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CRANIAL SEXUAL DIMORPHISM AND MICROGEOGRAPHICAL VARIABILITY OF THE FOREST DORMOUSE (*Dryomys nitedula* PALL., 1779)

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ABSTRACT. Craniometric relationship in the Forest dormouse (*Dryomys nitedula)* were studied on 64 adult specimens collected in the three main localities of the species in Bulgaria – Central Balkan, Vitosha Mountain and the foothill territories in Southeastern Bulgaria. Samples were subject to analysis of sexual dimorphism and microgeographic criteria. The results revealed that the Forest dormouse possesses well-expressed sexual dimorphism of the cranial characters. A discriminate function, which determines the sex of Forest dormouse individuals, was worked out on the basis of 48 craniometric characters. The craniometric characters of both male and female Forest dormice are microgeographically determined but maintain high craniometric similarity between populations. Ecological differences appear to be the main reasons for distinct patterns of microgeographic variation found in Bulgarian Forest dormice, despite their apparent morphological similarity.

Key words: Craniometric variability, forest dormouse, *Dryomys nitedula*, microgeographic differentiation, sexual dimorphism

AĞAÇ FARESİNDE (*Dryomys nitedula* PALL., 1779) KRANİAL EŞEYSEL DİMORFİZM VE MİKROCOĞRAFİK DEĞIŞKENLİK

ÖZET. Ağaç faresi, *Dryomys nitedula'*nın Bulgaristan'da yaşadığı üç ana lokaliteden (Orta Balkan, Vitoşa Dağı ve güneydoğu Bulgaristan'daki tepelik alanlar) toplanan 64 ergin örnekte kraniometrik değerler eşeysel dimorfizm ve mikrocoğrafik kriterler açısından araştırılmıştır. Sonuçlar ağaç farelerinin kranial karekterlerinde belirgin bir eşeysel dimorfizmin var olduğunu ortaya çıkarmıştır. Örneklerin eşeyini belirleyen bir diskriminant fonksiyon 48 kranial karakterde çalışmaktadır. Hem erkek hemde dişilerin kraniometrik karaterleri mikrocoğrafik olarak belirlenebilir, ancak populasyonlar arasında yüksek bir kraniometrik benzerlik te korunur. Görünüşte morfolojik benzerliklere rağmen Bulgaristan ağaç farelerinde saptanan belirgin mikrocoğrafik varyasyon tiplerinin ana nedenleri ekolojik farklılıklar olabilir.

Anahtar sözcükler. Kraniometrik değişkenlik, ağaç faresi, *Dryomys nitedula*, mikrocoğrafik farklılaşma, eşeysel dimorfizm

INTRODUCTION

An especially important stage in registering the microevolution changes in mammal populations is the determination of micro-geographical variability and the evaluation of their craniometric similarity and distinction. The phenotipic variability of the species found by revealing their population morphology also provides a possibility to analyze the direction and intensity of natural selection in habitats with different ecological conditions (1); (2).

Examination of the species' cranial morphology is a basic approach for revealing intraspecific systematic structure in traditional mammalian taxonomy (3). On the grounds of this information, an analysis of the intraspecific systematic relationships, the descriptions of which are still directly connected with the craniometric parameters of the populations, is also carried out. In a number of cases the mammal populations were given subspecific status on the basis of the results from the analysis of variation in cranial morphology.

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The analysis of microgeographic cranial variability is one of the first and basic stages in intraspecific biomorphological examinations in mammalogy .

Both multiple comparative analysis data and estimation of the phenotipic microgeographic cranial variability data were not prevoiusly available for the Forest dormouse (*Dryomys nitedula* Pall.,1779) in the southeastern part of the Balkan Peninsula. Thus, the objective of this study was to analyze the microgeographic variation of the cranial morphometric traits in both sexes of *D. nitedula* from localities with different ecological conditions.

MATERIAL AND METHODS

The somatometric and cytotaxonomic characteristics of the Forest dormouse in Bulgaria are similar to the typical for the species in Central and Western Europe (4).

Variability of metric traits was studied on skulls of 64 adult specimens of Forest dormouse collected in the three main localities (5) of the species in Bulgaria: 1 – Central Balkan (n=23, female =11, male =12), 2 - foothill territories in Southeastern Bulgaria (n=21, female =10, male =11) and 3 - Vitosha Mountain (n=20, female =10, male =10) which differ (6) in their ecological conditions (Fig. 1).

Only adult individuals were measured to minimize the effect of allometric variation associated with growth. To establish age the criteria proposed by (7) were used. The skulls used in this study are now stored in the craniological collection of mammals in the Laboratory of Mammalogy in the Institute of Zoology, BAS, Sofia.

Forty eight linear measurements were taken on each skull, using caliper with a resolution of 0.01mm: 1-Codylobasal length; 2-Basal length; 3-Basilar length; 4-Condylobasilar length; 5-Occipitonasal length; 6-Length of the upper diastema; 7-Length of the incisive foramen; 8-Face cranium length; 9-Cranium length; 10-Nasal length; 11-Upper molar series from the alveoles; 12-Upper molar series from the dental crowns; 13-Length of ear capsule; 14-Interorbital width; 15-Occipital width; 16-Nasal width; 17-Palatal length; 18-Rostral width; 19-Palatilar length; 20-Zygomatic width; 21-Rostral height; 22-Cranium height from the tympanic bullas; 23-Cranium capsule width; 24-Width of the upper incisive; 25-Condyloincisive length; 26-Length of upper incisive; 27-Mandible length; 28-Nasal- interparietal length; 29-Nasal-occipital length; 30-Lower molar series from the alveloles; 31-Lower molar series from the dental crowns; 32-Articular height; 33-Cranium height; 34-Interparietal - foramen magnum height; 35-Mandible height taken at M_2; 36-Frontalia length; 37-Parietalia length; 38-Width between M^1; 39-Width between M^3; 40-Width of the brain capsule; 41-Rostrum width; 42-Crown width of the right M^1; 43-Postorbital width; 44-Occipitomaxillar length; 45-Occipital height; 46-Height of the zygomatic arch; 47-Length from posterior face of M^3 to the proximal exposed point of the incisor; 48-Length from posterior face of M^3 to anterior face of incisor at its distal end.

To avoid undesirable variation due to potential asymmetry, only the left side was measured in paired characteristics.

The measurement points and denominations of the variables were used as defined in the following sources for craniometric description of the rodent skull: No 1-23 in (8); No 24 in (9); No 25-35 in (10); No 36-46 in (11) and No 47-48 in (12).

Basic statistical parameters: mean ($\overline{X}$) and standard deviation (SD) were calculated for each sample separately for both sexes.

Craniological differences between the sexes were checked on the basis of the univariate and multivariate description of the cranium. The following statistics were computed for each linear metric parameter: coefficient of sexual dimorphism $CD_{sex}=(X_{male}-X_{female})/X_{female}*100$; coefficient of variation $CV=SD/\overline{X}$ as estimation of variability; t-test for comparison of the mean values. The multidimensional craniometric diversity of the both sexes was studied by use of Factor analysis (Extraction method – Principal components; Factor rotation – Varimax normalized) and the estimation of the multidimensional craniological differentiation was implemented using Discriminant analysis (Stepwise Discriminant Function Analysis with Model Definition – Forward Stepwise).

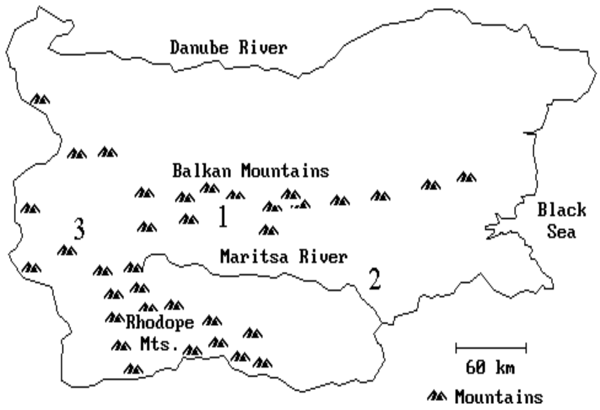


Fig. 1. Geographic situation of the craniometrically studied populations of the Forest dormouse (*Dryomys nitedula* Pall., 1779) from Bulgaria: 1 - Central Balkan, 2 – Foothill territories in Southeastern Bulgaria, 3-Vitosha Mountain.

The interpopulational craniological similarity within each one sex group of Forest dormouse was estimated by revealing both their craniometric similarity by use of Kluster analysis (UPGMA) based on the Squared Mahalanobiis Distances obtained from Discriminant Functions analysis of the studied craniometrical parameters and the similarity of their craniometric variability using Kluster analysis (UPGMA) based on the standardized coefficients of variation CV_{sd}= (CV - CV_{mean})/SD_{CV} of all the 48 studied skull traits.

Univariate and multivariate analyses were conducted using the statistical package StatSoft (13).

The method of analysis of variation flow using the coefficient of variation (CV) was employed to investigate the intrapopulational variability of the particular traits separately for males and females (1). When graphically represented, cranial traits were organized by decreasing absolute values.

RESULTS

The mean values of the cranial characters of the Forest dormouse in Bulgaria are shown for males in Table 1 and for females in Table 2.

The craniometric variability of all the studied characters expresses a similar pattern (Fig. 2).

The sexual cranial dimorphism is similar in all the characters studied. Statistically proven differences in the mean values of any trait were not found (Fig. 3).

The estimation of the sexual craniometric diversity implemented by use of Factor analysis (Table 3) showed that it is not strongly expressed in the Forest dormouse.

There were 5 principal components found, which were bound in a higher degree (loading >0.700) with the following variables: with the first factor No 1, 2, 3, 4, 5, 10, 20, 25, 41, 44, 47 and 48; with the second one No 18 and 37; with the third one No 38 and 39; with the fourth one No 30 and 31. Discriminant analysis (Wilks' Lambda: 0.40758; approx. F=4.025; p<0.0005; Percent of correct classifications: male - 93.10; female-80.95; total-88.00.) revealed a well manifested multidimensional craniologic differentiation between the both sexes in the Forest dormouse . It is mainly due to differences in 13 (No 2, 27, 6, 44, 33, 46, 19, 16, 45, 7, 26, 14 and 5) of the 48 analyzed cranial traits.

Table 1. Basic descriptive statistics – mean ($\overline{X}$), standard deviation (SD), and coefficient of variation (CV) for 48 cranial measurements (in mm) taken in male Forest dormouse (*Dryomys nitedula* Pall., 1779) from Bulgaria. The variables are described in "Material and Methods"

	All populations in Bulgaria n=33			Population 1 n=12			Population 2 n=11			Population 3 n=10		
NAME	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV
VAR1	24.2	0.95	3.9	24.4	1.08	4.4	23.8	0.73	3.1	24.6	0.97	3.9
VAR2	22.4	0.98	4.4	22.6	1.02	4.5	21.9	0.70	3.2	22.9	1.04	4.5
VAR3	20.7	1.01	4.9	20.8	1.19	5.7	20.2	0.72	3.6	21.1	0.96	4.6
VAR4	22.6	0.92	4.0	22.8	1.10	4.8	22.2	0.64	2.9	23.0	0.88	3.8
VAR5	26.7	0.90	3.4	26.8	1.01	3.8	26.4	0.85	3.2	27.1	0.76	2.8
VAR6	6.0	0.45	7.5	6.1	0.60	9.9	5.9	0.31	5.3	6.0	0.43	7.2
VAR7	3.3	0.50	15.3	3.3	0.50	15.5	3.3	0.24	7.3	3.3	0.74	22.5
VAR8	12.4	0.82	6.6	12.4	0.92	7.4	12.1	0.87	7.3	12.8	0.50	3.9
VAR9	15.7	0.55	3.5	15.9	0.52	3.3	15.7	0.68	4.4	15.7	0.37	2.4
VAR10	8.6	0.54	6.3	8.5	0.61	7.2	8.3	0.37	4.5	9.0	0.40	4.5
VAR11	4.2	0.32	7.6	4.2	0.27	6.5	4.3	0.41	9.5	4.2	0.25	6.0
VAR12	3.8	0.15	4.0	3.8	0.12	3.1	3.8	0.20	5.3	3.9	0.15	3.8
VAR13	7.4	0.37	5.0	7.4	0.36	4.9	7.2	0.35	4.9	7.6	0.35	4.7
VAR14	4.0	0.15	3.8	4.0	0.12	3.0	4.0	0.18	4.4	4.2	0.10	2.3
VAR15	12.9	0.33	2.6	12.8	0.36	2.8	12.9	0.38	2.9	12.8	0.24	1.9
VAR16	2.7	0.24	9.2	2.7	0.30	11.1	2.7	0.21	7.8	2.5	0.18	7.1
VAR17	11.0	0.43	3.9	11.0	0.40	3.6	11.0	0.25	2.3	11.0	0.67	6.0
VAR18	4.7	0.62	13.2	4.5	0.65	14.3	4.5	0.64	14.2	5.2	0.17	3.3
VAR19	9.3	0.55	5.9	9.4	0.64	6.8	9.2	0.35	3.8	9.4	0.68	7.3
VAR20	15.6	0.69	4.5	15.6	0.92	5.9	15.4	0.49	3.2	15.7	0.57	3.6
VAR21	4.8	0.29	6.0	4.9	0.23	4.7	4.6	0.24	5.2	5.0	0.31	6.2
VAR22	10.2	0.41	4.0	10.3	0.40	3.9	10.1	0.32	3.2	10.3	0.52	5.1
VAR23	9.6	0.47	4.9	9.6	0.48	5.0	9.6	0.52	5.5	9.7	0.43	4.4
VAR24	1.3	0.10	7.5	1.3	0.10	7.8	1.3	0.09	7.5	1.3	0.10	7.7
VAR25	24.0	0.98	4.1	24.1	1.17	4.9	23.7	0.71	3.0	24.5	0.96	3.9
VAR26	3.7	0.34	9.1	3.6	0.27	7.6	3.8	0.31	8.1	3.9	0.45	11.5
VAR27	14.0	0.77	5.5	14.1	0.43	3.1	13.8	0.52	3.8	14.2	1.46	10.3
VAR28	14.7	0.83	5.7	15.0	0.96	6.4	14.4	0.44	3.1	14.6	0.94	6.4
VAR29	18.6	0.65	3.5	18.8	0.65	3.5	18.5	0.65	3.5	18.6	0.67	3.6
VAR30	4.1	0.35	8.6	4.2	0.21	4.9	4.0	0.19	4.8	4.0	0.69	17.1
VAR31	3.9	0.31	8.0	3.9	0.24	6.2	3.8	0.26	6.9	4.0	0.48	12.2
VAR32	6.8	0.63	9.2	6.9	0.63	9.1	6.5	0.63	9.6	7.1	0.49	6.8
VAR33	7.2	0.27	3.8	7.2	0.18	2.5	7.2	0.41	5.7	7.3	0.15	2.0
VAR34	3.4	0.37	11.0	3.5	0.35	10.1	3.3	0.45	13.5	3.4	0.31	9.0
VAR35	2.9	0.25	8.7	3.0	0.17	5.6	2.8	0.30	10.7	2.9	0.27	9.3
VAR36	8.4	0.56	6.7	8.4	0.54	6.4	8.5	0.39	4.5	8.1	0.74	9.1
VAR37	6.4	0.54	8.6	6.5	0.63	9.6	6.1	0.39	6.3	6.4	0.50	7.8
VAR38	3.8	0.22	5.9	3.7	0.29	7.9	3.8	0.20	5.2	3.9	0.09	2.3
VAR39	3.6	0.36	10.0	3.4	0.42	12.3	3.6	0.37	10.2	3.8	0.11	3.0
VAR40	12.4	0.29	2.3	12.4	0.31	2.5	12.4	0.24	2.0	12.3	0.34	2.7
VAR41	4.9	0.33	6.8	4.9	0.38	7.7	4.8	0.37	7.6	5.1	0.14	2.7
VAR42	0.9	0.15	16.6	1.0	0.16	16.6	1.0	0.17	17.4	0.8	0.07	8.5
VAR43	6.8	0.66	9.6	6.7	0.88	13.1	6.9	0.58	8.4	6.9	0.29	4.1
VAR44	18.6	0.88	4.7	18.9	0.77	4.1	18.1	0.89	4.9	18.8	0.79	4.2
VAR45	6.6	0.39	5.9	6.8	0.45	6.7	6.5	0.36	5.5	6.4	0.24	3.8
VAR46	1.1	0.21	19.1	1.1	0.17	15.2	1.1	0.20	17.7	1.1	0.29	27.2
VAR47	11.3	0.42	3.7	11.4	0.36	3.2	11.2	0.34	3.1	11.3	0.58	5.1
VAR48	9.9	0.44	4.5	10.0	0.31	3.1	9.8	0.29	3.0	9.9	0.73	7.3

Table 2. Basic descriptive statistics – mean ($\overline{X}$), standard deviation (SD), and coefficient of variation (CV) for 48 cranial measurements (in mm) taken in female Forest dormouse (*Dryomys nitedula* Pall., 1779) from Bulgaria. The variables are described in "Material and Methods"

NAME	All populations in Bulgaria n=31			Population 1 n=11			Population 2 n=10			Population 3 n=10		
	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV	$\overline{X}$	SD	CV
VAR1	23.9	0.87	3.6	24.1	1.10	4.6	23.6	0.40	1.7	23.8	0.69	2.9
VAR2	21.7	1.16	5.4	21.9	1.07	4.9	20.7	1.68	8.1	21.9	0.65	3.0
VAR3	20.1	1.17	5.8	20.2	1.13	5.6	19.3	1.54	8.0	20.5	0.86	4.2
VAR4	22.3	0.69	3.1	22.4	0.78	3.5	21.8	0.20	0.9	22.3	0.65	2.9
VAR5	26.4	0.93	3.5	26.3	1.04	3.9	26.1	0.40	1.6	26.6	1.02	3.8
VAR6	6.1	0.53	8.8	6.3	0.50	7.9	5.9	0.65	11.1	5.9	0.24	4.2
VAR7	3.3	0.39	11.8	3.4	0.24	7.1	3.1	0.29	9.3	3.6	0.52	14.4
VAR8	12.0	0.90	7.5	11.8	0.84	7.1	11.9	1.28	10.7	12.4	0.62	5.0
VAR9	15.7	0.80	5.1	15.9	1.01	6.4	15.4	0.40	2.6	15.4	0.47	3.0
VAR10	8.3	0.69	8.4	8.2	0.74	9.1	8.0	0.73	9.1	8.6	0.50	5.8
VAR11	4.1	0.36	8.9	4.0	0.27	6.8	3.9	0.45	11.6	4.2	0.37	8.8
VAR12	3.8	0.21	5.6	3.8	0.22	5.8	3.9	0.23	6.0	3.9	0.18	4.7
VAR13	7.3	0.39	5.4	7.2	0.38	5.3	7.2	0.60	8.4	7.4	0.10	1.3
VAR14	4.1	0.20	4.9	4.2	0.24	5.7	4.1	0.19	4.8	4.0	0.06	1.6
VAR15	12.7	0.46	3.6	12.8	0.56	4.4	12.6	0.46	3.7	12.7	0.31	2.4
VAR16	2.6	0.16	6.0	2.6	0.16	6.2	2.6	0.18	6.9	2.7	0.14	5.2
VAR17	10.9	0.62	5.6	11.0	0.60	5.4	10.6	0.89	8.4	11.1	0.33	2.9
VAR18	4.6	0.63	13.7	4.3	0.71	16.4	4.5	0.53	11.9	5.1	0.28	5.5
VAR19	9.5	0.46	4.8	9.5	0.38	4.0	9.3	0.65	7.1	9.7	0.36	3.7
VAR20	15.4	0.72	4.6	15.5	0.74	4.7	15.5	0.50	3.3	15.3	0.87	5.7
VAR21	4.7	0.24	5.2	4.8	0.21	4.5	4.6	0.23	5.1	4.8	0.27	5.6
VAR22	10.1	0.43	4.3	10.2	0.33	3.2	9.9	0.66	6.7	10.1	0.34	3.4
VAR23	9.5	0.46	4.9	9.6	0.50	5.2	9.4	0.21	2.2	9.3	0.52	5.5
VAR24	1.3	0.11	8.9	1.3	0.12	9.7	1.2	0.14	11.1	1.3	0.08	5.9
VAR25	23.6	0.96	4.1	23.7	1.16	4.9	23.2	0.71	3.1	23.7	0.80	3.4
VAR26	3.5	0.43	12.1	3.6	0.55	15.1	3.4	0.35	10.5	3.6	0.29	8.1
VAR27	14.2	0.89	6.3	14.4	1.16	8.1	13.9	0.81	5.9	14.3	0.39	2.7
VAR28	14.5	0.77	5.3	14.8	0.82	5.6	13.9	0.91	6.6	14.6	0.35	2.4
VAR29	18.4	1.14	6.2	18.8	0.93	5.0	17.4	1.85	10.6	18.4	0.47	2.6
VAR30	4.0	0.29	7.2	4.1	0.23	5.7	3.9	0.40	10.1	4.0	0.26	6.5
VAR31	3.9	0.25	6.4	3.9	0.31	7.8	4.0	0.25	6.3	3.9	0.21	5.5
VAR32	6.8	0.64	9.4	7.0	0.55	7.9	6.5	0.92	14.1	6.8	0.40	5.8
VAR33	7.2	0.36	5.0	7.2	0.50	6.9	7.2	0.13	1.8	7.2	0.21	2.9
VAR34	3.4	0.39	11.5	3.5	0.29	8.3	3.3	0.61	18.3	3.4	0.42	12.3
VAR35	2.8	0.26	9.1	2.9	0.28	9.6	2.8	0.29	10.5	2.8	0.18	6.3
VAR36	8.2	0.71	8.6	8.5	0.74	8.7	7.8	0.90	11.6	8.0	0.25	3.1
VAR37	6.5	0.57	8.9	6.6	0.66	10.0	6.1	0.10	1.6	6.5	0.61	9.3
VAR38	3.8	0.34	9.0	3.7	0.44	11.9	3.8	0.30	7.9	3.8	0.22	5.6
VAR39	3.8	0.34	9.1	3.8	0.43	11.4	3.7	0.34	9.2	3.8	0.24	6.2
VAR40	12.4	0.36	2.9	12.4	0.34	2.8	12.5	0.52	4.1	12.4	0.32	2.6
VAR41	4.9	0.26	5.4	4.9	0.28	5.7	4.9	0.32	6.6	4.9	0.23	4.7
VAR42	0.9	0.17	18.8	0.9	0.16	18.2	0.9	0.26	29.0	0.9	0.06	7.0
VAR43	6.8	0.81	11.8	6.8	0.79	11.6	7.4	0.83	11.2	6.5	0.73	11.1
VAR44	18.2	0.75	4.1	18.1	0.94	5.2	18.6	0.21	1.1	18.3	0.61	3.3
VAR45	6.8	0.35	5.1	6.9	0.30	4.3	6.8	0.47	6.9	6.5	0.23	3.6
VAR46	1.0	0.25	24.3	1.0	0.19	18.6	1.2	0.15	12.2	0.9	0.30	33.9
VAR47	11.0	0.63	5.7	11.1	0.48	4.3	10.6	1.05	9.9	11.1	0.28	2.5
VAR48	9.6	0.53	5.5	9.7	0.32	3.3	9.4	0.96	10.2	9.7	0.29	3.0

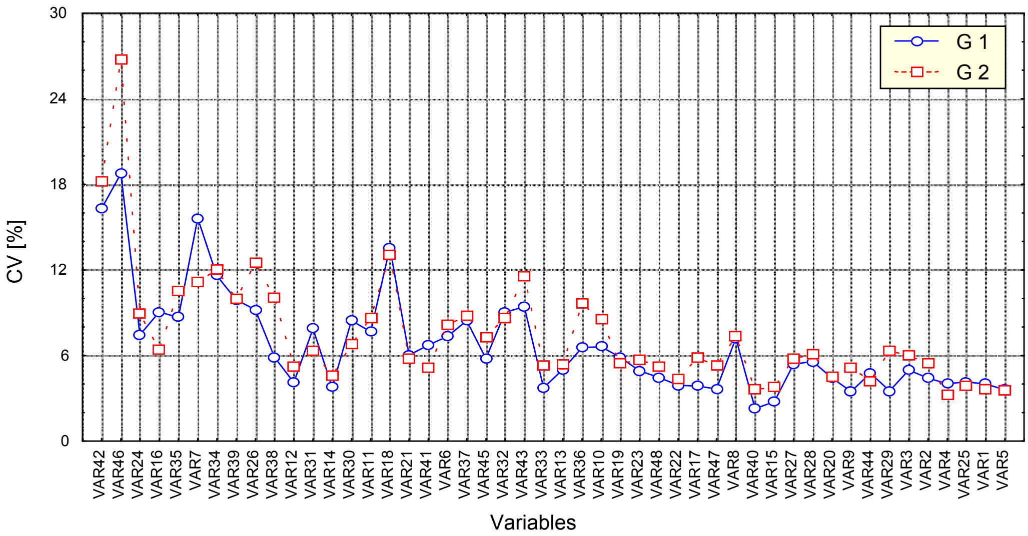


Fig. 2. Morphometric variation of the cranial measurments in male (G1) and female (G2) Forest dormouse (*Dryomys nitedula* Pall., 1779) from Bulgaria.

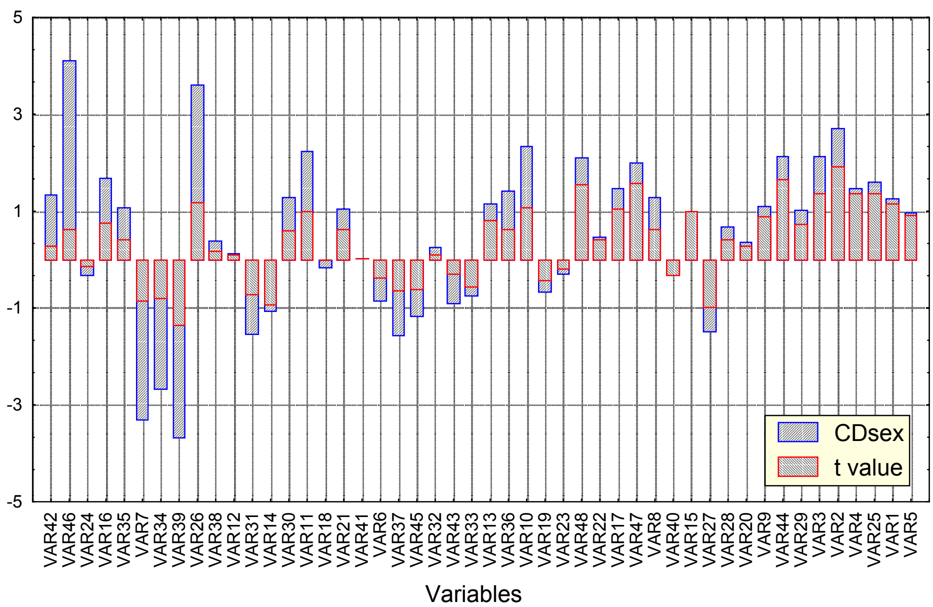


Fig. 3. Sexual craniometric dimorphism (CD_{sex}) and estimation of the differences in the mean values (t value) of the cranial variables in male and female Forest dormouse (*Dryomys nitedula* Pall., 1779) from Bulgaria.

Table 3. Factor analysis results (Method: Principal components) of the craniometric diversity in male and female Forest dormouse (*Dryomis nitedula* Pall., 1779) from Bulgaria.

Eigenvalues

Case	Eigenval	% Total	Cumul. E	Cumul. %
1	15.00699	31.26456	15.00699	31.26456
2	4.84281	10.0892	19.8498	41.35376
3	4.23334	8.81946	24.08314	50.17322
4	3.37472	7.03066	27.45786	57.20388
5	2.50503	5.2188	29.96289	62.42268

The different types of analysis were implemented to estimate the inter- and intrapopulational craniometric variability and similarity of the Forest dormouse in Bulgaria separately for males and females showed the following:

Unvariate analysis of variance (ANOVA):

A) In males the size of characters No Var 2, 3, 4, 6, 10, 13, 14, 20, 21, 22, 25, 26, 27, 29, 30, 33, 34, 37, 38, 45 and 46 influences (effects are significant at $p<0.05$) their intrapopulational craniometric differentiation.

B) In females the size of characters No Var 2, 3, 4, 6,10, 13, 14, 21, 22, 25, 26, 29, 30, 33, 34, 37, 38, 45 and 46 influences (effects are significant at $p<0.05$) their intrapopulational craniometric differentiation.

Factor analysis:

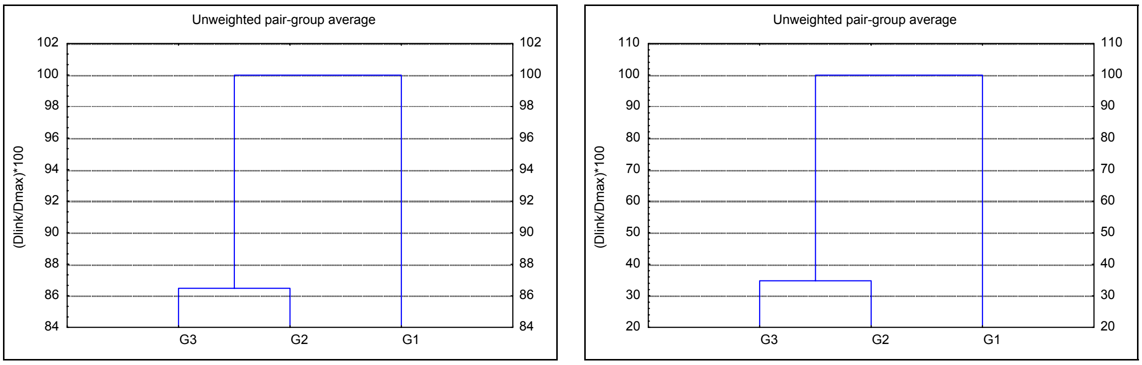
A) In males the first 5 principal components explain 75.1% of the total variation. The most discriminanting individual variables (loadings are > 0.700) are NoNo Var 17, 19, 27, 30, 31, 44, 47 and 48, included in Factor 1, which explains 34,7 % of total variance; NoNo Var 11, 38 and 39, included in Factor 2, explaining 12 of % total variance; NoNo Var 15 and 33, included Factor 3, explaining 11,4 % of total variance; NoNo Var 13 and 36, included in Factor 4, explaining 8,9 % total variance; NoNo Var 1, 3, 4, 5, 8 10, 20, 24, 25, 26, 28 and 41, included in Factor 5, explaining 8.0 % of total variance

B) In females the first 5 principal components explain 72.48% of the total variation. The most discriminanting individual variables (loadings are > 0.700) are NoNo Var 1, 2, 3, 4, 5, 17, 19, 20, 21 23, 25, 32, 40, 44, 47 and 48, included in Factor 1, which explains 35,69 % of total variance; NoNo Var 12 and 31, included in Factor 2, explaining 14.26 % of total variance; NoNo Var 7 and 18, included in Factor 3, explaining 10, 05 % of total variance; NoNo Var 38, included in Factor 4, explaining 6.71 % of total variance; NoNo Var 14 and 36, included in Factor 5, explaining 5.77 % of total variance.

Kluster analysis based on the Squared Mahalanobiis Distances obtained from Discriminant Functions analysis of the studied craniometrical parameters:

A) In Forest dormouse males the craniometric similarity is well expressed between the populations from Vitosha and those ones from the mountains in South-eastern Bulgaria, while the Central Balkan population exhibits a degree of craniometric detachment. (Fig. 4A)

B) In Forest dormouse females the intrapopulational craniometric similarity is identical with the one revealed in males (Fig. 4B).



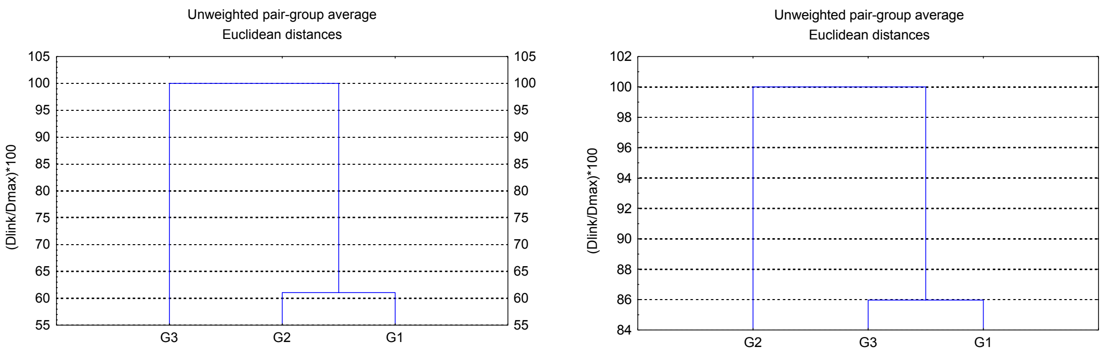
A B

Fig. 4. Distance phenogram, based on the Squared Mahalanobiis Distances, depicting craniometric similarity in males (A) and females (B) of Forest dormouse (*Dryomys nitedula* Pall., 1779) from Central Balkan (G1), foothill territories in Southeastern Bulgaria (G2) and Vitosha Mountain (G3).

Kluster analysis based on standardized coefficients of variation of the 48 studied cranial parameters confirms the specific interpopulational craniological variability:

A) In Forest dormouse males the Vitosha mountain population exhibited the most specific craniological variability (Fig. 5A).

B) In Forest dormouse females the highest specific craniological variability was found in the South foothills sample (Fig. 5B)



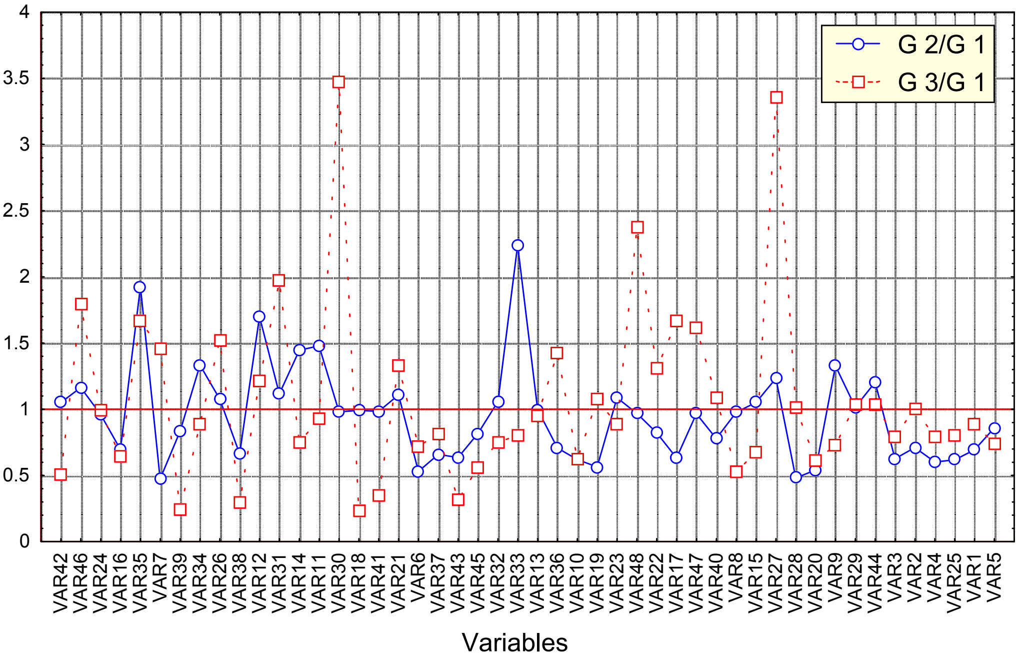
A B

Fig. 5. Distance phenogram based on the standardized coefficients of variation of the 48 craniometrical parameters depicting the similarity in the craniometric variability of males (A) and females (B) of Forest dormouse (*Dryomys nitedula* Pall., 1779) from Central Balkan (G1), foothill territories in Southeastern Bulgaria (G2), Vitosha Mountain (G3)

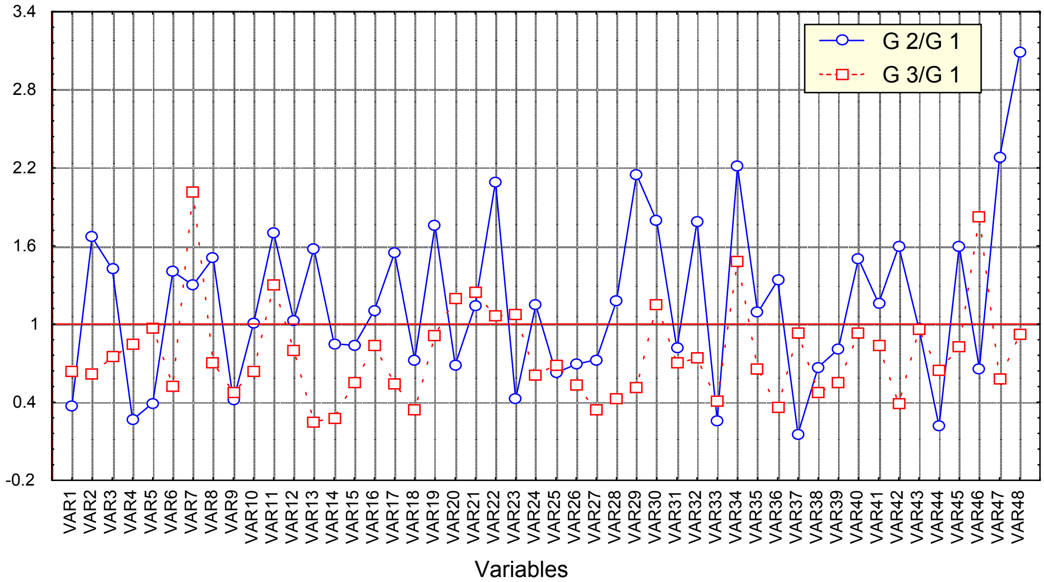
In the "variability flow" analysis were used the relative values of the coefficient of variation (CV) of the functionally uniform cranial traits of the studied populations in relation to those of the Central Balkan population expressing the lowest specific variability. The obtained results were:

A) In males the craniological variability was quite specific for each one locality (Fig. 6A).

B) The same holds true in respect of females but due to different set of cranial traits (Fig. 6B).



A



B

Fig. 6. Relative interpopulational differences in the variability (coefficients of variation ratio) of the cranial characters in male (A) and female (B) Forest dormouse (*Dryomys nitedula* Pall., 1779) from foothill territories in Southeastern Bulgaria (G 2/G 1) and Vitosha Mountain (G3/G1). The ratios were computed using of the coefficients of variation of cranial characters of Central Balkan population (G1) as denominators.

DISCUSSION

Univariate analysis of the cranial sexual dimorphism in Bulgarian Forest dormice showed that both sexes manifested similar type of variation and differences between the mean values of the cranial traits were not found to be statistically significant. In contrast to this result the multivariate cranial sexual differentiation of the Forest dormouse was well expressed, so the results from Discriminant Function Analysis of the sexual differences in the skull metric structure allowed craniometric sex differentiation of Forest dormouse with high statistical reliability (p=0.01). A stepwise discriminant function analysis allowed us to identify a set of 13 variables with a sufficient discriminating ability. They were included in the two classification functions:

Y_{male} = -38.86 * Var2 + 26.92 * Var27 + 43.45 * Var6 +25.42 * Var41 + 109.74 * Var33 - 75.16 * Var46 - 9.47 * Var19 + 41.57 * Var16 + 39.09 * Var45 + 15.85 * Var7 - 57.92 * Var26 + 212.59 * Var14 + 50.71 * Var5 - 1466.93;

Y_{female} = -43.92 * Var2 + 28.96 * Var27 + 46.9 * Var6 + 33.57 * Var41 + 112.88 * Var33 – 82.05 * Var46 - 7.93 * Var19 + 36.85 * Var16 + 42.22 * Var45 +17.59 * Var7 - 60.85 * Var26 + 216.35 * Var14 + 51.7 * Var5 – 1519.24;

Unknown individuals should be attributed to the sex for which the function gives the highest score.

The interpopulational univariate craniometric diversity of the Forest dormouse in Bulgaria depended on the size of many cranial traits. Thus, twenty one of the 48 cranial and dental measurements in males had influence on the interpopulational cranial differentiation, 19 of which (NoNo Var 2, 3, 4, 6,10, 13, 14, 21, 22, 25, 26, 29, 30, 33, 34, 37, 38, 45 and 46) being the same in females and only two (No 20 and 27) – specific for males.

Analysis of the multivariate interpopulational craniometric diversity in the both sexes showed that it was not highly expressed. Probably the craniometric diversity could be due to the parameters NoNo Var 17, 19, 44, 47 and 48 in the highest extend. For males it could be mainly connected with variables NoNo Var 17, 19, 27, 30, 31, 44, 47 and 48 and for females with variables NoNo Var 1, 2, 3, 4, 5, 17, 19, 20, 21 23, 25, 32, 40, 44, 47 and 48, included in the first factors explaining the greatest part of the total variance of the interpopulational diversity in Bulgarian Forest dormouse. The multivariate comparative craniometric analysis of Bulgarian populations revealed microgeographic dependance of size in both males and females meanwhile high degree of interpopulational craniometric similarity was maintained. It was more strongly expressed in females than in males but follows a common trend: the populations from Vitosha mountain and Souteastern mountains were the most similar ones, while the Central Balkan population was different.

The specific craniometric differentiation of the main Forest dormouse populations in Bulgaria was confirmed by cranial variability, which was most strongly expressed in males from Vitosha Mountain and in females from the Southeastern mountains

The high degree of specific craniometric variability of the populations from diverse localities was as well displayed by the different relative variation of the functionally uniform cranial traits in both male and female individuals. It was specific for each particular population and was due to typical for the sex group set of cranial characters.

The metric characterization drawn from present study could be used for the taxonomic conclusions and description of the biological diversity of *D. nitedula*. It should help to gain better knowledge about microevolution of Forest dormouse in its biogeographical range.

REFERENCES

1. Yablokov A.V., Variability of mammals, 1-363, Sciences, Moskva, 1966, (in russian).
2. Schvarz S. S., Evoluconnaya ekologia zhivotnykh,1-198, AN SSSR Ural Filial, Svredlovsk, 1969, (in russian).
3. Mayr E., Populations, species and evolution, 1-779,The Belknap press, Harvard Univ. Press, Cambridge, 1963.
4. Markov G. G., Tzocheva K., Dobryanov D., Karyotaxonomic characterization of Forest Dormouse (*Dryomys nitedula* Pall., 1779) in Bulgaria. Acta zool. Bulg., v. 49, 13-19 , 1997.

5. Markov, G., Mammals in Bulgaria, 1-155 Sciences and Art, Sofia, 1959, (in bulgarian) .
6. Tishkov, Ch., The climate of the mountain regions in Bulgaria, 1-210, Bulgarian Academy of Sciences, Sofia, 1976.
7. Lozan, M., Age determination of *Dryomys nitedula* Pall. and of *Muscardinus avellanarius* L. Zool. Zh., v. 40, (11), 1740-1743, 1961 (in Russian with English summary).
8. Niethammer, J., Krapp F., Hanbuch der Saugetiere Europas, v.1, 1-237, Akademische Verlagsgeseltschaft, Wiesbaden, 1978.
9. Spitzenberger F., Englisch H., Die Alpinenwaldmouse (*Apodemus alpicola* Heinrich, 1952) in Osterreich. Bonn. Zool. Beitr., v. 46, (1-4) 249-260, 1996.
10. Ventura J., Gozalbez J., Taxonomic review of *Arvicola terrrestris* (L. 1758) (Rodentia, Arvicolidae) in the Iberian Peninsula Bonn. Zool. Beitr., v. 40, 3/4, 227-242, 1989.
11. Pietch, M,. Biometrische analyse an Schädelen von neun Kleinsäuger – Arten aus der Familie Arvicolidae (Rodentia), Z. Zool. Evolut. Forsch., v. 18, 196-211, 1980.
12. Corbet, G., The taxonomic status of British Water voles, “Genus *Arvicola*”, J. Zool., Lond., v. 161, 1-4, 301-316 1970.
13. Statistica for Windows, Release 4.3 StatSoft, 1993.