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Craniometrical characteristics of some *Sorex araneus* chromosomal races

Natalia M. Okulova*, Alexander E. Balakirev & Victor N. Orlov

ABSTRACT. Skulls of 504 immature common shrews (*Sorex araneus*) representing seven chromosomal races (Moscow, Lepel, Manturovo, Yagry, Serov, Tomsk, and Neroosa) were examined using 24 morphometric variables and 15 indices derived from them. The races were found to differ in a number of dimensions and proportions of the skull. Each race has its own morphological appearance. Cluster analysis of craniometrical data showed that the Tomsk race was separated from other races. Factor analysis revealed the main trend of craniometrical variability in *S. araneus* chromosomal races. The craniometrical diversity of the species is determined by the variation of characters related to the length of dental rows and the width of the mouth cavity.

KEY WORDS: *Sorex araneus*, chromosome races, skull dimension, craniometric features.

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Краниометрические характеристики некоторых хромосомных рас *Sorex araneus*

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РЕЗЮМЕ. По 24 промерам и 15 индексам проведено сравнение 504 черепов сеголеток обыкновенной бурозубки, относящихся к 7 хромосомным расам. Показано, что расы достоверно отличаются друг от друга по большому числу размерных признаков и пропорций черепа, каждая раса имеет свой морфологический облик. С помощью факторного анализа определено основное направление внутривидовой изменчивости черепа — изменение общих размеров, а также зубных рядов или их отделов (главным образом, длины зубных рядов и ширины ротовой полости).

КЛЮЧЕВЫЕ СЛОВА: *Sorex araneus*, хромосомные расы, размеры черепа, краниометрические особенности.

Introduction

In European Russia, the common shrew *Sorex araneus* L., 1758 has almost 20 known chromosomal races formed in this species by Robertsonian fusions from an ancestral acrocentric karyotype (Bulatova *et al*., 2000; Kozlovsky *et al*., 2000; Orlov *et al*., 2004) and it is of interest to compare this variability with other aspects of phenotype and genotype. Craniometric measurements are obvious features for such a comparison. Many authors have studied geographical and population variability in the skull dimensions of *S. araneus* (Dolgov, 1968, 1972, 1985; Senyk, 1973; Sharova, 1975a, b; Puchkovsky, 1981; Yudin, 1989; Gabitova & Moskvitina, 1992; Bolshakov *et al*., 1996), but these studies have revealed little geographical patterning except some examples of clinal variation (Dolgov, 1985). Modern methods of multidimensional statistical analysis make a reappraised of craniometrical variation in *S. araneus* worthwhile, particularly within the context of the chromosomal variation within the species.

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The first investigations comparing craniometry with chromosomal variation in common shrews gave negative results. A canonical discriminant analysis of 8 mandibular dimensions in three chromosomal races from England showed geographic but non-racial distinctions (Searle & Thorpe, 1987). However, all the interracial hybrids were united in a group separated from the parental races. Sulkava *et al*. (1985) found that upper dental row lengths (row length, intermediate tooth row length and molar row length) of *S. araneus* from Scandinavia did not relate to chromosome races but reflected geography.

However, more recent investigations have shown that morphological distinctions exist among chromosomal forms in a number of cases. So, Hausser *et al*. (1991) showed that the Swiss Valais and Vaud races can be separated morphologically. The Valais race was later renamed as *S. antinorii* (Brünner *et al*., 2002) on the basis of morphological, karyological and biochemical distinctiveness. In the Ural Mountains, 12 populations were subjected to discriminant analysis using four metric and eight craniometric variables and separated into two or three clusters corresponding to the Serov race and a group of similar races Sok and Yuruzan (Gabitova & Moskvitina, 1992; Vasil'ev & Sharova, 1992). Thus, southern and northern Ural forms are distinguishable. In the same way, the southern Ural populations are separated from Altai populations. By canonical discriminant analysis a clear morphological distinction in the cranial and postcranial skeleton was demonstrated between populations of the Novosibirsk and Tomsk chromosomal races and their hybrids (Polyakov *et al*., 2002). In one of the most recent studies carried out by analogous methods involving mandibular measurements, little difference was found between Polish chromosomal races that belong to the West and East European karyotypic groups (Wójcik *et al*., 2000), consistent with data showing an absence of cytochrome *b* variation between karyotypic groups (WEKG and EEKG) in Poland and also consistent with recent isolation or a bottleneck in their evolution (Ratkiewicz *et al*., 2002). Polly (2001, 2003, 2007) has investigated differences between populations of *S. araneus* using dental shape variables. He has found small but significant differences between chromosomal races that could not be attributed to geography. Thus, there are varied results from studies of morphometric characteristics in different chromosomal races of common shrew. In particular much needs to be done on races inhabiting European Russia. Therefore, this study examines craniometrical characteristics for seven chromosomal races of *Sorex araneus* from central and northern regions of European Russia.

The findings in this paper have already been published in Russian (Okulova *et al*., 2004).

Material and methods

In this study use was made of 504 skulls of immature common shrews from the Zoological Museum of Moscow University (ZMMU), the Zoology and Ecology Department of Moscow Pedagogic University (MPGU) and the private collection of one of the authors (PC). Animals were captured during summer months from the following localities:

1 — Yagry Island, Severodvinsk, Arkhangelsk Province, 1997–2000, Yagry race*, coll. Balakirev A.E., PC, 54 specimens.

2 — Ramenye Village, Velsk District, Arkhangelsk Province, 1981–1982, Manturovo race*, coll. Kupriyanova I.F. and Nedosekina I.B., MPGU, 53 specimens.

3 — Dan Village, Kortkeros District, Komi Republic, 1981–1983, 1987, Manturovo race, coll. Kupriyanova I.F. and Nedosekina I.B., MPGU, 92 specimens.

4 — Middle Pechora, Komi Republic, 1925, Serov race, coll. Chirkova A., ZMMU, 14 specimens.

5 — Pechoro-Ilichsky Nature Reserve, Komi Republic, 1938, Serov race, coll. is unknown, ZMMU, 22 specimens.

6 — Paleh Village, Ivanovo Province, 2000, Moscow race*, coll. Balakirev A.E., PC, 5 specimens.

7 — Demidovo Village, Pestyaky District, Ivanovo Province, 1998–2000, Moscow race*, coll. Balakirev A.E. and Shantzeva Yu.V., PC, 25 specimens.

8 — Town Vitchuga, Ivanovo Province, 2000, Moscow race, coll. Balakirev A.E., PC, 2 specimens.

9 — Berezinsky Nature Reserve, Lepel District, Vitebsk Province, Belarus. 1995–2000, Lepel race*, coll. Kashtaljan A.P., ZMMU, 94 specimens.

10 — Gidrouzel Village, Tom-Chumish, Prokopyevsk District, Kemerovo Province. 1957, 1962, Tomsk race, coll. Shtilmark F.R., Okulova N.M., and Koshkina T.V., ZMMU, 52 specimens.

11 — Zvenigorod Biological Station of Moscow State University, Odintzovo District, Moscow Province. 1979, 1997–2001, Moscow race, coll. Shenbrot G.J. et al., ZMMU, 44 specimens.

12 — Dmitrovsk District, Kursk Province, 1926-1927, 1930, Neroosa race, coll. is unknown, ZMMU, 24 specimens.

13 — Talowaya District, Voronezh Province. 1948, 1989, Neroosa race, coll. Kulukina N.M. and Kovalskaya Yu.M., ZMMU, 12 specimens.

14 — Borovsk District, Voronezh Province, 1919, 1921, 1949, Neroosa race, coll. Obolensky C. and Obraztzov B., ZMMU, 11 specimens.

The localities were chosen to represent chromosomal races established either by direct karyotyping of some specimens (marked by an asterisk) or on the basis of their location within a well-established range. A.I. Kozlovsky carried out the karyotyping of animals from localities 1, 2, 3, 6 and 7. Karyological data from localities 9 and 10 were taken from the literature (Bulatova *et al*., 2000; Polyakov *et al*., 2000). N.S. Bulatova and N.A. Shchipanov have identified common shrews from the Pechoro-Ilichsky Nature Reserve as the Serov race (Shchipanov *et al*., 2005).

A total of 24 measurements were taken (Fig. 1). The measurements were carried out using an ocular micrometer in a binocular microscope MBS to an accuracy of 0.1 mm for GSL, CBL, BS and HS and to within 0.05 mm for all other measurements. All measurements are given in mm.

Fifteen indices were calculated from these measurements: 1 — index of skull breadth (ISB=BS/CBL); 2 — index of skull height (ISH=HS/CBL); 3 — zygomatic index (ZY=ZB/BS); 4 — index of the eye-sockets (IES=IS/ZB); 5 — index of the rostrum (IR=BR/BS); 6 — index of the upper premolar dental row (IPR=LIR/LUR); 7 — facial index (FI=FP/CBL); 8 — index of mandibular height (IMH=HM/LM); 9 — incisor index (II=LLI/LDR1); 10 — molar index (MY=LMR/LDR2); 11 — index of the length of the mandibular process (ILMP=AC/AA); 12 — index of the position of the mandibular aperture (IPAP=IA/HE); 13 — index of rostrum length (IRL=LR/ZB); 14 — relative length of the upper dental row (ILUR=LUR/CBL); 15 — relative length of the lower dental row (ILLR=LDR1/LM).

Immature animals were exclusively used to reduce the influence of age variation. Sexes were not distinguished because it has been shown that sexual dimorphism accounts for the only 2.8% of morphological

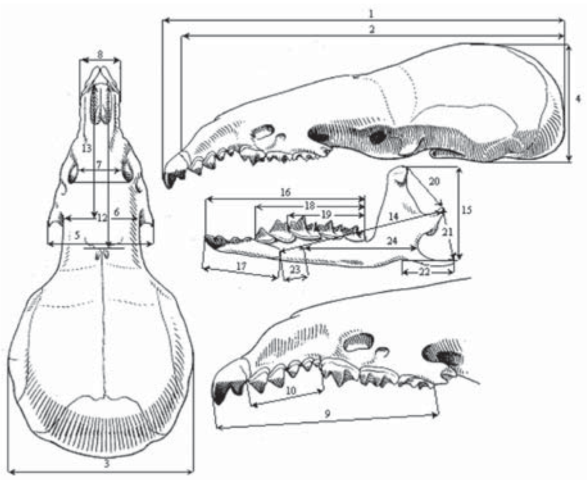

Figure 1. Skull measurements taken (after Yudin, 1989).
1 — skull length (GSL): maximum length with incisors; 2 — condylobasal skull length (CBL): the distance from the posterior edge of the occipital bone to the anterior edge of the maxilla; 3 — maximum breadth of skull (BS); 4 — maximum height of skull without the tympanic bones (HS); 5 — zygomatic breadth (ZB): the distance between the external edges of the zygomatic arches of the maxilla; 6 — interorbital space (IS): the minimal breadth of the frontal bones in the orbits near their limit with the maxilla; 7 — minimal distance between the naso-orbital foramina (DNO); 8 — breadth of rostrum (BR): the distance between the external edges of the nasal bones level with the first and second intermediate teeth; 9 — length of the upper dental row (LUR): the maximal length of the upper dental row measured from below; 10 — the length of the upper intermediate dental row (LIR) measured from below; 11 — the breadth of the osseous palate (BOP); 12 — the length of the facial part of skull (FP): the distance from the anterior edge of the supraorbital foramina to the anterior edge of the maxilla; 13 — rostrum length (LR): the distance from the line joining the anterior edges of the naso-orbital foramina to the anterior edge of the maxilla; 14 — maximum length of mandible (LM): the distance from the base of the lower incisor to the top of articular process measured from the lateral side; 15 — the height of mandible (HM): the distance from the top of coronoid process to the edge of the mandible in the region of the angular process measured from the lateral side; 16 — the length of the lower dental row (LDR1): the maximal length of the lower dental row with the incisor, measured from the lateral side, 17 — length of lower incisor (LLI) from the lateral side; 18 — length of the lower dental row Pm+M (LDR2) without the incisors, measured from the lateral side; 19 — length of the lower molar row (LMR) measured from the lateral side, 20 — distance between the tips of the condylar and coronoid processes of the mandible (AC); 21 — distance between the tips of the condylar and angular processes of the mandible measured (AA); 22 — length of the angular process (LA); 23 — distance from the base of the incisor to the posterior edge of the mandibular aperture (IA); 24 — distance from the hind edge of the mandibular aperture to the posterior edge of the mandible measured between the angular and articular processes (HE).

variability in *S. araneus* while geographical variability is as much as 30 times more (Vasil'ev & Sharova, 1992). The following abbreviations were used for standard statistical parameters: M — arithmetical mean; p — significance level. All standard statistical calculations were carried out using Statistica 6.0.

Seven population samples belonging to five races (330 shrews) were selected to study year-by-year variation in morphology. We used 10 skull measurements to examine this over 2–4 successive years using one-way ANOVAs (Lakin, 1973; Sheffe, 1990; Computer biometrics, 1990).

We also examined the relative influence of chromosomal race and geography on morphology, using two-way ANOVAs. Four populations were selected for study: two of the Neroosa race (Voronezh Province — 39–42º E and Kursk Province — 36–37º E) and two of the Moscow race (Demidovo Village, Ivanovo Province — 39–42º E and Zvenigorod Biological Station, Moscow Province — 36–37º E); these populations are remote from one another in a longitudinal direction. Twenty-two skulls from each population were included in the analysis. The influence of factors is symbolized by η, with a coefficient of determination, $R=\eta^2$. The significance of the factors was determined with an F-test. We also used cluster analysis with single linkage. The cluster analysis was performed on the means of all 24 variables. Principal components analysis with varimax rotation was also carried out in Statistica 6.0.

Results and discussion

All measurements and indices displayed significant distinction between races excepting IPAP. Siivonen (1979) regards this index as a species-specific characteristic and our data support this. The characteristics of each race are described below, and the data are given in Tabs 1, 2 and 3.

Western-European karyotypic group

Moscow race. The common shrews of this race have small longitudinal and vertical skull dimensions, and so ISB and ISH values are large. Distinguishing features are large ZB, BR and BOP, very small GSL, LUR and especially LIR, moderate FP and rather short LR. Length and height of the mandible (LM, HM) are moderate; LDR1 and especially LLI are rather short while LMR is no lower than the average. The angular process is short and the articular process is situated relatively low on the mandible, as a result, AA is very small.

Eastern-European karyotypic group

Neroosa race. The skull of this race is similar to the Moscow race in general form but is more gracile, characterised by small size overall. The skull breadth is reduced and the ISB is quite large. Just as in the Moscow race, the Neroosa skulls have a large ZB and BR. BOP is very small, and DNO, IS, FP and LR are even smaller then in the Moscow race. The lengths of dental rows and especially LIR are the shortest of all the races but the relative length of the latter is not extreme. The incisors are short, but relative to the dental row length they are large. The angular process is moderately long and is not noticeably displaced.

Table 1. The means (M) and standard errors (s.e.) for skull measurements of different chromosome races of *S. araneus*.

Skull measurements	Yagry race		Moscow race		Serov race		Lepel race		Manturovo race		Tomsk race		Neroosa race	
	M±s.e.	n	M± s.e.	n	M± s.e.	n	M± s.e.	n	M± s.e.	n	M± s.e.	n	M± s.e.	n
GSL	20.495±0.070	53	19.979±0.057	71	20.925±0.097	30	20.610±0.039	94	20.768±0.033	145	21.813±0.066	52	19.736±0.054	47
CBL	19.738±0.069	53	19.227±0.052	72	20.186±0.107	30	19.912±0.039	94	20.060±0.035	145	21.005±0.062	52	19.032±0.054	47
BS	9.663±0.036	53	9.578±0.031	69	9.770±0,052	29	9.836±0.019	94	9.777±0.017	144	10.304±0.032	51	9.374±0.034	47
HS	6.370±0.037	53	6.209±0.024	73	6.344±0.117	31	6.107±0.022	94	6.223±0.019	145	6.456±0.033	52	6.047±0.029	47
ZB	5.032±0.023	53	5.171±0.016	73	4.991±0.034	36	5.092±0.012	94	5.062±0.013	141	5.469±0.022	52	5.199±0.023	47
IS	3.491±0.015	53	3.546±0.014	76	3.523±0.023	36	3.510±0.012	94	3.577±0.011	145	3.717±0.020	52	3.511±0.019	47
DNO	2.411±0.012	53	2.511±0,011	75	2.506±0.019	36	2.482±0.008	94	2.478±0.006	145	2.586±0.013	52	2.466±0.010	47
BR	1.739±0.011	53	1.815±0.011	76	1.785±0.011	36	1.809±0.007	94	1.739±0.005	145	1.960±0.009	52	1.899±0.010	47
LUR	8.678±0.030	53	8.638±0.021	74	8.850±0.036	35	8.594±0.017	94	8.689±0.015	145	9.362±0.030	51	8.638±0.025	47
LIR	2.972±0.018	53	2.879±0.013	75	3.064±0.013	36	2.893±0.008	94	2.999±0.009	145	3.304±0.016	52	2.887±0.013	47
BOP	2.033±0.011	52	2.145±0.010	73	2.162±0.015	33	2.122±0.007	94	2.119±0.007	142	2.257±0.009	51	2.159±0.012	47
FP	9.745±0.044	53	9.222±0.044	76	9.927±0.052	35	9.226±0.038	94	9.256±0.023	145	9.682±0.035	51	8.941±0.039	47
LM	8.285±0.037	53	8.422±0.025	75	8.595±0.047	31	8.454±0.019	94	8.415±0.018	134	9.161±0.026	52	8.465±0.026	47
HM	4.612±0.015	53	4.606±0.015	74	4.592±0.030	31	4.568±0.013	94	4.532±0.011	134	5.161±0.018	52	4.650±0.016	47
LDR 1	8.004±0.023	53	7.923±0.022	74	8.189±0.042	31	7.874±0.015	94	7.990±0.016	138	8.559±0.022	52	7.964±0.026	47
LLI	3.954±0.032	53	3.835±0.015	74	3.990±0.022	31	3.768±0.014	94	3.906±0.011	138	4.090±0.028	52	3.874±0.016	47
LDR 2	5.350±0.013	53	5.377±0.015	74	5.462±0.027	31	5.347±0.011	94	5.366±0.011	138	5.805±0.013	52	5.415±0.018	46
LMR	3.681±0.011	52	3.764±0.012	75	3.760±0.019	31	3.737±0.009	94	3.702±0.007	138	3.921±0.011	52	3.778±0.013	47
AC	2.811±0.019	53	2.818±0.015	74	2.824±0.022	31	2.762±0.014	94	2.785±0.013	127	3.129±0.019	52	2.869±0.022	47
AA	2.696±0.017	52	2.628±0.014	72	2.584±0.071	23	2.652±0.012	78	2.682±0.010	98	2.796±0.016	51	2.682±0.022	42
IA	1.130±0.017	53	1.177±0.013	72	1.186±0.023	30	1.172±0.012	93	1.145±0.010	138	1.267±0.016	52	1.172±0.019	47
HE	5.602±0.024	53	5.663±0.020	72	5.774±0.041	30	5.637±0.058	93	5.679±0.040	137	6.157±0.026	52	5.715±0.026	47
LA	2.414±0.025	52	2.379±0.014	72	2.568±0.026	23	2.337±0.014	78	2.446±0.014	101	2.547±0.020	51	2.373±0.024	47
LR	5.406±0.029	53	5.236±0.023	76	5.450±0.034	36	5.343±0.016	94	5.449±0.014	144	5.718±0.024	51	5.185±0.022	47

Table 2. The means (M) and standard errors (s.e.) for skull indices in the different chromosome races of *S. araneus*.

Skull measurements	Yagry race		Moscow race		Serov race		Lepel race	
	M±s.e.	n	M± s.e.	n	M± s.e.	n	M± s.e.	n
ISB	0.490±0.002	54	0.499±0.001	68	0.484±0.002	27	0.494±0.001	94
ISH	0.319±0.002	54	0.329±0.001	72	0.316±0.006	28	0.307±0.001	94
ZY	0.522±0.003	54	0.542±0.002	66	0.515±0.004	29	0.518±0.001	94
IES	0.700±0.004	54	0.686±0.003	73	0.706±0.005	36	0.690±0.003	94
IR	0.182±0.001	54	0.191±0.002	69	0.184±0.002	29	0.184±0.001	94
IPR	0.342±0.002	54	0.334±0.001	73	0.347±0.002	35	0.337±0.001	93
FI	0.494±0.002	54	0.479±0.002	72	0.493±0.003	30	0.463±0.002	94
IMH	0.556±0.003	54	0.547±0.002	74	0.534±0.003	31	0.540±0.002	94
II	0.491±0.003	54	0.484±0.002	74	0.487±0.002	31	0.479±0.001	94
MY	0.688±0.001	53	0.670±0.002	74	0.689±0.002	31	0.699±0.001	94
ILMP	1.043±0.010	53	1.075±0.008	71	1.131±0.065	23	1.044±0.008	78
IPAP	0.202±0.003	54	0.208±0.003	72	0.206±0.004	30	0,226±0.019	93
IRL	10.372±0.055	54	10.300±0.047	76	10.464±0.065	36	10.259±0.031	94
ILUR	0.439±0.002	54	0.450±0.001	70	0.439±0.002	29	0.432±0.001	93
ILLR	0.962±0.003	54	0.941±0.003	74	0.953±0.005	31	0.932±0.002	94
	Manturovo race		Tomsk race		Neroosa race			
	M± s.e.	n	M± s.e.	n	M± s.e.	n		
ISB	0.487±0.001	144	0.490±0.002	51	0.493±0.002	47		
ISH	0.310±0.001	145	0.307±0.001	52	0.318±0.002	47		
ZY	0.518±0.001	140	0.531±0.002	51	0.555±0.003	47		
IES	0.708±0.002	141	0.680±0.004	52	0.676±0.004	47		
IR	0.178±0.001	144	0.190±0.001	51	0.203±0.001	47		
IPR	0.345±0.001	145	0.353±0.001	51	0.334±0.001	47		
FI	0.462±0.001	145	0.461±0.001	51	0.470±0.002	47		
IMH	0.539±0.002	129	0.564±0.002	52	0.550±0.002	47		
II	0.489±0.001	138	0.478±0.003	52	0.487±0.002	47		
MY	0.690±0.001	138	0.676±0.001	52	0.698±0.001	46		
ILMP	1.037±0.007	95	1.012±0.009	51	1.072±0.013	42		
IPAP	0.213±0.013	137	0.206±0.003	52	0.206±0.004	47		
IRL	10.463±0.028	144	10.965±0.045	51	10.370±0.043	47		
ILUR	0.433±0.001	145	0.446±0.001	51	0.454±0.001	47		
ILLR	0.950±0.002	133	0.935±0.003	52	0.941±0.003	47		

Lepel race. Animals of this race have a moderately long skull, which is broad and flat, with a moderately long zygomatic arch, but with wide eye-sockets and rostrum. The absolute and relative lengths of the facial part of the skull are small. The mandibles are of moderate length; the lower dental row and especially the lower incisors are short; otherwise the length of the molar row is moderate. The angular process is rather short and the articular process is slightly raised. As a result both AC and AA are very small.

Manturovo race. A rather long skull with moderate breadth and height characterises the Manturovo race. The zygomatic breadth is rather small and the interorbital breath quite large. The rostrum and facial part of skull are of moderate length but the former is rather narrow. The upper dental row is of average size. The length of the lower dental row and the lower incisor are moderate but the lower molar dental row is slightly shortened especially at the expense of the premolars. The angular process is of average size while the articular process is somewhat larger than normal.

Table 3. Influence of year-by-year variation (η^2) on craniometric characters in different races of common shrew from specified sites.

Measurements	Yagry race	Manturovo race	Moscow race		Lepel race	Neroosa race	
	Yagry Island, n=50	Dan, n=92	Demidovo, n=19	Zvenigorod Biological Station, n=41	Berezinsky Nature Reserve, n=87	Kursk District, n=24	Voronezh District, n=17
GSL	0.179**	ns	ns	0.183***	ns	ns	ns
CBL	0.188**	ns	ns	0.304***	ns	0.551***	ns
LUR	0.126*	ns	ns	0.267**	ns	ns	ns
HS	ns	0.09*	ns	0.306*	ns	ns	ns
ZB	ns	0.107*	ns	0.214*	ns	ns	ns
BS	0.227**	ns	ns	0.154*	ns	0.333*	ns
LM	ns	ns	0.102*	0.201*	ns	ns	ns
LIR	ns	ns	ns	ns	ns	ns	ns
BR	ns	ns	ns	ns	0.214***	ns	ns
BOP	ns	ns	ns	ns	ns	ns	ns

n — number of individuals; ns — not significant; * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Yagry race. This is a newly described race with diagnostic chromosomes *go*, *hi*, *kq*, *mp*, *nr* (Orlov *et al*., 2004). It is characterised by the following traits: a moderately long skull with principal longitudinal dimensions (GSL, CBL, LUR, LIR and LDR1) of average length, but transverse measurements (BS, ZB, BR and especially IS, DNO and BOP) comparatively narrow. The height of the skull (ISH) is large. Long lower incisors and an extended facial part of skull with a small rostrum length are race-specific features. The height of the mandible and the length of lower dental row are small. ILMP is rather large, the mandibular processes are moderate. The dimensions of the upper dental row are also moderate.

Ural races

Serov race. This race has a very long, moderately wide and rather high skull which narrows at the eye-sockets. The extremely long facial part of skull is also characteristic. The values for ZB and IS are moderate and the rostrum has a moderate length and width. The upper dental row and BOP are long as is the mandible, although the height is moderate. The lower dental row is absolutely rather long and its relative length is the greatest among the all races studied. The premolars are small while the length of the lower incisors is moderate. The length of the angular process is extremely large in comparison to other races but the articular process is displaced downward as in the Moscow race.

Siberian races

Tomsk race. Shrews of this race have a larger skull then all other races examined. The facial part of skull is relatively rather short and the rostrum is wide. The length of the upper dental row (especially the premolars) is relatively large. The mandible is relatively high and relative length of the lower molar row is low. The premolars are rather large. The angular process is extended.

In the light of our new data, it is interesting to reconsider the result of V.A. Dolgov (1968, 1985). Although he made three measurements only (CBL, LUR and BR) he showed that the large skulled populations from Altai and Sayan were different from the wide-nosed populations from Western Siberia and the Ural mountains, which in turn were distinct from the Karelian populations, which were characterised by rather small skulls, and those from South-Western Europe with moderate large skulls, very long dental rows and a wide rostrum.

The influence of year-by-year variation on skull dimensions of *Sorex araneus*. As shown in Tab. 3, annual variation was significant for 7 of 10 measurements in the Zvenigorod sample (Moscow race) and for 4 of 10 in the Yagry race. However, very little of the morphological variation is accounted for year-to-year variation, not more than 6%. Based on these findings, we pooled data from all years for racial comparison.

The influence of race and geographical location on variability. ANOVAs revealed that geographical location is not significant for any measurements. On the other hand, race affected 8 out of 10 measurements studied (all except LUR and BS, Tab. 4).

Thus, we conclude that only race significantly influenced variation, not geography as such. This result can be tested by including more distant populations in the analysis. However, we imagine that clinal geographical variability in *S. araneus* results from the differences which characterise the chromosome races.

Table 4. Impact of chromosome race (η^2) on craniometric measurements.

Dimensions	Parameters of analysis		
	η^2	F	*p*
GSL	0.483	24.17	<0.0001
CBL	0.286	11.12	<0.0001
LUR			ns
BS			ns
BOP	0.102	3.15	<0.05
FP	0.535	28.11	<0.0001
HS	0.399	14.65	<0.0001
BR	0.421	19.28	<0.0001
LM	0.391	18.74	<0.0001
LIR	0.084	2.88	<0.05

ns — not significant

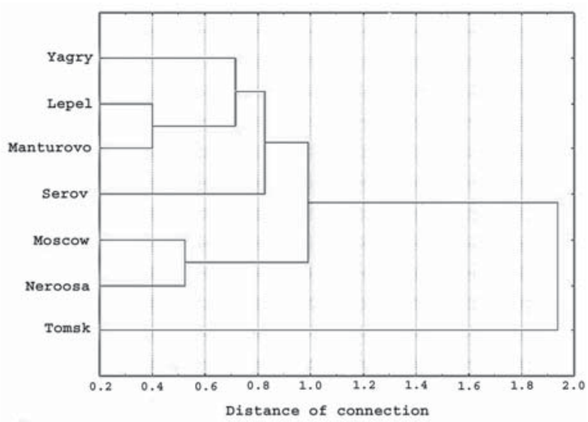

Figure 2. Relationships of different chromosome races of common shrew based on 24 skull variables.

Analysis of interracial relationships. The results of a cluster analysis of 24 mean skull dimensions are presented in Fig. 2. The Tomsk race is distinct from all other chromosomal races, which form two clusters. One cluster consists of the Moscow and Neroosa races. In the other cluster, the Lepel and Manturovo races are situated closest each other, the Yagry race is next closest, and the Serov race furthest of all.

We used principal components analysis on the 24 skull measurements. For simplicity, only the variables which had factor loadings of 0.7 and above are included in Tab. 5. These were GSL, CBL, BR and LUR; overall, factors I and II described 89.09% of the variation. Factor 1 includes skull length (GSL and CBL) and length of the lower dental row, and Factor 2 includes rostral breadth (BR). These data suggest that chromosome race differentiation is reflected by general skull length and facial breadth.

In principal component space, the two European races (Neroosa and Moscow) are almost completely

Table 5. Factor loading in the principal components analysis.

Dimensions	Factor 1	Factor 2
GSL	0.970	0.080
CBL	0.958	–0.031
BR	0.018	0.969
LUR	0.716	0.495
Cumulative value	3.073	1.048
Dispersion explained (%)	62.67	26.42
Dispersion explained (Overall %)	89.09	

separated from the Tomsk race (Fig. 3). The Neroosa and Moscow races also formed a separate cluster in cluster analysis. Races such as Lepel and Manturovo overlap with the Tomsk race only slightly. The principal component approach confirmed the large distance of the Tomsk race from other races as indicated in the cluster analysis. This confirms earlier findings that the Siberian common shrews are distinct from European-Ural shrews; indeed the former are considered as a separate subspecies (Yudin, 1989).

The distinctive features identified here using craniometry emphasise the fact that the races are not only chromosomal categories, but are also distinct intraspecific groups marked by a complex of features including skull shape. In conclusion, craniometry can allow researchers to distinguish chromosome races of common shrew. Further studies are needed to accurately determine relationships of chromosomal races based on this method.

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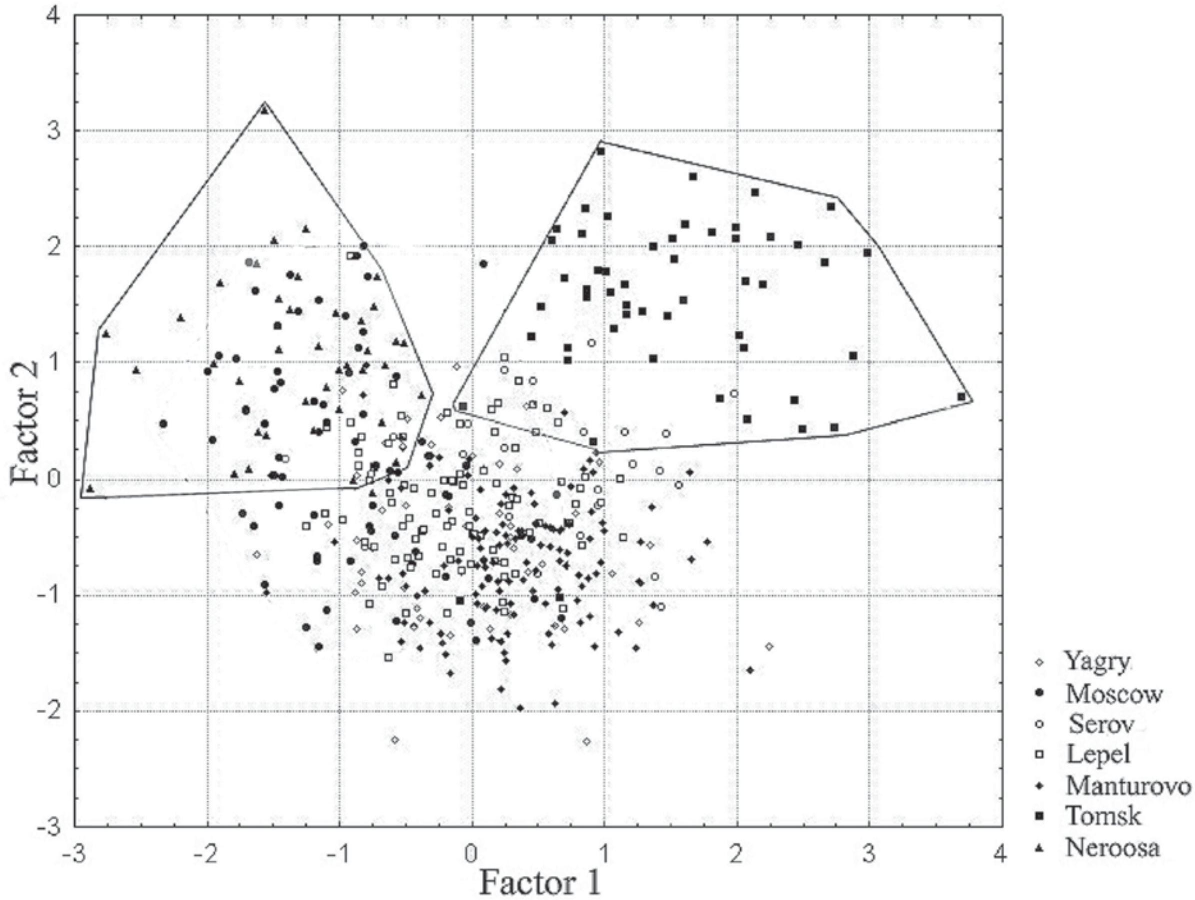

Figure 3. The distribution of specimens of common shrew belonging to specified chromosomal races along two principal component axes calculated from 24 skull variables.

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