

Some karyological records and a new chromosomal form for *Spalax* (Mammalia: Rodentia) in Turkey

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Abstract. The karyotypes of 73 specimens of subterranean mole rats of the superspecies *Spalax leucodon* Nordmann, 1840 from 21 localities, and six specimens of the superspecies *Spalax ehrenbergi* Nehring, 1898 from three localities in Turkey were analysed. *S. leucodon* has $2n = 56$, $NF = 78$ in the populations from Thrace; and $2n = 48$, $NF = 71$; $2n = 50$, $NF = 70$; $2n = 50$, $NF = 72$; $2n = 54$, $NF = 75$; $2n = 56$, $NF = 72$; $2n = 58$, $NF = 72$; $2n = 60$, $NF = 74$; $2n = 60$, $NF = 76$; $2n = 60$, $NF = 77$ in the populations from Anatolia. *S. ehrenbergi* has $2n = 56$, $NF = 72$ in the Adana population, and $2n = 52$, $NF = 74$ in the Elbeyli population. According to these karyological findings based on chromosome morphology, the diploid chromosome number of $2n = 48$, $NF = 71$ reported here is new for *Spalax leucodon* in Turkey. The karyological peculiarities and distributional area of mole rats in the European part of Turkey have been determined in detail, and shown that only the $2n = 56$ form is distributed in Thrace.

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

Introduction

The classification of extant spalacids is still obscure, and no consensus is yet in sight. Savić & Nevo (1990) used only the genus name *Spalax* to avoid confusion until a thorough taxonomic revision could take chromosomal and genetic data into account. Therefore, the generic name *Spalax* is used in this paper.

The subterranean mole rats of the family Spalacidae are distributed throughout eastern and south-eastern Europe, Asia Minor, the Caucasus, Transcaucasia, Syria, Iraq, Israel, Jordan and north-eastern Africa (Topachevskii 1969, Corbet 1978, Savić & Nevo 1990). To date, more than 50 chromosomal forms of *Spalax* have been reported. Karyologically the most diverse of these areas is Turkey.

In morphological terms, two species (*S. leucodon* and *S. ehrenbergi*) of blind mole rat have been determined in Turkey (Mursaloğlu 1979, Kıvanç 1988), but Coşkun (2004a) described a new species (*Nannospalax munzuri*) and also accepted *N. nehringi tuncelicus*, which he described previously (Coşkun 1996), as a valid species, based primarily on karyological and some morphological characters.

A taxonomic evaluation of Spalacidae in Turkey, based merely on morphology, is unrealistic in view of karyological and genetic studies (Nevo et al. 1994) because, to date, more than 30 karyological forms of *Spalax* in Turkey have been described. Based on genetic analysis these forms are good biological species (Nevo et al. 1995). Diploid chromosome

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number (2n) and fundamental number of chromosomal arms (NF) range from 36 to 62 (2n) and from 68 to 84 (NF) for *Spalax leucodon* and from 48 to 58 (2n) and from 74 to 90 (NF) for *Spalax ehrenbergi*, respectively (Tables 1 and 2). Thus, splitting the species based primarily on chromosome numbers produces a more realistic taxonomy in *Spalax* (N e v o et al. 1995). Despite the high variation in chromosome numbers, none of the exact distribution areas of any chromosomal form (or species) in Turkey are known, and new forms are being discovered continuously.

The purpose of this study was to describe the karyotypic characteristics of several *Spalax* populations from Turkey to fill at least partially some gaps in our knowledge about karyological forms, their distributional areas and evolutionary trends in Turkey.

Materials and Methods

Samples of the superspecies *Spalax leucodon* (n=73) were collected from 27 localities and of the superspecies *S. ehrenbergi* (n=6) from three localities in Turkey. The karyotypes, sample sizes and collecting sites are given in Table 3. Sample localities and their distribution are shown in Fig. 1. To catch animals alive, one gallery of the burrow system was opened. When an animal came to close the opening the gallery was cut about 40-50 cm behind the opening with a hoe, and the animal was trapped.

Karyotypes were prepared from bone marrow according to F o r d & H a m e r t o n (1956). The diploid number of chromosomes (2n), the number of autosomal arms (NFa), and the total number of chromosomal arms (NF) were determined from photos of the metaphase plates. The karyotype preparations and museum specimens have been deposited in the Department of Biology, the Faculty of Arts and Sciences, University of Zonguldak Karaelmas.

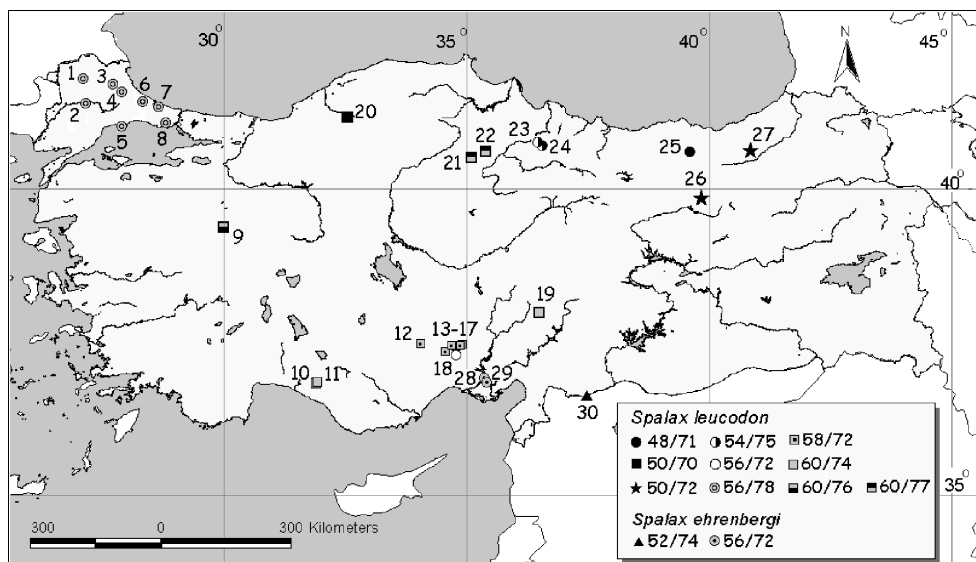


Fig. 1. Distribution of studied karyotypes of *Spalax leucodon* and *S. ehrenbergi* in Turkey. The numbers of localities are as in Table 3.

Results

Ten chromosomal forms ($2n/NF = 48/71, 50/70, 50/72, 54/75, 56/72, 56/78, 58/72, 60/74, 60/76$ and $60/77$) of the superspecies *Spalax leucodon* and two chromosomal forms ($2n/NF = 52/74$ and $56/72$) of the superspecies *S. ehrenbergi* were determined from 30 localities across Turkey (Fig. 1, Table 3).

Spalax leucodon superspecies

Gümüşhane 35 km NE population: The karyotype of this population was $2n = 48, NF = 71$ and $NFa = 67$. The X chromosome was medium-sized submetacentric. The autosomal set contained 10 pairs of bi-armed, one pair was heteromorphic (subtelocentric / acrocentric) and 12 pairs were acrocentric chromosomes (Fig. 2).

Karabük 10 km W population: Ten animals from these localities revealed a karyotype of $2n = 50, NF = 70$ and $NFa = 66$. The X chromosome was medium-sized submetacentric, and the Y chromosome was small acrocentric. The autosomal set contained nine pairs of bi-armed, and 15 pairs of acrocentric chromosomes.

Rize (Ovit mountain pass) and Başköy populations: These populations had a karyotype of $2n = 50, NF = 72$ and $NFa = 68$. The X chromosome was medium-sized submetacentric. The autosomal set had 10 pairs of bi-armed and 14 pairs of acrocentric chromosomes (Fig. 3).

Erbaa population: Three female animals from these two localities revealed a karyotype of $2n = 54, NF = 75$ and $NFa = 71$. The X chromosome was medium-sized submetacentric. The autosomal set contained nine pairs of bi-armed, one heteromorphic pair (subtelocentric / acrocentric) and 16 pairs of acrocentric chromosomes (Fig. 4).

Pozantı 15 km S population: The karyotype of this population was $2n = 56, NF = 72$, and $NFa = 68$. The X chromosome was medium-sized metacentric, and the Y chromosome was small acrocentric. The autosomal set had seven pairs of bi-armed and 20 pairs of acrocentric chromosomes.

Tayakadın, Akalan, Sofular, Vize, Hayrabolu, Yeniçiftlik, Halkalı, and Koyunbaba populations: The karyotype of these eight populations was $2n = 56, NF = 78$ and $NFa = 74$. The X chromosome was medium-sized submetacentric, and the Y chromosome was small acrocentric. The autosomal set contained 10 pairs of bi-armed and 17 pairs of acrocentric chromosomes.

Ereğli, Ulukışla and Pozantı populations: The karyotype of these populations consisted of 58 chromosomes ($2n$). The number of autosomal arms (NFa) was 68, the fundamental number (NF) was 72, the X chromosome was medium-sized submetacentric, and the Y chromosome was small acrocentric. The autosomal set can be divided into three groups: one pair of submetacentric, five pairs of subtelocentrics, and 22 pairs of acrocentrics.

Akseki and Göksun populations: These populations had a karyotype of $2n = 60, NF = 74$ and $NFa = 70$. The X chromosome was medium-sized submetacentric, and the Y chromosome of the Göksun population was small subtelocentric. The autosomal set had 6 pairs of bi-armed and 23 pairs of acrocentric chromosomes.

Kütahya population: This population had a karyotype of $2n = 60, NF = 76$, and $NFa = 72$. The X chromosome was medium-sized metacentric, and the Y chromosome was small subtelocentric. The autosomal set had seven pairs of bi-armed and 22 pairs of acrocentric chromosomes.

Havza and Karaali populations: The karyotype of these populations were $2n = 60, NF = 77$ and $NFa = 73$. The X chromosome was medium-sized submetacentric; the Y chromosome of the Karaali population was small acrocentric. The autosomal set contained seven pairs of

bi-armed, one pair of heteromorphic (subtelocentric / acrocentric) and 21 pairs of acrocentric chromosomes (Fig. 5).



Fig. 2. The karyotype of a female *Spalax leucodon* from the Şamanlı plateau of Gümüşhane province ($2n = 48$, $NF = 71$). The chromosome pair in the square is heteromorphic.

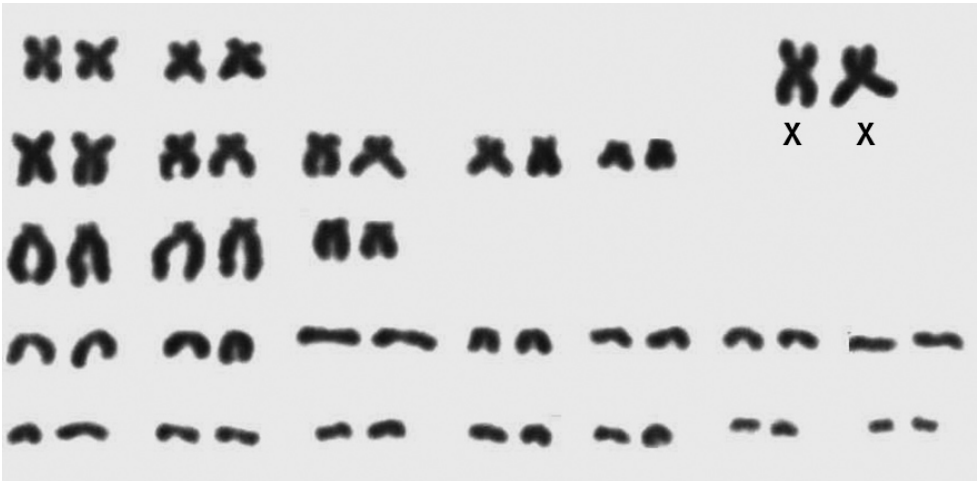


Fig. 3. The karyotype of a female *Spalax leucodon* from the Ovit mountain pass in Rize province ($2n = 50$, $NF = 72$).

Spalax ehrenbergi superspecies

Elbeyli population: The karyotype of the Elbeyli population was $2n = 52$, $NF = 74$ and $NFa = 70$. The X chromosome was medium-sized submetacentric, and the Y chromosome was small acrocentric. The autosomal set contained 10 pairs of bi-armed and 15 pairs of acrocentric chromosomes.



Fig. 4. The karyotype of a female *Spalax leucodon* from Erbaa 2 km W ($2n = 54$, $NF = 75$). The chromosome pair in the square is heteromorphic.



Fig. 5. The karyotype of a female *Spalax leucodon* from Karaali ($2n = 60$, $NF = 77$). The chromosome pair in the square is heteromorphic.

Adana populations: These populations had $2n = 56$, $NF = 72$, and $NFa = 68$. The X chromosome was medium-sized submetacentric, and the Y chromosome was small acrocentric. The autosomal set had seven pairs of bi-armed and 20 pairs of acrocentric chromosomes.

Table 1. Chromosomal records of *Spalax leucodon* superspecies from Turkey. sm: submetacentric, st: subtelocentric, a: acrocentric, m: metacentric, 2n: diploid chromosome number, NF: chromosome arm number, X: X chromosome, Y: Y chromosome.

Locality	2n	NF	X	Y	References
Bayındır	36	70	–	–	S ö z e n et al. 1999
Havran, Selçuk	38	74	st	a	S a v i c & S o l d a t o v i c 1979
Balıkesir, İzmir	38	74	st	a	N e v o et al. 1994, 1995
Bigadiç	38	74	sm	a	S ö z e n 2004
Dikili, Bigadiç	38	74	sm	a	T e z et al. 2002
Beyşehir	40	72	sm	–	N e v o et al. 1994, 1995
Ağrı and Van	48	68	sm	a	C o ş k u n 2003
Aydın	50	–	–	–	N e v o et al. 1994, 1995
Keltepe	50	70	sm	a	S ö z e n 2004
Erzurum, Sarıkamış	50	70	sm	–	N e v o et al. 1994, 1995
Erzurum, Susuz, Ardahan	50	72	sm	a	S ö z e n et al. 2000a
Erzurum and Kars	50	70	sm	a	C o ş k u n 2003
Sebil	52	72	sm	a	S ö z e n & K ı v a n ç 1998b
Çamlıyayla	52	72	sm	a	S ö z e n et al. 2000b
Bolu and Karamürsel	52	70	sm	a	S ö z e n 2004
Gölpazarı and Sakarya	52	70	sm	a	M a t u r & S ö z e n 2005
Eflani, Daday, Başçiftlik	54	72	sm	a	S ö z e n 2004
Yozgat	54	74	sm	st	Y ü k s e l & G ü l k a ç 2001
Bolu	54	–	sm	–	N e v o et al. 1994, 1995
Bingöl	54	–	–	–	N e v o et al. 1994, 1995
Tunceli, Elazığ, Bingöl	54	74	sm	a	C o ş k u n 2004a
Gülek	56	72	m	a	S ö z e n & K ı v a n ç 1998a
Tekir	56	72	m	a	S ö z e n et al. 2000b
Aşağıçiftlik, Safranbolu	56	74	sm	a	S ö z e n 2004
Çorlu, Karaevli (in Thrace)	56	78	sm	a	S o l d a t o v i c & S a v i c 1978
Eceabat (in Thrace)	56	76	sm	a	S ö z e n 2004
Tunceli	58	68	sm	a	C o ş k u n 2004a
Madenköy	58	72	sm	a	S ö z e n & K ı v a n ç 1998a
Ulukışla (center)	58	72	sm	a	S ö z e n et al. 2000b
Sarıkavak	58	78	sm	a	S ö z e n 2004
Ulukışla 30 km W	60	72	sm	a	S ö z e n et al. 2000b
Aksaray 12 km E	60	74	sm	a	S ö z e n et al. 2000b
Aksaray 35 km W	60	76	sm	st	S ö z e n et al. 2000b
Akşehir	60	76	sm	st	S ö z e n et al. 1999
Malatya, Pınarbaşı	60	78	sm	a	N e v o et al. 1994, 1995
Kayseri, Gürün	60	78	sm	–	T e z et al. 2001
Nallıhan, Beypazarı, Bakırlı, Kartalkaya	60	78	sm	st	S ö z e n 2004
Bilecik, İnegöl, İnönü	60	78	sm	st	M a t u r & S ö z e n 2005
Malatya	60	80	sm	st	Y ü k s e l 1984
Kırşehir, Nevşehir, Kayseri	60	80	sm	st	Y ü k s e l & G ü l k a ç 2001
Malatya, Yazlıhan	60	80	sm	st	G ü l k a ç & Y ü k s e l 1989
Batıkent, Sarayköy	60	80	sm	st	S ö z e n 2004
Arguvan	60	82	sm	–	G ü l k a ç & Y ü k s e l 1989
Ankara, Afyon	60	82	sm	st	S ö z e n et al. 1999
Burdur	60	84	sm	st	S ö z e n et al. 1999
Denizli	60	–	–	–	N e v o et al. 1994, 1995
Karaman	60	–	–	–	N e v o et al. 1994, 1995
Kütahya, Afyon, Konya, Sivas, Ankara, Kayseri, Havza, Suşehri	62	–	–	–	N e v o et al. 1994, 1995

Discussion

The $2n = 48$ karyotype was formerly reported from Ağrı and Van as $2n = 48$, $NF = 68$ (Coşkun 2003) for the superspecies *S. leucodon*. The $2n = 48$ karyotype determined here from Gümüşhane (locality no: 25) is different in its chromosome morphology (NF) from the Ağrı and Van populations and it is recognized as new for Turkey.

The $2n = 50$ forms were formerly reported from Aydın (Nevo et al. 1994, 1995), Keltepe (Sözen 2004) and Eastern Anatolia (Nevo et al. 1994, 1995, Sözen et al. 2000a, Coşkun 2003) for the superspecies *S. leucodon* (Table 1). These three areas are geographically very distant from each other and the chromosome morphologies are also different. Thus these three forms are regarded as different forms. The chromosome morphology of the Kahyalar population is identical with the Keltepe population. So, the new record from Kahyalar has enlarged the distribution range of this form eastward. The $2n = 50$ karyotype from Başköy and Ovit determined here is similar to the $2n = 50$ forms reported from Eastern Anatolia. The new record from Başköy and Ovit has enlarged the distribution range of this form westward. However, the NF value of $2n = 50$ forms in eastern Anatolia was given as 70 (Nevo et al. 1995, Coşkun 2003) and 72 (Sözen et al. 2000) (Table 2), with 72 in the Başköy and Ovit populations (Fig. 3). The $2n = 54$ karyotype determined here differs in NF number from the other $2n = 54$ populations of the superspecies *S. leucodon* (Table 1, Fig. 4).

There were only three karyological records for *Spalax leucodon* from the European part of Turkey (Table 1). Seventeen animals from eight localities in Thrace were karyotyped here and the results showed that Thrace is inhabited by a single form ($2n = 56$). However, the NF value of the Eceabat population (Sözen 2004) is different from the others (Table 1).

The $2n = 56$ form recorded here from the Elmalı area of Tekir (Pozantı 15 km S) is the same as that given from the Gülek (Sözen & Kıvanç 1998b) and Tekir (Sözen et al. 2000b) populations for the superspecies *S. leucodon*.

Table 2. Chromosomal records of *Spalax ehrenbergi* superspecies from Turkey. sm: submetacentric, st: subtelocentric, a: acrocentric, m: metacentric, 2n: diploid chromosome number, NF: chromosome arm number, X: X chromosome, Y: Y chromosome.

Locality	2n	NF	X	Y	References
Yayladağ	48	74	m	-	Coşkun 2004b
Hatay	52	74	sm	a	Coşkun 2004b
Kilis	52	74	sm	a	Sözen et al. 1999
Elazığ	52	76	sm	st	Yüksel 1984
Adıyaman and Hilvan	52	76	m	st	Yüksel & Gülkaç 1992
Diyarbakır and Urfa	52	76	-	-	Nevo et al. 1994, 1995
Birecik, Siverek, Diyarbakır, Elazığ	52	76	sm	-	Ivanitskaya et al. 1997
Mardin	52	76	m	-	Coşkun 2004c
Urfa	52	80	sm	-	Ivanitskaya et al. 1997
Suruç	54	76	m	st	Yüksel & Gülkaç 1992
Batman and Siirt	56	66	sm	a	Coşkun 2004c
Tarsus	56	72	-	-	Nevo et al. 1994, 1995
Tarsus	56	72	m	-	Ivanitskaya et al. 1997
Gaziantep	56	82	sm	-	Ivanitskaya et al. 1997
Gaziantep	56	90	m	st	Yüksel & Gülkaç 1992
Gaziantep	58	82	-	-	Nevo et al. 1994, 1995

Table 3. Localities and karyotypes of the animals examined. Population numbers are the same as indicated in Fig. 1. n: sample size, sm: submetacentric, st: subtelocentric, a: acrocentric, 2n: diploid chromosome number, NF: chromosome arm number, X: X chromosome, Y: Y chromosome.

Pop. No	Localities and coordinates	n ♂♂	n ♀♀	2n	NF	X	Y
<i>Spalax leucodon</i> superspecies							
1.	Koyunbaba 1 km S, Kırklareli	41°42' N, 27°05' E	3	-	56	78	sm a
2.	Hayrabolu 13 km N, Kırklareli	41°19' N, 27°08' E	1	2	56	78	sm a
3.	Sofular 1 km S, Kırklareli	41°38' N, 27°41' E	3	-	56	78	sm a
4.	Vize 10 km E, Kırklareli	41°30' N, 27°53' E	1	1	56	78	sm a
5.	Yeniçiftlik village of Tekirdağ	40°58' N, 27°52' E	2	-	56	78	sm a
6.	Akalan village of Istanbul	41°15' N, 28°25' E	1	-	56	78	sm a
7.	Tayakadın village of Istanbul	41°16' N, 28°39' E	1	-	56	78	sm a
8.	Halkalı, Istanbul	41°02' N, 28°47' E	-	2	56	78	sm -
9.	Kütahya 3 km S	39°24' N, 29°59' E	4	5	60	76	sm st
10.	Akseki 20 km SE, Antalya	36°54' N 31°66' E	-	1	60	74	sm -
11.	Akseki 22 km SE, Antalya	36°54' N 31°66' E	-	1	60	74	sm -
12.	Ereğli, Konya	37°43' N, 34°17' E	2	2	58	72	sm a
13.	Ulukışla 22 km SE, Niğde	37°25' N, 34°34' E	1	2	58	72	sm a
14.	Ulukışla 21 km SE, Niğde	37°29' N, 34°42' E	5	5	58	72	sm a
15.	Ulukışla 25 km SE, Niğde	37°23' N, 34°34' E	1	2	58	72	sm a
16.	Pozantı 13 km N, Adana	37°30' N, 34°54' E	1	-	58	72	sm a
17.	Pozantı 10 km N, Adana	37°29' N, 34°53' E	-	1	58	72	sm -
18.	Pozantı 15 km S, Adana	37°23' N, 34°50' E	1	1	56	72	m a
19.	Göksun, Kahramanmaraş	38°01' N, 36°29' E	2	2	60	74	sm st
20.	Kâhyalar village of Karabük	41°08' N, 32°34' E	4	1	50	70	sm a
21.	Karaali village of Gümüşhacıköy	40°49' N, 35°09' E	1	2	60	77	sm st
22.	Havza 3 km N, Samsun	40°59' N, 35°38' E	-	2	60	77	- -
23.	Erbaa 12 km W, Tokat	40°44' N, 36°27' E	-	2	54	75	sm -
24.	Erbaa 2 km W, Tokat	40°41' N, 36°55' E	-	1	54	75	sm -
25.	Gümüşhane 35 km NE	40°34' N, 39°36' E	-	2	48	71	sm -
26.	Başköy 3 km SE, Erzincan	39°52' N, 39°50' E	-	1	50	72	sm -
27.	Rize 25 km SE (Ovit mountain pass)	40°37' N, 40°50' E	-	1	50	72	sm -
<i>S. ehrenbergi</i> superspecies							
28.	Adana 5 km S	36°57' N, 35°21' E	-	1	56	72	sm -
29.	Şeyhmurat, Adana	36°53' N, 35°24' E	1	2	56	72	sm a
30.	Elbeyli 2 km S, Kilis	36°40' N, 37°28' E	1	1	52	74	sm a
Total				36 + 43 =	79 samples		

The 2n = 58 karyotypic form was formerly determined from Madenköy and Ulukışla in southern Turkey by S ö z e n & K ı v a n ç (1998a) and S ö z e n et al. (2000b), from Sarıkavak by S ö z e n (2004), and from Tunceli by C o ş k u n (2004a) for the superspecies *S. leucodon*. The chromosome morphology of the 2n = 58 form reported from Ereğli, Alihoca, Madenköy and Pozantı is identical with the Madenköy and Ulukışla populations. The new records from Ereğli, Ulukışla 21 km, 22 km and 25 km SE, and Pozantı enlarge the distribution range of the 2n = 58 / NF = 72 form westward and eastward.

The karyotypes of the *Spalax* populations in central Anatolia have been found to be 2n = 60 and 62, and the NF value is more diverse, varying between 72 and 84 for the superspecies *S. leucodon* (Table 1). The diploid karyotype of the Kütahya, Akseki, Göksun, Havza and

Karaali populations is similar on the basis of the $2n$ value to those reported from most parts of central Anatolia listed in Table 1, but there are some differences in NF values among these populations. Akseki 20 km SE is reported to be the most southern margin of the $2n = 60$ form in Turkey.

The NF values of the Gümüşhane 35 km NE (Şamanlı Plateau) were determined as NF = 71, Erbaa as NF = 75, and Havza and Karaali populations as NF = 77 (Table 3, Figs 2, 4, and 5), but their diploid chromosome number is different: one heteromorphic pair (acrocentric / subtelocentric) seems to be common to all. These three forms are located close to each other in north-eastern Anatolia (Fig. 1), and this common chromosome pair may reflect phylogenetic relationships among them.

The $2n = 52$, NF = 74 karyotype was previously recorded from Hatay (Coşkun 2004b) and from Kilis (Söz en et al. 1999) for the superspecies *S. ehrenbergi* (Table 2). The karyotype determined here from Elbeyli is the same. Elbeyli is the most eastern margin of the distribution of this form.

The $2n = 56$, NF = 72 karyotype was previously recorded from Tarsus (Nevo et al. 1994, Ivanitskaya et al. 1997) for the superspecies *S. ehrenbergi* (Table 2). The karyotype determined here from Adana is the same in terms of chromosome morphology. The new records here enlarge the distribution of this form eastward.

A taxonomic revision of species and subspecies of *Spalax* in Turkey was carried out by Kıvanç (1988) using only morphological data. According to Nevo et al. (1995), this attempt at a revised taxonomy was unrealistic in view of their own karyotype and allozyme study. Moreover, some subspecies indicated by Kıvanç (1988) have more than one karyotype; for example, *Spalax leucodon cilicicus* has at least nine chromosomal forms ($2n/NF = 50/70, 52/72, 54/72, 54/72, 56/72, 58/72, 58/72, 60$ and 62) (Nevo et al. 1995, Söz en & Kıvanç 1998a,b, Söz en et al. 1999, 2000b, Söz en 2004) (see Table 1). Additionally, Nevo et al. (1995) considered the populations with different diploid chromosome numbers, $2n$, to be good biological species. Thus, splitting the populations based on karyotypes produces a more realistic taxonomy in *Spalax* (Nevo et al. 1995).

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