

1-1-2016

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KEFELİOĞLU, HALUK and SELÇUK, AHMET YESARİ (2016) "Taxonomic status of Neomys species (Mammalia: Soricomorpha) and their distribution in Turkey," *Turkish Journal of Zoology*. Vol. 40: No. 6, Article 1. <https://doi.org/10.3906/zoo-1507-46>

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Taxonomic status of *Neomys* species (Mammalia: Soricomorpha) and their distribution in Turkey

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Received: 31.07.2015 • Accepted/Published Online: 24.12.2015 • Final Version: 06.12.2016

Abstract: The genus *Neomys* is distributed throughout the Palearctic. *Neomys teres* is widely distributed in the Black Sea region, whereas *Neomys anomalus* is narrowly distributed in the West Palearctic region. Similarly, in Turkey, *Neomys anomalus* shows a wide distribution, but *Neomys teres* is distributed in the Black Sea highlands. These two species can be differentiated from each other morphologically and karyologically. *N. anomalus* and *N. teres* are different in terms of penis structure. The karyotypes of *Neomys anomalus* and *Neomys teres* are $2n = 52$. The karyotype of the *Neomys teres* population in Turkey is not yet known. *Neomys anomalus* has adapted to terrestrial habitats while *Neomys teres* is a semiaquatic species. *Neomys teres* usually prefers the water's edges, especially small streams and creeks. Terrestrial invertebrates and aquatic invertebrates occur in the diet of both species.

Key words: *Neomys*, chromosome, morphology, phylogeny, Turkey

1. Introduction

The present study is a review of morphological, karyological, and genetic data on *Neomys* spp. published by different researchers (Kahmann and Çağlar, 1960; Spitzenberger, 1968; Kryštufek et al., 1998, 2000; Kryštufek and Vohralík, 2001; Tez et al., 2010; Arslan and Zima, 2014) from Turkey. Based on these studies, it is reported that *Neomys anomalus* and *Neomys teres* are distributed across Turkey.

2. Results and discussion

Species: *Neomys teres* Miller, 1908

Type locality: 40 km north of Erzurum (Turkey)

Synonyms: *schelkovnikovi* Satunin, 1913; *leptodactylus* Satunin, 1914; *balkaricus* Ognev, 1926

Species: *Neomys anomalus* Cabrera, 1907

Type locality: San Martin de la Vega, Jarama River, Madrid (Spain)

Synonyms: *amphibius* Brehm, 1826; *milleri* Mottaz, 1907; *mokrzeckii* Martino 1917; *soricoides* Ognev, 1922; *josti* Martino, 1940; *rhenanus* Lehmann, 1976

2.1. Western Palearctic distribution

The species of the genus *Neomys* Kaup 1829 are distributed across suitable habitats in the Palearctic region. They occur in an extensive area from Arctic Scandinavia to mountains in the Mediterranean zone, in Britain, in Siberia, and from

Lake Baikal to Turkey (Ellerman and Morrison-Scott, 1951; Corbet, 1978; Hutterer, 2005).

Neomys teres is distributed in a narrow area in the Western Palearctic region in all of the Caucasus, which includes Armenia (Churchfield et al., 2006), Georgia (Sokolov and Tembotov, 1989), the Black Sea mountains, and Van and Bolu in Turkey (Figure) (Kryštufek et al., 1998; Kryštufek and Vohralík, 2001). On the other hand, *Neomys anomalus* is distributed in the West Palearctic region and the range includes Spain, the Voronezh region of Russia, and Turkey (Ellerman and Morrison-Scott, 1951; Corbet, 1978; Niethammer and Krapp, 1990; Wilson and Reeder, 2005).

2.2. Distribution in Turkey

Neomys teres samples from Ulubey (Ordu), Meryemana (Trabzon) (Spitzenberger and Steiner, 1962), Kutul (Artvin), and the Yalnızçam Pass (Kars) were investigated by Spitzenberger (1968). Those from Bendimahi Canyon (Muradiye/Van) were investigated by Obuch (1994), and samples from Seyfe (Amasya) and Safranbolu (Karabük) were investigated by Kryštufek et al. (1998). Furthermore, there are records listed by Kryštufek et al. (1998) concerning Topcam (Ordu), Tamdere (Giresun), Çamlık (Rize), Ovid Mountain (Rize), and Lake Abant (Bolu). Moreover, there are samples obtained from Kayseri and Erzurum investigated by Tez et al. (2010) and samples

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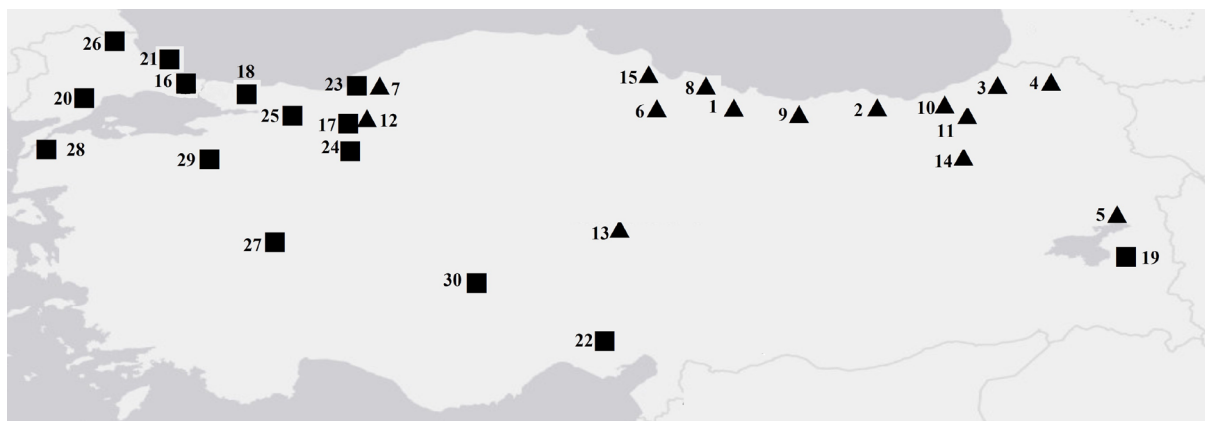


Figure. Distribution of *Neomys teres* and *Neomys anomalus* species in Turkey (square = *Neomys anomalus*, triangle = *Neomys teres*). 1: Ulubey (Ordu), 2: Meryemana (Trabzon), 3: Kutul (Artvin), 4: Yalnızçam (Kars), 5: Bendimahi Canyon (Muradiye, Van), 6: Seyfe (Amasya), 7: Safranbolu (Karabük), 8: Topçam (Ordu), 9: Tamdere (Giresun), 10: Çamlık (Rize), 11: Ovid Mountain (Rize), 12: Lake Abant (Bolu), 13: Kayseri, 14: Erzurum, 15: Samsun, 16: Belgrad Forest (İstanbul), 17: Lake Abant (Bolu), 18: İrve creek (İstanbul), 19: Erçek Mountain (Van), 20: Paşaalandere (Tekirdağ), 21: Lake Terkos (İstanbul), 22: Yeşiloba (Adana), 23: Yenice, Çayır (Zonguldak), 24: Abant (Bolu), 25: Hanyatak village (Sakarya), 26: Longoz forest, Dupnisa cave, Demirköy (Kırklareli), 27: Lake Eber (Afyon), 28: Çırpılar (Çanakkale), 29: Uludağ (Bursa), 30: Balkusan (Karaman).

from Samsun, which were investigated by us, but which have not been published yet (Figure).

Concerning *Neomys anomalus*, there are records about the samples from Belgrad Forest (İstanbul) and Lake Abant (Bolu) (Kahmann and Çağlar, 1960); the Ömerli region and İrve creek (İstanbul) (Osborn, 1965); Erçek Mountain (Van), Paşaalandere (Tekirdağ), and Lake Terkos (İstanbul) (Spitzenberger, 1968); and Yeşiloba (Adana), Yenice, Çayır (Zonguldak), Lake Abant (Bolu), Hanyatak village (Sakarya), a floodplain forest, Dupnisa Cave, Demirköy (Kırklareli), Lake Eber (Afyon), Çırpılar (Çanakkale), Uludağ Mountain (Bursa), and Balkusan (Karaman) (Kryštufek et al., 1998) (Figure).

2.3. Taxonomic status

Cabrera (1907) characterized *Neomys anomalus* collected from Spain (Madrid) with the skull shape less round, larger tail, differentiated body colors on the lateral side, and shorter or no fringe hair in comparison with *N. fodiens*. Miller (1908) described *N. teres* from 40 km north of Erzurum (2134 m altitude) for the first time and suggested that this species was mistakenly recognized as *N. fodiens*. Miller (1908) further emphasized the similarity of this species to *Neomys anomalus* and reported that larger skull size, more coarse teeth, and wider rostrum were the traits differentiating this species from *N. anomalus*. Ellerman and Morrison-Scott (1951) claimed that *N. teres* collected from Anatolia was a subspecies of *Neomys anomalus*. Spitzenberger and Steiner (1962) recognized the *N. teres* samples collected from Meryemana (2 samples) and Ulubey (3 samples) as a subspecies of *N. fodiens* (as *N. fodiens teres*) according to 10 external morphological characters. Osborn (1965) recorded *N. fodiens* from the Caucasian

border of Turkey. While Corbet (1978) considered *N. teres* as a synonym of *N. fodiens*, he indicated that *N. anomalus* occurs in Turkey. Niethammer and Krapp (1990) reported that *N. anomalus* was recorded in Turkey according to Spitzenberger (1968). Hutterer (2005) claimed that *N. schelkovnikovi* ranges over the Caucasus Mts. (Armenia, Georgia, Azerbaijan) and that its range even extends to Turkey and Iran. Additionally, he considered *N. teres* as a synonym of *N. fodiens* and stated that *N. anomalus* is distributed in the West Palearctic and Turkey (Hutterer, 2005). Wolsan and Hutterer (1998) and Sokolov and Tembotov (1989) claimed that *N. schelkovnikovi* is distributed across the Caucasus and Turkey.

Kryštufek et al. (1998) reported that there are two distinct *Neomys* species in Turkey based on the internal, external, skull, and penis characteristics of 44 studied samples. *N. anomalus* is distributed at up to 2100 m altitude in the Anatolia and Thrace regions of Turkey and it has a smaller body size compared to *N. teres*. *N. teres*, which was previously included in *N. fodiens*, has a larger body. Furthermore, *N. schelkovnikovi* from the Caucasus (Niethammer and Krapp, 1990; Corbet and Hill, 1991) was recognized as a junior synonym of *N. teres*. *N. anomalus* is a species with a shorter tail and almost ventral keel compared to *N. teres*. Zaitsev (1999) proposed that *N. schelkovnikovi* has an intermediate position between *N. fodiens* and *N. anomalus* in terms of morphological and anatomical characteristics and thus supported the view of Kryštufek et al. (1998). Hutterer (2005) supported the opinion of Kryštufek et al. (1998) in this regard and included *N. schelkovnikovi* as a synonym of *N. teres*. Contrary to Kryštufek et al. (1998), Bannikova and

Kramerov (2005) stated that *N. teres* was a synonym of *Neomys schelkovnikovi* based on molecular studies of the the glans penis characteristic (Pucek, 1964; Yudin, 1970).

As can be observed from the taxonomical data given so far, while several researchers recognized *N. teres* as a separate species (Kryštufek et al., 1998), some considered it as a subspecies of *Neomys anomalus* (Ellerman and Morrison-Scott, 1951), and some others as a subspecies of *N. fodiens* (Spitzenberger and Steiner, 1962). On the other hand, several studies (Bannikova and Kramerov, 2005) considered *N. teres* as a synonym of *N. schelkovnikovi*.

Based on the given information so far, the taxonomical status of *N. teres* in Turkey is rather complicated. In order to illuminate the taxonomical status of the species, it is necessary to conduct chromosomal, genetic, and morphological studies. On the contrary, there is no significant confusion concerning the taxonomical status of *N. anomalus*.

2.4. Morphology

Since the teeth crown sections of *Neomys* species occurring in Turkey are red in color, they are called red-tooth insectivores. The reason for this red colorization is iron aggregation (Strait and Smith, 2006).

2.4.1. *Neomys teres*

The tail length is about 64%–85% of the head-body length (Kryštufek and Vohralík, 2001) (Table). The body is notably in two colors. The dorsal side is always black, the

abdominal region is silver gray, and the colors of the dorsal side and abdominal region are sharply differentiated from each other (Miller, 1908). The glans penis elongates distally and tapers. The length of the glans penis ranges between 10.8 and 14.6 mm (Kryštufek and Vohralík, 2001). The skull is in a quite rough and set shape (Miller, 1908). Moreover, there is a notable lambda region in the skull (Kryštufek and Vohralík, 2001). While the hind legs are gray, the same as the body color, the paws are blackish (Miller, 1908). Short stiff hairs that help develop swimming skill cannot be found in 43.8% of samples (Kryštufek et al., 2000).

2.4.2. *Neomys anomalus*

Tails of samples are round and there are stiff hairs on the bottom part of the body that enhance swimming. This characteristic reveals that the animals are more territorial compared to the other members of this genus. The ventral side of the body is white and the bottom of the neck is lightly yellowish. While the dorsal part of the body is black, the front and hind paws are white, and the tail part has two different colors, brownish black and white (Cabrera, 1907). *N. anomalus* is distinguished from *N. teres* by the head-body, tail, and foot lengths and it is a smaller species in terms of these characteristics (Table) (Kryštufek and Vohralík, 2001). Hairs enhancing swimming skill were not found in the samples from Thrace (Kryštufek et al., 2000). Whereas the length of the glans penis is 7–8 mm,

Table. H-B (head-body), T (tail), Hf (hind foot), E (ear), W (weight), CL (condylobasal length), BH (braincase height), BB (braincase breadth), CH (coronoid height of mandible), IB (interorbital breadth), RB (rostrum breadth), ML (mandible length), MaxTR (maxilla tooth row length), MTR (mandibular tooth row length).

Species	Reference	N	H-B	T	Hf	E	W	CL	BH	BB	CH	IB	RB	ML	MaxTR	MTR
<i>Neomys teres</i>	Miller, 1908	1♂	88	58	18.5	5	-	22.4	6.0	11.4	-	-	-	14.4	10.4	9.4
<i>N. fodiens teres</i>	Spitzenberger and Steiner, 1962	2♂, 2♀, 1?	89	60	16.8	-	23.8	21.6	-	-	-	4.4	2.0	-	-	-
			95	64	17.2	-	20.2	22.2	6.8	-	-	4.6	2.1	-	-	-
			96	65	18.2	-	24.0	22.8	6.8	11.8	-	4.8	2.2	-	-	-
			82	70	18.5	-	10.2	-	-	-	-	4.1	2.0	-	-	-
			89	66	16.8	-	17.5	20.9	6.4	10.9	-	4.2	1.9	-	-	-
<i>Neomys teres</i>	Kryštufek and Vohralík, 2001	15–23	85–101	53–73	18.2–22.1	-	11–28	21.6–23	-	10.4–11.8	4.7–5.1	-	-	-	-	-
<i>Neomys anomalus</i>	Cabrera, 1907	-	73	60	17.5	8	-	20.5	-	10	-	4	-	-	9.6	-
<i>Neomys anomalus</i>	Osborn, 1965	3	87	53	18	-	-	-	-	-	-	-	-	-	-	-
			77	47	17	-	-	-	-	-	-	-	-	-	-	-
			82	47	17	-	-	-	-	-	-	-	-	-	-	-
<i>Neomys anomalus</i>	Spitzenberger, 1968 (in Niethammer and Krapp, 1990)	11	72–84	45–56	-	-	-	19.6–21.5	-	-	4.35–4.8	-	-	-	-	-
<i>Neomys anomalus</i> (in Thrace)	Kryštufek and Vohralík, 2001	12–13	72–89	45–55	14.8–17.8	-	7–20	19.4–20.9	-	9.7–10.7	4.35–4.80	-	-	-	-	-
<i>Neomys anomalus</i> (in Asia Minor)	Kryštufek and Vohralík, 2001	17–20	76–90	46–60	15.5–18.3	-	10–18	20.1–21.8	-	9.9–11.1	4.4–5.0	-	-	-	-	-

the maximum width is 4–5 mm. The tip of the penis is cylindrical in shape (Pucek, 1964). It does not taper, the penis lateral flaps are curtailed, and horny spines on the surface are not dense (Kryštufek and Vohralík, 2001).

2.5. Karyology

The karyotype of *N. teres* was reported by Sokolov and Tembotov (1989) from the Caucasus. The karyotype characteristics were determined as $2n = 52$, $NFa = 94$, and $NF = 98$, and the X and Y chromosomes were subtelocentric. Arslan and Zima (2014) stated that the karyotype characteristics of this species have not yet been reported from Turkey.

In the *N. anomalus* karyotype, the number of diploid chromosomes is $2n = 52$. Meylan (1966), Rimsa et al. (1978), Zima et al. (1998), and Chassovnikarova et al. (2009) reported the same diploid chromosome number from Switzerland, Yugoslavia, Czechoslovakia, Romania, and Bulgaria. The karyotype exhibits variation in the range of $NF = 90–98$ (Chassovnikarova et al., 2009). In the karyotype, 10 pairs of metacentric, 10 pairs of submetacentric, 2 pairs of subtelocentric, and 3 pairs of acrocentric chromosomes were usually recognized (Meylan, 1966; Rimsa et al., 1978; Zima, 1984). While the morphology of the X chromosome was reported as subtelocentric, submetacentric, and metacentric, the morphology of the Y chromosome was assessed as subtelocentric, submetacentric, and acrocentric (Fredga and Levan, 1969; Rimsa et al., 1978; Jimenez et al., 1984; Zima, 1984; Ivanitskaya, 1989; Arslan and Zima, 2014). Chassovnikarova et al. (2009) reported C and NOR band characteristics of 3 males and 2 females collected from the Veleka River in the Stranca Mountains of Bulgaria. The karyotype was characterized as $2n = 52$, $NF = 98$, $NFa = 94$, with 10 pairs of metacentric, 10 pairs of submetacentric, 2 pairs of subtelocentric, and 3 pairs of acrocentric chromosomes. The X and Y chromosomes were submetacentric. Although this karyotype is congruent with studies reported by Meylan (1966), Rimza et al. (1978), Jimenez et al. (1984), and Zima et al. (1998), a difference was indicated in the morphology of the X chromosome.

Arslan and Zima (2014) reported karyotypic data for *N. anomalus* from Turkey based on specimens investigated from Demirköy (Kırklareli), Lake Abant (Bolu), Uludağ Mountain (Bursa), Yenice (Zonguldak), Lake Eber (Afyon), and Çirpılar (Çanakkale). The karyotype characteristics were $2n = 52$, $NFa = 94$, and $NF = 98$; the X chromosome was subtelocentric and the Y chromosome was submetacentric.

2.6. Phylogeny

Kryštufek et al. (2000) conducted a phylogenetic study on *N. teres* and *N. anomalus* samples from Turkey, *N. anomalus* from Slovenia, and *N. fodiens* from Macedonia according to 375–378 base pairs of 12S rRNA and 355 base

pairs of the mtDNA *cyt b* gene. The *N. anomalus* samples from Turkey and Slovenia were closely related to each other. Furthermore, *N. teres* was found to be more closely related to *N. anomalus* than to *N. fodiens*, and *N. fodiens* represented a far distant branch diverging from both species. Kryštufek et al. (2000) suggested three possible explanations for the fact that *N. fodiens* and *N. teres* are morphologically similar to each other but different from *N. anomalus* with the strong adaptation of the two species to the semiaquatic life. Genetically, the status of the affinity of *N. teres* with *N. anomalus* and the distance from *N. fodiens* were correlated with allopatric diversification from the ancestral species, *N. fodiens*, during the ice ages.

Bannikova and Kramerov (2005) conducted phylogenetic studies on *N. fodiens* (Siberia), *N. anomalus* (western Russia), and *Neomys schelkovnikovi* (northern Caucasus) based on the inter-SINE-PCR method. They concluded that *N. teres* is a synonym of *N. schelkovnikovi*. This result differs from the findings of Kryštufek et al. (1998). Furthermore, contrary to the findings of Kryštufek et al. (2000), Bannikova and Kramerov (2005) concluded that *N. anomalus* and *N. fodiens* are closely related; however, *N. schelkovnikovi* (synonym: *N. teres*) was represented as a basal lineage of both derived sister species. Although these findings contradict those reported by Kryštufek et al. (2000), morphological data indicate the full conformity. In terms of the glans penis structure of *Neomys teres* it is apparent that *N. fodiens* is quite different from *N. anomalus* (Pucek, 1964; Yudin, 1970).

Castiglia et al. (2007) achieved results similar to those of Kryštufek et al. (2000) through the maximum likelihood method based on 272 mtDNA base pairs according to GenBank data of *N. anomalus* and *N. teres* from Turkey and *N. fodiens* samples (Italy, Slovenia, Ukraine, Finland, France, and Macedonia) reported by Kryštufek et al. (1998). The study revealed that *N. anomalus* and *N. teres* are close relatives, but *N. fodiens* is a species exhibiting significant difference.

This situation suggests that there is a need for phylogenetic studies on *Neomys* species from various geographical regions in Turkey.

2.7. Habitat

Neomys teres is a semiaquatic species and it exhibits limited distribution compared to the other congeneric species. On the other hand, *N. anomalus* is a smaller species with European distribution, especially in the Western Balkans (Kryštufek and Tvrtković, 1988). *N. teres* prefers water fronts, particularly minor running waters and creeks. The species reveals superior diving and swimming skills. They nest among tree roots along waterfronts and rarely dig their nests themselves (Churchfield, 1990). Habitats of *N. anomalus* are usually located at low altitudes (650 m above sea level) and the species is territorial compared to

other *Neomys* species (Spitzenberger, 1968; Kryštufek and Vohralík, 2001). It can be found almost everywhere in Anatolia (Figure). It is particularly spotted frequently in areas with aqueous habitats containing dense vegetation. Aqueous invertebrates (Trichoptera larvae, Plecoptera nymphs, Ephemeroptera nymphs, Coleoptera adults and larvae, Diptera larvae, *Gammarus*, *Asellus*) (Churchfield,

1990; Niethammer and Krapp, 1990; Churchfield et al., 2006) and grassland invertebrates (Staphylinidae, Coleoptera larvae, Culicidae, Tipulidae, Lepidoptera, Heteroptera, Chilopoda, Araneae, Opiliones, Gastropoda, Lumbricidae) are included in the diets of both species. The most appealing feed for capturing *Neomys* is *Calliphora vomitoria* larvae (Churchfield et al., 2006).

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