Sylvaemus* as a separate genus, gave some diagnostic characters for *Sylvaemus hermonensis* as the following: “cusps t1 and t5 or t3 and t5 connected by a ridge, palatal margin with a characteristic posterior medial protrusion and t1 large and crescent-shaped with, in most cases, an anterior and posterior connection with t5”. Based on internal and external features, our specimens are consistent with the original definition of *A. hermonensis*. We found no difference among morphological data from 52 specimens obtained from Bolu, Bursa, Kütahya, Izmir, Isparta, and Antalya by Filippucci et al. [7] (Figure 4). After the description *A. hermonensis* in Israel by Filippucci et al. [12], *A. hermonensis* was recorded

from eastern, western and southern Anatolia [7, 9, 21]. *Apodemus mystacinus* was recorded from Turkey by Danford and Alston [3], Doğramacı [29], and Musser et al. [30] (Figure 4). Danford and Alston [3] defined *Mus mystacinus* from Mersin (Turkey) and gave the diagnostic characters as the following: "tail length almost as long as the head and body length, dorsal gray pelage mixes with black at the upper fur, flank a light russet color, ventral pelage a light white with a sharp dorsal and ventral boundary sharp, tail clearly bicolored with a dark brownish black dorsal surface and white ventral surface". Our specimens are very similar to this description.

Our karyological data from *A. mystacinus* were compared with those obtained from Greece [31], Yugoslavia [25, 32] and Turkey by Doğramacı and Kefelioğlu [28] (Table 3). These comparisons indicate that our data and the data from Yugoslavia, Greece and Turkey (Mersin, İzmir and Trabzon) are very similar.

A discriminant function analysis seems suitable technique to evidence these interspecific differences and to use practical purpose [16] and Barčiová and Macholán [17] separated the *A. sylvaticus* and *A. flavicollis* using cononical discriminant function.

In our study, two discriminant functions separated *A. mystacinus* from the other two species *A. sylvaticus*, *A. hermonensis*. but *A. sylvaticus* have not been showed clear discrimination of the *A. hermonensis* (Figure 7). It may be caused by limited number of specimens of *A. sylvaticus* which species is founded for the first time from central Anatolia.

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