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MORPHOMETRIC VARIATION IN STONE MARTEN *MARTES FOINA* IN WESTERN ALPS IN RELATION TO CLIMATE

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ABSTRACT – Morphometric variation of 16 characters of 65 adult male skulls of *Martes foina* from North-Western Italy and Central-Western Switzerland was examined. Analysis of variance showed significant differences among these local populations especially related to the masticatory apparatus. These features were strictly correlated with the second factor derived by principal component analysis (PCA), while the first one was correlated with the size of the skull. The results of discriminant analysis revealed a clear separation between Italian and Swiss stone marten skulls with 90.77 % correct classification and without any misclassification between Italian and Swiss groups. Using Mann-Whitney test, no significant differences were found between environmental parameters of the selected weather stations for the Swiss and Italian groups. Geographic isolation appears to be the main reason for the pattern of geographic variation found in these peripheral populations of stone marten.

Key words: *Martes foina,* Stone marten, Morphometric variation, Climate, Western Alps.

RIASSUNTO – *Variazione morfometrica nella faina* Martes foina *nelle Alpi occidentali in relazione al clima* – **E'** stata analizzata la variazione morfometrica in 16 caratteri rilevati su 65 crani di maschi adulti di *Martes foina* provenienti dall'Italia nord-occidentale e dalla Svizzera centro-occidentale. L'analisi della varianza ha indicato che esistono differenze significative tra queste popolazioni specialmente per quel che riguarda l'apparato masticatorio. Questi caratteri si sono rivelati strettamente correlati con il secondo fattore derivato dall'analisi delle componenti principali (PCA), mentre il primo è risultato correlato con le dimensioni del cranio. Secondo l'analisi discriminante esiste una chiara differenziazione tra i crani di faina italiani e quelli svizzeri con 90.77% di corrette classificazioni e senza alcuna errata attribuzione tra i due gruppi. Non è stata individuata alcuna differenza significativa tra i parametri ambientali che caratterizzano le stazioni meteorologiche del gruppo italiano e di quello svizzero. L'isolamento geografico sembra essere la principale causa della variazione geografica osservata in queste popolazioni periferiche di faina.

Parole chiave: *Martes foina,* Faina, Variazione morfometrica, Clima, Alpi occidentali.

INTRODUCTION

Craniometrical investigations on stone marten *Martes foina* have been focused on diagnostic characters which allow sex determination (De Marinis et al., 1990; Rossolimo & Pavlinov, 1974;) or separation between this species and pine marten *Martes martes* (Altuna, 1973; Anderson, 1970; Gerasimov, 1985; Steiner &

Steiner, 1986). Few studies has been carried out on the morphological variation of the stone marten referred to local population differences (Anderson, 1970; Delibes & Amores, 1986; De Marinis & Pandolfi, 1991; Reig, 1992; Reig & Ruprecht, 1989).

Variation in body size in mammalian carnivores could be related to life history, geoclimatic features, competition and size of potential prey (Gittleman, 1985). The purposes of this study were: to elucidate pattern of geographic variation of the stone marten skull and, examining the relationship between morphological and environmental variation, to hypothesize the causal factors of morphological variation.

MATERIAL AND METHODS

Cranial morphology of 65 adult males of stone marten from North-Western Italian Alps (Piemonte n=34 and Valle d'Aosta n=11) and Central-Western Swiss Alpine foothills (cantons of Zurich and Bern n=10, and cantons of Valais, Vaud and Geneve n=10), was examined. The four samples were considered as separate groups in all analyses, pooling specimens from geographically contiguous localities.

Sixteen measurements were recorded on each specimen with a digital calliper to the nearest 0.01 mm (Fig. 1). To include the whole data set for multivariate analysis, missing values due to partially broken skulls, were estimated from the existing data for each specimen by stepwise multiple regression (Bekele et al., 1993; Fandos & Reig, 1993). The data matrix was filled up with the estimated values.

Basic statistics and analysis of variance were used to assess inter-group variations in skull morphology. Tukey multiple range test was applied comparing the differences of the means for each pair of local populations.

Principal component analysis (PCA) was applied as an exploratory method to find association patterns among the set of variables used. Three components were extracted from the character correlation matrix. Discriminant function analysis was performed in order to statistically distinguish the different groups. Centroids of groups were tested for equality by one way multivariate analysis of variance, using Wilks' likelihood ratio method. Scores were projected on the first two discriminant axes to assess the morphometric relationship among groups.

Data transformation by log function was used to approximate independence from relative magnitude of original variables (Owen, 1988).

To investigate the relationship between skull morphology and environment, geoclimatic data were used as an indicator of environmental conditions influencing each local population. Seven parameters were chosen to represent potentially selective climatic factors: mean maximum and minimum annual temperature, mean maximum and minimum January temperature, mean maximum and minimum July temperature, mean annual precipitation. Altitude was used to represent geographic factors. Climatic data were obtained from Brockhaus (1983) and were based on 30 years summaries over the period 1931/60. The environmental conditions for the Swiss and Italian samples has been described by data recorded in five Swiss and three Italian weather stations. Differences between the two groups of weather stations were investigated with Mann-Whitney test.

RESULTS

Basics statistics showed that skulls from Swiss Alpine foothills were larger than those from Italian Alps (Tab. 1). The F values were significantly different in 10 out of 16 variables. Length, width as well as height exhibited significant differences among groups. The results of the Tukey test revealed significant differences only when samples from the two countries were compared.

Principal component analysis yielded three factors which explained 66.1 % of the total variance (Tab. 2). Loadings on the first principal component were high in value and positive with similar magnitude, indicating that this component can be interpreted as representing a general size variation of the **skull** (Neff & Marcus, 1980). The first principal component explained 44.5% of the total variance. Different loadings in value and in sign occurred simultaneously in the second and in the third component. This suggested that shape dependent changes were also included in the pattern of variation. The second principal component seemed to describe the variability of the viscero-cranium. Rostrum width, distance between P4 and facial length had the highest correlation with component II. The third principal component is dominated by postorbital width.

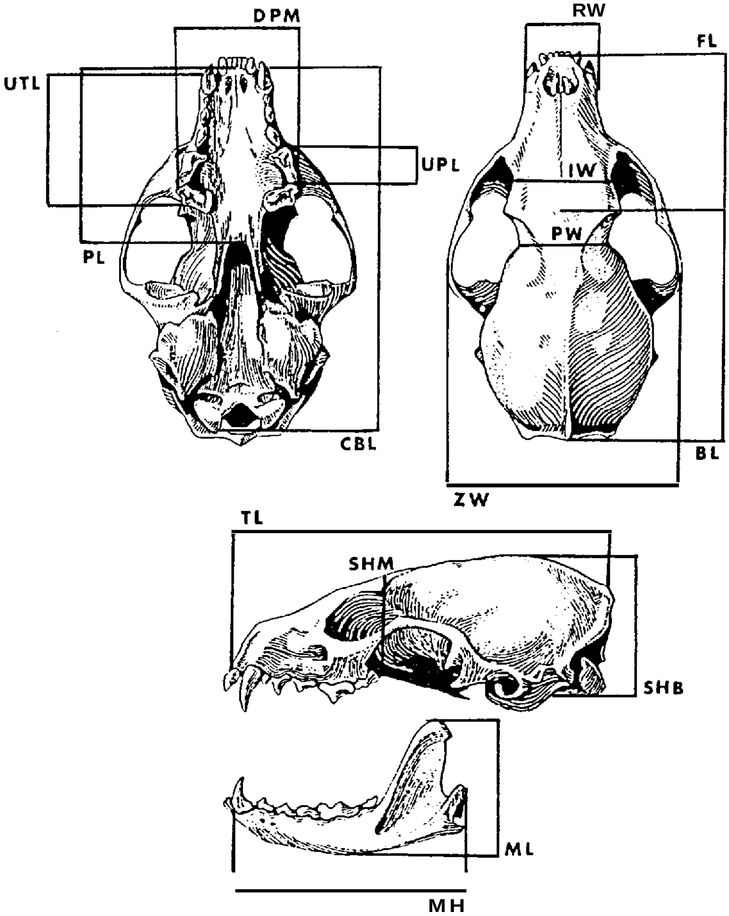

Fig. 1 – Sixteen skull measurements used in this study. CBL condylobasal length; TL total length; FL facial length; BL braincase length; PL palatal length; RW rostrum width; DPM distance between last upper premolars; ZW zygomatic width; IW interorbital width; PW postorbital width; SHM skull height behind M1; SHB skull height between bullae; UTL upper toothrow length; UPL last upper premolar length; ML mandible length; MH mandible heigth.

Tab 1 – Sample statistics of four populations of stone marten from Western Alps. Mean ($\bar{x}$), standard deviation (SD) and F values obtained by one way analysis of variance. ns: not significant. Significance values are as follows: * $P<0.05$; ** $P<0.01$; **** $P<0.0001$. Switz. 1: cantons of Zurich and Bern; Switz. 2: cantons of Valais, Vaud and Geneva; Italy 1: Piemonte; Italy 2: Valle d'Aosta.

VARIABLE	SWITZ. 1 N = 10	SWITZ. 2 N = 10	ITALY 1 N = 34	ITALY 2 N = 11		
	$\bar{x}$ (S.D.)	**$\bar{x}$ (S.D.)**	$\bar{x}$ (S.D.)	$\bar{x}$ (S.D.)	F	P
Condylobasal length	82.26 (1.53)	82.46 (2.21)	81.95 (1.61)	81.79 (1.36)	ns	
Total length	86.70 (1.37)	87.18 (2.23)	85.93 (1.64)	84.91 (1.43)	3.77	*
Braincase length	56.56 (1.18)	56.56 (1.70)	55.23 (1.44)	54.67 (1.61)	4.93	**
Facial length	36.43 (1.16)	36.81 (1.52)	36.65 (1.21)	36.51 (0.72)	**ns**	
Palatal length	39.71 (0.76)	40.63 (1.18)	39.29 (1.14)	39.01 (0.86)	5.15	**
Upper toothrow length	33.73 (0.60)	33.84 (1.01	33.80 (0.74)	33.76 (0.69)	ns	
Mandible length	55.34 (1.16)	55.60 (1.58)	54.89 (1.38)	54.86 (0.74)	ns	
Rostrum width	18.12 (0.68)	17.85 (0.47)	17.08 (0.47)	16.80 (0.57)	16.68	****
Distance betw. P^4	29.66 (1.12)	29.41 (0.80)	28.32 (0.89)	27.98 (0.76)	10.16	****
Interorbital width	23.11 (0.63)	22.57 (0.92)	21.96 (0.83)	21.95 (0.76)	6.10	**
Postorbital width	19.14 (0.55)	19.37 (1.14)	18.20 (0.92)	18.72 (1.50)	4.45	**
Zygomatic width	52.97 (1.28)	52.39 (1.90)	51.69 (1.54)	51.94 (1.91)	ns	
Skull height behind M^1	23.62 (0.52)	23.60 (0.67)	23.23 (0.59)	22.91 (0.72)	3.31	*
Skull height betw. bullae	29.01 (0.70)	29.10 (0.80)	28.36 (0.85)	27.88 (0.61)	5.95	**
Mandible height	25.61 (0.45)	25.93 (1.83)	24.91 (1.48)	25.45 (1.07)	ns	
P^4 length	8.49 (0.21)	8.85 (0.35)	8.94 (0.33)	8.79 (0.21)	6.08	**

Tab. 2 – Loadings of 16 skull characters on the first three principal components (PCI, PCII, PCIII) extracted from correlation matrix for 65 males *M. foina*.

VARIABLE	PCI	PCII	PCIII
Palatal length	0.758	-0.265	0.066
Rostrum width	0.623	0.546	0.009
Zygomatic width	0.500	0.469	0.275
Interorbital width	0.592	0.444	0.179
Postorbital width	0.455	0.241	-0.519
Skull height behind M^1	0.792	0.174	-0.300
Skull height between bullae	0.586	0.418	-0.183
Distance between P^4	0.537	0.501	-0.379
Upper toothrow length	0.712	-0.458	-0.087
P^4 length	0.398	-0.406	-0.323
Mandible length	0.836	-0.325	0.178
Mandible height	0.619	-0.136	0.214
Total length	0.890	-0.138	0.205
Condylobasal length	0.821	-0.401	0.127
Braincase length	0.713	0.325	0.350
Facial length	0.605	-0.551	-0.235
EIGENVALUE	7.12	2.39	1.07
% VARIANCE EXPLAINED	44.50	14.90	6.70

The first two discriminant functions accounted respectively for 75.18% and 18.71% of the variation among samples (Tab. 3). The first function was affected mainly by length measurements (total and condylobasal length). The total length exhibited the highest contribution to the second function followed by facial and braincase length and skull height behind M^1. The plot of the centroids showed a separation in two groups: Swiss and Italian populations (Fig. 2). These two groups revealed differences in size, the former group is the largest one, as indicated by its position in the discriminant space. This analysis showed 90.77 % correct determination without any misclassification between Italian and Swiss groups (Tab. 4).

Using Mann-Whitney test, no significant differences were found between environmental parameters of the selected weather stations for the Swiss and Italian samples.

Tab. 3 – Standardized coefficients of the first two discriminant functions (DFI, DFII) separating geographic samples of *M. foina* males, derived from 16 cranial variables of 4 populations.

VARIABLE	DFI	DFII
Palatal length	-0.62765	-0.64414
Rostrum width	-0.52096	-0.05251
Zygomatic width	0.49170	0.27584
Interorbital width	-0.45653	0.30999
Postorbital width	-0.17647	0.43812
Skull height behind M^1	-0.13440	-1.06086
Skull height between bullae	-0.10992	0.26859
Distance between P^4	-0.61948	0.03607
Upper toothrow length	0.28200	0.63232
P^4 length	0.99940	-0.64162
Mandible length	-0.57367	0.80432
Mandible height	-0.13208	0.62322
Total length	-1.42388	-2.68309
Condylobasal length	1.17684	0.52573
Braincase length	0.79965	1.03679
Facial length	0.59932	1.04431
EIGENVALUE	3.95	0.98
CUMULATIVE %	75.18	93.89
Test of equality of group centroids: F = 3.92, d.f. = 48, P<0.00001		

Tab. 4 – A posteriori classification matrix: number of individuals classified in each group; total number of individuals and the percentage of correct classification. SW 1: cantons of Zurich and Bern; SW 2 cantons of Valais, Vaud and Geneva; IT 1: Piemonte; IT 2: Valle d'Aosta.

	SW 1	SW 2	IT1	IT 2	TOTAL	%
SW 1	9	1	0	0	10	90
SW 2	2	8	0	0	10	80
IT 1	0	0	33	1	34	97
IT 2	0	0	2	9	11	82

DISCUSSION

Univariate analysis of the geographic variation among the four populations of the stone marten indicated that the most significant differences were related to the size of the viscero-cranium (rostrum width and distance between P^4). Association of measurements by principal component analysis showed that general size of the skull and the shape of the viscero-cranium contributed to explain the morphological variability among populations. The Swiss group had larger skulls with shorter and broader viscero-cranium. No significant differences were recorded in the environmental parameters between the Swiss and the Italian samples.

The geographic variation observed in skull morphology seems to be not influenced by the environmental changes. Geographic barriers may determine separation among populations. The geographic isolation of these populations could be considered as a possible causal factor of morphological differentiation.

Variation in cranial size of the stone marten in Europe exhibits an East-West trend of size decrease (Reig, 1992). No significant relationship between size of the skull and any environmental variables was found (Reig, 1992). The multivariate pattern of geographic variation recorded in the Italian peninsula does not confirm this general trend of skull variation (De Marinis & Pandolfi, 1991). A North-South trend of size increase has been observed in the Italian peninsula as well as in the Iberian peninsula (Reig, 1992). According to these results, the existence of some degree of isolation of the Italian populations of stone marten as compared to the Central-European populations studied can be suggested.

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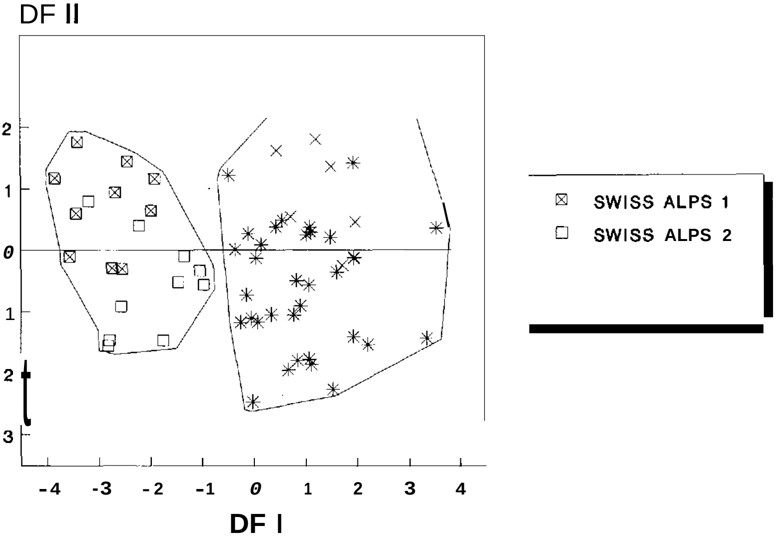

Fig. 2 – Plot of the first two discriminant functions for the 4 populations of *Martes foina* males. Swiss Alps 1: cantons of Zurich and Bern; Swiss Alps: 2 cantons of Valais, Vaud and Geneva; Italy 2: Ital. Alps 1: Piemonte; Ital. Alps 2: Valle d'Aosta.

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