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Morphometric variability in karyologically polymorphic populations of the wild *Mus musculus domesticus* in Greece

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A number of geographically defined Robertsonian (Rb) populations of the wild house mouse *Mus musculus domesticus* Schwarz and Schwarz, 1943 occurs in several areas of Europe (including Greece) and northern Africa. A multivariate analysis of 26 morphometric characters studied in 6 populations from Greece was performed to detect possible morphological variability in populations having different chromosome number. A morphological polymorphism among all the studied populations was found but this is attributed rather to geographical than to karyotypic relations.

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Key words: *Mus musculus domesticus*, morphometric variability, Rb populations, Greece

Introduction

The use of morphometrics in a species like the house mouse could be a valuable tool for the elucidation of microevolution processes. Although a number of morphometric analyses of different genetically determined European taxa of the genus *Mus* have been done (Engels 1980, Darviche and Orsini 1982, Kraft 1984/85, Gerasimov *et al.* 1990, Chondropoulos *et al.* 1995, etc) the intraspecific geographical variation of morphometric characters has been little studied (for a review see Thorpe 1981).

The occurrence of a chromosomal variability in the wild house mouse *Mus musculus domesticus* Schwarz and Schwarz, 1943 has been long known. This variability is due to centric fusions of acrocentric chromosomes, known as Robertsonian (Rb) translocations. A number of Rb populations with different centric fusions are distributed in various areas of Europe and northern Africa (Britton-Davidian *et al.* 1989). In Greece Rb populations have been studied by Giagia *et al.* (1983, 1986, 1987), Giagia-Athanasopoulou *et al.* (1994), Tichy and Vucak (1987), Winking *et al.* (1988), and a number of Rb races were found having caryotypes with 2n = 22–32. The need of multivariate morphometric analysis in

order to reveal differences among Rb populations in the wild house mouse has been identified long ago (Thorpe 1981).

In the present study we give some data on the morphometric variation in 6 populations of the wild house mouse *M. m. domesticus* from Greece. Moreover, we compare the relationships of these populations as they derived from the morphometric and karyological comparisons, taking the chromosome variability of the studied populations into account.

Materials and methods

A total of 115 wild mice (76 males, 39 females) was examined. All animals were adults as indicated by their tooth wear condition. These individuals originated from six sites, four mainland and two insular (Fig. 1). The mainland population samples were collected from the city of Patra (PAT, 18 males and 14 females with chromosome number 2n = 30, 31, 32), the campus of Patra University (UOP, 17 males and 17 females, 2n = 30) and the neighbouring villages Ano Kastritsi (AKA, 21 males and 10 females, 2n = 29), and Kato Kastritsi (KKA, 6 males and 5 females, 2n = 30). All these localities lie in the Achaia Prefecture, NW Peloponnisos. The island population samples came from around the village of Mouzaki on Zakynthos island, Ionian Sea (ZAK, 10 males and 5 females, 2n = 40), and of village Zipari on Kos island, SE Aegean Sea (KOS, 4 males and 2 females, 2n = 40).

For the biometrical study of this material we used the following 26 linear characters and two ratios:

External characters: (H+B) – head-plus-body length, TL – tail length, HFL – hind foot length, EL – ear length.

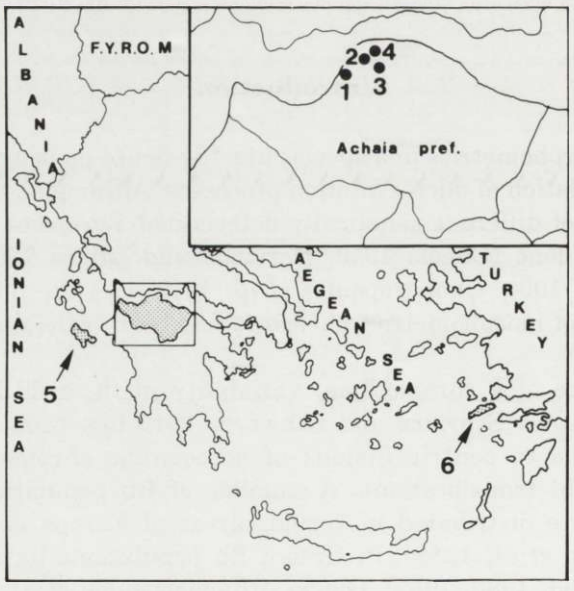

Fig. 1. Map of Greece indicating the localities of the *Mus* populations sampled: 1 – city of Patra (PAT), 2 – campus of Patra University (UOP), 3 – Ano Kastritsi (AKA), 4 – Kato Kastritsi (KKA), 5 – Zakynthos island (ZAK), 6 – Kos island (KOS).

Cranial and dental characters: CBL – condylobasal length, BL – basal length, DL – diastema length, NL – nasal length, PL – palatal length, ML – mandible length, ZW – zygomatic width, I-M^3 – distance between incisor and third molar of maxilla, M^1L – length of the first maxillar molar, M^1W – width of the first maxillar molar, M^2L – length of the second maxillar molar, M^2W – width of the second maxillar molar, M^3L – length of the third maxillar molar, M^3W – Width of the third maxillar molar, M_1L – length of the first mandibular molar, M_1W – width of the first mandibular molar, M_2L – length of the second mandibular molar, M_2W – width of the second mandibular molar, M_3L – length of the third mandibular molar, M_3W – width of the third mandibular molar, UMSL – length of the maxillar molar series, LMSL – length of the mandibular molar series.

Ratios: (H+B)/TL – head-plus-body length/tail length, ZC – zygomatic coefficient [ZC = A/B, where A is the width of the anterior part of the malar process (dorsal ramus) and B is the width of the upper part of the zygomatic arch].

The definition of the external and cranial characters are given by Niethammer and Krapp (1978) and Darviche and Orsini (1982). These characters were measured by means of a rule and a Preisser Digi-Met. digital vernier calliper, respectively. Molar series length (UMSL, LMSL) were measured with this calliper too. As length and width of each molar its greatest dimensions along and across the longitudinal cranial axis were recorded. Molar measurements were taken with a microscope having lenses fitted with two micrometric scales arranged vertically each other. Measurements of the external characters were taken to the nearest mm, all other linear characters to the nearest 0.01 mm.

Subsequent analysis was performed on the 26 linear measurements and the two ratios, separately. All variables were log-transformed to make their allometric relationships linear. MANOVA tests and Mahalanobis distances (Morrison 1976) were used to detect differences among populations and to construct a UPGMA phenogram (Sneath and Sokal 1973). Canonical Variate Analysis was used for the ordination of specimens along the canonical variates (CV). Ratios were analysed by univariate ANOVA's and Tukey's HSD test (Sokal and Rohlf 1995). Association among geographic and Mahalanobis distances was tested by Mantel's test for matrix comparisons, described by Sokal (1979).

Statistical analysis was performed in SYSTAT (Wilkinson 1987) and NT-SYS (Rohlf 1992).

Results and discussion

The two sexes were pooled for subsequent analysis, since no sexual dimorphism was found in any large sample (more than 10 specimens in each sex) (MANOVA, $p > 0.05$).

The basic statistics of the 6 populations are presented in Table 1. The six-group Canonical Analysis revealed that the population centroids are different (MANOVA, Wilk's $\Lambda = 0.097$, $p < 0.0001$). The Mahalanobis distances (Table 2) and their corresponding p-values showed that KOS is different from all the other populations, ZAK and PAT cannot be considered different ($p = 0.04$), while the other three populations group together.

The above results are confirmed by the plot of the first two canonical variates (Fig. 2) and the UPGMA phenogram (Fig. 3). The first CV discriminates UOP, AKA and KKA from PAT, ZAK and KOS and accounts for 50.7% of the between group variability. From the canonical coefficients (Table 3) one can interpret this axis as a contrast between the characters TL on the one hand and BL, CBL, M^2L on the other. The second CV separates KOS from all other populations and reflects a contrast between PL, TL, LMSL, CBL on the one hand and BL on the other (Table 3). Subsequent CVs are not significant ($p > 0.01$).

Table 1. Basic statistics (mean and standard deviation in mm, coefficient of variation in %) of the six populations of *Mus musculus*. For the description of the characters see text. For abbreviations of the populations see Fig. 1. *n* – number of animals examined.

Character	Population																	
	PAT (*n* = 32)			UOP (*n* = 34)			KKA (*n* = 11)			AKA (*n* = 31)			ZAK (*n* = 15)			KOS (*n* = 6)		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
H+B	79.97	9.76	12.2	75.98	6.74	8.9	71.18	8.34	11.7	74.06	7.81	10.5	76.53	6.98	9.1	75.33	4.37	5.8
TL	80.27	6.43	8.0	74.36	8.73	11.7	72.91	6.22	8.5	73.32	7.15	9.8	78.57	5.32	6.8	82.33	4.68	5.7
HFL	17.25	1.05	6.1	17.06	1.37	8.0	17.36	0.81	4.7	17.32	1.08	6.2	17.93	1.87	10.4	17.83	1.17	6.6
EL	14.19	1.55	11.0	13.60	1.67	12.3	13.45	0.82	6.1	13.94	1.46	10.5	14.13	2.13	15.1	13.25	0.42	3.2
CBL	19.88	1.30	6.6	19.41	1.00	5.2	18.63	1.38	7.4	18.99	1.22	6.4	19.39	1.24	6.4	19.41	0.65	3.4
BL	18.09	1.29	7.1	17.69	1.00	5.6	16.91	1.38	8.1	17.24	1.26	7.3	17.72	1.25	7.1	17.54	0.73	4.2
DL	5.26	0.44	8.3	4.95	0.40	8.0	4.75	0.54	11.5	4.85	0.56	11.6	5.35	0.47	8.8	5.29	0.26	5.0
NL	7.58	0.59	7.7	7.43	0.53	7.2	6.94	0.82	11.8	7.09	0.71	10.0	7.53	0.56	7.4	7.41	0.32	4.4
PL	10.86	0.89	8.2	10.56	0.54	5.1	10.12	0.71	7.0	10.30	0.68	6.6	10.53	0.76	7.3	10.48	0.42	4.0
ML	11.08	0.54	4.9	10.81	0.49	4.6	10.59	0.67	6.4	10.52	0.69	6.6	11.26	0.69	6.1	11.33	0.45	4.0
ZW	11.01	0.62	5.7	10.83	0.38	3.5	10.46	0.48	4.6	10.64	0.59	5.5	10.88	0.56	5.2	10.96	0.23	2.1
I-M^3	8.11	0.54	6.6	7.73	0.46	5.9	7.41	0.76	10.2	7.54	0.68	9.0	8.21	0.60	7.4	8.06	0.36	4.5
M^1L	1.92	0.18	9.1	1.84	0.13	6.8	1.89	0.21	11.0	1.82	0.15	8.3	1.91	0.17	9.0	1.83	0.11	6.1
M^1W	1.09	0.10	9.5	1.05	0.05	4.7	1.03	0.03	2.8	1.05	0.04	4.2	1.10	0.05	4.6	1.05	0.04	3.4
M^2L	0.93	0.07	7.7	0.95	0.05	5.1	0.95	0.04	4.3	0.94	0.06	6.1	0.95	0.06	6.2	0.94	0.04	4.3
M^2W	0.93	0.08	8.5	0.91	0.05	5.3	0.90	0.06	7.0	0.89	0.07	7.6	0.96	0.04	4.3	0.95	0.05	5.5
M^3L	0.62	0.09	14.0	0.59	0.06	9.5	0.59	0.04	7.0	0.58	0.04	6.6	0.59	0.03	4.3	0.63	0.08	12.8
M^3W	0.64	0.08	12.9	0.61	0.03	5.2	0.59	0.03	4.9	0.60	0.04	6.8	0.61	0.03	5.1	0.67	0.08	11.9
M_1L	1.43	0.07	4.7	1.41	0.07	5.1	1.38	0.06	4.6	1.40	0.07	4.8	1.45	0.07	4.5	1.42	0.13	9.4
M_1W	0.88	0.07	7.6	0.85	0.05	5.8	0.81	0.03	3.7	0.85	0.03	3.6	0.88	0.06	7.1	0.83	0.04	5.0
M_2L	0.91	0.06	6.5	0.90	0.05	6.0	0.91	0.04	4.5	0.92	0.06	6.6	0.91	0.06	6.9	0.93	0.06	6.6
M_2W	0.86	0.06	6.5	0.85	0.04	4.2	0.83	0.03	3.1	0.85	0.03	3.1	0.86	0.07	8.6	0.87	0.05	6.3
M_3L	0.62	0.09	14.2	0.61	0.05	7.8	0.57	0.04	7.4	0.59	0.05	8.1	0.62	0.04	6.2	0.71	0.07	9.9
M_3W	0.60	0.06	10.2	0.60	0.04	7.1	0.57	0.07	12.2	0.59	0.03	5.3	0.58	0.06	9.6	0.62	0.06	9.3
UMSL	3.50	0.23	6.7	3.43	0.15	4.4	3.48	0.15	4.3	3.39	0.22	6.4	3.46	0.17	4.9	3.38	0.20	5.8
LMSL	3.08	0.17	5.5	3.08	0.13	4.3	3.05	0.10	3.2	3.10	0.19	6.0	3.05	0.19	6.3	3.22	0.33	10.2
Ratios																		
(H+B)/TL	1.00	0.10	10.4	1.03	0.11	10.5	0.98	0.06	5.7	1.01	0.08	7.7	0.97	0.07	7.2	0.92	0.06	6.0
ZC	0.49	0.08	15.5	0.54	0.10	17.9	0.49	0.08	17.4	0.56	0.13	23.6	0.58	0.10	17.4	0.63	0.13	20.0

Table 2. Squared Mahalanobis Distances between the populations studied. All pairwise corresponding T^2 tests are significant at 1%, except those indicated with asterisk (*). For abbreviations of the populations see Fig. 1.

	Population					
	PAT	UOP	KKA	AKA	ZAK	KOS
PAT	0					
UOP	7.536	0				
KKA	10.001	5.567*	0			
AKA	6.701	2.179*	3.821*	0		
ZAK	5.614*	11.939	14.658	12.669	0	
KOS	15.200	20.852	24.635	20.381	20.944	0

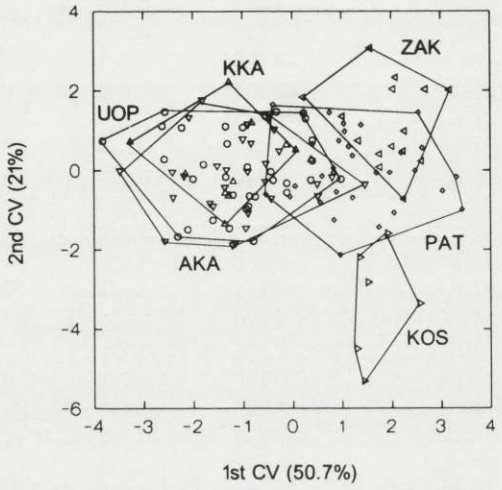

Fig. 2. First and second Canonical Variate (CV) plot. For abbreviations of the populations see Fig 1.

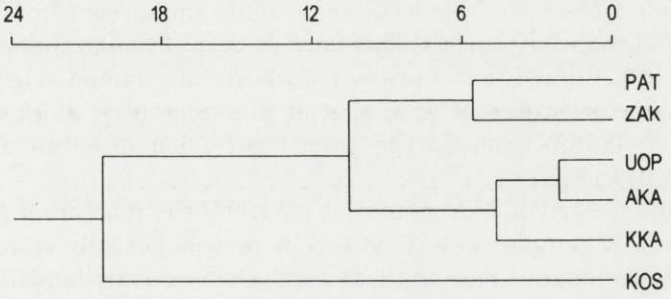

Fig. 3. UPGMA phenogram based on the Mahalanobis distances between the centroids of the populations. For abbreviations of the populations see Fig. 1.

Table 3. Canonical coefficients (standardized by the within group standard deviations) for the first two canonical axes.

Character	1st CV	2nd CV
H+B	0.366	0.239
TL	0.768	−0.773
HFL	−0.157	0.011
EL	−0.225	0.217
CBL	−0.808	−0.937
BL	−0.870	2.213
PL	−0.142	−1.403
NL	−0.425	0.451
DL	1.343	−0.184
I-M^3	0.472	0.215
ZW	−0.166	−0.401
ML	0.155	0.001
M^1L	−0.082	0.216
M^1W	0.527	0.510
M^2L	−0.740	0.077
M^2W	0.275	0.092
M^3L	−0.190	0.010
M^3W	0.406	−0.295
M_1L	0.151	0.444
M_1W	0.170	0.490
M_2L	−0.108	−0.193
M_2W	0.136	−0.202
M_3L	0.237	−0.444
M_3W	−0.166	−0.362
UMSL	0.495	0.371
LMSL	−0.453	−0.888

Univariate ANOVAs on the log-transformed ratios gave $p = 0.045$ and $p = 0.008$ for (H+B)/TL and ZC, respectively. However, since Tukey's HSD tests (Sokal and Rohlf 1995) failed to reveal significant pairwise differences at 5%, we considered that all the examined populations show no difference regarding these two ratios. This fact supports the conclusion that all the examined populations belong to the same taxon, *M. m. domesticus*, since the two ratios are generally considered as discriminant characters between this taxon and the second mouse taxon living in Greece (*Mus macedonicus* Petrov and Ruzic, 1983) (Chondropoulos *et al.* 1995).

The studied populations are known to be karyologically variable including both all--acrocentric (ZAK and KOS, 2n = 40) and Rb ones (PAT, 2n = 30, 31, 32; AKA, 2n = 29, 30; KKA and UOP, 2n = 30) (Giagia *et al.* 1986, 1987 and unpubl.). The above Rb races belong to the same karyotypic system *sensu* Capanna (1982).

According to our data a clear morphological variation is revealed concerning both the all-acrocentric and Rb populations, but Table 2 and Fig. 3 show the interpopulation variability does not distinguish the acrocentric population from the Rb ones, the PAT population being morphologically closer to ZAK than to the three other Rb populations of the same system (UOP, AKA, KKA). On the other hand, the mice from KOS are roughly equidistant from all the others independently of their karyotypes. This implies that although the members of the karyotypic system studied in the present work are of common origin they have a genic constitution not different from that of the acrocentric stock mice. Britton--Davidian *et al.* (1989) came to the same conclusion after an electrophoretic comparison of allozymes.

In a previous paper (Chondropoulos *et al.* 1995) the mice from Ionian islands (including the ZAK sample) were found to be morphologically closer to the mice from Patra (PAT sample) than to those from Dodecanisa islands (including the KOS sample), a finding which is in accordance with the results of the present study. In that work the difference between Ionian and Dodecanisa samples was not significant due to the small size of the latter sample. The equidistance of the

KOS sample from all others revealed in the present study may reasonably be interpreted as the effect of the increased number of the characters examined. This has led to the increased Mahalanobis distance found between the KOS and ZAK samples. In any case the KOS sample is rather small so that the results concerning this population should be accepted with some reservation.

Geographic and Mahalanobis distances are in accordance as tested by Mantel's test. Indeed, matrix correlation was very high (R = 0.891) and after 1000 permutations of the matrices this accordance cannot happen due to chance only (p = 0.004). Therefore, our results indicate that the relationships revealed by the morphometric analysis and the geographical origin of the studied mice match. Indeed the Rb populations of northwestern Peloponnisos seems to be closer to the geographically neighbouring ZAK population compared to the much more distant KOS one. These relationships do not necessarily reflect any phylogenetic divergence since it is known, that at least in some instances ecological factors also play an important role (Corti and Thorpe 1989).

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