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The Morphological Analysis of *Mus domesticus* and *Mus macedonicus* (Mammalia: Rodentia) in Turkey

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Abstract: We examined 529 specimens of *Mus domesticus* and *Mus macedonicus* from Turkey, in terms of their morphological, bacular, and phallic aspects. The zygomatic index (ZI) varied from 0.32 to 0.47 in *M. domesticus*, and 0.60 to 0.85 in *M. macedonicus*. The head plus body length/tail length (H+B/T) index varied from 0.87 to 1.05 in *M. domesticus*, and 1.08 to 1.78 in *M. macedonicus*. The zygomatic plate is straight or convex in *M. domesticus* and *M. macedonicus*. The ventral wing of the parietal is generally tortuous in *M. domesticus* and is protruding or straight in *M. macedonicus*. The anterolabial cusp on M^1 is missing or indistinct in *M. domesticus* and is forwardly prominent in *M. macedonicus*. Characteristics of the baculum and phallus did not differentiate *M. domesticus* from *M. macedonicus*.

Key Words: *Mus domesticus*, *Mus macedonicus*, ZI index, H+B/T index, morphology, Turkey

Türkiye'de Yayılış Gösteren *Mus domesticus* and *Mus macedonicus* (Mammalia: Rodentia)'un Morfolojik Analizi

Özet: Türkiye'deki değişik yerlerden toplanan *Mus domesticus* and *Mus macedonicus*'a ait 529 örnek morfolojik, bakulum ve fallus özellikleri bakımından incelendi. ZI indeksi *M. domesticus*'ta 0.32 - 0.47 and *M. macedonicus*'ta ise 0.60 - 0.85 olarak belirlendi. H+B/T indeksi *M. domesticus*'ta 0.87 - 1.05 and *M. macedonicus*'ta ise 1.08 - 1.78 arasında değiştiği saptandı. Zygomatic plaka *M. domesticus* ve *M. macedonicus*'ta düz ya da dış bükeydir. Parietal kemiklerin ventral kenarları *M. domesticus*'ta zıkzak, *M. macedonicus*'ta ise düz ya da öne doğru girinti yapmış biçimdedir. M^1'de anterolabial mine adacığı *M. domesticus*'ta kayıp olmuş ya da az belirgin *M. macedonicus*'ta ise belirgindir. Bakulum ve phallus özellikleri *M. domesticus*'u *M. macedonicus*'tan ayırmadı.

Anahtar Sözcükler: *Mus domesticus*, *Mus macedonicus*, ZI indeksi, H+B/T indeksi, Morfoloji, Türkiye

Introduction

The taxonomy and distribution of the genus *Mus* have been investigated in Europe, and specifically in Bulgaria, Greece, and the Caucasus. *Mus spretus* Lataste, 1883, *Mus spicilegus* Petényi, 1882, *Mus macedonicus* Petrov and Ružíć, 1982, *Mus musculus* L., 1758, and *Mus domesticus* Rutty, 1772 were recorded from Europe (Marshall and Sage, 1981; Thaler et al. 1981a; Thaler et al. 1981b; Sage, 1981; Orsini et al. 1983; Bonhomme et al. 1983; Auffray et al. 1990; Musser and Carleton, 1993; Macholán and Zima, 1994). Ondrias (1966) recorded the presence of *M. m. domesticus*, *M. m. brevirostris*, *M. m. praetextus*, and *M. m. spicilegus* from Greece and the Aegean islands. Kock (1974) stated that *M. m. spicilegus* and *M. m. brevirostris* were distributed in the Aegean islands. Vohralík and Sofianidou (1992) referred to specimens in Greece of the genus *Mus*, such as *M. abbotti* and *M. domesticus*. Kock et al. (1994) recorded *M. m. praetextus* from north-east Syria. Mezhzherin et al. (1998) examined Caucasian specimens of the genus *Mus*, and identified *M. musculus*, *M. domesticus*, and *M. praetextus*. According to Harrison and Bates (1991), and Musser and Carleton (1993), *M. macedonicus* lives in Turkey, but they did not record

specimens. Kryštufek and Macholán (1998) recorded this species in Turkey from Burdur, Konya, and Manisa. Özkan (1999), and Özkan and Kryštufek (1999) found *M. domesticus* in Bozcaada and *M. macedonicus* in Gökçeada, in Turkey. According to Kryštufek and Vohralík (2001), *M. musculus* and *M. macedonicus* are distributed in Turkey, and the genus *Mus* is in need of thorough revision in Turkey. Gözcelioğlu et al. (2005) reported *M. domesticus* from Ankara, Bolu, Düzce, Zonguldak, and Bartin, and *M. macedonicus* from Ankara and Bolu, all in Turkey, based on morphological, karyological, and morphometric characters, as well as 2 alleles of isocitrate dehydrogenase. The studies above show that the morphological aspects, distribution, and taxonomy of the genus *Mus* in Turkey are not known in detail.

The aim of the present study was to contribute to the knowledge of the morphology, taxonomy, and distribution of *M. domesticus* and *M. macedonicus* in Turkey.

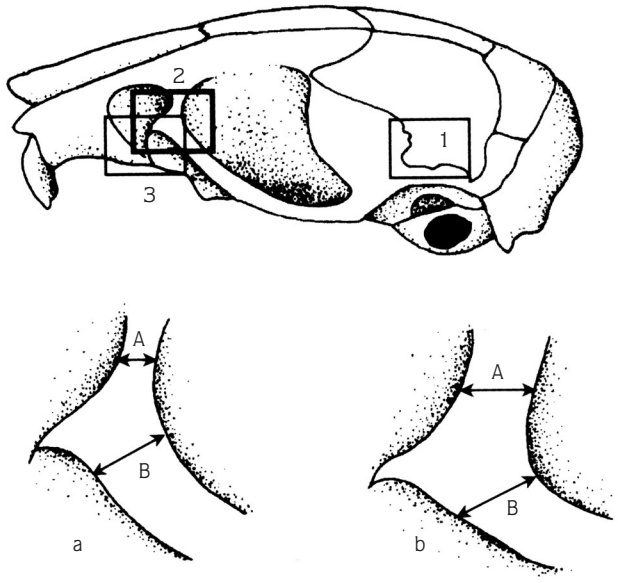

Figure 1. Some morphological characteristics of the skull of a *Mus* specimen. 1. The *sutura squamalis*. 2. ZI=A/B. 3. The zygomatic plate. a. *M. domesticus*. b. *M. macedonicus*.

Materials and Methods

The present study examined 529 specimens of *Mus* collected from Turkey. Identification of all specimens followed Marshall and Sage (1981), Orsini et al. (1983), Marshall (1986), Auffray et al. (1990), Macholán (1996), and Mezhzherin et al. (1998), based on distinguishing characteristics such as coloration, zygomatic index (ZI) (ZI: width of the anterior part of the malar process/width of upper part of the zygomatic arch), the index of head plus body length/tail length (H+B/T), the zygomatic plate, the occlusal surface of M_1, and the *sutura squamalis* (the shape of the ventral wing of the parietals) (Figure 1). Preparation of the phalli and bacula followed Lidicker (1968). Taxonomic terminology for the genus *Mus* is based on Auffray et al. (1990) and Macholán (1996). Coloration, zygomatic plate, the occlusal surface of M_1, relative tail length, ZI, the *sutura squamalis*, and baculum and phallus were examined in each specimen of *M. domesticus* and *M. macedonicus*.

Results

Mus domesticus Rutty, 1772

1772. *Mus domesticus* Rutty, Essay Nat. Hist. Co. Dublin, 1: 281. Dublin, Ireland.

Habitat: Specimens of *M. domesticus* were collected from houses, gardens, and cultivated and bushy areas.

Distribution: We collected 168 specimens from 33 locations in Asiatic Turkey (Figure 2).

General Characters: The H+B/T index is ≤ 1. There is a variation in coloration in *M. domesticus* populations in Turkey. Coloration in the dorsal aspect varies from black to pale brown. Specimens from the Black Sea region are darker than those from other localities, and the dorsal coloration is dark, dark brown, reddish brown, pale brown, and pale reddish brown. The 30 skins we examined from Ankara were lighter in colour than those from northern Anatolia. Dorsal coloration in the Ankara specimens is reddish brown, pale grey, and pale brown. The pelage becomes lighter towards the flanks. The line of demarcation along the flanks is indistinct. The belly is darkish grey, reddish, grey, and reddish grey; the tips of the hairs are white, and there are white spots of diverse shapes on the belly (n = 5). The ears are internally and externally sparsely covered with tiny dark brown hairs. The dorsal surface of the tail is dark or dark brown in some specimens and its ventral surface is moderately light in colour. The soles are naked and dark, or dark brown in coloration. The hind and forefeet are dorsally covered with dark hairs.

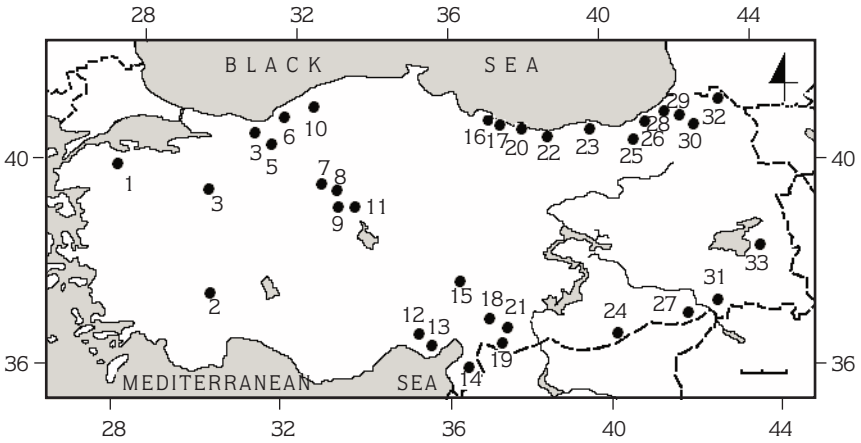

Figure 2. Locations of *M. domesticus* in Turkey (see text for designation numbers).

Skull: The skull is slender. In the zygomatic plate, there is a variation in *M. domesticus*; it is smooth or rounded (Table 1). We determined individual variations in the *sutura squamalis*. The ventral wing of the parietal is tortuous or smooth (Table 1). In the ZI, the anterior part of the malar process is narrower than the width of the upper part of the zygomatic arch; therefore, the ZI is generally ≤ 0.50.

Dentition: The incisor notches in *M. domesticus* were of 3 types (Table 2). We determined 2 different types of occlusal surfaces of M_1 in populations of *M. domesticus* (Figure 3). The anterolabial cusp on M^1 is missing or indistinct (Figure 4). The lingual outline of M^2 is straight or convex (Figure 4).

Baculum and Phallus: We examined both bacula inside the phallus and those removed from the phallus. The baculum has distal and proximal parts. There are 2 lateral processes on the tip of the distal baculum (Figure 5). The proximal baculum is composed of a base and shaft. The shaft is tapered and moderately curved, and its tip is bulbous. The base is laterally broadened, and its tip is pointed. There is a concavity, both ventrally and dorsally.

Table 2. Occurrence of the incisor notch in the squamalis of *Mus domesticus* and *Mus macedonicus*

Species	No notch	One notch	Two notches
M. domesticus	25	27	7
M. macedonicus	56	159	21

Specimens examined totalled 168 (numbers in brackets are the location designation numbers on the map in Figure 2): Gönen 2 (1), Burdur 2 (2), Bozüyük 2 (3), Düzce 5 (4), Abant 10 (5), Zonguldak 10 (6), Sarayköy 9 (7), Ankara 20 (8), Gölbaşı 3 (9), Bartın 7 (10), Bala 11 (11), Tarsus 2 (12), Yumurtalık 1 (13), Reyhanlı 2 (14), Göksun 1 (15), Kurupelit 6 (16), Gelemen 2 (17), Türkoğlu 2 (18), Kilis 2 (19), Fatsa 6 (20), Karkamış 1 (21), Kesap 6 (22), Ceylanpınar 4 (23), İkizdere 16 (24), Ardeşen 4 (25), Şırnak 1 (26), Hopa 5 (27), Borçka 10 (28), Ardanuç 2 (29), Posof 3 (30), Nusaybin 5 (31), Van 2 (32), and Yomra 4 (33).

Table 1. Patterns of anterior edges in the zygomatic plate and the *sutura squamalis* in *Mus domesticus* and *Mus macedonicus*

Species	Zygomatic Plate			Sutura squamalis		
	Straight	Convex	Concave	Protruding	Straight	Tortuous
M. domesticus	90	74	1	-	61	103
M. macedonicus	220	126	-	176	170	-

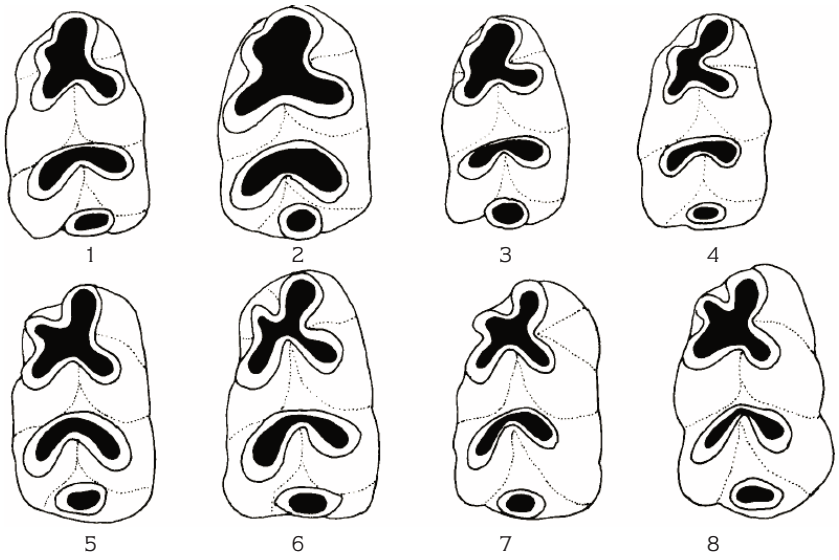

Figure 3. Occlusal area of M_1 in lower left of *M. domesticus* and *M. macedonicus* in Turkey.
M. domesticus: 1. Ankara; 2. Bala; 3. Ankara; 4. Yomra.
M. macedonicus: 5. Büyükkarıştıran; 6. Edirne; 7. Nusaybin; 8. Beyşehir.

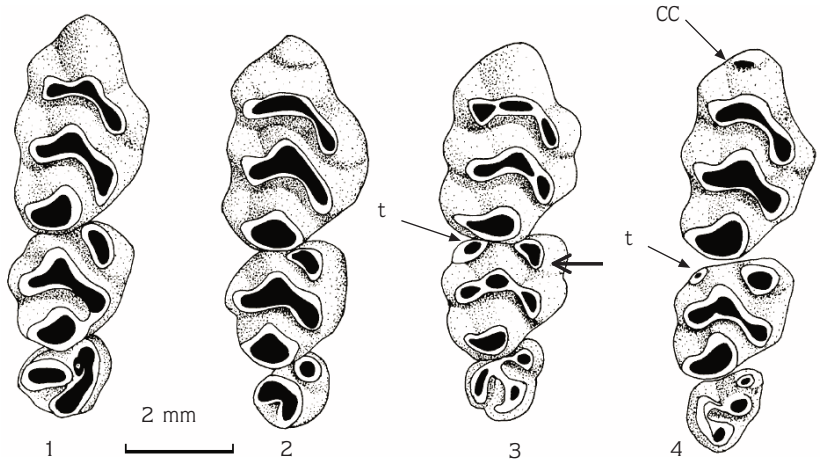

Figure 4. Right upper tooth row of *Mus* in Turkey. *M. macedonicus* (1, 3, 4) and *M. domesticus* (2.). CC shows small mesial cusp in M^1. Arrow displays concavity in M^2. Çorum (1, 4), Bala (2), and Şırnak (3).

Mus macedonicus Petrov and Ružíć, 1982

1982. *Mus macedonicus* Petrov and Ružíć. Drugi simpozijum o fauni SR Srbije-Zbornik, Beograd, 175. Valandovo, Macedonia, Yugoslavia.

Habitat: We collected *M. macedonicus* at the edges of cultivated areas, crop areas, bushy areas, and near roads and houses.

Distribution: Localities of the specimens examined are shown in Figure 6.

General Characters: H+B/T index is ≥ 1. There is a considerable individual variation in coloration in specimens from various localities in Turkey. The dorsal coloration in specimens from Kayseri and Kırşehir varies from dark brown to pale light brown with yellowish

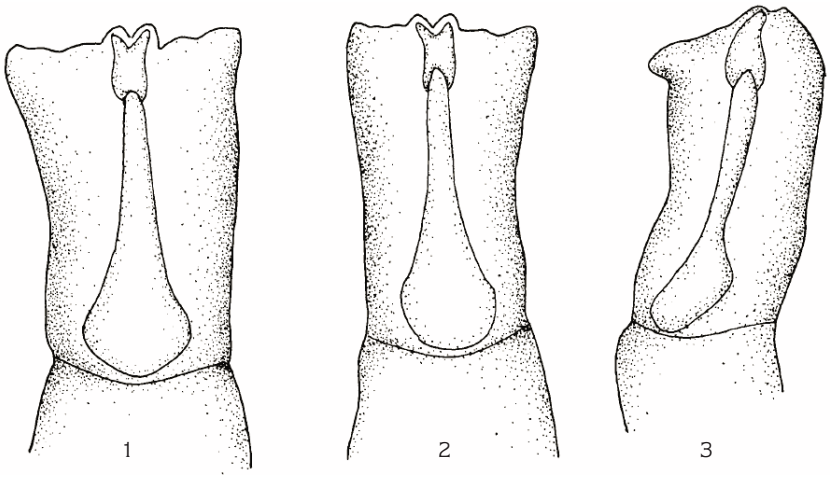

Figure 5. Phallus of *M. domesticus* from İkizdere; dorsal (1), ventral (2), and, lateral (3) views.

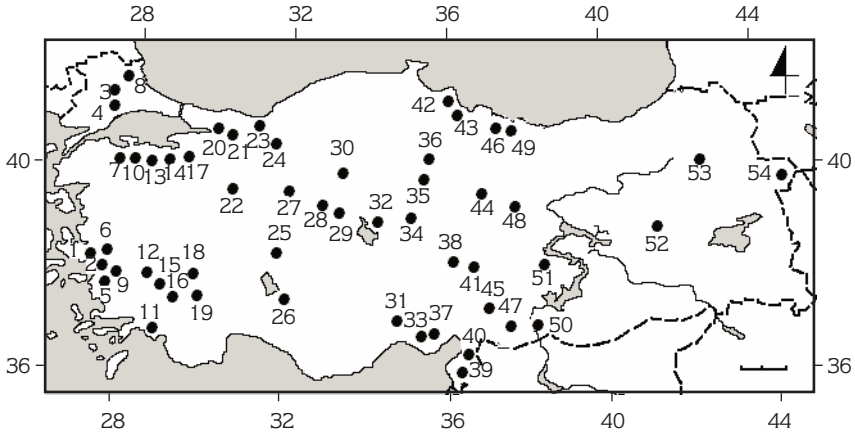

Figure 6. Locations of *M. macedonicus* in Turkey (see text for designation numbers).

tinges, becoming lighter ventrally. The median line is markedly darker. Five specimens from Çorum and Tokat have dark and reddish dorsal fur. Specimens from İzmir and Dalaman showed a different coloration pattern in comparison to specimens from the other localities. Their dorsal coloration was dark-reddish brown. We observed reddish-pale belly coloration in specimens from Denizli and Bursa. In specimens from southeast Turkey, we observed dark, reddish, and pale brown coloration with reddish tinges dorsally. The pelage becomes lighter towards the flanks. The line of demarcation along the flanks is distinct. The belly is whitish grey, pure white, yellowish white, and reddish white. The ears are internally and externally sparsely covered with tiny white hairs. The dorsal surface of the tail is dark brown, and its ventral surface is moderately light in colour. The soles are naked and brown. The hind and forefeet are dorsally covered with white hairs.

Skull: The skull is slender. The zygomatic plate is smooth or rounded (Table 1). There is a concavity in the middle of the zygomatic plate in Mersin and Balıkesir specimens. The *sutura squamalis* seems to be a distinguishing character for *M. macedonicus*; it is smoothed or protruded anteriorly (Table 1). The ventral wing of the parietal in an Adana specimen with a ZI of 0.66, in 2 Bursa specimens, and in a Samsun specimen with a ZI of 0.86 is tortuous in shape. The width of the

upper part of the zygomatic arch is narrower than the anterior part of the malar process; therefore, the ZI is generally ≥ 0.50.

Dentition: This species generally has an incisor notch (Table 3). We determined T3 in M^2 in some Çorum and Şırnak specimens, and a CC cusp in M^1 in Çorum specimens. There is moderately individual variation in the occlusal surface of M^1 in *M. macedonicus*. Generally, the anterolabial cusp on M^1 is forwardly prominent (Figure 3) in contrast to that of *M. domesticus*. The lingual outline of M^2 is straight or convexly rounded (Figure 4).

Baculum and Phallus: We examined both bacula inside the phallus and those removed from the phallus. The baculum has distal and proximal parts. There are 2 lateral processes on the tip of the distal baculum (Figure 5). The proximal baculum is composed of a base and shaft. The shaft is tapered and moderately curved, and its tip is bulbous. The basal part is laterally broadened and its tip is pointed. There is a concavity, both ventrally and dorsally.

Specimens examined totalled 361 (numbers in brackets are the location designation numbers on the map in Figure 6): Bayındır 4 (1), Ovacık 17 (2), Pınarhısar 10 (3), Büyükkarıştıran 10 (4), Ödemiş 2 (5), Kemalpaşa 4 (6), Gönen 3 (7), Demirköy 9 (8), Karagöl 1 (9), Manyas 3 (10), Dalaman 8 (11), Dazkırı 3 (12), Karacabey 2 (13), Muratdere 6 (14), Buldan 5 (15), Acıpayam 16 (16), *Mus*tafakemalpaşa 16 (17), Akşehir 8 (18), Beyşehir 10 (19), Kocaeli 1 (20), Adapazarı 2 (21), Gökçekısık 1 (22), Düzce 3 (23), Abant 1 (24), Konya 6 (25), Burdur 9 (25), Bala 1 (27), Gölbaşı 8 (28), 30 km W of Ankara 5 (29), Sarayköy 8 (30), Kılbasan 2 (31), Şereflikoçhisar 5 (32), Sebil 2 (33), Kırşehir 4 (34), Sungurlu 27 (35), Çorum 10 (36), Tarsus 6 (37), Bünyan 2 (38), Madenboyu 3 (39), Reyhanlı 4 (40), Pınarbaşı 5 (41), Kurupelit 7 (42), Gelemen 11 (43), Tokat 10 (44), Türkoğlu 24 (45), Fatsa 8 (46), Nizip 4 (47), Hafik 8 (48), Efirli 7 (49), Karkamış 2 (50), Malatya 1 (51), Muş 12 (52), Horasan 2 (53), and Aralık 2 (54)

Discussion

According to Harrison and Bates (1991), the bellies of some *M. musculus* specimens are snow white, while in other specimens they are greyish white. The demarcation line on the flanks is distinct, and the tail is bicoloured. The colour description given by Harrison and Bates (1991) for *M. musculus* is consistent with that of *M. macedonicus*. Boursot et al. (1993) stated that the belly coloration in *M. m. domesticus* is pure white (as in some desert forms; *preatextus*), and the dorsal coloration is light sandy yellow. In this study, we did not find any *M. domesticus* specimens with pure white bellies. According to Mezhzherin et al. (1998), the belly is dark in *M.*

Table 3. A comparison of ZI and H+B/T, on average, of the genus *Mus*.

Species	Country or locality	ZI	H+B/T	References
M. d. domesticus	Greece	0.48		Orsini et al. (1983)
M. d. domesticus	Israel	0.52	1.03	Orsini et al. (1983)
M. domesticus	Ankara, Bolu, Zonguldak, Bartin	0.25-0.46	0.73-1	Gözcelioğlu et al. (2005)
M. domesticus	Turkey	0.32-0.47	0.87-1.05	Present study
M. m. domesticus	Greece, Bulgaria	0.47	1.07	Orsini et al. (1983)
M. spicilegus	Greece	0.74		Orsini et al. (1983)
M. spicilegus	N. Bulgaria	0.80		Orsini et al. (1983)
M. spicilegus	N. Austria	0.78		Orsini et al. (1983)
M. *m. musculus*	N. Bulgaria	0.48		Orsini et al. (1983)
M. *m. musculus*	Austria	0.45		Orsini et al. (1983)
M. macedonicus	Ankara, Bolu	0.50-0.80	0.76-1.46	Gözcelioğlu et al. (2005)
M. macedonicus	Turkey	0.60-0.85	1.08-1.78	Present study
M."spretoides"	Israel	0.80	1.28	Auffray et al. (1990)
M."spretoides"	Bulgaria, Greece	0.74	1.49	Auffray et al. (1990)

domesticus and white in *M. praetextus*, and there is a white spot on the belly in many *Mus* specimens from the Caucasus. The belly is generally darkish in *M. domesticus*, and white and greyish white in *M. macedonicus* in Turkey. We also determined a white spot on the bellies of some *Mus* specimens, especially those from the Black Sea region.

We compared the ZI values given by Orsini et al. (1983) and Auffray et al. (1990) for some *Mus* species with those measurements in the present study (Table 3). The ZI values given by Orsini et al. (1983) for *M. m. domesticus*, *M. spicilegus*, and *M. m. musculus* are different from those in this study. Our ZI values ranged from 0.32 to 0.47, on average, in 10 populations of *M. domesticus* (especially smaller in the population from the Black Sea region), and it varied from 0.60 to 0.85, on average, in 14 populations of *M. macedonicus*. The ZI values of 27 Turkish Thrace specimens were 0.85 on average, moderately larger than those of *M. "spretoides"* from Greece and Bulgaria, and similar to those found in Israel populations. The ZI value for *M. domesticus* in Turkey was smaller than that of *M. m. domesticus* from Israel, but similar to that of *M. m. domesticus* from Bulgaria and Greece. Harrison and Bates (1991) stated that the anterior part of the molar process in *M. musculus* is narrower than the upper part of the zygomatic arches. This description is consistent with Turkish *M. domesticus* specimens. Furthermore, the ZI described by Harrison and Bates (1991) for *M. macedonicus* is consistent with that of *M. macedonicus* in Turkey. Gözcelioğlu et al. (2005) gave the ZI values for *M. domesticus* from Ankara, Bolu, Zonguldak, and Bartin as 0.25-0.46, and for *M. macedonicus* from Ankara and Bolu as 0.50-0.80. These values are consistent with those in the present study.

Auffray et al. (1990) determined H+B/T values for *M. m. domesticus* and *M. spretoides* from Bulgaria, Greece, and Israel (Table 3). Table 3 shows that the H+B/T value of *M. domesticus* in Turkey is consistent with that of *M. m. domesticus* in Israel, Bulgaria, and Greece, and the H+B/T value of *M. macedonicus* in Turkey is lower than that of *M. spretoides*. Mezhzherin et al. (1998) stated that the mean tail length was 64.4 mm in *M. musculus*, 81.4 mm in *M. domesticus*, and 75 mm in *M. praetexus* from the Caucasus. In the present study, we determined that the tail length was 76.9-79.3 mm in *M. domesticus* from the Black Sea region, close to the Caucasus, and 64-73.2 mm in *M. macedonicus* in Turkey. The tail length of *M. domesticus* from the Caucasus is consistent with that of *M. domesticus* from the Black Sea region. According to Gözcelioğlu et al. (2005), the H+B/T value of *M. domesticus* from Ankara, Bolu, Zonguldak, and Bartin is 0.73-1.0, and *M. macedonicus* from Ankara and Bolu is 0.76-1.46. The H+B/T values given by Gözcelioğlu et al. (2005) for both species seem to be less than in the present study.

According to Ondrias (1966), in *M. musculus* specimens from Greece, the upper incisor teeth have a distinct notch directly behind the cutting edge of each incisor. In contrast to Ondrias' findings (1966), we determined 1-2 notches in some specimens of the genus *Mus* in Turkey, while the notch was absent in other specimens. As in the description given by Macholán (1996), we also found specimens with smooth upper incisors in both *M. domesticus* and *M. macedonicus* in Turkey. The occlusal morphology of M^1 in *M. m. domesticus* described by Orsini et al. (1983) was compared with that in *M. domesticus* in Turkey, and a similarity was found between the 2 populations. Harrison and Bates (1991) described t3 on M^2 of *M. musculus*. We observed this character in some *M. macedonicus* specimens. We determined that the occlusal area of M^1 and the upper tooth row observed by Macholán (1996) for *M. domesticus* from Europe were similar to those of *M. domesticus* from Turkey. While Macholán (1996) described the CC cusp on the occlusal area of M^1 in *M. musculus*, we found the CC cusp in both *M. macedonicus* (n = 25) and *M. domesticus* (n = 20). We also determined the CC cusp on the lingual side of M^2 in 2 *M. domesticus* specimens from Düzce and Ankara. Mezhzherin et al. (1998) stated that the occlusal area of M^1 was an important morphological characteristic. Their description of the occlusal area of M^1 for *M. domesticus* in the Caucasus is consistent with that of *M. domesticus* in Turkey. In addition, the occlusal area of M^1 determined for *M. praetextus* is similar to that for *M. macedonicus* in Turkey. Kryštufek and Macholán (1998) recorded *M. macedonicus* from Bardakçı (Manisa), Burdur, Suludere (Burdur), and Karabulut (Konya), and reported that the lingual side of M^2 was convex in *M. macedonicus*. We found that the lingual side of M^2 was convex in both *M. macedonicus* and *M. domesticus* in Turkey, in agreement with Kryštufek and Macholán (1998); however, there was a concavity in the lingual side of M^1 and M^2 in *M. macedonicus* specimens from Şırnak.

The zygomatic plate illustrated by Kock et al. (1994) for *M. m. praetextus* from northeast Syria is similar to that of specimens from southeast Turkey. According to Macholán (1996), in *M. domesticus*, the anterior margin of the zygomatic plate is straight and vertical, or concave, and the suture on the ventral wing of the parietal follows a tortuous course. As in Macholán (1996), we found variations in the anterior margin of the zygomatic plate in *M. domesticus* in Turkey. These findings given by Macholán (1996) for the anterior margin of the zygomatic plate and the ventral wing of the parietal are consistent with those of *M. domesticus* in Turkey. On the basis of the zygomatic plate, Mezhzherin et al. (1998) distinguished *M. musculus*, *M. domesticus*, and M. praetexus in the Caucasus. According to Mezhzherin et al. (1998), the zygomatic plate in *M. praetextus* is round, protruding angled in *M. musculus*, and round or triangular in *M. domesticus*. We determined that the zygomatic plate was round and smooth in *M. domesticus*, and round, straight, and angled in *M. macedonicus* in Turkey. We also examined the zygomatic plates of 4 *M. praetexus* specimens from Syria, and found results similar to those given by Mezhzherin et al. (1998). We noted variations in the zygomatic plate in both *M. domesticus* and *M. macedonicus*.

This study focussed mainly on the morphology and distribution of *M. domesticus* and *M. macedonicus*. Following this, it is necessary to study the geographical and genetic variations of these 2 species, especially *M. domesticus*.

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