

Karyotypic variation of the common shrew *Sorex araneus* in Belarus, Estonia, Latvia, Lithuania and Ukraine

Alina V. MISHTA, Jeremy B. SEARLE and Jan M. WÓJCİK

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Karyotypes of 55 common shrews *Sorex araneus* Linnaeus, 1758 from 24 geographically distinct sites in Eastern Europe (Belarus, Estonia, Latvia, Lithuania, Ukraine) were obtained using G-banding. Ten chromosome races were found, six of which had been described previously in the following countries: the Gołdap race in Poland (Fedyk 1986), the Białowieża race in Poland (Fredga and Nawrin 1977), the Pskov race in Russia (Zaitsev and Bulatova 1999), the Kiev race in Ukraine (Mishta 1994), the Lepel race in Belarus (Bulatova *et al.* 2000) and the Neroosa race in Russia (Bulatova *et al.* 2000). The four new races were characterised by the following meta-centrics: *gr*, *hk*, *ip*, *mn*, *oq* (Tallinn race), *hk*, *mn* (Zuvintas race), *hk* (Turov race) and *hi* (Bobruysk race). The relationships of the different chromosome races of common shrew in Eastern Europe are examined.

Institute of Zoology, Ukrainian Academy of Sciences, 01601 Kiev-30, B. Khmelnytsky str. 15, Ukraine, e-mail: alina@mishta.pp.kiev.ua (AVM); Department of Biology, University of York, P.O. Box 373, York YO10 5YW, U.K., e-mail: jbs3@york.ac.uk (JBS); Mammal Research Institute, Polish Academy of Sciences, 17-230 Białowieża, Poland, e-mail: jwojcik@bison.zbs.bialowieza.pl (JMW)

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Introduction

The common shrew *Sorex araneus* Linnaeus, 1758 shows phenomenal karyotypic variability involving Robertsonian fusions and whole-arm reciprocal translocations. The diploid number of the species varies from $2n = 20$ to $2n = 33$ and numerous chromosome races have been described over its extensive distribution, each characterised by a particular set of acrocentrics and metacentrics (Searle and Wójcik 1998). Until 1995, almost all the known chromosome races were from western and central Europe, even though a larger part of the range of the common shrew occurs in eastern Europe and Siberia (ie the Former Soviet Union). Since that time, there has been an extensive investigation of the karyotypic variation in the Former Soviet Union, in a project funded by INTAS. Here we present data collected in the territory of Belarus, Estonia, Latvia, Lithuania and Ukraine to complement other studies in European Russia (Orlov *et al.* 1996, Zaitsev and Bulatova 1999, Bulatova *et al.* 2000, Kozlovsky *et al.* 2000) and Siberia (Polyakov *et al.* 1996, 1997a, b, 2000a, b).

Material and methods

Animals were collected between summer 1996 and autumn 1998 at 14 sites of Ukraine, 4 sites of Belarus, 2 sites of Estonia, 2 sites of Latvia and 2 sites of Lithuania (Fig. 1). Shrews were caught using trapping fences and live traps.

Mitotic preparations of chromosomes were made from bone marrow and from spleen according to the method of Ford and Hamerton (1956), directly in the field. G-banding was applied in the laboratory by a modified version of Seabright's (1971) technique. The nomenclature for the karyotypes of individual shrews and of chromosome races follows Searle *et al.* (1991) and Hausser *et al.* (1994).

Results and discussion

Chromosome races

The details of karyotypes and collection sites of each shrew caught are presented in Table 1. The collection sites are mapped in Fig. 1.

As found elsewhere in the common shrew, the variable chromosomes were *g-r*. All individuals were characterised by the XX/X₁Y₂ sex chromosome system and the autosomal metacentrics *af*, *bc* and *tu*. The metacentric *jl* was also usually present in a homozygous metacentric state, although one individual was a heterozygote carrying metacentric *jl* and acrocentrics *j* and *l* (Table 1).

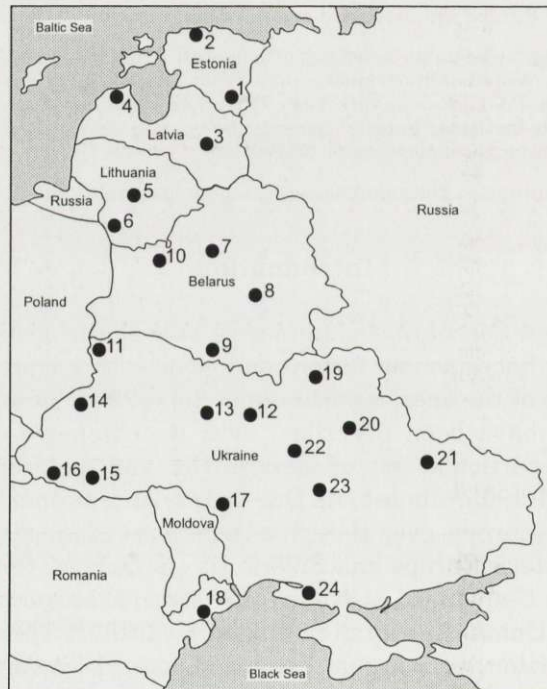


Fig. 1. Map showing collection sites (black circles) of the common shrew in Belarus, Estonia, Latvia, Lithuania and Ukraine (see Table 1).

Often the individuals caught in different sites had different karyotypes. Although the sample sizes were small, we have tentatively named those with distinctly different karyotypes as different races, trying to apply the rules of Hausser *et al.* (1994) for the description of new forms. We appreciate that further study will help to define these races further.

We consider there to be ten races within the five countries that we sampled. One of these races was found in Lithuania, two each in Estonia and Latvia, three in Ukraine and four in Belarus (some races were found in more than one country). Four of the ten races have not been described previously and we first present these. Our current understanding of the distribution of all the races that we found is summarised in Fig. 2.

Tallinn race

XX/X₁Y₁Y₂, *af, bc, g/r, hk, ip, jl, mn, oq, tu*

Type locality: Tallinn, NW Estonia, 59°25'N, 24°40'E

Shrews collected from northern Estonia (Tallinn: 2 individuals) and eastern Latvia (Laudona: 2 individuals) carried the metacentrics *gr, hk, ip, mn, oq* (Fig. 3). All four shrews were homozygous metacentric for all these elements, except one individual from Latvia which was heterozygous for *gr*. This race is characterised by metacentric *ip* which is found in races in Finland, metacentrics *gr* and *mn* found in races in Poland and *hk* found in both Poland and Finland. Clearly, its karyotypic characteristics reflect its geographic position along the seaboard between Poland and Finland.

Zuvintas race

XX/X₁Y₁Y₂, *af, bc, g, hk, i, jl, m/n, o, p, q, r, tu*

Type locality: Lake Zuvintas, Alitus district, S Lithuania, 54°26'N, 23°40'E

Six out of 7 individuals collected from two sites in Lithuania were homozygous metacentric for *hk*, and homozygous acrocentric for *g, i, m, n, o, p, q, r*. One animal was heterozygous for metacentric *mn* (Fig. 4). As indicated above, both *hk* and *mn* are metacentrics found in nearby Poland.

Turov race

XX/X₁Y₁Y₂, *af, bc, g, h/k, i, jl, m, n, o, p, q, r, tu*

Type locality: Turov district, S Belarus, 52°00'N, 27°56'E

Bobruysk race

XX/X₁Y₁Y₂, *af, bc, g, h/i, jl, k, m, n, o, p, q, r, tu*

Type locality: Bobruysk district, Berezina river, E Belarus, 53°02'N, 29°15'E

Representative karyotypes for these races are shown in Figs 5 and 6. It must be noted that the Turov and Bobruysk races are represented by only one and two

Table 1. The karyotypes of *Sorex araneus* from Belarus, Estonia, Latvia, Lithuania and Ukraine (only variable chromosome arms *g-r* are indicated). Localities analysed in the present study are mapped in Fig. 1 with the codes listed here. *n* – sample size, 2*na* – diploid autosome number, abbreviations of races as in Table 2. ¹ – data from Orlov *et al.* (1996), ² – data from Bulatova *et al.* (2000), ³ – data from Ivanitskaya (1985); no information provided on sex of individuals karyotyped, ⁴ – data from Baker *et al.* (1996); no information provided on sex of individuals karyotyped, ⁵ – data from Mishta (1994), ⁶ – preparation originated from I. Zagorodniuk, ? – unscorable preparations. M – male, F – female.

Locality	Latitude/Longitude	<i>n</i> , sex	2 <i>na</i>	Chromosome formula	Race
1	2	3	4	5	6
Estonia					
1 Ruusmae	57°38'N, 27°07'E	2F	18	<i>gm, hk, ip, jl, nr, oq</i>	Ps
2 Tallinn	59°25'N, 24°40'E	2M	18	<i>gr, hk, ip, jl, mn, oq</i>	Ta
Latvia					
3 Laudona	56°42'N, 26°11'E	1F	19	<i>g/r, hk, ip, jl, mn, oq</i>	Ta
		1F	18	<i>gr, hk, ip, jl, mn, oq</i>	
4 Slitere	57°39'N, 22°19'E	3F	25	<i>g/r, hk, i, jl, m, n, o, p, q</i>	Go
		1M	24	<i>gr, hk, i, jl, m, n, o, p, q</i>	
		1F	24	<i>g/r, hk, i, jl, m/n, o, p, q</i>	
		1M	23	<i>gr, hk, i, jl, m/n, o, p, q</i>	
Kaliningrad region					
Kurish Spit ¹	55°40'N, 21°00'E	1M, 2F	22	<i>gr, hk, i, jl, mn, o, p, q</i>	Go
		2M, 1F	24	<i>g/r, hk, i, jl, m/n, o, p, q</i>	
Lithuania					
5 Krekenava	55°33'N, 24°00'E	1M, 1F	26	<i>g, hk, i, jl, m, n, o, p, q, r</i>	Zu
6 Zuvintas	54°26'N, 23°40'E	4M	26	<i>g, hk, i, jl, m, n, o, p, q, r</i>	Zu
		1F	25	<i>g, hk, i, jl, m/n, o, p, q, r</i>	
Belarus					
Lepel ²	54°40'N, 28°30'E	1M	19	<i>gm, hk, ip, jl, nq, o/r</i>	Lp
		1F	20	?	
		1F	21	?	
7 Besiady	54°13'N, 27°46'E	1F	22	<i>g/m, hk, ip, jl, n/q, o/r</i>	Lp
		1M	23	<i>g/m, hk, ip, jl, n/q, o, r</i>	
8 Bobruysk	53°02'N, 29°15'E	1M, 1F	27	<i>g, h/i, jl, k, m, n, o, p, q, r</i>	Bo
Gomel ³	52°24'N, 31°00'E	1	19	?	
		1	25	?	
9 Turov	52°00'N, 27°56'E	1F	27	<i>g, h/k, i, jl, m, n, o, p, q, r</i>	Tu
10 Lesnoe Ozero	54°00'N, 25°28'E	1M, 1F	22	<i>gr, hn, ik, jl, m, o, p, q</i>	Bi
		1M	23	<i>g/r, hn, ik, jl, m, o, p, q</i>	
		1M	23	<i>g, hn, ik, jl, m/p, o, q, r</i>	
		1M	24	<i>g/r, hn, ik, jl, m, o, p, q</i>	
Ukraine					
11 Shatskie Ozera	51°29'N, 23°47'E	1M	21	<i>gr, hn, ik, jl, m/p, o, q</i>	Bi
Chernobyl ⁴	51°12'N, 30°17'E	14	24–26	?	
Kiev ⁵	50°23'N, 30°26'E	1F	23	<i>g/m, hi, jl, ko, n, p, q, r</i>	Ki
		1F	22	<i>gm, hi, jl, ko, n, p, q, r</i>	

Table 1 – concluded.

1	2	3	4	5	6	
12	Boyarka	50°19'N, 30°18'E	1M	23	<i>g/m, hi, jl, ko, n, p, q, r</i>	Ki
13	Zhitomir	50°17'N, 28°33'E	1M	24	<i>g, hi, jl, ko, m, n, p, q, r</i>	Ki
			1M, 1F	24	<i>g/m, hi, jl, k/o, n, p, q, r</i>	
			1M	25	<i>g/m, hi, jl, k, o, n, p, q, r</i>	
14	Roztochie	49°57'N, 23°45'E	1M	24	<i>g/m, hi, jl, k/o, n, p, q, r</i>	Ki
15	Mykulychyn	48°23'N, 24°36'E	2M	23	<i>gm, hi, jl, k/o, n, p, q, r</i>	Ki
16	Rahov	48°02'N, 24°10'E	1M	25	<i>g, hi, jl, k/o, m, n, p, q, r</i>	Ki
			1F	24	<i>g/m, hi, jl, k/o, n, p, q, r</i>	
17	Britavka	48°10'N, 29°08'E	1M	22	<i>gm, hi, jl, ko, n, p, q, r</i>	Ki
			1F	23	<i>g/m, hi, jl, ko, n, p, q, r</i>	
18	Vilkovo	45°25'N, 29°35'E	1M, 1F	24	<i>g/m, hi, jl, k/o, n, p, q, r</i>	Ki
19	Berezivka	51°22'N, 32°09'E	1F	18	<i>go, hi, jl, kr, mn, pq</i>	Ne
20	Tishki	50°07'N, 33°06'E	1M	18	<i>go, hi, jl, kr, mn, pq</i>	Ne
21	Zmiev	49°37'N, 36°19'E	1M, 1F	18	<i>go, hi, jl, kr, mn, pq</i>	Ne
22	Kanev	49°43'N, 31°30'E	1F	21	<i>g, hi, jl, k/r, mn, o, pq</i>	Ne
			1F	23	<i>g, hi, jl, k/r, mn, o, p, q</i>	
	Kanev	49°43'N, 31°30'E	5M, 1F	20	?	
			1M, 3F	21	?	
			2M	22	?	
	Brovary ⁶	50°30'N, 30°45'E	1M	19	?	
23	Vodianoye	48°45'N, 32°32'E	2F	20	<i>g/o, hi, jl, k/r, mn, pq</i>	Ne
			1M	21	<i>g, hi, jl, k/r, mn, o, pq</i>	
24	Golaja Pristan'	46°32'N, 32°30'E	2M	18	<i>go, hi, jl, kr, mn, pq</i>	Ne

Table 2. Characteristics of the chromosome races found in Belarus, Estonia, Latvia, Lithuania and Ukraine, including a reference to the first description in each case.

Race	Distribution	Karyotype	References
Tallinn (Ta)	N Estonia, E Latvia	<i>g/r, hk, ip, jl, mn, oq</i>	This study
Gołdap (Go)	NE Poland, Kaliningrad, W Latvia	<i>g/r, h/k, i, jl, m/n, o, p, q</i>	Fedyk 1986
Zuvintas (Zu)	Lithuania	<i>g, hk, i, jl, m/n, o, p, q, r</i>	This study
Turov (Tu)	S Belarus	<i>g, h/k, i, jl, m, n, o, p, q, r</i>	This study
Lepel (Lp)	N Belarus	<i>g/m, hk, ip, jl, n/q, o/r</i>	Bulatova <i>et al.</i> 2000
Pskov (Ps)	SE Estonia, NW European Russia	<i>gm, hk, ip, jl, nr, oq</i>	Zaitsev and Bulatova 1999
Białowieża (Bi)	E Poland, W Belarus, NW Ukraine	<i>g/r, h/n, ik, j/l, m/p, o, q</i>	Fredga and Nawrin 1977
Bobruysk (Bo)	E Belarus	<i>g, h/i, jl, k, m, n, o, p, q, r</i>	This study
Kiev (Ki)	W Ukraine	<i>g/m, hi, jl, k/o, n, p, q, r</i>	Mishta 1994
Neroosa (Ne)	W European Russia, E Ukraine	<i>g/o, hi, j/l, k/r, mn, p/q</i>	Bulatova <i>et al.</i> 2000

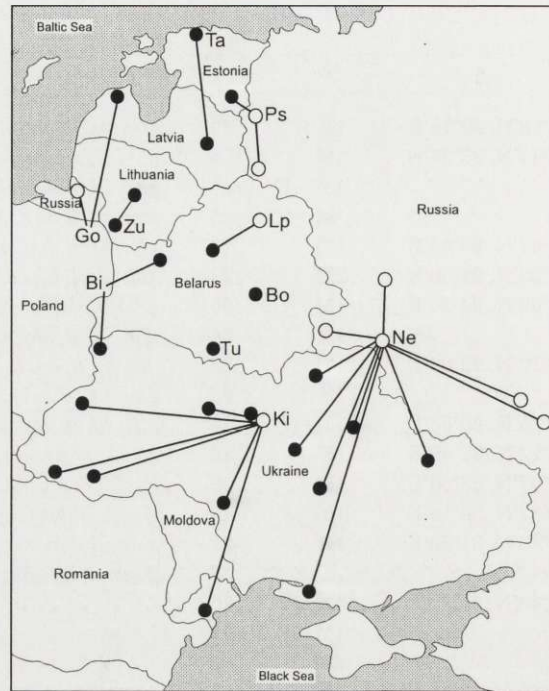


Fig. 2. The distribution of chromosome races in Belarus, Estonia, Latvia, Lithuania, Ukraine and the Kaliningrad region (see Table 2), based on data from the present study (black circles) and samples (open circles) from Mishta (1994), Orlov *et al.* (1996), Zaitsev and Bulatova (1999) and Bulatova *et al.* (2000). Abbreviations (as in Table 2) indicate localities of the first description of each race and circles connected by continuous lines show sites with the same karyotypes. See Wójcik (1993) and Fedyk (1995) for details on the distribution of the Gołdap and Białowieża races in Poland.

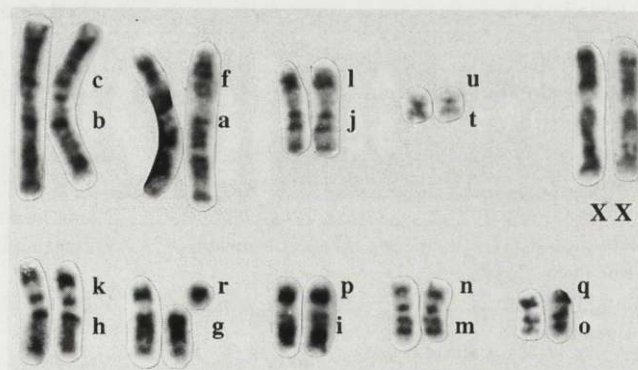


Fig. 3. G-banded karyotype of *Sorex araneus* of the Tallinn race.

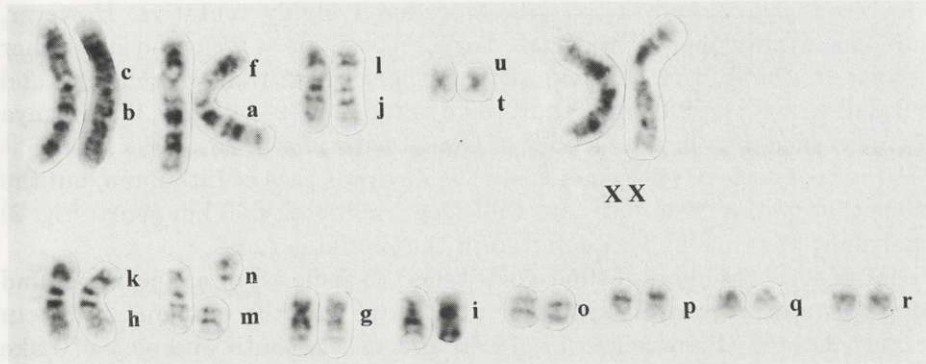


Fig. 4. G-banded karyotype of *Sorex araneus* of the Zuvintas race.

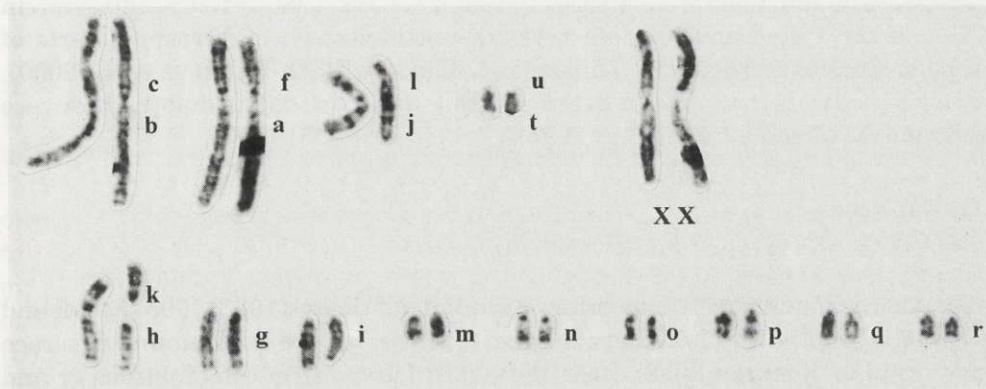


Fig. 5. G-banded karyotype of *Sorex araneus* of the Turov race.

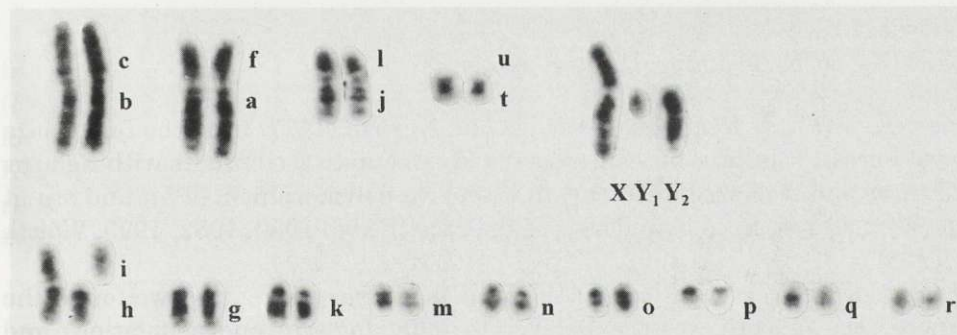


Fig. 6. G-banded karyotype of *Sorex araneus* of the Bobruysk race.

specimens, respectively, and so must be considered highly tentative. However, these individuals have more acrocentric karyotypes ($2na = 27$) than any other shrews so far collected from Belarus. All the other shrews that we collected and those of Bulatova *et al.* (2000) had an autosome number of 19–24 there. Ivanitskaya (1985) found a specimen in the vicinity of Gomel with $2na = 25$.

The Turov race is clearly very similar to the Zuvintas race of Lithuania, but the populations that define these races are well separate (about 500 km apart: Fig. 2) and no polymorphism for *hk* was detected in the Zuvintas race.

The Bobruysk race is of interest because it has the same set of metacentrics and acrocentrics as races from elsewhere in the range of the common shrew: in north-eastern Poland (Banaszek *et al.* 1996) and to the south and east of Lake Baikal (Král *et al.* 1981). But these other races are characterised by polymorphism for *jl* rather than *hi*.

The remaining six chromosome races that we found in Ukraine, Belarus and the Baltic States have been described previously, four in neighbouring countries (Fig. 2): the Gołdap and Białowieża races in Poland (Fedyk 1986, Fredga and Nawrin 1977) and the Pskov and Neroosa races in north-western and western parts of European Russia, respectively (Zaitsev and Bulatova 1999, Bulatova *et al.* 2000). The Lepel race was first found in Belarus by Bulatova *et al.* (2000) and the Kiev race first found in Ukraine by Mishta (1994).

Gołdap race

XX/XY₁Y₂, *af, bc, g/r, h/k, i, jl, m/n, o, p, q, tu*

This race is found locally in north-eastern Poland (Fedyk 1986, 1995, Fedyk and Leniec 1987) and in the Kaliningrad region (Orlov *et al.* 1996). We found this race in one population on the Baltic coast of western Latvia. Arm combinations *gr* and *mn* were polymorphic in the Latvian samples; these polymorphisms plus that involving *hk* have been found elsewhere in the range of this race. The Gołdap race is almost certainly found elsewhere in western Latvia and western Lithuania (Fig. 2).

Białowieża race

XX/XY₁Y₂, *af, bc, g/r, h/n, ik, jl, m/p, o, q, tu*

This race was first described by Fredga and Nawrin (1977) from the Białowieża Primeval Forest. It is distributed in eastern Poland up to the borders with Belarus and Ukraine and is characterised by an extensive polymorphism of *hn* and *mp* at the northern and western boundaries of the race (Fedyk 1980, 1982, 1995, Wójcik 1991, 1993).

Given its known distribution in Poland, it is not surprising that we found the Białowieża race in both western Belarus (5 individuals in one population) and north-western Ukraine (one individual). These six individuals displayed polymorphism for autosomes *jl, gr* and *mp*.

Pskov race

XX/XY₁Y₂, *af, bc, gm, hk, ip, jl, nr, oq, tu*

This race was first described by Zaitsev and Bulatova (1999) in north-western Russia. We found shrews with the same chromosomal characteristics nearby, in one population in south-eastern Estonia (Ruusmae). Both individuals caught had a homozygous metacentric karyotype.

Lepel race

XX/XY₁Y₂, *af, bc, g/m, hk, i/p, jl, n/q, o/r, tu*

Bulatova *et al.* (2000) found this race at one locality in northern Belarus. We found it at a second site (Besiady). One of the individuals was heterozygous for four different arm combinations, the other was a triple heterozygote.

Kiev race

XX/XY₁Y₂, *af, bc, g/m, hi, jl, k/o, n, p, q, r, tu*

This race was first described from the vicinity of Kiev (Mishta 1994). We found this race in 7 further sites in western Ukraine (Boyarka, Zhitomir, Roztochie, Mykulychyn, Rahov, Britavka, Vilkoivo). The polymorphisms involving arm combinations *gm* and *ko* were widespread.

So, we now know the range of the Kiev race with some confidence. It is distributed over much of western Ukraine from the Carpathian mountains in the extreme west to the Danube delta in the south and Kiev in the north (Fig. 2). It may be found even further north than this. The conventional preparations of Baker *et al.* (1996) on shrews from Chernobyl showed an autosome number of 24 to 26 compatible with the Kiev race. Shrews with a karyotype similar to the Kiev race were found in eastern Slovakia, not far from the Ukrainian border (Zima and Král 1985). The Danube delta in Romania is inhabited by shrews with the karyotype of the Ulm race (Zima 1983).

Neroosa race

XX/XY₁Y₂, *af, bc, g/o, hi, j/l, k/r, mn, p/q, tu*

This race was first described by Bulatova *et al.* (2000). We found it in six sites from eastern Ukraine and it can be presumed to be the predominant race there (Fig. 2). At four of the sites (6 shrews) all individuals had a fully metacentric karyotype, but at the two sites to the west of the river Dniper (Vodianoye and Kaney), there was polymorphism for arm combinations *go*, *kr* and *pq*. The Neroosa race is found in neighbouring parts of western European Russia (Bulatova *et al.* 2000).

Relationships with other chromosome races

The characteristics of the ten chromosome races are summarised in Table 2. It is noticeable that most of the races possess metacentric *hk*. This metacentric is also found in the Łęgucki Młyn race (Wójcik 1986) and Gołdap race (Fedyk 1986, 1995)

in Poland and in the Lemi race (Halkka *et al.* 1987) in south-eastern Finland. So, our data allow the range of *hk* to be determined: it occurs along the coast of the Baltic Sea from north-eastern Poland to south-eastern Finland. Further sampling is needed to establish whether the site with metacentric *hk* to the south of Belarus is isolated or whether there is a link to populations with *hk* to the north. This may be crucial to an understanding of the origin and spread of this particular metacentric.

Also of interest are the distributions of metacentrics *gr* and *ip*. We have shown that *gr* occurs beyond eastern Poland, not only through the presence of the Góldap and Białowieża races in more easterly countries, but also with the Tallinn race. Metacentric *gr* must now be considered a metacentric characteristic of the coastal regions of Estonia, Latvia and Lithuania as well as eastern Poland.

Likewise, our study and that of Bulatova *et al.* (2000) have added to the distribution of *ip*. Races with this metacentric occur far beyond the Finnish range originally described by Halkka *et al.* (1987). The metacentric occurs in the Tallinn race of Estonia and Latvia, the Lepel race of Belarus and the Pskov race of European Russia and Estonia. It appears that this metacentric may have originated in the Ural Mts before spreading to Finland (Polyakov *et al.* 2000b); there is clearly a need to understand how it penetrated into the extreme western parts of European Russia and the Baltic States as well.

One of the most interesting races that we have been able to delimit with some accuracy is the Kiev race. It is characterised by the metacentrics *gm* and *hi*, well known to occur over much of western Europe (Searle 1984, Wójcik 1993, Searle and Wójcik 1998). These metacentrics occur in European Russia as well, within the widespread Moscow race (Aniskin and Lukianova 1989, Orlov *et al.* 1996, Bulatova *et al.* 2000). Thus, the 'karyotypic group' (Hausser *et al.* 1994) that has been best documented: the West European Karyotypic Group (Searle 1984), not only occurs over much of western Europe but is also well-represented in eastern Europe as well. However, while the Kiev race appears to be part of a continuous distribution of the West European Karyotypic Group extending to Great Britain in the west, the Kiev race appears to be geographically isolated from the Moscow race. The Neroosa race occurs in between these forms. The Neroosa race is characterised by metacentrics *go* and *hi*, and can be derived from the Moscow race by a single whole-arm reciprocal translocation (Bulatova *et al.* 2000). In this way, the West European Karyotypic Group and its derivatives can be considered to have a single continuous range.

Several of the races that we have found in Belarus, Estonia, Latvia, Lithuania and Ukraine have karyotypes including metacentrics characteristic of more than one lineage. Thus, the Tallinn race has metacentrics *gr* and *hk* characteristic of lineages associated with Poland as well as *ip* associated with Finland. The Lepel and Pskov races also carry *hk* and *ip* and additionally *gm*, one of the widespread metacentrics of western Europe. This apparent reticulate evolution will be considered in more depth in a later phylogenetic paper utilising the complete data set collected during the INTAS project. Likewise, the colonisation history of all the races and karyotypic groups that we describe here will be considered in that paper.

Also of interest are the two races within Belarus with highly acrocentric karyotypes: the Bobruysk and Turov races. Previously races with acrocentric karyotypes have been found in peripheral regions of the range of the common shrew: the French Alps, Massif Central in France, Macedonia, northern Poland, the coast of Finland and Lake Baikal (Zima *et al.* 1994, Searle and Wójcik 1998). The Bobruysk and Turov races occur in the heart of the east European range of the common shrew. Clearly, further sampling is required to elucidate this situation.

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