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Research Article

# Comparison of the Morphometric Characteristics of Some Species of the Genus *Microtus* Schrank, 1798 (Mammalia: Rodentia) in the Central Anatolia Region of Turkey

Serdar GÖZÜTOK[1*], İrfan ALBAYRAK[2]
[1]Department of Wildlife Ecology and Management, Faculty of Agricultural and Natural Sciences, University of Bolu Abant İzzet Baysal, Gölköy Campus, 14030, Bolu, Turkey
[2]Department of Biology, Faculty of Science and Arts, University of Kırıkkale, 71450, Yahşihan, Kırıkkale, Turkey
*Corresponding Author: serdargozutok@ibu.edu.tr

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**Abstract**

The aim of this study was to determine and compare some morphometric characteristics of *Microtus* species occurring in the central Anatolia, Turkey. This study is based on 209 specimens of *Microtus* spp. collected the central Anatolia between 2003 and 2010. Some features concerning pelage coloration, cranial characters, tooth morphotype, and baculum morphology of the species were recorded to determine and evaluate their taxonomic characteristics. It was determined that four species of the genus *Microtus* occur in the study area, including *Microtus dogramacii, Microtus guentheri*, *Microtus hartingi,* and *Microtus mystacinus*. *Microtus hartingi* has been found to be widespread throughout central Anatolia. *Microtus guentheri* is located in the type locality and nearby provinces. *M. guentheri* and *M. hartingi* were not found to be sympatric. Among species, *M. hartingi* has the longest hind foot and *M. mystacinus* has the longest tail. The UPGMA trees were constructed for each sex, using skull and external measurements of *Microtus* specimens. As a result, *M. dogramacii* and *M.* guentheri being the most similar, and *M. mystacinus* is the sister species to these. But, it was determined that *M. hartingi* is distinctively from the these species.

**Keywords:** *Microtus*, Cricetidae, taxonomy, Turkey, morphometric

## Orta Anadolu Bölgesindeki *Microtus* Schrank, 1798 (Mammalia: Rodentia) Cinsine Ait Bazı Türlerin Morfometrik Karakteristiklerinin Karşılaştırılması

**Öz**

Bu çalışmanın amacı Türkiye'nin Orta Anadolu bölgesinde bulunan *Microtus* türlerinin bazı morfometrik karakterlerini belirlemek ve karşılaştırmaktır. Bu çalışma 2003 ila 2010 yılları arasında Orta Anadolu'daki çeşitli yerlerden elde edilen 209 *Microtus* spp. örneğine dayanmaktadır. Türlerin taksonomik karakteristiklerini belirlemek için kürk rengi, kafatası özellikleri, diş morfotipleri ve baculum morfolojileri ile ilgili bazı özellikler kaydedilmiş ve değerlendirilmiştir. Çalışma alanında *Microtus* cinsine ait dört tür, *Microtus dogramacii, Microtus guentheri*, *Microtus hartingi* ve *Microtus mystacinus* tespit edilmiştir. *Microtus hartingi* Orta Anadolu bölgesinin genelinde yaygın olarak bulunmaktadır. *M. guentheri* tip yeri ve yakınındaki illerde tespit edilmiştir. *Microtus guentheri* ve *M. hartingi* simpatrik olarak bulunmamaktadır. Türler arasında *M. hartingi* en uzun ard ayak uzunluğuna ve *M. mystacinus* en uzun kuyruk uzunluğuna sahiptir. Her tür ve her eşey için kafatası ve dış ölçüler kullanılarak UPGMA ağacı oluşturulmuştur. Çalışmamız sonucunda *M. dogramacii* ve *M.* guentheri'nin birbirine en çok benzeyen türler olduğu, *M. mystacinus*'un bu türlere yakın olduğu ve *M. hartingi*'nin bu türlerden ayırt edici şekilde farklı olduğu görülmüştür.

**Anahtar Sözcükler:** *Microtus*, Cricetidae, taksonomi, Türkiye, morfometrik

## Introduction

The genus *Microtus* represents one of the best known cases of rapid mammalian radiation resulting in about 65 extant species distributed throughout the Palearctic and Nearctic regions (Chaline et al., 1999; Jaarola et al., 2004). Turkey is

rich in terms of the number of species, including some endemic ones. Several *Microtus* species were described as new species from Anatolia, including *Microtus guentheri* from Kahramanmaraş by Danford and Alston (1880), *Microtus majori* and *Microtus roberti* from Trabzon by Thomas (1906), *Microtus pontius* from Bayburt by Miller (1908), *Microtus lydius* from İzmir by Blackler (1916), *Microtus dogramacii* from Amasya by Kefelioğlu and Kryštufek (1999), *M anatolicus* from Konya by Kryštufek and Kefelioğlu (2001), and *Microtus elbeyli* from Kilis by Yiğit et al., (2016). Kryštufek and Vohralík (2005) gave distribution records in Anatolia of nine species of the genus *Microtus,* which they included in the subfamily Arvicolinae of the family Muridae. These species were divided into three main groups, including pine voles (subgenus *Terricola*), and *arvalis* and *socialis* groups (subgenus *Microtus*). *M. subterraneus, M. daghestanicus,* and *M. majori* were assigned to the pine vole group, *M. rossiaemeridionalis,* and *M. obscurus* were recorded in the *arvalis* group, and *M. guentheri, M. anatolicus, M. dogramacii,* and *M. socialis* were recorded in the *socialis* vole group. Musser and Carleton (2005) recorded the following *Microtus* species from Turkey: *M. anatolicus, M. arvalis*, *M. daghestanicus*, *M. dogramacii*, *Microtus guentheri*, *M. socialis*, *M. subterraneus*, *M. majori*, and *M. levis*. Selçuk et al., (2018) carried out a geometric morphometrics analysis of the skulls of *M. anatolicus, M. dogramacii, M. guentheri,* and *M. levis*. However, the taxonomic status and distribution of *Microtus* species in Asia Minor is still under discussion. The aim of this study is to determine some diagnostic morphological characteristics of *Microtus* species in the Central Anatolia region of Turkey.

**Material and Methods**

This study was based on 209 specimens belong to genus *Microtus* obtained between September 2003 and June 2010 in the Central Anatolia region of Turkey. The study area is shown on the map in Figure 1. Specimens were obtained from live traps and snap traps. Following Thomas (1905), in addition to weight and four standard external measurements, 15 cranial and dental measurements were taken from each specimen using Vernier calipers. Specimens were preserved as conventional museum specimens following Mursaloğlu (1965). Fusion of the basisphenoid sutures, degree of tooth wear, fur colour, and field notes were used to define adulthood in species. Only adult specimens were used for morphological comparison and evaluation.

Determination of pelage coloration was made according to Ridgway (1886) and bacula was prepared according to Lidicker (1968). The occlusal patterns of molar teeth were evaluated following Niethammer and Krapp (1982). Variance analyses between the males and females specimens were made according to Parker (1979). Morphometric data were evaluated using the Rectangular Matrix prepared in the NTSYS-pc package program (ver 2.2). UPGMA (Unweighted Pair Group Method Using Aritmetric Averages), Maximum Parsimony and Maximum Likelihood trees were constructed using morphometric data used to determine morphological similarity of the species to each other (Swofford, 2002). In statistical analyses, $p \leq 0.05$ was used as the significance level. For each measurement minimum and maximum values, arithmetic mean and standard deviations were calculated. The specimens are deposited at the Bolu Abant İzzet Baysal University, Agriculture and Natural Sciences Faculty, Wildlife Ecology and Management Department.

**Results**

Four species of *Microtus* were recorded in the study area, including *M. dogramacii*, *M. guentheri*, *M. hartingi*, and *M. mystacinus*. The distribution of *Microtus* specimens in the study area is shown in Figure 1.

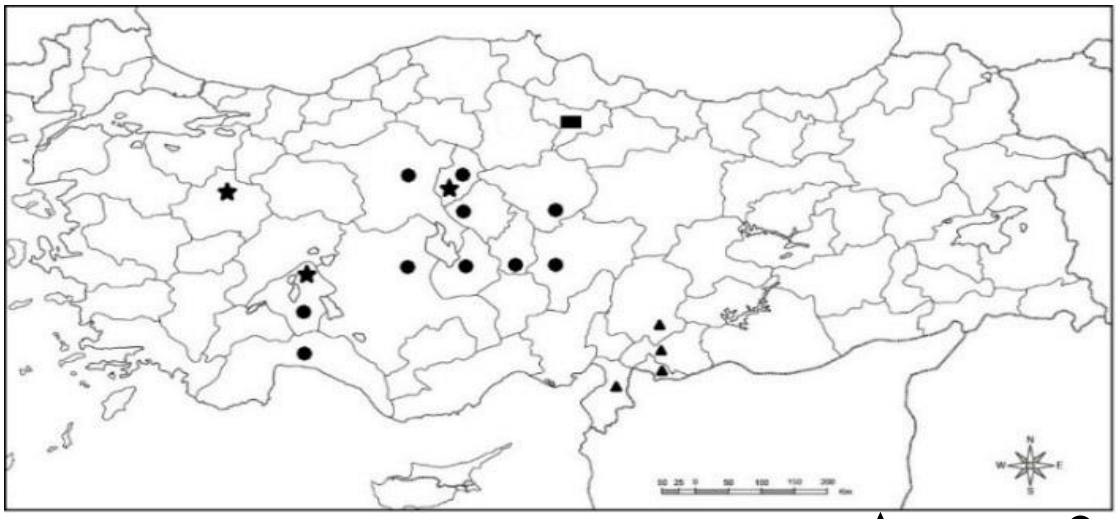

Figure 1. The *Microtus* specimens' localities in Central Anatolia (■: *M. dogramacii,* ▲: *M. guentheri,* ●: *M. hartingi,* ★ : *M. mystacinus*)

***Microtus dogramacii* Kefelioğlu and Kryštufek, 1999**

The baculum length is 2.47-2.51 mm and the proximal width is 1.12-1.14 mm. The proximal part of the baculum is triangular and has a rounded tip. The shaft narrows proximally to distally, slightly expanding near the distal part to form a knob shaped tip. The dorsal surface of the proximal part has a small pit and pronounced cupping ventrally with ridges at its borders (Figure 2). Skull has a light concavity from frontal to anterior at the interorbital region (Figure 3).

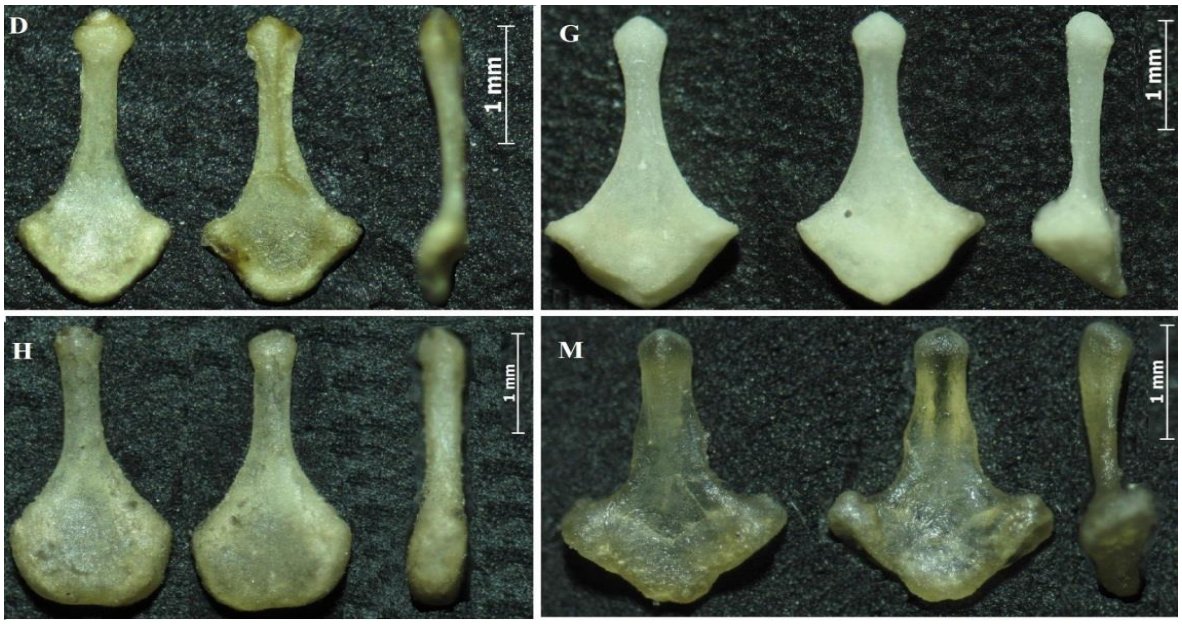


**Figure 2.** Bacula of *Microtus* species (D: *M. dogramacii,* G: *M. guentheri*, H: *M. hartingi*, M: *M. mystacinus,* from left to right: dorsal view, ventral view, and lateral view).

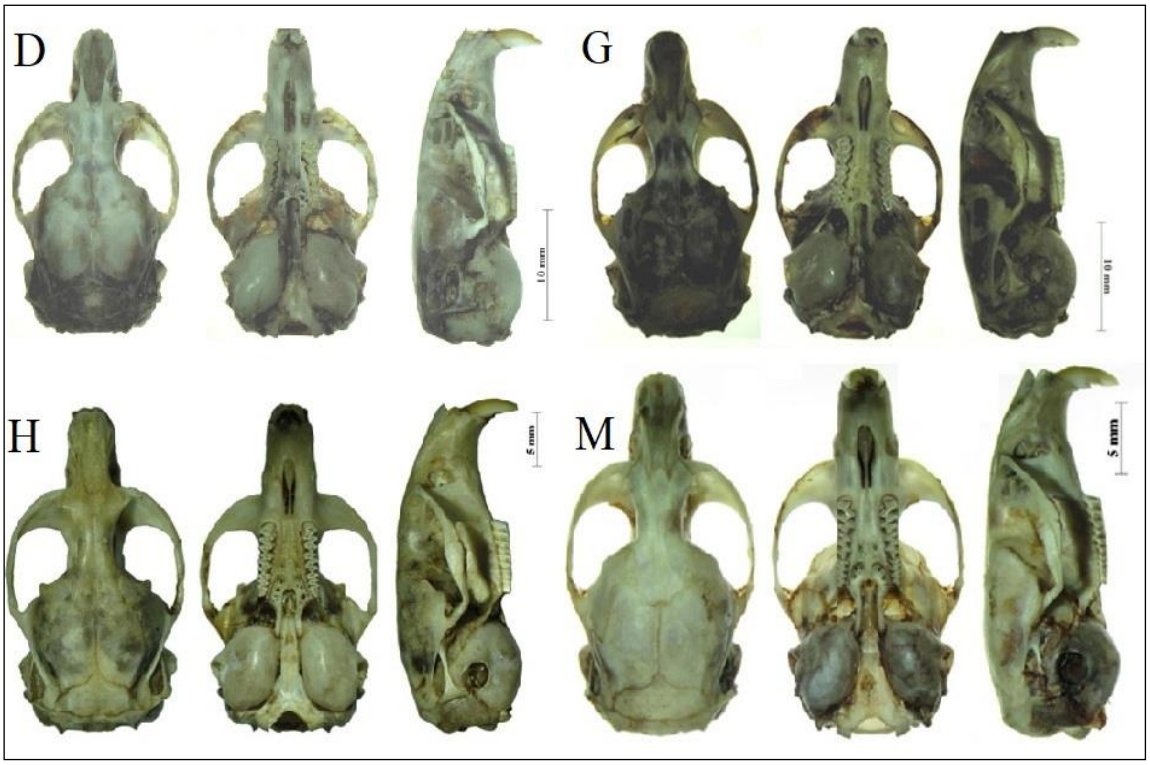


**Figure 3.** Skulls of *Microtus* species (D: *M. dogramacii,* G: *M. guentheri*, H: *M. hartingi*, M: *M. mystacinus,* from left to right: dorsal view, ventral view, and right lateral view)

In adult specimens, dorsal pelage coloration from the tip of the nose to the root of the tail is pale reddish light brown and the ventral colour is pale off-white. Tooth morphotypes of *Microtus* spp. and their percentages in our specimens are shown in Table 1.

**Table 1.** Morphotypes and percentages of $M^3$ and $M^2$ of *Microtus* species ($M^3$: third upper molar, $M^2$: second upper molar)

| Species | Morphotypes | | | | | |
|---|---|---|---|---|---|---|
| | $M^3$ | | | | $M^2$ | |
| | Duplicata | Normal | Simplex | Complex | Agrestis | Non-Agrestis |
| *M. dogramacii* | 67% n= 4 | 33% n= 2 | 0 | 0 | 100% n = 6 | 0 |
| *M. guentheri* | 26% n= 14 | 69% n= 37 | 3.7% n= 2 | 0 | 92% n = 49 | 8% n = 4 |
| *M. hartingi* | 27% n= 60 | 70% n= 151 | 1% n= 3 | 2% n= 4 | 98% n= 215 | 2% n = 3 |
| *M. mystacinus* | 48% n= 13 | 52% n= 14 | 0 | 0 | 96% n = 26 | 4% n = 1 |

External and skull measurements and body weights of adults of *M. dogramacii* are recorded in Table 2.

***Microtus guentheri* (Danford and Alston, 1880)**

The baculum length is 2.69-2.75 mm, the proximal width is 1.29-1.48 mm and the distal width is 0.42-0.44 mm. The proximal part of the baculum is triangular and there is a depression in the median line along the length of the baculum. The tip of the distal part is pointed and looks like a knob (Figure 2). The dorsal profile of the skull is convex (Figure 3). In adult specimens, dorsal pelage coloration from the nose tip to the tail root is pale blackish brown. The ventral colour varies from pale greyish off white to slightly whitish grey. The dorsal and ventral colours merge gradually on the flanks. External and skull measurements and body weights of adult *Microtus guentheri* are recorded in Table 3.

**Table 2.** Summary data of weight (g), external and cranial measurements (mm) of adult *Microtus dogramacii* (♂♂, ♀♀) (n: number of individuals, r: range, m: mean, ± Sd: standard deviation)

| Measurements | n | r | m | ± Sd |
|---|---|---|---|---|
| Head and body length | 3 | 101-118 | 109.6 | 8.50 |
| Total length | 3 | 130-141 | 136.6 | 5.85 |
| Tail length | 3 | 23-29 | 27 | 3.46 |
| Hind foot length | 3 | 16-19 | 17.6 | 1.52 |
| Ear length | 3 | 12-14 | 13.3 | 1.15 |
| Weight | 3 | 39-46 | 41.6 | 3.78 |
| Occipitonasal length | 2 | 25.8-27.2 | 26.5 | 0.96 |
| Condylobasal length | 2 | 25.5-26.9 | 26.2 | 0.97 |
| Palatal foramina length | 3 | 4.3-4.5 | 4.4 | 0.13 |
| Palatal length | 3 | 12.6-13.5 | 13.1 | 0.49 |
| Basilar length | 2 | 22.7-23.9 | 23.3 | 0.84 |
| Nasal breadth | 3 | 2.7-3.0 | 2.8 | 0.15 |
| Interorbital breadth | 3 | 3.7-4.1 | 3.9 | 0.20 |
| Braincase breadth | 2 | 7.3-7.8 | 7.5 | 0.31 |
| Zygomatic breadth | 3 | 15.0-16.1 | 15.5 | 0.52 |
| Nasal length | 3 | 7-7.5 | 7.3 | 0.30 |
| Diastema length | 3 | 7.2-8.1 | 7.6 | 0.43 |
| Height of braincase | 2 | 10.2-10.5 | 10.3 | 0.24 |
| Maxillary toothrow length | 3 | 5.6-6.1 | 5.8 | 0.22 |
| Mandible length | 3 | 15.2-16.2 | 15.7 | 0.53 |
| Mandible toothrow length | 3 | 5.6-6.1 | 5.8 | 0.26 |
| Tail length /Head and body length (%) | 3 | 19.4-28.7 | 24.8 | 4.79 |

Six specimens were examined from Amasya: Boyalı village (4♂♂, 2♀♀)

**Table 3.** Summary data of weight (g), external and cranial measurements (mm) of adult *Microtus guentheri* (♂♂, ♀♀) (n: number of individuals, r: range, m: mean, ±Sd: standard deviation)

| Measurements | n | r | m | ±Sd |
|---|---|---|---|---|
| Head and body length | 58 | 95-130 | 106.1 | 7.12 |
| Total length | 58 | 116-165 | 134.6 | 9.40 |
| Tail length | 58 | 21-39 | 28.5 | 3.15 |
| Hind foot length | 58 | 13-20 | 18.6 | 1.09 |
| Ear length | 58 | 11-19 | 13.8 | 1.22 |
| Weight | 57 | 25-52.5 | 33.4 | 5.74 |
| Occipitonasal length | 46 | 25.1-29.5 | 27.1 | 1.05 |
| Condylobasal length | 47 | 24.8-29.6 | 26.8 | 1.06 |
| Palatal foramina length | 58 | 3.9-5.5 | 4.5 | 0.27 |
| Palatal length | 59 | 12.8-18 | 13.8 | 0.76 |
| Basilar length | 46 | 22.5-26 | 24.0 | 0.92 |
| Nasal breadth | 57 | 2.4-3.4 | 2.9 | 0.21 |
| Interorbital breadth | 57 | 3.4-4 | 3.7 | 0.13 |
| Braincase breadth | 45 | 5.2-7.2 | 6.1 | 0.44 |
| Zygomatic breadth | 53 | 14.2-18.1 | 15.4 | 0.79 |
| Nasal length | 57 | 6.2-9.1 | 7.3 | 0.56 |
| Diastema length | 59 | 7.2-8.7 | 7.9 | 0.34 |
| Height of braincase | 45 | 9.8-11.6 | 10.6 | 0.37 |
| Maxillary toothrow length | 60 | 5.4-6.7 | 6.1 | 0.26 |
| Mandible length | 61 | 15.1-18.4 | 16.5 | 0.66 |
| Mandible toothrow length | 61 | 5.3-6.6 | 5.9 | 0.23 |
| Tail length /Head and body length (%) | 58 | 21.6-32 | 26.8 | 2.33 |

Sixty-three specimens examined from Gaziantep: Islahiye (24♂♂, 3♀♀), Hatay: Hassa (5♂♂, 2♀♀), Kahramanmaraş: Türkoğlu (13♂♂, 6♀♀) and Kilis: Musabeyli (10♂♂).

***Microtus hartingi* Barrett-Hamilton, 1903**

The baculum length is 2.76-2.85 mm and the proximal width is 1.01-1.4 mm. The proximal part of the baculum is oar-shaped and in a number of specimens, there is a slight recess in the middle of this part. From the proximal end to the middle of the baculum, the width decreases continuously and then it extends parallel to the distal tip. The distal tip is slightly pointed and knob-like. (Figure 2). The dorsal profile of the skull is slightly domed (Figure 3). In adult specimens dorsal pelage coloration from the nose tip to the tail root is pale light brown. The ventral colour varies from light grey to yellowish off-white. The dorsal and ventral colours merge gradually on the flanks. External and skull measurements and body weights of adult *Microtus hartingi* are recorded in Table 4. Owing to statistical differences, measurements of the sexes are given separately (Table 4).

**Table 4.** Summary data of weight (g), external and cranial measurements (mm) of adult *Microtus hartingi* (♂♂, ♀♀) (n: number of individuals, r: range, m: mean, ±Sd: standard deviation)

| | Male | | | | Female | | | |
|---|---|---|---|---|---|---|---|---|
| Measurements | n | r | m | ±Sd | n | r | m | ±Sd |
| Head and body length | 100 | 95-135 | 112 | 8.98 | 63 | 96-135 | 115.9 | 9.20 |
| Total length | 100 | 125-170 | 144.5 | 11.42 | 63 | 128-169 | 147.8 | 10.09 |
| Tail length | 100 | 24-45 | 31.9 | 4.40 | 63 | 25-43 | 31.9 | 3.79 |
| Hind foot length | 100 | 20-24 | 21.2 | 0.84 | 63 | 18-23 | 20.8 | 1.05 |
| Ear length | 98 | 11-16 | 13.6 | 1.27 | 62 | 10-17 | 13.2 | 1.58 |
| Weight | 99 | 28-67 | 43.6 | 9.11 | 63 | 23.5-89 | 48.6 | 12.90 |
| Occipitonasal length | 80 | 22-31.3 | 28.5 | 1.58 | 54 | 25.4-31.5 | 28.9 | 1.34 |
| Condylobasal length | 80 | 22-31 | 28.1 | 1.51 | 55 | 24.9-31 | 28.4 | 1.42 |
| Palatal foramina length | 103 | 3.7-10.1 | 4.9 | 0.63 | 72 | 4-6.2 | 4.9 | 0.43 |
| Palatal length | 103 | 11.1-16 | 14.4 | 0.78 | 72 | 12-16.6 | 14.4 | 0.87 |
| Basilar length | 80 | 19.4-27.8 | 25.1 | 1.39 | 55 | 22-27.5 | 25.4 | 1.28 |
| Nasal breadth | 104 | 2.7-3.9 | 3.2 | 0.22 | 71 | 2.8-5.5 | 3.3 | 0.33 |
| Interorbital breadth | 97 | 3.5-4.1 | 3.7 | 0.13 | 71 | 3.4-4 | 3.7 | 0.12 |
| Braincase breadth | 88 | 5.5-13.4 | 8.8 | 3.06 | 61 | 5.2-13.5 | 8.7 | 3.16 |
| Zygomatic breadth | 92 | 13.1-19.7 | 16.5 | 1.12 | 62 | 13.8-18.8 | 16.9 | 1.00 |
| Nasal length | 103 | 6.6-9.3 | 8.1 | 0.56 | 71 | 6.6-9.4 | 8 | 0.59 |
| Diastema length | 103 | 6-9.6 | 8.4 | 0.56 | 72 | 6.9-9.6 | 8.4 | 0.58 |
| Height of braincase | 76 | 9.9-13 | 11.4 | 0.50 | 49 | 9.5-12.2 | 11.4 | 0.45 |
| Maxillary toothrow length | 105 | 5.7-7.3 | 6.4 | 0.35 | 73 | 5.7-7.1 | 6.4 | 0.35 |
| Mandible length | 104 | 13.8-19.2 | 17.4 | 0.99 | 73 | 13.4-19.8 | 17.4 | 1.14 |
| Mandible toothrow length | 107 | 5.6-7.4 | 6.3 | 0.39 | 73 | 5.7-7.1 | 6.4 | 0.33 |
| Tail length/Head and body length (%) | 100 | 21-38.4 | 28.4 | 3.63 | 63 | 20.8-38.3 | 27.6 | 3.88 |

One hundred and thirteen specimens were examined from Aksaray: Güzelyurt (7♂♂, 4♀♀), Yapılcan village (1♀), Ankara: Akyurt (1♂, 1♀), Gölbaşı (3♀♀, 1♀), Kalecik (5♀♀), Antalya: Korkuteli (4♂♂, 4♀♀), Isparta: Süleyman Demirel University Campus (1♀, 2♂♂), Eğirdir (1♀), Keçiborlu (4♀♀), Kırıkkale: Delice (2♂♂), Tatlıcak village (4♂♂), Yahşihan: Kırıkkale University Campus (2♂♂, 1♀), Aşağımahmutlar village (1♀), Kırşehir: Kaman (2♂♂), Hamit (4♂♂, 10♀♀), Akçaağıl (2♂♂), Kayseri: Yeşilhisar (1♂, 1♀), Konya: Bozkır (1♂), Cihanbeyli (1♀), Nevşehir: Ürgüp (33♂♂, 7♀♀) and Yozgat: Sorgun (1♂, 1♀).

In this study, pelage coloration, cranial and external measurements and baculum morphology of the *Microtus guentheri* specimens from the type locality were found to be clearly different compared to specimens from the Central Anatolia region. *M. lydius* described by Blackler (1916) from İzmir and *Microtus lydius ankaraensis* described by

Yiğit and Çolak (2002) from Ankara are similar to our specimens from Central Anatolia in terms of external and cranial morphometric measurements and baculum morphology. Moreover, *M. lydius* from İzmir with its longer tail and greyish-white abdomen has been demonstrated to be different from *M. guentheri*. However, *M. lydius* was accepted as a junior synonym of *M. guentheri* by Musser and Carleton (2005) and Kryštufek et al., (2010).

In this study it was concluded that the specimens from Central Anatolia are *M. hartingi*, the type locality for which is Larissa, Greece and which was described before *M. lydius*. Based on the priority rule, it was concluded that the name of the species should be *M. hartingi*. Kryštufek et al., (2009) constructed a phylogeny of social voles, using a sequence analysis of the mitochondrial cytochrome b gene. This analysis showed that *M. guentheri* was composed of two allopatric sibling species, and *M. guentheri* was reported to have been distributed in Syria and Israel, whereas *M. hartingi* was distributed in the Balkans and Anatolia. This study also reported *M. guentheri* (west) samples from Anatolia, including Kırşehir, Antalya, Isparta, and from the Balkans, including Macedonia and Greece. In our study species differentiation was made by using external and skull measurements, pelage coloration and baculum morphology (Figure 3). Osborn's (1962) specimens of *M. hartingi* were similar to specimens from Thrace and Anatolia, so that these specimens may also belong to *M. hartingi.*

***Microtus mystacinus* (de Filippe, 1865)**

The baculum length is 2.45-3.0 mm and the proximal width is 1.53-1.86 mm. The proximal part of the baculum is triangular. The distal tip is somewhat rounded. The shaft is expanded laterally from about the middle of the shaft to the distal tip (Figure 2). Processes of interparietal bones extend through the interorbital region to back parts of nasals (Figure 3). In adults, dorsal pelage coloration from the nose tip to the tail root is light greyish brown and the ventral colour is light yellowish off-white or greyish off-white. The dorsal and ventral colours merge gradually on the flanks. External and skull measurements and body weights of adult *Microtus mystacinus* are recorded in Table 5. Owing to statistical differences, measurements for each sex are given separately (Table 5).

Twenty-seven specimens were examined from Isparta: Aksu, Yılanlı village (8♂♂, 7♀♀), Kırıkkale, Sulakyurt (2♂♂), Bahşılı (8♂♂, 1♀) and Kütahya: Bölcek village (1♂).

**Table 5.** Summary data of weight (g), external and cranial measurements (mm) of adult *Microtus mystacinus* (♂♂, ♀♀) (n: number of individuals, r: range, m: mean, ±Sd: standard deviation)

| | Male | | | | Female | | | |
|---|---|---|---|---|---|---|---|---|
| Measurements | n | r | m | ±Sd | n | r | m | ±Sd |
| Head and body length | 14 | 96-121 | 109 | 7.92 | 8 | 100-121 | 108 | 6.85 |
| Total length | 14 | 139-165 | 153.5 | 9.21 | 8 | 142-165 | 151.3 | 8.23 |
| Tail length | 14 | 39-49 | 44.5 | 3.08 | 8 | 39-47 | 43.3 | 2.72 |
| Hind foot length | 14 | 18-20 | 19 | 0.83 | 8 | 17-20 | 19 | 1.07 |
| Ear length | 14 | 9-17 | 13 | 1.84 | 8 | 9-16 | 13.5 | 2.07 |
| Weight | 14 | 25.5-46.5 | 34 | 6.32 | 8 | 25-35 | 29.6 | 3.53 |
| Occipitonasal length | 15 | 24.7-28.1 | 25.7 | 0.89 | 7 | 23.9-25.3 | 24.7 | 0.43 |
| Condylobasal length | 15 | 24.2-27.1 | 25.3 | 0.78 | 7 | 23.5-25.5 | 24.5 | 0.68 |
| Palatal foramina length | 16 | 3.9-4.8 | 4.2 | 0.28 | 8 | 3.9-4.6 | 4.3 | 0.25 |
| Palatal length | 17 | 12.1-13.4 | 12.7 | 0.34 | 8 | 12.1-12.9 | 12.6 | 0.27 |
| Basilar length | 15 | 21.1-24.3 | 22.4 | 0.76 | 7 | 20.7-22.1 | 21.6 | 0.49 |
| Nasal breadth | 17 | 2.5-3.1 | 2.9 | 0.15 | 8 | 2.6-3 | 2.8 | 0.20 |
| Interorbital breadth | 17 | 3.3-3.8 | 3.6 | 0.12 | 8 | 3.2-3.8 | 3.5 | 0.21 |
| Braincase breadth | 15 | 5.7-11.9 | 9.4 | 2.31 | 7 | 6.1-10.9 | 7.6 | 2.10 |
| Zygomatic breadth | 17 | 13.7-15.4 | 14.3 | 0.55 | 7 | 13.6-14.6 | 14 | 0.33 |
| Nasal length | 17 | 6.4-8.2 | 7.2 | 0.59 | 8 | 6.5-7.3 | 6.9 | 0.33 |
| Diastema length | 17 | 6.7-7.7 | 7.1 | 0.28 | 8 | 6.6-7.2 | 6.9 | 0.20 |
| Height of braincase | 15 | 8.2-10.5 | 9.7 | 0.55 | 7 | 9.4-9.8 | 9.6 | 0.13 |
| Maxillary toothrow length | 17 | 5.5-6.1 | 5.7 | 0.15 | 8 | 5.5-6 | 5.7 | 0.14 |
| Mandible length | 17 | 14.4-16.1 | 15.2 | 0.47 | 8 | 14.7-15.9 | 15.2 | 0.38 |
| Mandible toothrow length | 17 | 5.4-6 | 5.7 | 0.17 | 8 | 5.5-5.9 | 5.7 | 0.15 |
| Tail length /Head and body length (%) | 14 | 36.3-48.0 | 40.9 | 3.63 | 8 | 36.3-45 | 40.2 | 2.86 |

**Discussion**

Numerous studies have been conducted in Anatolia to solve the complexity of the taxonomic status of the genus *Microtus,* resulting in a variety of often conflicting arrangements, e.g. [(Misonne (1957), Lehmann (1966), Çağlar (1967), Felten et al., (1971) Kurtonur (1975), Doğramacı (1989), Kefelioğlu (1995), Yiğit and Çolak (1998), Yiğit and Çolak (2002), Jaarola et al., (2004), Yiğit et al., (2006), Gözütok and Albayrak (2009), Yorulmaz et al., (2013), Arslan and Zima, 2014; Markov et al., 2014)]. This study has clarified the taxonomic status of *Microtus* spp, in Central Anatolia and provided diagnostic morphological characteristics to distinguish between the four identified species.

*M. dogramacii* was recorded from Aksaray and Konya except in the type locality (Jaarola et al., 2004). In this study, it was noted that *M. dogramacii* is similar to *M. guentheri* and the bacula of both are smaller than those of other species and have different morphologies. There are no differences between the external and cranial measurements and given by Kefelioğlu and Kryštufek (1999) and Kryštufek and Vohralík (2005) and those of our specimens from the type locality. However, Kryštufek and Vohralík (2005) recorded the Duplicata morphotype in $M^3$ and the Agrestis morphotype in $M^2$ in half of their specimens, whereas our specimens have Duplicata and Normal morphotypes in $M^3$, and all have the Agrestis morphotype in $M^2$.

Neuhäuser (1936) noted that *M. g. guentheri* was distributed in the provinces of Kahramanmaraş, Mersin, Ankara, Yozgat, Tokat, İstanbul, Sinop, Samsun, and *M. g. lydius* was recorded from the provinces of İzmir, Muğla, Afyon, Isparta, Kütahya, and Eskişehir. Ellerman (1948) recorded *M. g. guentheri* from Kahramanmaraş and *M. g. lydius* from İzmir. Ellerman and Morrison-Scott (1951) accepted *M. lydius* as a subspecies of *M. guentheri* in their revision of mammals of the Palaearctic region.

Yiğit and Çolak (2002) recorded *M. guentheri* from Kahramanmaraş, Hatay, Gaziantep (Nizip), Kilis and *M. lydius* from İzmir and Aydın. *M. lydius ankaraensis* was described as a new subspecies from Ankara, and distribution records of this subspecies were given from Ankara, Denizli, Kütahya, Eskisehir, Afyon, Burdur, Beysehir, Ankara, Kırıkkale and Kırşehir. *M. guentheri* differs from the other *Microtus* species from Central Anatolia in that it has the smallest ratio of tail length to head and body length and its baculum has a different shape. *M. guentheri* was described by Danford and Alston (1880) from Kahramanmaraş and hence our topotype specimens belong to the nominate subspecies *M. g. guentheri,* which was confirmed by comparison skull measurements, and non-metric characters (tail features, pelage coloration and number of plantar tubercles on the hind feet). No differences were found when compared with the data for *M. g. guentheri* given by Kefelioğlu (1995), Çolak et al., (1997) and Yiğit and Çolak (2002). The specimens taken from Kahramanmaraş and Mersin by Danford and Alston (1880) and Kefelioğlu (1995) were also included in *M. g. guentheri*. Our *M. guentheri* specimens from Kahramanmaraş, Gaziantep, Kilis, and Hatay differ in terms of smaller body size, pelage coloration, and baculum morphology from *M. hartingi* in Central Anatolia. *Microtus guentheri* has often been recorded by other authors from Central Anatolia, but these specimens may actually belong to *M. hartingi.*

*M. l. ankaraensis* was described by Yiğit and Çolak (2002) and differs from *M. g. guentheri*. *M. lydius* is actually a junior synonym of *M. hartingi.* Therefore *M. l. ankaraensis* should also belong to this species, which is confirmed from distributional records, baculum morphology and external and skull morphometric data.

The data for *M. g. hartingi* given by Ondrias (1965) are consistent with our samples and these specimens were found to be on average larger than ours. There are no differences between the measurements of our specimens of *M. g. guentheri* and those of Ondrias (1965). Similarly, there are also no differences between the external and skull morphometric measurements and baculum morphology of our *M. guentheri* specimens and those of Çolak et al., (1997). Yiğit et al., (2012) examined the phenotypic characteristics of the Guentheri group. These authors recorded that the non-agrestis morphotype was found in $M^2$ in all specimens of *M. guentheri* from Bulgaria, Turkish Thrace and Western Anatolia and Normal, Simplex, Duplicata and Complex morphotypes were found in $M^3$. Consequently, they recorded that specimens from Bulgaria and Turkish Thrace could not be identified as *M. guentheri* and specimens from Western Anatolia should be *M. lydius* (=*M. hartingi*). In our *M. guentheri* specimens 92% (n=49) have the non-Agrestis morphotype for $M^2$ and 8% (n=4) have Agrestis morphotypes. For $M^3$, 26% (n=14) have the Duplicata morphotype, 69% (n=37) the Normal morphotype, and 3.7% (n=2) the Simplex morphotype in our *M. guentheri* specimens. In contrast, $M^3$ in our *M. hartingi* specimens from the Middle Anatolia Region have 27% (n=60) Duplicata morphotype, 70% (n=151) Normal morphotype, 1% (n=3) Simplex morphotypes and 2% (n=4) Complex morphotype.

In addition, the baculum morphology of *M. lydius,* reported by Yiğit et al., (2012), is similar to that of our *M. hartingi* specimens.

Markov et al., (2014) analysed 32 qualitative non-metric skull characters in *M. lydius lydius*, *M. l. ankarensis*, *M. guentheri guentheri,* and *M. hartingi strandzensis* from Anatolia and the Balkan Peninsula. Based on these skull characters, the highest degree of similarity was found between *M. l. lydius* and *M. l. ankarensis. M. g. guentheri* was closer to *M. h. strandzensis* than to *M. l. lydius* and *M. l. ankarensis*. In our study, *M. hartingi* and *M. guentheri* are easily distinguishable based on statistical analysis of external and skull morphometric measurements.

Although Selçuk et al., (2018) noted that *M. guentheri* has the largest skull, condylobasal length and occipitonasal length were larger in our specimens of *M. hartingi.*

Our *M. mystacinus* specimens differ from other *Microtus* species in that they have the longest tails (36-48% of the head and body length), six plantar tubercles on the hind foot, and the interparietal processes extend through the interorbital region to posterior of the nasals. Synonyms of *M. mystacinus* include *M. subarvalis* Meyer, Orlov & Skholl, 1969, *M. epiroticus* Ondrias, 1966, *M. rossiaemeridionalis* Ognev, 1924, and *M. levis* Miller, 1908 (Mahmoudi et al., 2014; 2017).

No differences were observed between the data for *M. epiroticus* given by Kefelioğlu (1995) and our data for *M. mystacinus.* However, the measurements given by other researchers could not be compared for *M. arvalis* and *M. levis,* because these specimens were not reliably identified using karyological data. There are no differences between the external and skull measurements and diagnostic characters of our specimens of *M. levis* and those of Ognev (1964), Mažeikytė et al., (1999), Massing (1999), Kefelioğlu, (1995).

Selçuk et al., (2018) reported that there was no sexual dimorphism in *M. levis* based on multivariate analysis of external and skull morphometrics, but inter-sexual differences were found in our specimens from skull measurements. In our study based on average values, *M. mystacinus* has the shortest conylobasal length and occipitonasal length. *M. hartingi* has the longest hind foot length and *M. mystacinus* has the longest tail length in our study (Figure 4; Figure 5).

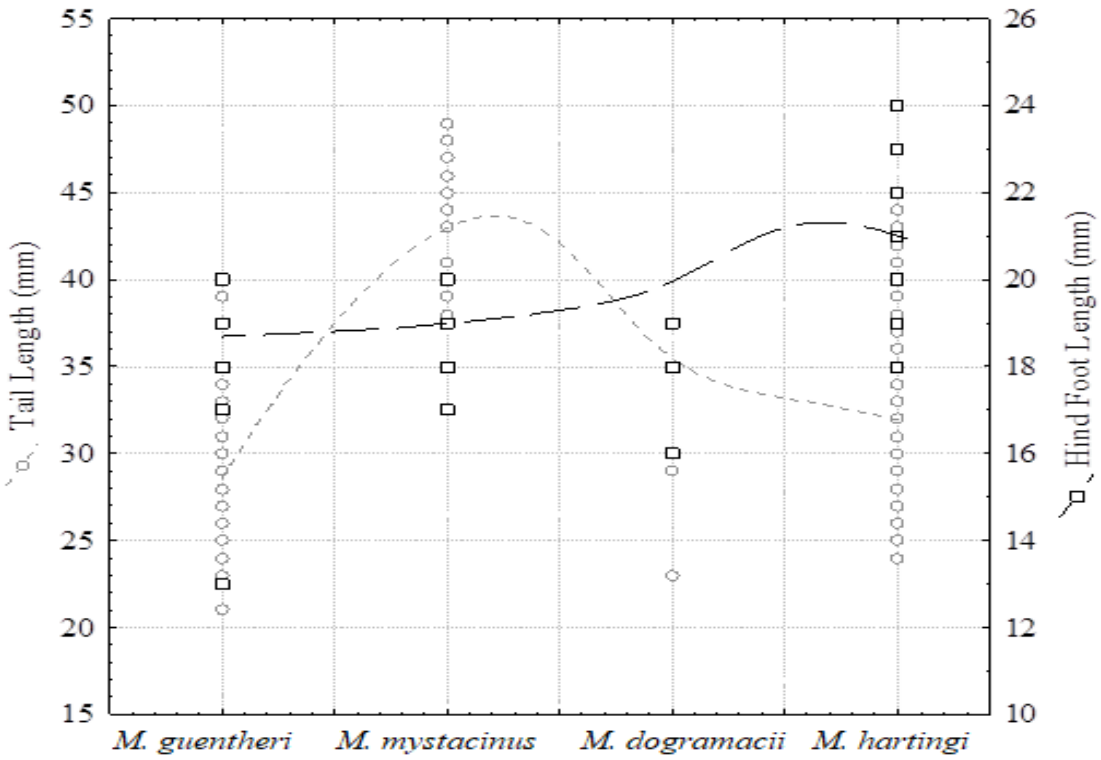


**Figure 4**. Scatterplot of hind foot length against tail length (in mm) of *Microtus* species from Central Anatolia

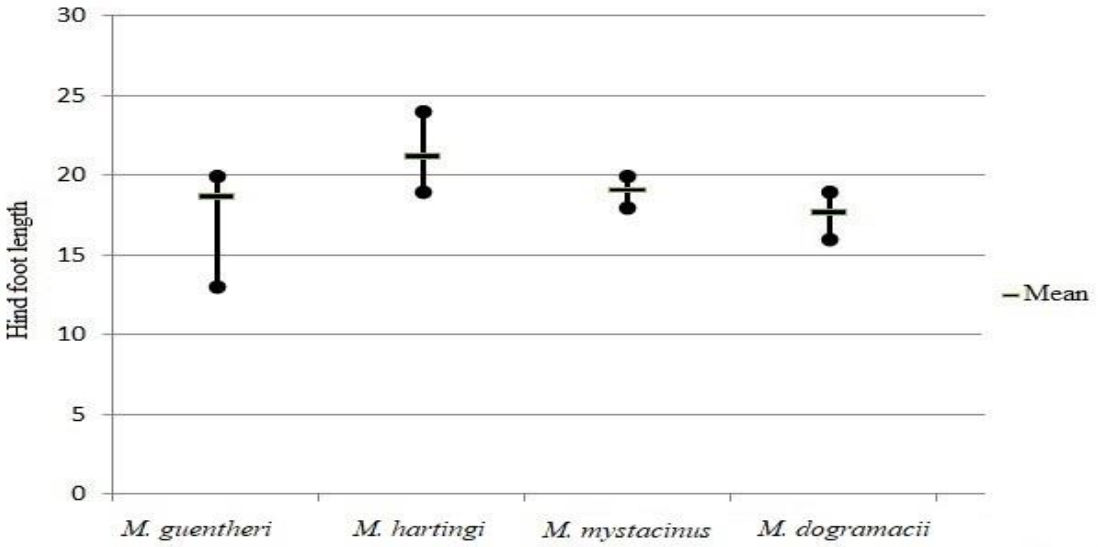


**Figure 5.** Comparison of hind foot lengths (in mm) of *Microtus* species from Central Anatolia

The UPGMA trees constructed for each sex, using skull and external measurements of specimens belonging to the genus *Microtus* from the Central Anatolia Region of Turkey, are shown in Figure 6.

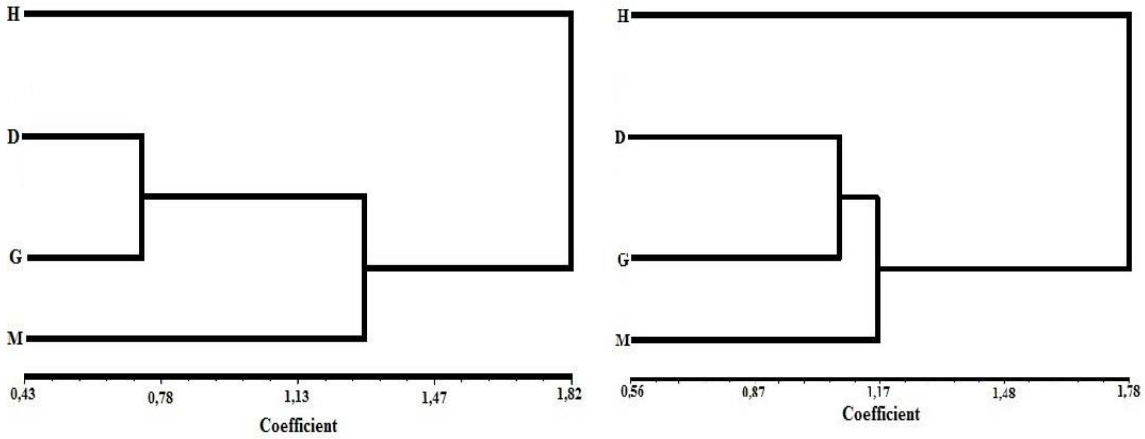


**Figure 6.** UPGMA tree constructed using morphometric characteristics of male specimens (left) and female specimens (right) of *Microtus* species (H: *M. hartingi*, G: *M. guentheri*, M: *M. mystacinus*, D: *M. dogramacii*)
Each sex shows a similar pattern of morphological similarity between species, with *M. dogramacii* and *M. guentheri* being the most similar, *M. mystacinus* is the sister species to these and *M. hartingi* is the most distinctively different.

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