



Contributions to the karyology and taxonomy of the genus *Spalax* Güldenstaedt, 1770 (Mammalia: Rodentia) in Turkey

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Abstract

The karyotypes of 17 specimens in 10 localities belonging to *Spalax leucodon* (Nordmann, 1840), and 2 specimens of *Spalax ehrenbergi* Nehring, 1898 from Kilis in Turkey were analysed. It was determined that *S. leucodon* has $2n = 36$ and $NF = 70$ in the Bayındır population; $2n = 60$, $NF = 82$ and $NFa = 78$ in Ankara (centrum, 15 km N, and 35 km S), Afyon 10 km E and Afyon 95 km SW populations; $2n = 60$, $NF = 84$ and $NFa = 80$ in the Burdur (centrum and 10 km W) population, and $2n = 60$, $NF = 76$ and $NFa = 72$ in the Akşehir 10 km SE population. *S. ehrenbergi* from 15 km E of Kilis has also $2n = 52$, $NF = 74$ and $NFa = 70$.

According to these karyological findings the diploid chromosome number of the Bayındır population, and the NF and NFa values of Burdur, Akşehir, and Kilis populations are new for the genus *Spalax* in Turkey.

Key words: *Spalax leucodon*, *Spalax ehrenbergi*, karyology, taxonomy, Turkey

Introduction

The subterranean mole rats belonging to the family Spalacidae are distributed throughout southeastern Europe, Asia Minor, Caucasus, Transcaucasus, Ukraine, Armenia, Syria, Palestine, Iraq, Israel, Jordan, and northeastern Africa (OGNEV 1947; ONDRIAS 1966; LAY and NADLER 1972; CORBET 1978; GIAGA et al. 1982; NEVO 1991; HARRISON and BATES 1991). To date, over 40 chromosomal forms of *Spalax* have been reported in the literature from these areas.

According to the most recent morphological studies there are two species (*S. leucodon* and *S. ehrenbergi*) and nine subspecies (*S. l. nehringi*, *S. l. armeniacus*, *S. l. cilicicus*, *S. l. anatolicus*, *S. l. turcicus*, *S. l. tuncelicus*, *S. e. intermedius*, *S. e. kirgisorum*, and *S. e. nevoi*) of blind mole rats in Turkey (KIVANÇ 1988; COŞKUN 1996 a, b). However, the results from karyological studies revealed nine karyological forms of *S. leucodon* ($2n = 38, 40, 50, 52, 54, 56, 58, 60$, and 62) and four karyological forms of *S. ehrenbergi* ($2n = 52, 54, 56$, and 58) in Turkey, and the number of chromosome arms (NF) for *S. leucodon* and *S. ehrenbergi* varied from 70 to 82 and from 72 to 90, respectively (SOLDATOVIC and SAVIC 1978; SAVIC and SOLDATOVIC 1979; YÜKSEL 1984; GÜLKAÇ and YÜKSEL 1989; YÜKSEL and GÜLKAÇ 1992, 1995; NEVO et al. 1994, 1995; IVANITSKAYA et al. 1997; SÖZEN and KIVANÇ 1998 a, b). NEVO et al. (1994, 1995) stated that each of the chromosomal forms is a separate biological species. They examined the populations using Nei's genetic distance between populations obtained by allozyme electrophoresis and claimed that

some populations having identical diploid chromosome numbers are different biological species, presumably representing about 20 such species in Turkey. They also showed that in Turkish *Spalax*, speciation and adaptation positively correlate with aridity stress and climatic unpredictability. $2n$ values and heterozygosity, H , increase toward the ecologically harsh, arid, and climatically unpredictable and geologically young central Anatolian Plateau from the west, north, south, and east (NEVO et al. 1994, 1995). The number of biological species determined by a combination of chromosome number, genetic distances, and ecogeography of *Spalax* is tend to increase by new studies (SÖZEN and KIVANÇ 1998 a, b).

The results of these studies demonstrate the necessity to reexamine the species and subspecies specified morphologically, and to determine the borders of chromosomal forms. The aim of this present study is to give the karyologic characteristics of the blind mole rats collected from given localities, and thereby to contribute to karyology, taxonomy, and speciation of the genus *Spalax* in Turkey.

Material and methods

The karyotypes of 1 female specimen from Bayındır (İzmir), 6 specimens (5 males, 1 female) from three localities in Ankara, 2 male specimens from 10 km SW of Afyon, 1 female specimen from 95 km SW of Afyon, 5 specimens (2 males, 3 females) from two localities in Burdur, and one female specimen from 10 km SW of Akşehir belonging to *Spalax leucodon* (Nordmann, 1840), and 2 male specimens of *Spalax ehrenbergi* Nehring, 1898 from 15 km E of Kilis in Turkey were analysed (Fig. 1, Tab. 1). Bayındır, Ankara, Afyon, Burdur, and Akşehir specimens were determined as *S. leucodon*, and specimens from Kilis as *S. ehrenbergi*. Karyotypes were prepared from bone marrow according to FORD and HAMERTON (1956), and about 25–30 metaphase cells, which were well-stained, and whose chromosomes were separate and distinct, were examined from each animal. The diploid number of chromosomes ($2n$), the number of autosomal arms (NFa), and the total number of chromosomal arms (NF) were determined together with metacentric (m), acrocentric (a), subtelocentric (st), and submetacentric (sm) according to centromere positions, and sex chromosomes. The karyotype preparations and the animals examined were deposited in Department of Biology, Faculty of Science, University of Ankara.

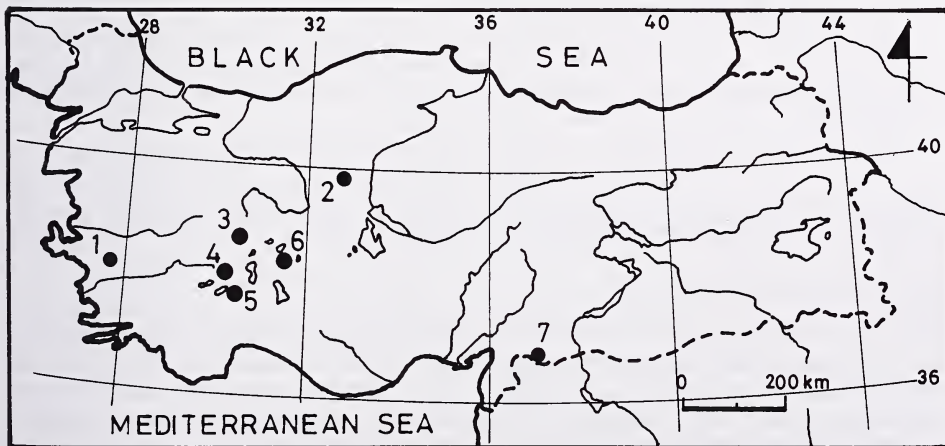


Fig. 1. Map of Turkey with localities of the analysed populations. 1. Bayındır, 2. Ankara, 3. Afyon 10 km W, 4. Afyon 95 km SW, 5. Burdur, 6. Akşehir, 7. Kilis 15 km E.

Table 1. The location and the number of animals examined.

<i>Spalax leucodon</i> (Nordmann, 1840)			
Locality	Male	Female	Total
Bayındır	–	1	1
Ankara (Centrum)	1	1	2
Ankara 15 km N	–	1	1
Ankara 35 km S	3	–	3
Afyon 10 km E	2	–	2
Afyon 95 km SW	–	1	1
Burdur 5 km S	2	2	4
Burdur 10 km W	–	1	1
Akşehir 10 km SE	1	1	2
<i>Spalax ehrenbergi</i> Nehring, 1898			
Kilis 15 km E	2	–	2

Results

Spalax leucodon (Nordmann, 1840)

Bayındır (Izmir) population: The karyotype of one female specimen from Bayındır in western Turkey was analysed. According to this analysis the Bayındır population has a karyotype of $2n = 36$, $NF = 70$. The karyotype contains 5 pairs of metacentric, 10 pairs of submetacentric, 2 pairs of subtelocentric, and 1 pair of acrocentric chromosomes (Fig. 2 a).

Ankara (centrum, 15 km N, and 35 km S), Afyon (10 km E, Afyon 95 km SW) populations: We determined the karyotypes of these five populations as $2n = 60$, $NF = 82$, and $NFa = 78$. The X chromosome is a medium-sized submetacentric, and the Y chromosome is the smallest subtelocentric. The autosomal set contains 10 pairs of subtelocentric, and 19 pairs of acrocentric chromosomes (Fig. 2 b).

Burdur 5 km S and 10 km W populations: The karyotype of Burdur populations has $2n = 60$, $NF = 84$, and $NFa = 80$. The X chromosome is a medium-sized submetacentric, and the Y chromosome is the smallest subtelocentric. The autosomal set contains 11 pairs of subtelocentric and 18 pairs of acrocentric (Fig. 3 a).

Akşehir 19 km SE population: The Akşehir populations have a karyotype of $2n = 60$, $NF = 76$, and $NFa = 72$. The X chromosome is a medium-size submetacentric, and the Y chromosome is the smallest subtelocentric. The autosomal set contains 7 pairs of subtelocentric and 22 pairs of acrocentric chromosomes (Fig. 3 b).

Spalax ehrenbergi Nehring, 1898

Kilis 15 km E population: The karyotype of 2 male specimens from 15 km east of Kilis was examined. The karyotype contains of $2n = 52$ chromosomes, $NF = 74$, and $NFa = 70$. The X chromosome is a medium sized submetacentric and the Y chromosome is acrocentric. The autosomal set of this population has 4 pairs of metacentric, 3 pairs of submetacentric, 3 pairs of subtelocentric, and 15 pairs of acrocentric chromosomes (Fig. 4).

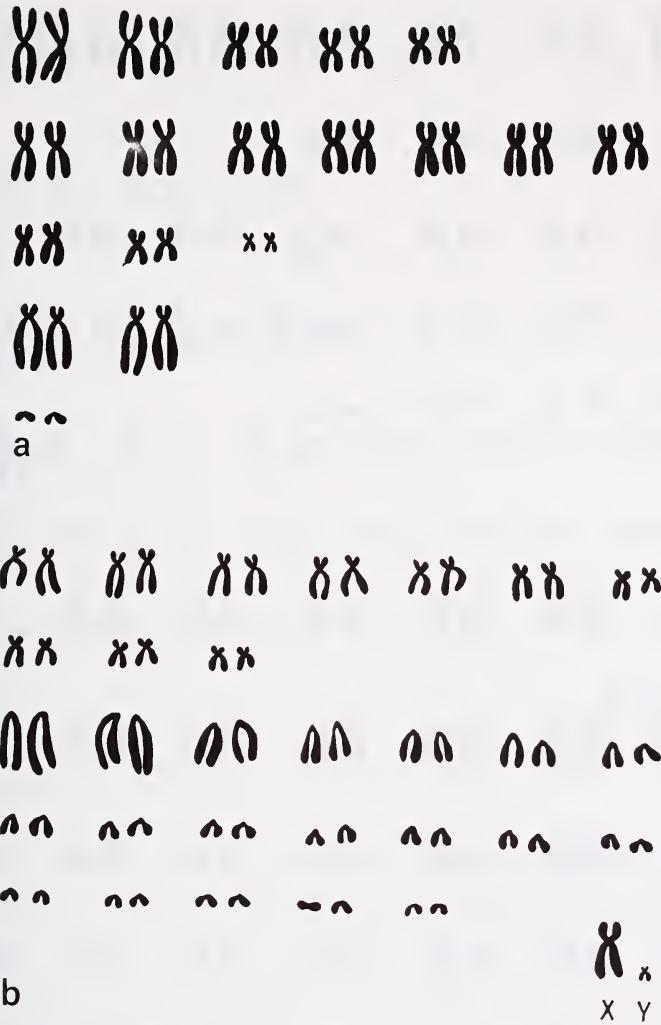


Fig. 2. The karyotype of a female *Spalax leucodon* from Bayındır (a), a male from Ankara (b).

Discussion

The first karyological analysis of the blind mole rat *Spalax leucodon* in Turkey was introduced by SOLDATOVIC and SAVIC (1978) from the Thrace region of Turkey (Çorlu and Karaevli), and corresponding investigations on the Asian part of Turkey (Havran and Selçuk) were performed by the same authors (SAVIC and SOLDATOVIC 1979). Later, new karyotypes were determined from the territory of Malatya by YÜKSEL (1984); from Malatya, Yazıhan, and Arguvan by GÜLKAÇ and YÜKSEL (1989); from Kırşehir, Nevşehir, Kayseri, and Yozgat by YÜKSEL and GÜLKAÇ (1995); from Balıkesir, İzmir, Beyşehir, Aydın, Erzurum, Sarıkamış, Bolu, Bingöl, Denizli, Pınarbaşı, Malatya, Kütahya, Afyon, Konya, Sivas, Ankara, Kayseri, Havza, and Suşehri by NEVO et al. (1994); from Malatya by IVANITSKAYA et al. (1997); from Sebil, Gülek by SÖZEN and KIVANÇ (1998a), and from Madenköy by SÖZEN and KIVANÇ (1998b).

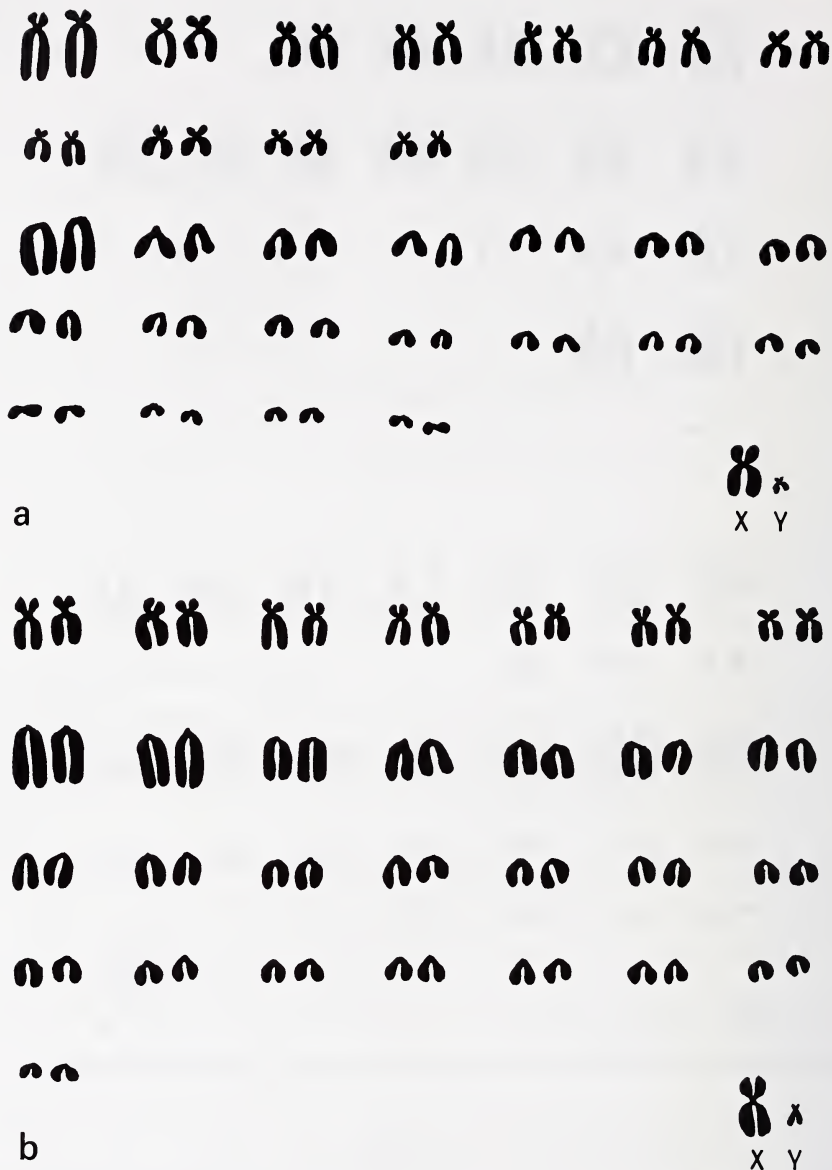


Fig. 3. The karyotype of a female *Spalax leucodon* from Burdur (a), a male from Akşehir (b).

The karyotype of *S. ehrenbergi* was first given by YÜKSEL (1984) from Elazığ, then by YÜKSEL and GÜLKAÇ (1992) from Adıyaman, Hilvan, Suruç, and Gaziantep; by NEVO et al. (1994) from Diyarbakır, Urfa, Gaziantep, and Tarsus; by IVANITSKAYA et al. (1997) from Tarsus, Gaziantep, Elazığ and Urfa (Tab. 2).

According to these studies the diploid karyotypes of *Spalax leucodon* in Turkey vary between $2n = 38$ and 62 , $NF = 70$ and 82 , and $NFa = 68$ and 78 . *Spalax ehrenbergi* also has a karyotype varying between $2n = 52$ and 58 , $NF = 72$ and 90 , and $NFa = 68$ and 86 .

The karyotype of *S. leucodon* determined in this study from Bayındır, $2n = 36$, $NF = 70$ is a first record for *S. leucodon* populations in Turkey, and also for all *Spalax* po-

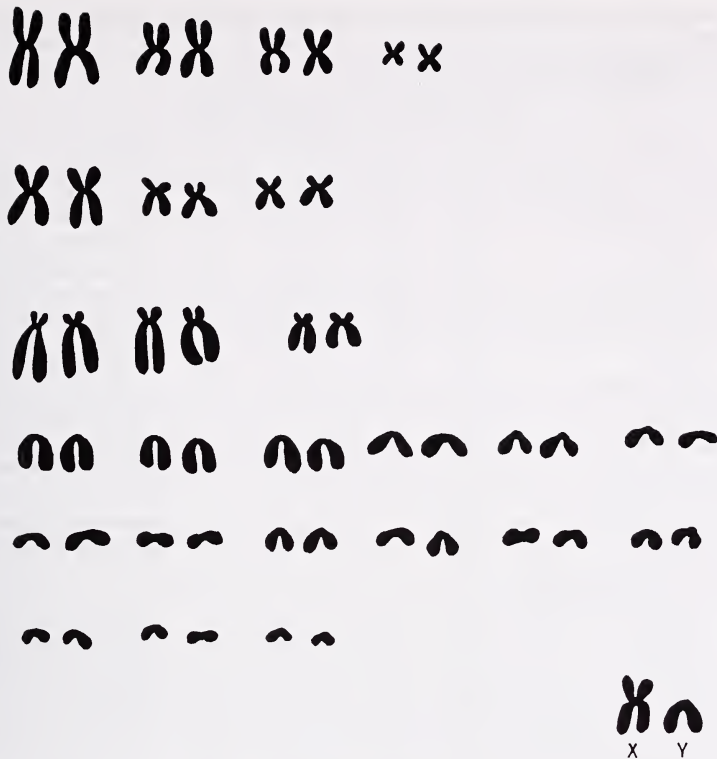


Fig. 4. The karyotype of a male *Spalax ehrenbergi* from Kilis.

pulations. This karyotype pattern is smaller than in all the other populations in the distribution area of the Spalacidae. The karyotypes given by SAVIC and SOLDATOVIC (1979) from Havran and Selçuk, and by NEVO et al. (1994, 1995) from Balıkesir and İzmir are close to this karyotype.

The diploid karyotypes of Ankara and Afyon populations determined here are identical with the Arguvan population given by GÜLKAÇ and YÜKSEL (1989) on the basis of chromosomal arm size and the chromosome morphology. These populations have $2n = 60$, $NF = 82$ and $NFa = 78$ containing 10 pairs of submetacentric, 19 pairs of acrocentric autosomal chromosomes, and a submetacentric X chromosome. In contrast to our findings, NEVO et al. (1994, 1995) specified the diploid chromosome number as being $2n = 62$ from 30 km S of Ankara and 35 km E of Afyon. This shows that two different chromosomal forms of *Spalax* are distributed in Ankara, and Afyon provinces.

The diploid karyotype of Afyon, Ankara, Burdur, and Akşehir determined here is $2n = 60$, but the NF and NFa values are different (Tab. 2). $NF = 84$, $NFa = 80$ of the Burdur population, and $NF = 76$, $NFa = 72$ of the Beyşehir population represents the first records for Turkish *Spalax*.

The diploid karyotype of *S. ehrenbergi* given by us is similar to the diploid chromosome number but different, on the basis of chromosomal arm size and the chromosome morphology, from karyotypes given by YÜKSEL (1984) from Elazığ by YÜKSEL and GÜLKAÇ (1992) from Adıyaman and Hilvan, by NEVO et al. (1994, 1995) from Diyarbakır and Urfa, and by IVANITSKAYA et al. (1997) from Birecik, Siverek, Diyarbakır and Elazığ, and from Urfa (Tab. 2).

Table 2. Chromosomal records of *Spalax leucodon* (Nordmann, 1840) and *Spalax ehrenbergi* Nehring, 1898 from Turkey.

*m: metacentric, sm: submetacentric, st: subtelocentric, a: acrocentric

<i>Spalax leucodon</i> (Nordmann, 1840)						
Locality	2n	NF	NFa	X	Y	Reference
Çorlu and Karaevli (in Thrace)	56	78	74	sm*	a*	SOLDATOVIC and SAVIC (1978)
Havran and Selçuk	38	74	70	st*	a	SAVIC and SOLDATOVIC (1979)
Malatya	60	78	74	sm	a	IVANITSKAYA et al. (1997)
Malatya	60	80	76	sm	st	YÜKSEL (1984)
Malatya and Yazıhan	60	80	76	sm	st	GÜLKAÇ and YÜKSEL (1989)
Arguvan	60	82	78	sm	–	GÜLKAÇ and YÜKSEL (1989)
Kırşehir, Nevşehir and Kayseri	60	80	76	sm	st	YÜKSEL and GÜLKAÇ (1995)
Yozgat	54	74	70	sm	st	YÜKSEL and GÜLKAÇ (1995)
Balıkesir and İzmir	38	74	70	st	a	NEVO et al. (1994, 1995)
Beyşehir	40	72	68	sm	–	NEVO et al. (1994, 1995)
Aydın, Erzurum	50	–	–	–	–	NEVO et al. (1994, 1995)
Sarıkamış	50	70	68	sm	–	NEVO et al. (1994, 1995)
Bolu and Bingöl	54	–	–	–	–	NEVO et al. (1994, 1995)
Denizli, Pınarbaşı	60	–	–	–	–	NEVO et al. (1994, 1995)
Malatya	60	78	74	sm	a	NEVO et al. (1994, 1995)
Kütahya, Afyon, Konya, Sivas, Ankara, Kayseri, Havza, Şuşehri	62	–	–	–	–	NEVO et al. (1994, 1995)
Gülek	56	72	68	m	a	SÖZEN and KIVANÇ (1998 a)
Sebil	52	72	68	sm	a	SÖZEN and KIVANÇ (1998 a)
Madenköy	58	72	68	sm	a	SÖZEN and KIVANÇ (1998 b)
Bayındır	36	70	–	–	–	This study
Ankara centrum, 15 km N, and 35 km S	60	82	78	sm	st	This study
Afyon 95 km SW and 10 km E	60	82	78	sm	st	This study
Burdur 5 km S and 10 km W	60	84	80	sm	st	This study
Akşehir 10 km SE	60	76	72	sm	st	This study
<i>Spalax ehrenbergi</i> Nehring, 1898						
Locality	2n	NF	NFa	X	Y	Reference
Elazığ	52	76	72	sm	st	YÜKSEL (1984)
Adıyaman and Hilvan	52	76	72	m*	st	YÜKSEL and GÜLKAÇ (1992)
Suruç	54	76	72	m	st	YÜKSEL and GÜLKAÇ (1992)
Gaziantep	56	90	86	m	st	YÜKSEL and GÜLKAÇ (1992)
Diyarbakır and Urfa	52	76	72	–	–	NEVO et al. (1994, 1995)
Gaziantep	58	82	78	–	–	NEVO et al. (1994, 1995)
Tarsus	56	72	68	–	–	NEVO et al. (1994, 1995)
Tarsus	56	72	68	m	–	IVANITSKAYA et al. (1997)
Gaziantep	56	82	78	sm	–	IVANITSKAYA et al. (1997)
Birecik, Siverek, Diyarbakır, Elazığ	52	76	72	sm	–	IVANITSKAYA et al. (1997)
Urfa	52	80	76	sm	–	IVANITSKAYA et al. (1997)
Kilis 15 km E	52	74	70	sm	a	This study

The sex chromosomes are variable in both *S. leucodon* and *S. ehrenbergi*. In most populations of *S. leucodon* in Turkey, the X chromosome was described as being submetacentric (SOLDATOVIC and SAVIC 1978; YÜKSEL 1984; GÜLKAÇ and YÜKSEL 1989; YÜKSEL and GÜLKAÇ 1995; IVANITSKAYA et al. 1997; SÖZEN and KIVANÇ 1998 a, b), subtelocentric in two populations in western Turkey (SAVIC and SOLDATOVIC 1979), and metacentric only in the Gülek population (SÖZEN and KIVANÇ 1998 a). The Y chromosome is acrocentric (SOLDA-

TOVIC and SAVIC 1978; SAVIC and SOLDATOVIC 1979; SÖZEN and KIVANÇ 1998 a, b), or subtelocentric (YÜKSEL and GÜLKAÇ 1995; YÜKSEL 1984; GÜLKAÇ and YÜKSEL 1989; SÖZEN and KIVANÇ 1998 a, b). We found that the X chromosome is also submetacentric in all populations studied, and that the Y chromosome is subtelocentric. In *S. ehrenbergi* populations, the X chromosome is submetacentric (YÜKSEL 1984; IVANITSKAYA et al. 1997) or metacentric (YÜKSEL and GÜLKAÇ 1992; IVANITSKAYA et al. 1997), and the Y chromosome is subtelocentric (YÜKSEL 1984; YÜKSEL and GÜLKAÇ 1992; IVANITSKAYA et al. 1997). We determined that the X chromosome is submetacentric, and the Y chromosome is acrocentric in the Kilis population.

The subterranean Spalacidae probably originated from a muroid-cricetoid stock in Asia Minor or vicinity, during Oligocene times, about 30–40 mya, and radiated adaptively underground in the Balkans, steppic Russia and Middle East, extending into North Africa (SAVIC and NEVO 1990).

The major important evolutionary feature was karyotypic evolution, mainly based on Robertsonian changes (SAVIC and NEVO 1990). More than 40 karyotypes ($2n = 38-62$, $NF = 72-124$) occur across the eastern Mediterranean range of the family. Most karyotypes represent biospecies adapted to their different ecologies at multiple organizational levels. Three major chromosomal trends ($2n = 38-62$) occur across the entire Eurasian and east Mediterranean range of Spalacidae, all starting in Western Turkey. These involve: (1) the Near East and North Africa ($2n = 38 \rightarrow 62$); (2) the Balkans ($2n = 38 \rightarrow 62$), and (3) the Ukrainian and Russian steppes, $2n = 38 \rightarrow 62$ (NEVO 1991; NEVO et al. 1995). This trend has also been revealed in Turkey itself supporting the idea of ecological speciation via chromosome speciation (NEVO et al. 1995). The chromosome number of *Spalax* tends to increase during adaptive radiation from humid areas toward the ecologically harsh, arid, and climatically unpredictable and geologically young central Anatolian Plateau from all directions (NEVO et al. 1994, 1995). The Bayındır population ($2n = 36$, $NF = 70$) determined in this study is now acceptable to be the speciation center of Spalacidae. But this concept should be supported by new molecular and fossil findings.

NEVO et al. (1995) determined 10 karyotypes and probably more than 20 new species, based on karyotypes and genetic distances, to the two superspecies *leucodon* and *ehrenbergi*, in Turkey. Later SÖZEN and KIVANÇ (1998 a, b) determined three new karyotypes in the superspecies *leucodon*. In the present study, we have determined four extra karyological forms for the two superspecies *leucodon* and *ehrenbergi*, one of them has a new $2n$ value (Bayındır population), and three of them have new NF and NFa values (Burdur, Akşehir, and Kilis populations). These results bring the total number of karyological forms or biospecies of Turkish *Spalax* to approximately 30.

According to the findings mentioned above, the borders of the areas of all chromosomal forms described from Turkey are not definite because of the possibility of the existence of new localities and chromosomal forms. It will certainly be necessary to analyse greater numbers of populations of the blind mole rats to determine the borders of the areas of all the described chromosomal variations from Turkey and to find possible new karyological forms and thereby to explain precisely speciation, phylogeny, systematics, and the evolutionary history of Spalacidae in Turkey.

Zusammenfassung

Zur Karyologie und Taxonomie der Gattung Spalax Gldenstaedt, 1770 (Mammalia: Rodentia) in der Trkei

Die Karyotypen von 17 Individuen der Art *Spalax leucodon* (Nordmann, 1840) aus 10 Probengebieten in der Trkei sowie von 2 Individuen der Art *Spalax ehrenbergi* Nehring, 1898 aus Kilis, Trkei, wur-

den analysiert. *S. leucodon* zeigte $2n = 36$ und $NF = 70$ in Bayindir; $2n = 60$, $NF = 82$ und $NFa = 78$ in Ankara (Zentrum, 15 km N und 35 km S), Ayfon (10 km O und 95 km SW); $2n = 60$, $NF = 84$ und $NFa = 80$ in Budur (Zentrum und 10 km W) und $2n = 60$, $NF = 76$ und $NFa = 72$ in Akşehir (10 km SO). *S. ehrenbergi* aus Kilis (15 km O) zeigte $2n = 52$, $NF = 74$ und $NFa = 70$. Nach unseren karyologischen Ergebnissen weisen die diploide Chromosomenzahl von Individuen aus Bayindir sowie die NF und NFa bei Individuen aus Budur, Akşehir und Kilis bei der Gattung *Spalax* in der Türkei bisher nicht beobachtete Werte auf.

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