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RESEARCH ARTICLE

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Craniometrical description of striped mouse (*Apodemus agrarius* Pallas, 1771) in Bulgaria as concerns of discovering of its European population patterns of similarity

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ABSTRACT

Comparative analysis of variations in 50 craniological parameters in 117 adult (59 male and 58 female) individuals of the striped mouse (*Apodemus agrarius* Pallas, 1771) in Bulgaria that belong to populations with 4 or 3 pairs metacentric chromosomes in the karyotype was performed. The identified craniological characteristic of the striped mouse populations in Bulgaria showed that the future analyses of its craniometric similarity to other European populations of *A. agrarius* should be performed based on: (i) their appurtenance to a specific chromosomal form and (ii) the presence of sexual dimorphism of their distinct craniological parameters. The skull morphometric characters, which do not exhibit sexual dimorphism, are quite effective for describing population geographical patterns of similarity. The comparative analysis of the population similarity *of A. agrarius* in European range manifested that the Bulgarian populations from both chromosomal forms are too similar to each other and ring-fenced in a separate group. Approximately similar level of craniological differentiation with the populations inhabiting Western Balkans and the central parts of Europe was calculated. The future use of expanded range of other phenetic craniodental characters as well as molecular genetic sources would certainly be necessity for understanding the evolutionary fate of the Bulgarian population of the species and their appropriate taxonomic designations.

Key words: striped mouse, *Apodemus agrarius*, skull morphometrics, geographic variation, Bulgaria

Introduction

The striped mouse *Apodemus agrarius* (Pallas, 1771) is a species widely distributed in the Eurasian temperate zone. It has disjunctive distribution in the Palaearctic, in two regions particularly, named Euro-Siberian and Far East-Chinese region. The south border of the European range of the species passes through the territory of the Republic of Bulgaria. (Karaseva et al., 1992, Panteleyev 1998, Gliwicz & Kryštufek, 1999).

The populations of the striped mouse in Bulgaria are distributed in a mosaic pattern (Markov, 1968; 1974). It inhabits mostly humid places, abounding in seeds, which are its basic food (Markov, 1968; Hristov, 1961; Mateva, 1972; Mitev, 1973). The availability of large food resources allows for the development of its large-number populations, which could inflict substantial damage to agricultural crops (Markov 1968).

The known localities of the species in Bulgaria show that this species inhabits mainly the lowlands of the country. Habitats of the striped mouse are mainly river wetlands, which in turn predetermines its distribution mainly in river valleys and in the vicinity of different types of water bodies (Markov, 1968, 1974; Mateva & Hristov, 1970; Mitev, 1980; Atanasova, 1990; Chassovnikarova, et al., 1995).

The subspecies structure of *Apodemus agrarius* is under discussion and needs revision (Gromov, 1995). There are data of tree subspecies of the striped mouse inhabiting Central and South-East Europe: *A. a. henrici* Lehmann, 1970 in Germany, which according to Bühme (1978) is a synonym of *A. a. agragarius*; *A. a. istrianus* Krystufek, 1985 in Slovenia and *A. a. kahmanni* Malec & Storch, 1963, in Macedonia (Bühme, 1978, Kahmann & Einlechner, 1992) and in the European part of Turkey (Kefelioğlu et al., 2003).

The fact that no detailed studies have been carried out on the craniological variability of the striped mouse populations in Bulgaria and their role in the common intraspecific taxonomic structure of *Apodemus agrarius* in Europe, determines the aims of this study, namely: (i) establishing a detailed craniological description of the species and analysing its population craniological variability in Bulgaria, and (ii) a demonstration of the phenotypic craniological similarity and differentiation of the Bulgarian populations within the European range of the species.

The established population chromosomal polymorphism of *A. agragarius* in Bulgaria – populations with 4 and 3 pairs of two-armed chromosomes in the karyotype (Chassovnikarova et al., 2009), requires that the analysis of the population cranial variability and degree of similarity has to includes specimens belonging to both chromosomal forms.

Materials and Methods

Sites and samples

The morphological study on the striped mouse in Bulgaria was based on an aggregate of 230 individuals of which 108 male and 122 female, originating from 6 geographic populations: Population 1: the Veleka river valley (in the vicinity of the village of Gramatikovo, 42.06N, 27.65E; N=72, male = 29, female = 43); Population 2: the estuary of the Veleka river (in the vicinity of the village of Sinemorets, 42.07N, 27.98E; N= 60, male =28, female = 32); Population 3: the Maritsa river valley (in the vicinity of the town of Simeonovgrad, 42.03N, 25.83E; N=16, male =7 female = 9); Population 4: the Iskar river valley (in the vicinity of Iskar Railway Station, 43.45N, 24.27E; N=20, male =9, female = 11); Population 5: the Rusernski Lom river valley, in the vicinity of the village of Ivanovo, 43.70N, 25.98E; N=44, male=24 female=20); Population 6: the Golyama reka river valley (in the vicinity of the town of Omurtag, 43.10N, 25.42E; N=18, male=11, female=7), their localities are presented in Figure 1.

Individuals from populations 2, 3 and 5 belong to chromosomal forms with 4 pairs of metacentric chromosomes, and individuals from populations 4 and 6 belong whit the chromosomal form with 3 pairs of metacentric chromosomes.

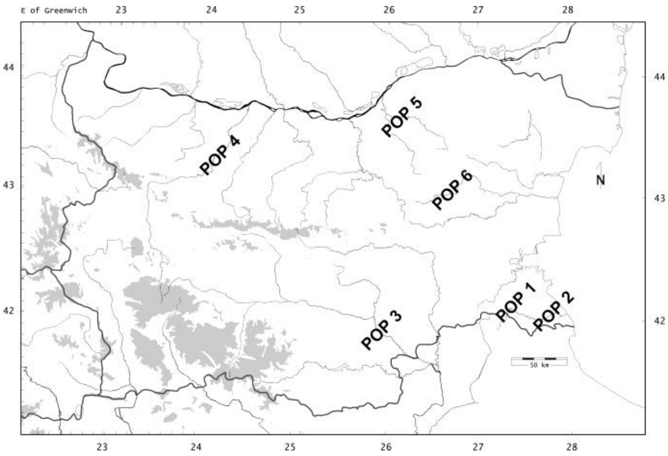

Figure 1. *Map showing the localities from which were collected the Bulgarian specimens of striped mouse (A. agrarius) that we examined: Population 1: The Veleka river valley; Population 2: The estuary of the Veleka river; Population 3: The Maritsa river valley; Population 4: The Iskar river valley; Population 5: The Rusenski Lom river valley; Population 6: The Golyama Reka river valley.*

For the assessment of chronologically similarity of the Bulgarian striped mouse populations with subspecies of *A. agrarius* - *A. a. agrarius*, *A. a. kahmani* and *A. a. istrianus*, inhabiting the western border of the European range of the species, are used the data of Maining & Hille (1995) on 13 populations, whose taxonomic status was established on the basis of electrophoretic and chronologically study of their representatives. These populations are preliminarily described as representative members of three subspecies of *A. agrarius*, in its European range – *A. a.agrarius*, *A. a. kahmani* and *A. a. istrianus*.

Catch of animals and age determination

Animals are caught using the “lines of traps” method (Novikov, 1953). Only adult individuals were included in the craniometric analysis. Age determination was based on the degree of upper molar wear, using the criteria proposed by Adamczewska-Andrzeewska (1973).

Measurements

The study focused on 50 cranial parameters and employed the Niethammer & Krapp (1978) craniometric measurement system used for small mammals. The topographical location of the parameters and their points of measurement are shown in Figure 2. Measurements were performed using a calliper gauge to the nearest 0.1 mm and using a binocular to the nearest 0.001 mm.

Data analysis

The initial craniometric parameters of Bulgarian populations of *A. agrarius* were tested for normality using Kolmogorov-Smirnov D-statistics, and for homogeneity of variances using Levene's test. The basic statistics - the mean (X) and the standard deviation (SD) were calculated for all studied craniometric characteristics of each investigated group of animals. To assess the effect of sex on the craniometric variation of skull measurements of Bulgarian populations, the t-test for independent samples was applied for detailed evaluation of the differences among means of the examined craniometrical parameters and when P <0.05, the data were considered significantly different.

The phenetic relationships among Bulgarian populations of *A. agrarius* and their craniometric similarity to the other craniometrical deterministic populations (Hille & Maining 1995) from the European range of the species were determined by Cluster Analyses (Joining Tree Clustering), using Single linkage and Euclidean distance matrix.

All calculations were performed using the statistical package STATISTICA 2008 version 8.0 (StatSoft Inc. 2008).

Results

Comparison of the mean values of cranial parameters between the two sexes belonging to the two chromosomal forms of the species (Table 1) showed:

(i) weakly manifested sexual dimorphism in the chromosomal form with 4 pairs two-armed chromosomes – only 3 parameters show statistically important differences between the two sexes, namely M8, M20 and M33.

(ii) more strongly manifested sexual dimorphism in the chromosomal form with 3 pairs of two-armed chromosomes – the mean values of 11 (22%) craniometric parameters M2, M3, M7, M8, M11, M25, M32, M33, M39, M47 and M50 are materially different in the two different sexes. Craniometric parameters describing skull lengths are more common. Five of these parameters (45%) are signs describing teeth size.

(iii) The mean values of the studied craniometric parameters of the two chromosomal forms show extremely similar variability. Female individuals belonging to the two chromosomes of *Apodemus agrarius* differ significantly in 24 (48%) of the studied craniometric parameters, namely M1, M2, M3, M4, M7, M8, M9, M16, M17, M19, M20, M21, M22, M24, M25, M26, M27, M28, M32, M35, M36, M37 and M50. These differences pertain mainly to the skull lenghts, as here belong in all parameters describing theeth sizes.

Male individuals belonging to the two chromosomal forms of *Apodemus agrarius* differ distinctly in 21 (42%) of the studied craniometric parameters, namely M1, M2, M3, M4, M9, M11, M12, M13, M16, M17, M19, M20, M21, M22, M24, M25, M26, M27, M28, M31, M32, M36, M37, M38, M39, M47 and M48. 17 (81%) of these parameters (M1-M4; M9; M16-M17; M19-M22; M24-M28; M32; M34-M37 overlap with the ones, which are distinctive features for the female individuals.

In this study, the comparative analysis of the craniologicly determined by Hille & Maining (1996) thirteen populations in Middle Europe and the Bulgarian populations belonging to the two different chromosomal forms is based only on these craniologic parameters, which do not show any sexual dimorphism. These are the following parameters: M5 (lenght of nasale), M9 (rostrum breadth), M12 (postorbital breadth), M14 (*foramen magnum* breadth), M30 (anterior palatine foramen length), M38 (M^1 breadth), M40 (M^3 breadth) and M41 (M^1 length).

The results of the Cluster Analyses, expressing the degree of population craniologic similarity of Bulgarian populations belonging to the two different chromosomal forms in the composite picture of the identified craniologic similarity on population level of the striped mouse in Europe, (Figure 3) show:

(i) relative homogenity of the specimens identified in the geographic populations from Germany, Kaliningrad, Russia, Slovenia and Croatia;

(ii) populations from Macedonia and Hungary form the second common group;

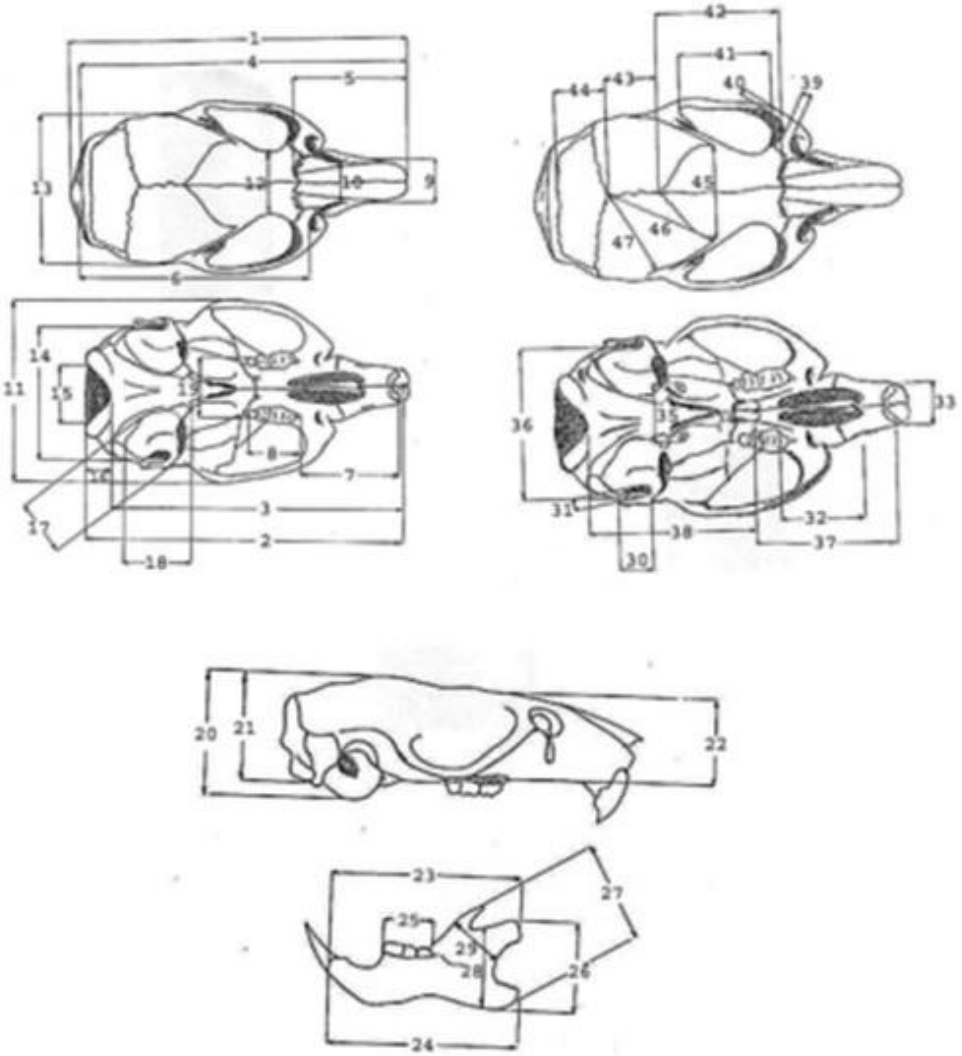

Figure 2. *Views of skull of striped mouse (Apodemus agrarius Pallas, 1771) showing craniometric variables according Niethammer & Krapp (1978) used in this study: total skull length (M1); condylobasal length (M2); basal length (M3); distance between os nasale anterior and parietale (M4);lenght of nasale (M5); distance between foramen infraorbitale and condylus occipital (M6); diastema (M7); lenght of maxillar teeth row (alveolare) (M8); rostrum breadth (M9); distance between foramen infraorbitales (M10); zygomatic breadth (M11); postorbital breadth (M12); skull breadth behind os zugomaticus (M13); mastoid breadth (M14); foramen magnum breadth (M15); foramen magnum height (M16); bullae ossae breadth (M17); bullae ossae length (M18); width of palate on the outside of* M^3 *(M19); height of the skull through bullae ossae (M20); height of the skull between bullae ossae (M21); height of the face part of the skull (M22); total mandible length I (M23); total mandible length II (M24); mandible alveoli teeth – row length (M25); mandible height I (M26); distance between procesus coronoideus and procesus condyloideus (M27); mandible height II(M28); width of ramus mandibularis (M29); anterior palatine foramen length (M30); bulle ossae meatus auditorius externus breadth(M31); palatine durum length (M32); distance between palatine durum posterior and foramen occipitalis (M33);sutura frontalis length (M34); sutura sagittalis length (M35); os interparietale length (M36); distance between bullae ossae lateralis (M37);* M^1 *breadth (M38);* M^2 *breadth (M39);* M^3 *breadth (M40);* M^1 *length (M41);* M^2 *length (M42);* M^3 *length (M43); M1 breadth (M44); M2 breadth (M45); M3 breadth (M46); M1 length (M47); M2 length(M48); M3 length (M49); thickness of incisiva (M50).*

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Table 1. *The number of specimens (N), mean length (X in mm) and standard deviation (SD) evaluation of the differences among theirs means (when P <0.05, the data were considered significantly different) separately for each craniometric parameter in the both sexes (male - Me, female - Fe) in the chromosomal form with 4 (G1) and 3 (G2) pairs of metacentric chromosomes and between their same sexes (G3) of Apodemus agrarius in Bulgaria. Symbols of the characters are the same as in Figure 2.*

Symbol	G1 (form with 4 pairs of metacentric chromosomes)							G2 (form with 3 pairs of metacentric chromosomes)							G3 G1 v G2	
	M			Fe			P value	M			F			P value	P value	
	N	X	SD	N	X	SD		N	X	SD	N	X	SD		M	F
M1	36	26,16	0,99	46	26,58	0,98	P>0.05	13	24,73	0,48	22	24,47	0,49	P>0.05	P<0.05	P<0.05
M2	36	24,30	1,31	46	24,48	0,98	P>0.05	13	23,44	0,66	22	22,80	0,30	P< 0.05	P<0.05	P<0.05
M3	36	22,30	1,08	46	22,60	0,97	P>0.05	13	19,56	0,59	22	19,00	0,38	P< 0.05	P<0.05	P<0.05
M4	37	24,64	1,00	47	24,98	0,95	P>0.05	13	23,65	0,50	22	23,61	0,56	P>0.05	P<0.05	P<0.05
M5	38	8,82	0,78	48	9,064	0,68	P>0.05	13	9,15	0,37	22	9,045	0,57	P>0.05	P>0.05	P>0.05
M6	36	18,19	0,80	46	18,50	0,70	P>0.05	13	18,12	0,46	22	17,82	0,39	P>0.05	P>0.05	P>0.05
M7	38	7,40	0,41	48	7,53	0,41	P>0.05	13	7,36	0,26	22	7,14	0,21	P< 0.05	P>0.05	P<0.05
M8	38	3,92	0,14	48	3,99	0,12	P< 0.05	13	4,03	0,23	22	3,80	0,28	P< 0.05	P>0.05	P<0.05
M9	38	3,78	0,21	48	3,84	0,14	P>0.05	13	4,13	0,18	22	3,99	0,21	P>0.05	P<0.05	P<0.05
M10	38	3,51	0,36	48	3,53	0,41	P>0.05	13	3,48	0,25	22	3,49	0,24	P>0.05	P>0.05	P>0.05
M11	38	12,80	0,54	48	12,84	0,42	P>0.05	13	12,38	0,49	22	12,06	0,41	P< 0.05	P<0.05	P>0.05
M12	38	4,39	0,23	48	4,46	0,19	P>0.05	13	4,253	0,18	22	4,24	0,14	P>0.05	P>0.05	P>0.05
M13	38	11,30	0,32	48	11,39	0,28	P>0.05	13	10,85	0,24	22	10,82	0,30	P>0.05	P<0.05	P>0.05
M14	36	10,78	0,29	47	10,89	0,35	P>0.05	13	10,74	0,51	22	10,68	0,51	P>0.05	P>0.05	P>0.05
M15	35	4,39	0,12	46	4,38	0,14	P>0.05	13	4,33	0,13	22	4,39	0,16	P>0.05	P>0.05	P>0.05
M16	35	3,99	0,16	46	3,97	0,17	P>0.05	13	4,16	0,08	22	4,09	0,13	P>0.05	P<0.05	P<0.05
M17	36	3,61	0,18	47	3,63	0,19	P>0.05	13	3,36	0,20	19	3,45	0,22	P>0.05	P<0.05	P<0.05
M18	36	4,61	0,26	47	4,64	0,19	P>0.05	13	4,65	0,25	19	4,63	0,24	P>0.05	P>0.05	P>0.05
M19	38	3,51	0,19	48	3,46	0,17	P>0.05	13	3,66	0,14	22	3,77	0,18	P>0.05	P<0.05	P<0.05
M20	35	9,19	0,32	47	9,35	0,32	P< 0.05	13	8,89	0,28	22	8,78	0,22	P>0.05	P<0.05	P<0.05
M21	37	7,65	0,28	47	7,73	0,33	P>0.05	13	7,19	0,20	22	7,12	0,20	P>0.05	P<0.05	P<0.05
M22	38	6,34	0,31	48	6,41	0,31	P>0.05	13	6,70	0,20	22	6,57	0,23	P>0.05	P<0.05	P<0.05
M23	37	13,22	0,68	47	13,11	0,54	P>0.05	13	13,0	0,37	22	12,92	0,37	P>0.05	P>0.05	P>0.05
M24	36	11,65	0,61	46	11,54	0,51	P>0.05	13	11,17	0,53	22	11,24	0,48	P>0.05	P<0.05	P<0.05
M25	37	3,88	0,13	47	3,89	0,12	P>0.05	13	4,61	0,31	22	4,29	0,24	P< 0.05	P<0.05	P<0.05
M26	37	6,24	0,38	46	6,20	0,32	P>0.05	13	5,82	0,27	22	5,66	0,20	P>0.05	P<0.05	P<0.05
M27	35	4,06	0,25	46	4,14	0,20	P>0.05	13	4,27	0,21	22	4,25	0,17	P>0.05	P<0.05	P<0.05
M28	35	5,51	0,37	46	5,61	0,30	P>0.05	13	6,44	0,38	22	6,23	0,28	P>0.05	P<0.05	P<0.05
M29	36	4,04	0,35	46	4,15	0,28	P>0.05	13	4,09	0,13	22	4,07	0,19	P>0.05	P>0.05	P>0.05
M30	38	4,81	0,30	48	4,92	0,27	P>0.05	13	4,93	0,21	22	4,89	0,20	P>0.05	P>0.05	P>0.05
M31	34	10,68	0,34	47	10,73	0,31	P>0.05	13	10,96	0,26	19	10,79	0,21	P>0.05	P<0.05	P>0.05
M32	38	11,05	0,55	48	11,24	0,44	P>0.05	13	11,82	0,22	22	11,39	0,23	P< 0.05	P<0.05	P<0.05
M33	37	8,78	0,59	46	9,06	0,57	P< 0.05	13	9,03	0,42	22	8,74	0,17	P< 0.05	P>0.05	P>0.05
M34	38	8,20	0,40	48	8,35	0,57	P>0.05	13	8,86	0,48	22	8,99	0,47	P>0.05	P>0.05	P>0.05
M35	38	4,03	0,41	47	4,09	0,49	P>0.05	13	4,38	0,50	22	4,50	0,51	P>0.05	P>0.05	P<0.05
M36	38	2,96	0,33	48	2,99	0,38	P>0.05	13	2,23	0,31	22	2,35	0,35	P>0.05	P<0.05	P<0.05
M37	38	7,61	0,41	48	7,64	0,27	P>0.05	13	8,09	0,34	22	8,19	0,25	P>0.05	P<0.05	P<0.05

Symbol	G1 (form with 4 pairs of metacentric chromosomes)							G2 (form with 3 pairs of metacentric chromosomes)							G3 G1 v G2	
	M			Fe			P value	M			F			P value	P value	
	N	X	SD	N	X	SD		N	X	SD	N	X	SD		M	F
M38	38	1,23	0,08	48	1,21	0,06	P>0.05	13	1,26	0,07	22	1,25	0,05	P>0.05	P<0.05	P>0.05
M39	38	1,06	0,08	48	1,02	0,08	P>0.05	13	0,96	0,08	22	1,06	0,10	P<0.05	P<0.05	P>0.05
M40	38	0,70	0,09	48	0,69	0,07	P>0.05	13	0,70	0,05	22	0,69	0,07	P>0.05	P>0.05	P>0.05
M41	38	1,88	0,14	48	1,90	0,10	P>0.05	13	1,94	0,21	22	1,87	0,12	P>0.05	P>0.05	P>0.05
M42	38	1,18	0,15	48	1,15	0,07	P>0.05	13	1,18	0,08	22	1,18	0,06	P>0.05	P>0.05	P>0.05
M43	38	0,70	0,09	48	0,73	0,08	P>0.05	13	0,72	0,12	22	0,70	0,03	P>0.05	P>0.05	P>0.05
M44	37	1,01	0,07	47	1,04	0,17	P>0.05	13	1,05	0,06	22	1,03	0,06	P>0.05	P>0.05	P>0.05
M45	37	0,98	0,06	47	0,97	0,08	P>0.05	13	1,01	0,04	22	0,98	0,05	P>0.05	P>0.05	P>0.05
M46	37	0,75	0,06	47	0,74	0,06	P>0.05	13	0,74	0,07	22	0,73	0,04	P>0.05	P>0.05	P>0.05
M47	37	1,75	0,06	47	1,73	0,07	P>0.05	13	1,78	0,06	22	1,71	0,05	P< 0.05	P<0.05	P>0.05
M48	37	1,21	0,09	47	1,21	0,07	P>0.05	13	1,27	0,11	22	1,23	0,04	P>0.05	P<0.05	P>0.05
M49	37	0,84	0,07	47	0,85	0,08	P>0.05	13	0,86	0,09	22	0,83	0,05	P>0.05	P>0.05	P>0.05
M50	37	1,34	0,13	48	1,33	0,07	P>0.05	13	1,31	0,08	22	1,26	0,07	P< 0.05	P>0.05	P<0.05

(iii) Bulgarian populations belonging to the two chromosomal forms are quite similar with each other and form a separate group. It shows approximately similar level of craniological differentiation to the populations inhabiting Western Balkans and central parts of Europe.

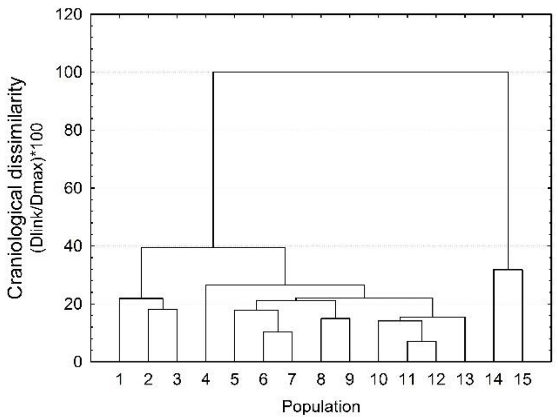

Figure 3. *Phenotypic craniometric dissimilarity among Bulgarian populations belonging to populations with 3 (Population 14, surroundings of settlement Iskar, Bulgaria) and 4 (Population 15, surroundings of settlement Plovdiv, Bulgaria) pairs metacentric chromosomes in his karyotype and their craniometric dissimilarity to the other craniometrical deterministic populations (Hille & Maining 1995) from the European range of the species: Population 1: surroundings of Bania Bansko, Macedonia; Population 2: surroundings of Lake Dojran, Macedonia; Population 3: Hortobagi national park, Eastern Hungary, Population 4: Harz mountains, Lower Saxony, Germany; Population 5: surroundings of settlement Radenči, north-eastern Slovenia; Population 6: surroundings of settlement Osthessen, Germany; Population 7: surroundings of settlement Berlin, Germany; Population 8: surroundings of settlement Ajdovščina, Slovenia; Population 9: surroundings of settlement Brandenburg, Germany; Population 10: surroundings of settlement Rovinj, Croatia; Population 11: surroundings of settlement Brežice, eastern Slovenia; Population 12: surroundings of settlement Görlitz, Germany; Population 13: surroundings of settlement Kaliningrad, Russia.*

Discussion

The produced description of *A. agrarius* in Bulgaria comprising 50 craniometric parameters presents a solid basis for the studying of its natural population variability showing their taxonomic intraspecific heterogenity and the description of their intra-population polymorphism and inter-populations variability. Being one of the most conservative skeleton elements, the skull has retained its structure and charasteristic architecture features over a long period of time. Therefore, a study on the skull gives information about the phylogenetic relations among animals. Studying the structure and variability of mammal skulls also provides a set of data on their adaptation and microevolution (Bolshakov, 1965; Yablokov, 1966; Bashenina, 1977; Rossolomo, 1978). The morhological analysis of a set of parameters allows for quantitive evaluation of natural populations variability, which is of vital importance for assessing the environmental flexibility and the state of microevolution process.

The craniometric analysis of the different sexes of individuals belonging to chromosomal forms with three and four pairs of two-armed chromosomes showed their craniologic characteristic feature. The craniologic sexual dimorphism is more strongly manifested in the chromosomal form with 3 pairs of two-armed chromosomes. Comparison of the craniometric parameters of same sexes belonging to the two chromosomal forms showed correspondence between the karyotypic and phenotypic differences and also showed that in Bulgaria the populations of *A. agrarius* are not homogeneous as far as craniometric phenotype is concerned. Members of both sexes belonging to the established chromosomal forms with 3 and 4 pairs of two-armed chromosomes are craniometrically identified according to a number of craniologic parameters. This is more clearly expressed in male individuals. The results yielded are consistent with the sexual dimorphism identified in a large number of rodents based on their somatometric characteristics (Panteleev et al. 1990), as their sexual variability may outweigh their geographic variability (Lapshov, 1973).

The identified craniological sexual characteristic feature of the chromosomal forms with three and four pairs of two-armed chromosomes necessitates that the analysis of population craniometric similarity of *A. agrarius* populations from its European range involve the analysis of Bulgarian populations on the level of their belonging to a specific chromosomal form, considering the presence of sexual dimorphism in the craniologic parameters studied. The comparative analysis of the relative population’s craniological similarity of *A. agrarius* from its European range shows that the Central European, South-Western and South-Eastern populations have a clear morphological differentiation. Such morphological differentiation in terms of sizes of the cranial parameters is also used in the craniometric subspecies differentiation of the populations of striped mouse in Europe. The geographic positioning of the localities of the Bulgarian populations in the south part of the Balkan peninsula and the hereby identified level of their craniological similarity to the populations inhabiting central parts of its European range and Western Balkans may be considered as support that Bulgarian populations belong to the subspecies of *Apodemus agrarius kahmanni* Malec and Storch, 1963 with described distribution from territories of Romania, Slovenia, Croatia, Serbia, Kosovo, Montenegro, Macedonia to Greece and European part of Turkey. Nevertheless the future use of expanded range of other phenetic craniodental characters as well as molecular genetic sources would certainly be necessity in understanding the evolutionary fate of the Bulgarian population of the species and their appropriate taxonomic designations.

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