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Taxonomic status of the genus *Spermophilus* (Mammalia: Rodentia) in Turkey and Iran with description of a new species

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Abstract

We report a new species of *Spermophilus* (Rodentia: Sciuridae), here designated as *S. torosensis* **sp. nov.**, distributed in the Taurus Mountains in southern Anatolia, Turkey. A total of 161 specimens of the genus *Spermophilus* from Turkey and Iran were analyzed for their morphological, morphometric, and karyological characteristics. Uni- and multi-variate statistical analyses of morphologic data for 95 adult specimens yielded 4 distinct groups. Taxonomic evaluations classified the specimens into 4 species *Spermophilus citellus, S. xanthopymnus, S. fulvus* and *S. torosensis* **sp. nov.** Morphometrics, coat coloration, a brush-shaped tail, and a NFa value of 72 are diagnostic characters that distinguish *S. torosensis* **sp. nov.** from the other species. In Turkey, *S. torosensis* **sp. nov.** was found in 6 locations. The karyotype of *S. fulvus also* is described for the first time as 2n= 36, NFa= 70 and NFa= 66; new karyotypic data is reported for *S. xanthoprymnus* from Iran and Turkey.

Key words: *Spermophilus citellus, Spermophilus xanthoprymnus, Spermophilus fulvus, Spermophilus torosensis* **sp. nov.**, sousliks, karyology, morphology, nonmetric characters, Turkey, Iran

Introduction

The genus *Spermophilus* is one of the most diverse and widely distributed representatives of the family Sciuridae, containing 41 species that are distributed through western North America, eastern Europe, and northern and central Asia (Herron *et al*. 2004, Wilson and Reeder 2005). In Turkey and Iran, three species are known to occur. *S. citellus* (Linnaeus, 1766) and *S. xanthoprymnus* (Bennett, 1835) are found in Turkey and *S. fulvus* (Lichtenstein, 1823) occurs in Iran; all are currently recognized species (Wilson and Reeder 2005).

Previous studies have utilized morphologic, karyologic, and genic data in investigating the systematics and taxonomy of species in the region. Mursaloğlu (1964, 1965) based on morphological and biometrical data reported *Spermophilus* (*Citellus) citellus thracius* (Mursaloğlu, 1964) from the European part of Turkey (Thrace) and *S. c. gelengius* (Mursaloğlu, 1965) (Central Anatolia) and *S. c. xanthoprymnus* (Eastern Anatolia) and *S. c. xanthoprymnus* from the Asiatic part of Turkey. Based on karyological differences, Zima and Kral (1984) recognized *S. citellus* as a taxon separate from *S. xanthoprymnus*. This difference was further

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established by Doğramacı *et al*. (1994) who reported that *S. citellus* from Thrace has 2n= 40 chromosomes and *S. xanthoprymnus* from Anatolia has 2n= 42 chromosomes.

In 2002, Özkurt *et al*. (2002) described a new karyological form the Taurus Mountains in southern Anatolia. Although the diploid number was the same as that for *S. citellus* populations from Thrace (2n= 40), the fundamental number of autosomal arms was different for the two populations: NFa= 66 or 74 for the population in Thrace, and NFa= 72 for the population in the Taurus Mountains (Doğramacı *et al*. 1994, Özkurt *et al*. 2002). Genic data (postalbumin region in SDS-PAGE) provided additional evidence supporting the distinctiveness of specimens from this region compared with *S. citellus, S. xanthoprymnus, and S. fulvus* (Çolak and Özkurt 2002, Çolak *et al*. 2006). However, until more evidence was available, Krystufek and Vohralik (2005) accepted the 2n= 40 form in the Taurus Mountains as *S. xanthoprymnus*.

More recently, however, Yiğit *et al*. (2005) using 16S rRNA, the mtDNA sequence and morphologic data from three karyotypic populations (2n= 40 from Thrace, the new karyotype of 2n= 40 from the Taurus Mountains, and 2n= 42 from Anatolia), proposed that the 2n= 40 population from southern Anatolia is similar to the 2n= 40 population in Thrace, and thus should be recognized as *S. citellus*. Later, Yiğit *et al*. (2006) recorded 2n=42, NFa=78, and NF=82 from Doğubeyazıt (Ağrı) and extended the distribution of *S. xanthoprymnus* to the region of eastern Anatolia bordering Iran.

One purpose of our study was to evaluate morphological, ecological, molecular and field observation data in order to better understand the systematics and taxonomy of *Spermophilus* in the region and to evaluate the taxonomic status of *Spermophilus* in the Taurus Mountains. Second, we wanted to investigate the evolutionary history of *Spermophilus* in Anatolia and nearby regions based on previous studies and our new data.

Materials and methods

A total of 161 specimens of the genus *Spermophilus* were analyzed based on karyological, morphological, and morphometric characteristics (Table 1, Figure 1). For additional reference, all recorded localities of *S. citellus, S. xanthoprymnus* and *S. torosensis* **sp. nov.** are indicated in Figure 1 to show current distributions of these three species in Turkey.

The measurements for morphometric analyses were taken from 95 adult specimens with unbroken skulls using a caliper with accuracy of 0.1 mm and a micrometer attached to a binocular microscope with an accuracy of 0.01 mm. The age class of animals was determined according to Krystufek and Vohralik (2005). Twenty-four cranial and dental measurements (Table 2) were utilized to determine the extent of morphometric variation and to discriminate among species of *Spermophilus*. Male and female samples were combined in the analyses due to the lack of sexual differences ($P>0.05$).

Measurements (in mm; except weight, in g) are: (1) total length, (2) tail length, (3) hind foot length, (4) ear length, (5) weight, (6) zygomatic width, (7) interorbital constriction, (8) condylobasal length, (9) occipitonasal length, (10) basal length, (11) nasal length, (12) nasal width, (13) facial length of skull, (14) braincase length, (15) mastoid width, (16) width of braincase with bullae, (17) occipital width, (18) diastema length, (19) palatal length, (20) incisive foramen length, (21) tympanic bulla length, (22) mandible length, (23) upper molar alveolar length, (24) lower molar alveolar length.

Univariate and multivariate statistical analyses of the external, cranial, and dental measurement data were performed using SYNTAX-pc, NTSYS-pc, and SPSS.

Karyotypes were prepared from bone marrow following the method of Ford and Hamerton (1956). Between 25 and 30 metaphase cells that were well-stained and whose chromosomes were separate and distinct were examined for each animal. The diploid number of chromosomes (2n), the number of autosomal arms (NFa), the total number of chromosomal arms (NF) and sex chromosomes were determined from photos of the metaphase plates according to centromere position. Specimens that were karyotyped and used in the analyses are indicated by an asterisk in Table 1.

TABLE 1. Localities and sample sizes (n) of male (m), female (f) and sex unknown (u) specimens examined.

Locality	Province	n (f)	n (m)	n (u)
Spermophilus torosensis **sp. nov.** (Özkurt, Sözen, Yiğit & Çolak, 2007) (n= 24)				
Salamut Plateau, Çaltalılıçukur village, Akseki	Antalya	8	3	
Kocaalan Plateau, Balcılar, Hadim	Konya	3	2	
Seyiricik Plateau, Ishaklı, Alanya	Antalya	1	2	
Kızılçayır Plateau, Payalılar, Alanya	Antalya	2	-	
14 km W of Mut	Mersin	2	-	
Alacabel mountain pass, Akseki	Antalya	-	1	
S. citellus (Lichtenstein, 1823) (n= 20)				
15 km W of Edirne	Edirne	9	5	
Evciler village, Pınarhisar, Kırklareli	Kırklareli	2	4	
S. xanthoprymnus (Bennett, 1835) (n= 96)				
3 km E of Doğubeyazıt	Ağrı	4	-	
14 km S of Gölbaşı	Ankara	4	3	
20 km SE of Polatlı	Ankara	15	8	2
Sarız	Kayseri	1*	1	
Ereğli	Konya	1*	1*	
25 km E and 30 km W of Erzincan, Tercan	Erzincan	9	6	1
Doğançayır, Eskişehir	Eskişehir	5	-	1
Gökçekýsýk, Eskişehir	Eskişehir	1	-	
Kelkit	Gümüşhane	-	1	
Kılbasan, Karaman	Karaman	3	1	
20 km E of Digor	Kars	1*	2*	
40 km E of Kırşehir	Kırşehir	1	2	
Yelişköy, Akşehir	Konya	1	-	
Konya	Konya	-	1	
27 km NW of Makü	Makü, Iran	2	1	
Madenköy	Niğde	3	6	
17 km E of Özalp	Van	2*	-	
30 km S of Başkale	Van	1*	5	
S. fulvus (Lichtenstein, 1823) (n= 21)				
30 km SE of Hamedan	Hamedan	3*	-	
15 km W of Mashad	Mashad	1*	4*	
15 km W of Zenjan	Zenjan	6*	5*	
10 km NW of Abhar	Abhar	-	1*	
Qazvin	Qazvin	-	1*	
	Total 91 + 66 + 4 = 161			

* Specimens including in karyological studies.

TABLE 2. Measurements (mm) and weight (g) of four *Spermophilus* species. n: sample size, SD: standard deviation.

	S. citellus (n= 10)	*S. torosensis* **sp. nov.** (n= 17)	*S. xanthoprymnus* (n= 50)	*S. fulvus* (n= 18)
Chr	mean±SD	mean±SD	mean±SD	mean±SD
TL	264.20±9.06	262.59±16.54	248.40±18.57	369.22±43.30
TaL	60.00±6.47	60.41±9.99	48.34±5.98	82.72±9.61
HFL	40.60±2.33	44.00±2.59	40.04±2.25	48.50±3.47
EL	7.70±1.19	7.41±1.03	7.26±1.83	4.44±0.76
W	241.10±40.86	264.59±75.89	218.00±64.70	568.28±151.22
ZW	28.38±0.88	29.48±2.19	28.45±1.67	38.04±2.11
IC	8.84±0.52	10.13±0.57	9.47±0.67	12.56±0.94
CbL	41.43±0.98	43.37±1.65	40.84±2.88	53.29±2.58
OnL	44.34±1.07	45.95±1.84	42.94±5.79	56.78±2.58
BL	36.80±0.83	38.41±2.21	36.22±2.31	48.22±3.60
NL	15.94±0.63	16.39±0.94	15.76±0.95	21.83±1.37
NW	6.91±0.48	7.04±0.29	6.78±0.70	8.71±0.73
FL	27.02±1.26	27.02±1.25	26.21±1.24	34.06±1.15
BcL	16.60±0.97	19.06±1.09	17.34±1.42	22.72±1.43
MW	14.55±1.03	16.47±0.59	14.84±1.41	20.25±0.97
WBB	15.77±0.58	16.45±0.59	15.76±0.56	18.69±1.00
OW	19.88±0.67	21.23±0.65	20.56±0.88	26.47±2.31
DL	11.25±0.37	11.58±0.78	11.12±1.17	14.12±1.95
PL	22.05±0.52	23.97±0.91	22.35±1.38	30.88±1.46
FIL	3.11±0.29	3.23±0.43	2.80±0.36	4.06±0.31
TBL	9.83±0.63	9.06±1.06	9.18±0.92	9.51±0.35
ML	28.82±0.85	29.71±1.41	28.76±1.58	38.01±2.10
UMAL	9.88±0.27	9.75±0.46	9.79±0.43	14.62±0.49
LMAL	9.46±0.44	9.73±0.45	9.41±0.37	13.20±0.56

Chr: Chararcters, TL: Total length, TaL: Tail length, HF: Hind foot length, EL: Ear length, W: Weight, ZW: Zygomatic width, IC: Interorbital constriction, CbL: Condylobasal length, OnL: Occipitonasal length, BL: Basal length, NL: Nasal length, NW: Nasal width, FL: Facial length of skull, BcL: Braincase length, MW: Mastoid width, WBB: Width of Braincase with Bullae, OW: Occipital width, DL: Diastema length, PL: Palatal length, FIL: Incisive foramen length, TBL: Tympanic bulla length, ML: Mandible length, UMAL: Upper molar alveolar length, LMAL: Lower molar alveolar length.

Specimens were prepared in the standard museum manner and deposited at the Department of Biology, Ankara University (n= 150), the Department of Biology, Zonguldak Karaelmas University (n= 2) and the Department of Biology, Zanjan University (n= 9).

Results

***Spermophilus citellus* (Linnaeus, 1766) Systema Naturae, 12th ed., 1:80.**

Type locality. "Austria": restricted by Martino and Martino (1940) to "Wagram, Niedersterrich" (Bauer, 1960:254).

Distribution. This species is distributed in Turkish Thrace except for the Istranca Mountains (Figure 1).

External characters. Dorsal coloration dark yellow and brown speckled. There is a white ring around the eyes. There is no demarcation line between flanks and venter. Venter is light yellow. Dorsally, the tail is colored like the dorsum; ventrally, the tail is same coloration as the venter. Hairs of the tail are longer than those of body giving the appearance of a brush. The forefoot has a yellowish tone, while the hind foot is yellow dorsally (Figure 2).

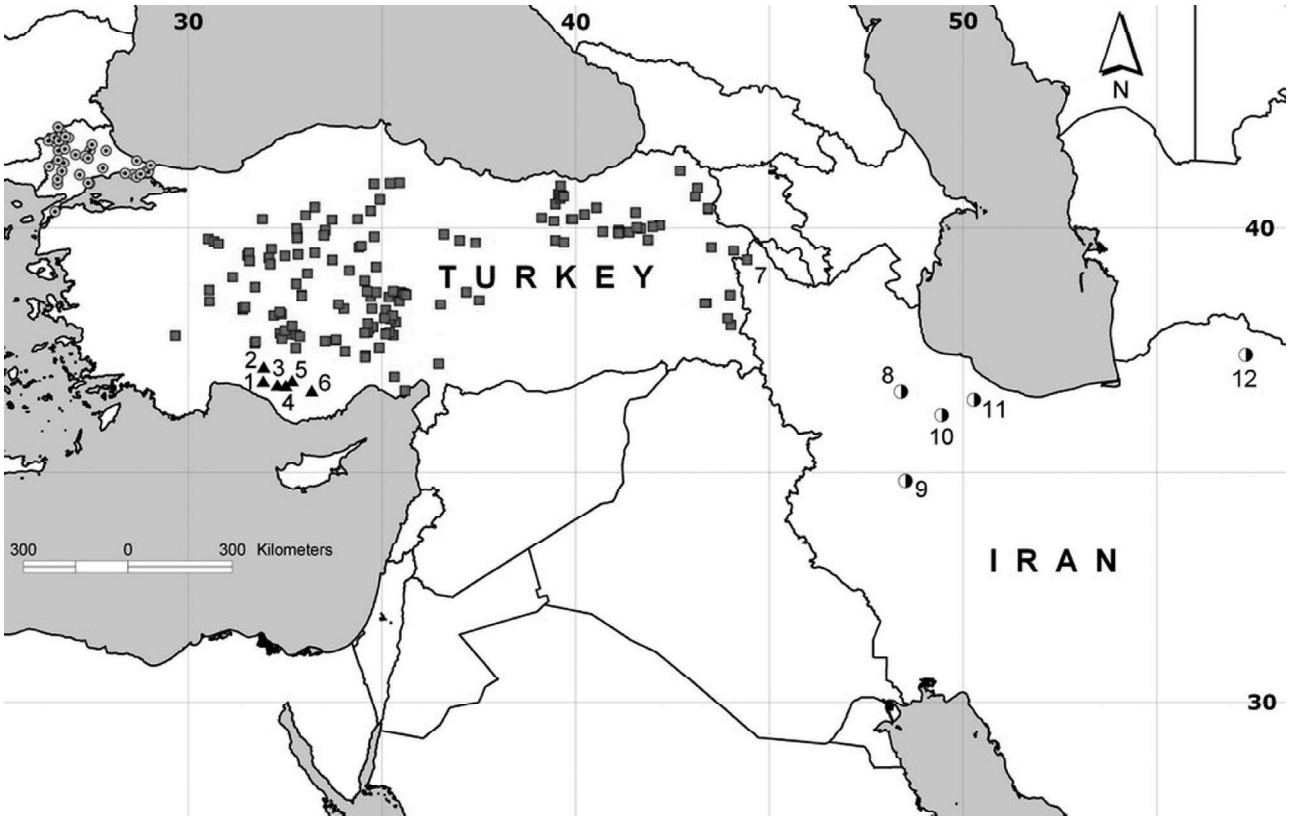

FIGURE 1. Distribution of *Spermophilus* species in Turkey and Iran. ⊙: *Spermophilus citellus*, ■: *S. xanthoprymnus*, ▲: *S. torosensis* **sp. nov.**, ◑: *S. fulvus*. Localities in Turkey: 1. Salamut Plateau, Akseki, Antalya (Type locality), 2. Alacabel, Akseki, 3. İshaklı Pletau, Alanya, 4. Payalılar, Alanya, 5. Kocaalan Plateau, Hadim, Konya, 6. Mut, Mersin, Localities in Iran: 7. Makü, 8. Zanjan, 9. Hamedan, 10. Abhar, 11. Qazvin, 12. Mashad.

Cranial characters. The cranium is uniformly convex in the dorsal aspect and concave in the ventral aspect. The anterior part of the nasal bone is wide, broader than the anterior surface of incisors and the posterior sutures of premaxillas, and tapering posteriorly. A postorbital process is present (Figure 4). In young specimens, the sagittal crest is not pronounced, but in adult and old adult specimens the supratemporal ridges begin posterior to the postorbital processes and converge posteriorly; with the lambdoidal crest a slight sagittal crest is formed. The anterior surface of the upper and lower incisors varies from white to yellow (41% and 47% of animals, respectively); the posterior surface is white. Posterior palatal foramina are located anterior to (n= 7) or equal to (n= 8) a line passing between M^2 and M^3, rarely posterior to (n= 1) the line. There is a spine-like (n= 5) or triangular (n= 11) process in the medial posterior margin of the palate.

Dentition. Dental formula is I 1/1 C 0/0 P 2/1 M 3/3 = 22. Pm^1 has 1 root. Pm^2, M^1, M^2, and M^3 have 3 roots. Pm_1 has 2 roots. M_1, M_2, and M_3 have 4 roots.

Karyology. Two karyotypes have been reported from specimens collected in the Turkish Thrace: 2n= 40, NF= 78, NFa= 74 (Doğramacı *et al*. 1994); and 2n= 40, NF= 69 NFa= 76 (Özkurt *et al*. 2002).

FIGURE 2. Dorsal and ventral aspects of *Spermophilus* species in Turkey: a) *S. citellus* from Thrace; b) *Spermophilus torosensis* **sp. nov.** from type locality in Akseki;and c) *S. xanthoprymnus* from type locality in Erzurum.

Spermophilus fulvus **(Lichtenstein, 1823). Naturwissenschaftliche Abhandlungen, Eversmann's Reise: 119.**

Type locality: *"*near the Kuvandzhur River, east of Mugodzhary Mountains, north of Aral Sea" [Kazakhstan] (Ognev, 1963:29).

Habitat. *Spermophilus fulvus* inhabits dry steppe areas with sparse grass and also the edges of cultivated areas.

Distribution. This species was collected from 5 localities in Iran (Figure 1, Table 1).

External characters. The dorsum is reddish with a yellowish tone (Figure 2). There is no demarcation line between the flanks and venter. The venter is pale grey. The base of the tail is the same color as the dorsum.. This coloration gets darker towards the tip of the tail, with a dark ring near the white tip. The hairs of the tail are longer than those of the body. Fore- and hind feet are whitish dorsally and darker ventrally.

Cranial characters. The skull is robust and about 25% larger than that of the other three species (Figure 4). Lambdoidal and sagittal crests are pronounced in adult and old adult specimens. Postorbital processes are prominent and heavily built. The skull is not uniformly convex in the dorsal aspect and appears more angular in a lateral view. Unlike the other three species, the rostrum is not tapered anteriorly; in dorsal view, the rostrum widens at the anterior end of the premaxillas. The mandible is also larger than that of the other three species but it is similar in general shape. The anterior edges of the zygomatic arch form an approximate right angle at the junction with the rostrum in adult animals, but this angle is obtuse in young specimens. The anterior surface of the incisors is white in most specimens, 70% of upper incisors and 85 % of lower incisors. Posterior palatal foramina are mostly (95%) located posterior to a line passing between M^2 and M^3. There is a spine-like process in the medial posterior margin of the palate.

Dentition. The dental formula is the same as in *S. citellus.* Pm^1 has 1 root. Pm^2, M^1, M^2, and M^3 have 3 roots. Pm_1 has 2 roots; M_1, M_2, and M_3 have 4 roots.

Karyology. The karyotype for specimens from Hamedan, Mashad and Zenjan (Iran) is 2n= 36, NF=70, and NFa= 66. All of the autosomal chromosomes are bi-armed. The X chromosome is large and submetacentric and the Y chromosome is the smallest of the acrocentric chromosomes.

***Spermophilus xanthoprymnus* (Bennett, 1835) . Proceedings of the Zoological Society of London, 1835:90.**

1835. *Citellus* [sic] *xanthoprymna* Bennett. Observations on several Mammalia from Trebizond and Erseroum, Proceedings of the Zoological Society of London , pp: 89- 90.

1877. *Spermophilus xanthoprymnus* Danford and Alston. On the Mammals of Asia Minor, Proceedings of the Zoological Society of London, pp: 277-278.

Type locality. "Erzurum", Turkey.

Distribution. This species lives in steppe areas and mountain slopes in central and eastern Anatolia and in northwestern Iran (Figure 1).

External characters. Dorsum is light brown or reddish brown with a yellow tone. A demarcation line between flanks and venter typically is absent; a pronounced line was present in two specimens. There is generally a white ring around the eyes and behind the ears. Venter is yellow, grey and white speckled. The tail is the same coloration as the body ventrally and dorsally. The hairs of the tail are longer than those of the body. Forefoot is yellow and hind foot is a pale whitish (Figure 2).

Cranial characters. The general morphological features are the same as in *S. citellus* (Figure 4). The anterior surface of the incisors is mostly yellow. The posterior palatal foramina are generally (90% of specimens) located anterior to a line passing between M^2 and M^3. There is a spine-like (40% of specimens) or triangular (60% of specimens) process in the medial posterior margin of the palate.

Dentition. The dental formula is the same as in *S. citellus.* Pm^1 has 1 root. Pm^2, M^1, M^2, and M^3 have 3 roots. Pm_1 has 2 roots (one specimen has 3 roots), M_1, M_2, and M_3 have 4 roots.

Karyology. In the present study, specimens from Digor, Özalp and Başkale in Turkey and from Makü in Iran had a karyotype of 2n= 42, NF= 78, NFa= 74. The X chromosome is submetacentric and the Y chromosome is the smallest acrocentric. The autosomal chromosomal complement is comprised of 17 pairs of bi-armed and 3 pairs of acrocentric chromosomes.

Specimens from Ereğli (Konya) and from Sarız (Kayseri) in Turkey had a karyotype of 2n= 42, NF= 80, NFa= 76. The X chromosome is submetacentric and the Y chromosome is the smallest acrocentric. The autosomal chromosomal complement is comprised of 18 pairs of bi-armed and 2 pairs of acrocentric chromosomes.

***Spermophilus torosensis* sp. nov.**

Holotype. Adult female; skull and skin; Department of Biology, Faculty of Science, Ankara University in Ankara 3877; collected 23 September 2000 by Şakir Özkurt and Mustafa Sözen.

Type locality. Turkey, Antalya, Akseki, Çaltılıçukur village, Eşekçukuru area of Salamut Plateau on the Taurus Mts, (36.90823E, 31.96114N, 1879 m) (Figure 5).

Paratypes. Seven females and three males collected from the type locality in July 1996 by Mustafa Sözen and in August 2000 by Şakir Özkurt and Mustafa Sözen. Voucher specimens (skulls and skins) are deposited in the Department of Biology, Faculty of Science, Ankara University (1829, 1835, 1839, 1943) and the Department of Biology, Faculty of Science, Ankara University (3395, 3427, 3485, 3559, 3874, 3883).

Diagnosis. The dorsal fur is light reddish brown; speckling is absent. The tail is thick and brush-like, and covered with long hairs that form a tuft at the tip. Measurements for tail length, braincase length, hind foot length, mastoid width, and interorbital constriction are greater than those for *S. citellus* and *S. xanthoprymnus*. Posterior palatal processes generally spine-like rather than triangular. Supraorbital ridges not converging posteriorly; lambdoidal and sagittal crests and ridges absent or obsolete. The karyotype is 2n= 40, NF-=75-76, and NFa= 72.

Measurements of holotype. External, cranial, and dental measurements (in mm; except weight, in g) are: total length, 256; tail length, 62; hind foot length, 39; ear length, 7; weight, 260; zygomatic width, 28.5; interorbital constriction, 9.8; condylobasal length, 41.5; occipitonasal length, 43.7; basal length, 36.4; nasal length, 14.8; nasal width, 6.7; facial length of skull, 25.1; braincase length, 18.9; mastoid width, 15.8; width of braincase with bullae, 15.8; occipital width, 20.9; diastema length, 11; palatal length, 23.2; incisive foramen length, 2.7; tympanic bulla length, 9.4; mandible length, 27.4; upper molar alveolar length, 9.94; lower molar alveolar length, 9.46.

Description. The fur on the dorsal surface of the body is reddish in coloration (Figure 2), but several specimens from Akseki (n= 3) are grey with reddish tone. The dorsal color becomes lighter on the flanks. There is no demarcation line between the flanks and the venter. The color of the venter varies from light yellow to whitish. The tail is reddish with dark hairs on the dorsal surface and whitish hairs on the ventral surface. The forefoot is covered with tiny whitish hairs on the dorsal surface, and the soles are naked. The hind foot is similar in color to the dorsal body coloration; the soles of the feet are naked. The dental formula is the same as in *S. citellus.* Pm^1 has 1 root. Pm^2, M^1, M^2, and M^3 have 3 roots. Pm_1 has 2 roots (one specimen has 3 roots), M_1, M_2, and M_3 have 4 roots. The cranial characters of *S. torosensis* are similar to those of *S. citellus* and *S. xanthoprymnus* (Figures 3, 4). The color of the anterior surface of the incisors varies from white to yellow. The posterior palatal foramina are generally (74%) located anterior to a line passing between M^2 and M^3. There is a spine-like (63% of animals) or triangular (37% of animals) process in the medial posterior margin of the palate. Morphometric analysis separates 3 similar species of *Spermophilus— S. citellus, S. xanthoprymnus,* and *S. torosensis* **sp. nov.** (Figure 7).

Habitat. *Spermophilus torosensis* is found in open areas above 1500 m in the Taurus Mountains in southern Anatolia from Akseki to Mut (Figure 1). This species inhabits rocky areas with sparse vegetation, but does not live in areas with deep soil. In some cases, individuals were observed living in stone walls built by villagers of Çukurköy in town of Akseki on the Morca Plateau in Antalya province (Figure 6).

FIGURE 3. Dorsal, ventral, and lateral views of cranium and lateral view of mandible of *Spermophilus torosensis* **sp. nov.** (holotype).

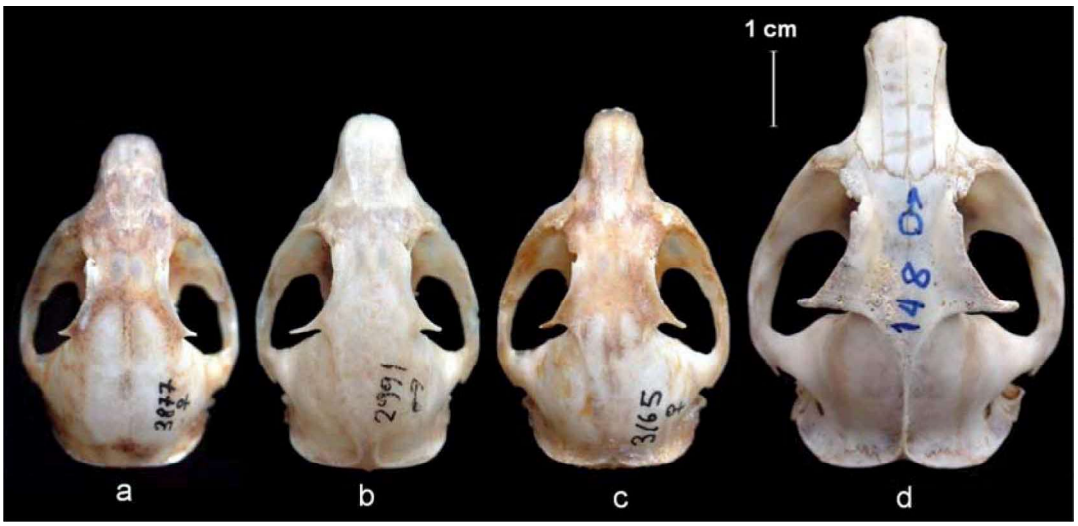

FIGURE 4. Dorsal aspects of skulls of *Spermophilus*: *a) S. torosensis* **sp. nov.;** b) *S. citellus*; c) *S. xanthoprymnus*; and d) *S. fulvu*s.

Co-specific rodent species. *Dryomys laniger* (Gliridae), *Nannospalax nehringi* (Spalacidae), *Apodemus mystacinus* (Muridae), *Chionomys nivalis* (Cricetidae).

Distribution. This new species is found above 1500 m in the Taurus Mountains in southern Anatolia from Akseki (Antalya) to Mut (Mersin) (Figure 1).

Dominant plant species present in and around type locality. Lamiaceae: *Marrubium globosum, Phlomis armeniaca,* Fabaceae: *Astragalus creticus,* Euporbiaceae: *Euphorbia kotschyana,* Thymelaeaceae: *Daphne oleoides,* Poaceae: *Bromus tomentollus, Festuca valesiaca.*

Other plant species in and around type locality. Liliaceae: *Allium scoroprasum, Ornithogahum orthophyllum,* Lamiaceae: *Scutellaria orientalis, Nepeta isaurica, Stachys lavandulifolia, Teucrium chamaedrys, Ziz-*

iphora clinopodioides, Ajuga chamaepitys, Acinos rotundifolius, Scrophulariaceae: *Veronica cuneifolia, Verbascum glomerulosum,* Poaceae: *Poa bulbosa, Dactylis glomerata, Hordeum bulbosum, Bromus japonicus, Elymus tauri,* Brassicaceae: *Alyssum minus, Erysimum sintenisianum, Alyssum condensatum, Barbarea minor,* Asteraceae: *Crepis sancta, Onopordum acanthium, Circium lappaceum,* Caryophyllaceae: *Minuartia globulosa, Minuartia leucocephala, Gypsophila curvifolia, Cerastium brachypetalum,* Geraniaceae: *Geranium tuberosum,* Campanulaceae: *Asyneuma virgatum,* Rubiaceae: *Cruciata taurica, Asperula setosa, Galium consanguineum,* Boraginaceae: *Onobrychis montana, Buglossoides arvensis,* Ranunculaceae: *Ranunculus damescenus,* Rosaceae: *Rosa pulverulenta,* Berberidaceae: *Berberis crataegina.*

Derivatio nominis. The name derives from Toros, Turkish for the Taurus Mountains in which the new species is distributed.

Karyology. The karyotype is 2n= 40, NF-=75-76, and NFa= 72 for specimens from Akseki, Mut and Hadim in southern Anatolia (Özkurt *et al*. 2002).

Morphometric analysis. In general, specimens collected from four different geographical regions were clearly separated based on the morphological characters. The results of a univariate ANOVA of the 24 characters used for the discrimination resulted in statistically significant differences ($P<0.001$) among groups except for the tympanic bullae length ($P>0.05$).

FIGURE 5. The habitat of *Spermophilus torosensis* **sp. nov.** in type locality (Eşekçukuru area of Salamut Plateau of Çaltılıçukur village in Akseki town of Antalya Province).

In the multivariate analysis, the total morphological variation was explained by 3 axes with eigen values greater than 1. The first axis explained most of the variation (94.18%); the second and the third axes explained 3.51% and 2.31% of the variation, respectively.

The characters that contributed most to the discrimination in the first axis were braincase length, diastema length, tympanic bulla length, and the upper and lower molar alveoli lengths. For the second axis, the highest loadings were for the interorbital constriction, length of the palate, length of the incisive foramen, mandible length and upper molar alveoli length. For the third axis, interorbital constriction, braincase length, occipital width, length of palate and lower molar alveoli length have the highest loadings.

In the discriminate function analysis, 97% of the samples were correctly classified into their original groupings (Figure 7). Three species (*S. citellus*, *S. fulvus,* and *S. xanthoprymnus*) were 100% correctly placed

in their proposed groups. Only 2 specimens from the *S. torosensis* **sp. nov.** exhibited a tendency to cluster with *S. xanthoprymnus;* however, their characteristics did not overlap with *S. xanthoprymnus*. This appears to be due to the high degree of morphological variation within *S. torosensis* **sp. nov.**

FIGURE 6. Burrow of *Spermophilus torosensis* **sp. nov.** in a man-made wall in Morca Plateau of Çukurköy in Akseki.

Discussion

Morphological and karyological analyses provide substantial insight into the discrimination of species and the description of new species. In this study, we used several approaches in evaluating the systematics and taxonomy of *Spermophilus* in the region and the status of the new species (*S. torosensis*) described herein.

The karyotype of *S. torosensis* was first determined from specimens from Akseki, Hadim and Mut in southern Anatolia by Özkurt *et al*. (2002) as 2n= 40, NF= 76 and NFa= 72 under the name of *S. xanthoprymnus*. However the karyology of *S. torosensis* differs from both *S. citellus* and *S. xanthoprymnus* in Turkey and is less variable. Although the same diploid number has been reported for *S. citellus*, the two different karyotypes known for this species differ from that of *S. torosensis* in number of autosomal arms and total number of chromosomal arms (NF= 78 NFa= 74 and NF= 69 NFa= 76; Doğramacı *et al*. 1994; Özkurt *et al*. 2002). The karyotype of the allopatrically distributed (in southern Anatolia) *S. xanthoprymnus* also differs from that of *S. torosensis*—2n= 42, NF= 67, 81, 82, and NFa= 64, 76, 78 for specimens from different localities in Turkey (Doğramacı *et al*. 1994, Özkurt *et al*. 2002, Arslan 2005, Yiğit *et al*. 2006) and 2n= 42, NF= 70 from Armenia (Orlov *et al.* 1969).

S. fulvus is discriminated clearly from *S. citellus*, *S. xanthoprymnus,* and *S. torosensis* based on larger body size, cranial measurements, and karyotype (2n= 36). In addition to metric characteristics, the location of the posterior palatal foramina (a nonmetric morphological character) also clearly distinguished *S. fulvus* from the other three species.

In addition to karyology, morphometric data also support the recognition of *S. torosensis* as a distinct species. Stepwise discriminant function analyses clustered the 4 taxa with a probability of over 95%. The morphological relationships were visualized in the UPGMA dendrogram based on the centroid values of the clusters described above. In the dendrogram (data not shown), *S. citellus* is more similar to *S. xanthoprymnus* than *S. torosensis*. Additionally, based on the morphometrical analyses, 3 species (*S. citellus, S. fulvus, and S.*

xanthoprymnus) were correctly classified for 100% of the specimens and only 2 specimens of *S. torosensis* showed a tendency to cluster with *S. xanthoprymnus* within the limit of statistical significance, but not with *S. citellus*. Despite the presence of such affinity, the 4 distinct species showed non-overlapping scatter plots with a probability greater than 0.95.

Yiğit *et al*. (2005) examined two different karyotypic populations of *Spermophilus* from western Turkey based on morphometric and genetic data (based on mtDNA and 16S rRNA). Their evaluation showed that the populations having 2n= 40 chromosomes from Thrace and Akseki in southern Anatolia belong to *S. citellus*. However their morphometrical analyses were obtained by averaging specimens belonging to different species (Yiğit *et al*. 2006). The averages and the centroid values of discriminant groupings are not equivocal; indeed the morphological distance obtained from centroid values show more real morphological relationships than the average. Moreover the nonmetric morphological characters showed clustering similar to that shown by the metric characters. In particular, the position of the foramen post palatines and the shape of the process at the posterior margin of the palatinum would be sufficient to separate the three previously described species as well as the one newly described species of *Spermophilus*.

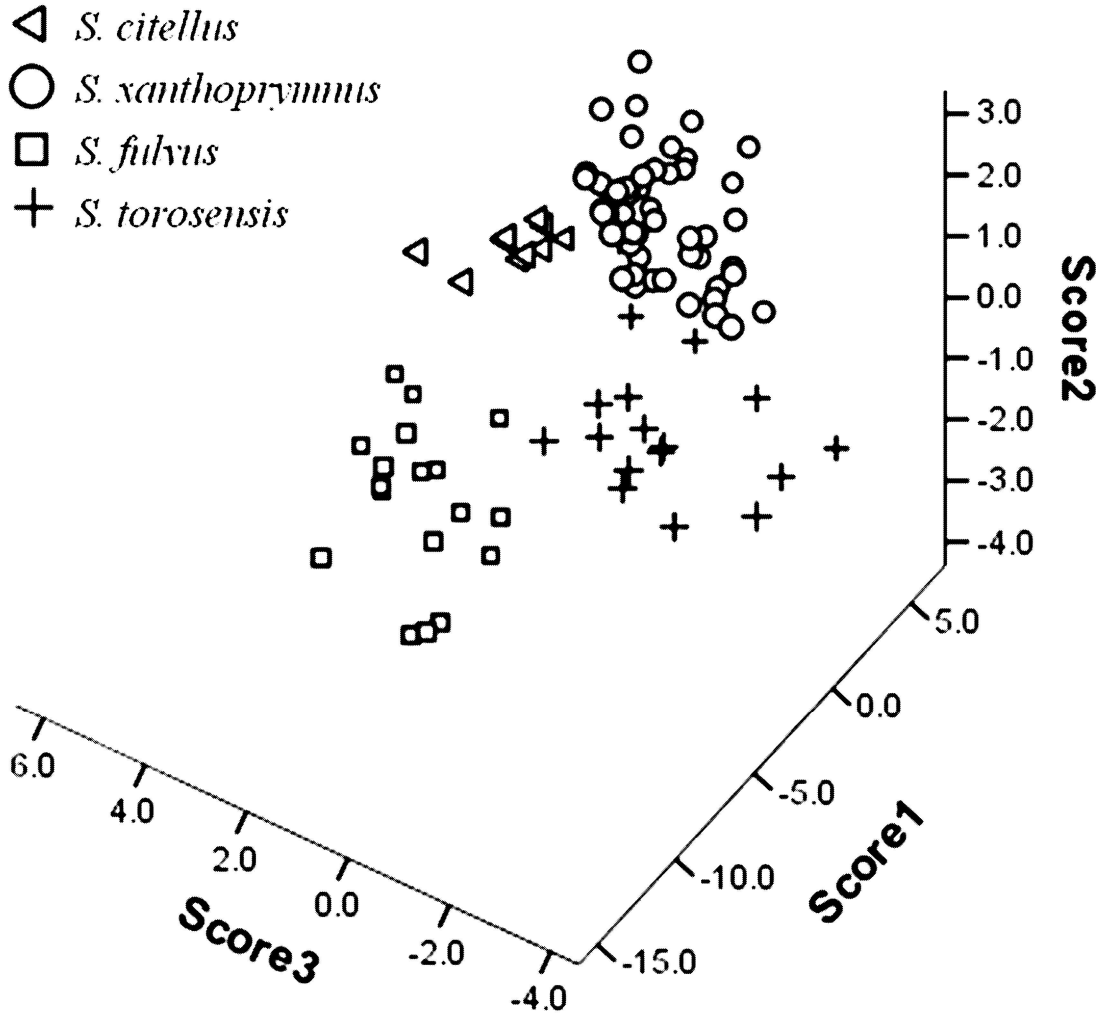

FIGURE 7. Scatter plot of four *Spermophilus* species in discriminant function analysis.

SDS-PAGE analysis of blood serum proteins (postalbumin) also corroborated previous results (Çolak and Özkurt 2002, Çolak *et al*. 2006) that found that specimens from Akseki in the Taurus Mountains (*S. torosensis*) were different from specimens of *S. citellus* in Thrace and from *S. xanthoprymnus* in Anatolia. Additionally, the globulin region of specimens from Thrace consisted of 8 electrophoretic bands, whereas there were 9-

10 bands in specimens from Anatolia (Çolak and Özkurt 2002). SDS-PAGE analysis also showed that *S. xanthoprymnus* from both Turkey and Iran had 2 bands in the prealbumin zone while *S. fulvus* in Iran had 3 bands (Çolak *et al*. 2006).

The results of SDS-PAGE analysis and the biometrical analysis of external and cranial character measurements gave similar results indicating that *S. torosensis* is more similar to *S. xanthoprymnus* than to *S. citellus* in Thrace. These results, however, differ from those based on 16S rRNA (Yiğit *et al.* 2005) and cyt b sequences (Herron *et al*. 2004), which are in general agreement. It could be proposed that the new described species is in an early stage of speciation, but the accumulation of sequence differences in rRNA, its geographical isolation, karyology, and morphological characteristics support the separation of *S. torosensis* from other *Spermophilus* species.

Until now there has been little evidence to explain the evolution of *Spermophilus* species in Anatolia. The earliest fossil species in Eurasia come from the late Miocene or early Pliocene (Black 1972, Qui 1991). Hosey (1982) noted that until the middle Pleistocene the Bosphorus was a geographic barrier, separating populations in the Balkan Peninsula from those in southwest Asia. Some *Spermophilus* fossils from the Pleistocene were found in Turkish Thrace and central Anatolia (Santel and Koenigswald 1998, Güleç *et al*. 1999). Osborn (1964) speculated that ground squirrels invaded Anatolia from the Caucasus.

Yiğit *et al.* (2005), based on biometric and genetic associations, proposed a rather recent immigration of *S. citellus* into western Anatolia via a land bridge between the Balkans and Anatolia, probably at least until the end of the Pleistocene. They also suggested that *S. xanthoprymnus* originated from *S. citellus* in a later invasion, moving from the central Anatolian steppe eastward.

If we presume that central Anatolia was colonized during the Pleistocene after the retreat of an extensive inner sea system, *S. xanthoprymnus* may have simply arrived earlier perhaps by way of a land bridge than *S. citellus* or originated from a mountainous population of *S. citellus*. A later invasion of Turkey by *S. citellus* perhaps about 20,000 years ago may have failed because the most appropriate habitats were already occupied. We are assuming that *S. xanthoprymnus* might have split from Akseki population of *S. citellus* (Yiğit *et al.* 2005).

We propose that *Spermophilus* moved from Europe to Anatolia during the Miocene or Pliocene and lived in the highlands of the Taurus Mountains because central Anatolia was occupied by an enclosed sea at that time. Then, when the Bosphorus appeared during the middle Pleistocene, the resulting barrier between populations in the Thrace and the Taurus Mountains allowed the Taurus Mountain population to evolve into a distinct species —*Spermophilus torosensis*. When the enclosed sea in Central Anatolia dried up, *Spermophilus torosensis*, taking advantage of this new ecosystem, evolved into a third species, *Spermophilus xanthoprymnus*.

An explanation for the karyological difference between the two species might be found in Nevo et al. (1994, 1995), who suggested that the karyological differences among species might originate by ecological factors; the low diploid number of chromosome among species usually is considered the ancestral population or species.

Nevo (1994) found that the speciation and adaptation of Turkish *Spalax* positively correlate with stress and climatic unpredictability; for example, the 2n values for *Spalax leucodon* increase toward the ecologically arid, climatically unpredictable, and geologically young central Anatolian Plateau from the west, north, south, and east, repeating from all directions. Similarly, the 2n value of the Turkish ground squirrel, *S. xanthoprymnus*, increased toward central Anatolia from the Southwest Mountain

The habitat structure of the Mediterranean sea region differs from the central Anatolian region with regard to altitude, topography, and vegetation. The local population size of *S. torosensis* living in such a habitat is considerably smaller than those in Anatolia because *S. torosensis* lives in small mountain steppe areas that are surrounded by stony areas (Figure 5) too difficult for digging burrows (personal observation). Those stony areas also have little or no vegetation that ground squirrels can eat. We caught some juveniles or young adults

in *Spalax* burrows, which consisted of tunnels up to 5-8 cm length, 15 to 20 cm under surface, which juveniles use for burrowing and hiding. Because suitable areas are very small, they cannot easily disperse to other regions. In addition, the altitude is a limitation for populations in the Taurus Mountains, because the ground is covered by snow about six months of the year at altitudes over 1900 m. In contrast to populations in Central Anatolia, *S. torosensis* has limited time, food, and space to reproduce.

Populations of *S. torosensis* and *S. xanthoprymnus* are geographically close on the northern side of the Taurus Mountains although no areas of sympatry have yet been reported. In plotting the distribution of *S. torosensis* from south to north towards the central Anatolian steppe, we found approximately 25 km separate the two populations in Hadim (Konya). Although it is possible that the two species might be in contact, in our view they appear to be two allopatric species. Because *S. torosensis* lives at a high altitude, it has a different breeding time from that of *S. xanthoprymnus*. Also, there are behavioral differences between the two species; for example, *S. torosensis* wakes up from hibernation in May when the snow melts, whereas *S. xanthoprymnus* starts to be active in mid-March. Their burrowing systems are different from each other: *S. xanthoprymnus* burrows are deeper and more complex, whereas the burrows of *S. torosensis* are simple and shallower. In summary, karyologic, morphologic, geographic, ecologic, and behavioural characteristics that we have studied and examined indicate that the population of *Spermophilus* in the Taurus Mountains is a new species, *S. torosensis*.

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