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CRANIOMETRIC VARIABILITY OF POLECAT *MUSTELA PUTORIUS* L. 1758 FROM NORTH-CENTRAL ITALY

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ABSTRACT – Craniometrical investigation was performed on 53 skulls of the polecat *Mustela putorius* from Northern and Central Italy (31 males, 17 females and 5 individuals of unknown sex). Sixteen measurements were taken on each specimen. On average males were 15.2% larger than females. Masticatory apparatus exhibited the most significant sex dimorphism. Skull size (PCI) greatly contributed *to* differentiate sexes explaining 80.46% of the total variance. The results are discussed in relation to the existing theories on sexual dimorphism in mustelids. A discriminant function which used only two skull measurements allowed a 100% of correct sex classification. A comparison among Italian and European populations across the entire Palearctic range of the species, provided an overall view of the pattern of geographic variation.

Key words: *Mustela putorius*, Polecat, Craniometry, Sexual dimorphism, Geographic variation, North-Central Italy.

RIASSUNTO – *Variabilità metrica nel cranio della puzzola* Mustela putorius *L.* 17-58 *nell'Italia centro-settentrionale* – Un indagine sulla variabilità metrica di 16 misure rilevate su crani di puzzola *Mustela putorius*, è stata condotta su campioni provenienti dall'Italia centro-settentrionale. I maschi risultano in media 15,2% più grandi delle femmine. L'apparato masticatorio è la regione del cranio maggiormente dimorfica. Le dimensioni dei cranio (PCI) contribuiscono in maniera notevole a differenziare i due sessi, spiegando l'80,46% della varianza totale. I risultati vengono discussi in relazione alle teorie proposte per spiegare l'esistenza del dimorfismo sessuale nei mustelidi. Una funzione discriminante basata sull'uso di due sole misure del cranio, fornisce una corretta classificazione dei sessi nel 100% dei casi. Un confronto tra popolazione italiana e popolazioni europee, distribuite nell'intera regione Paleartica, consente di analizzare nel suo complesso la variazione geografica delle dimensioni considerate nella puzzola.

Parole chiave: *Mustela putorius*, Puzzola, Cranionietria, Dimorfismo sessuale, Variazione geografica, Italia centro-settentrionale.

INTRODUCTION

Studies on the morphological characteristics of the polecat *Mustela putorius* have been dealing with comparative taxonomic problems (Ashton & Thompson, 1955; Heptner, 1964, Pocock, 1936; Rempe, 1970; Tetley, 1939 and 1945), age variation (Rottcher, 1965; Habermehl & Rottcher, 1967; Stubbe, 1969), sex, population and age differences (Buchalczyk & Ruprecht, 1977). These studies are relative to different European populations of polecats, while no detailed information is available on Italian populations. Cavazza (1912) and Toschi (1965) mainly reported scanty metrical data.

This study describes sexual variation using a multivariate approach in the light of the current theories on sex differences in mustelids, provides a craniometrical sex determination key applicable in morphological, taxonomic, ontogenetic, phylogenetic etc. investigations and outlines the cranial variation of the polecat in the Palearctic range of the species.

MATERIAL AND METHODS

Fifty-three skulls of polecat (31 males, **17** females and 5 individuals of unknown sex) were examined. The specimens were collected in North-Central Italy from 1888 to 1987 in the following regions: Piemonte (8), Liguria (11), Lombardia (2), Trentino Alto-Adige (1), Friuli-Venezia Giulia (2), Emilia-Romagna (3), Toscana (18), Abruzzo (3) and Molise **(3).** Two specimens were collected in Italy but have no locality data.

Only adults were used in the analyses in order to avoid disturbances due to age variation. The adult specimens were classified on the basis of the most common aging criteria used in mustelids (Buchalczyk & Ruprecht, 1977).

Sixteen measurements (10 cranial and 6 dental) were taken on each specimen with **a** digital calliper and recorded to the nearest 0.01 mm (Fig. 1). Missing values due to partially broken skulls, were estimated by stepwise multiple regression from the remaining set of variables available for the specimen examined (Bekele et al., 1993; Fandos & Reig, 1993; Giannico & Nagorsen, 1989; Wiig, 1989). The predicted values filled the gaps occurring in the data matrix. Estimates were separately made for males and females.

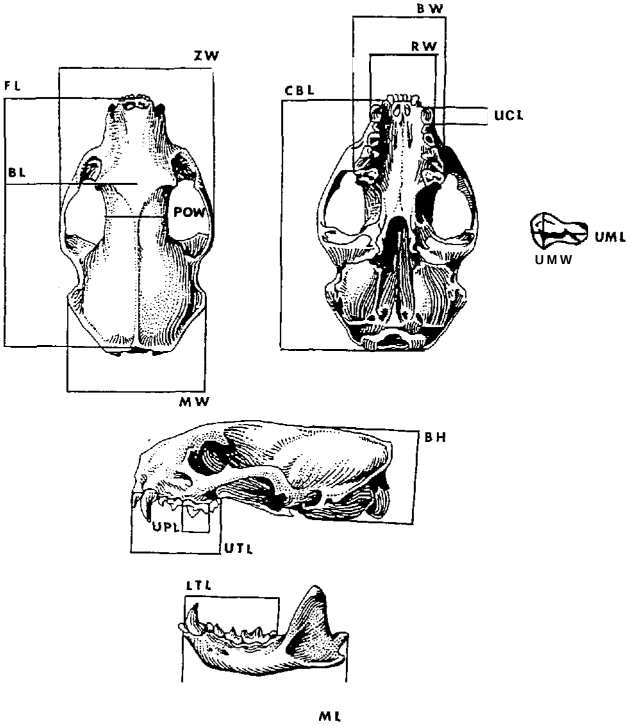

Fig. 1 – Skull measurements used in this study. 10 cranial: RW rostrum width; ZW zygomatic width; POW postorbital width; MW mastoid width; BW bimolar width; BH braincase height; CBL condylobasal length; FL facial length; BL braincase length; ML mandible length. 6 dental: UTL upper toothrow length; LTL lower toothrow length; UCL upper canine length; UPL last upper premolar length; UML upper molar length: UMW upper molar width.

Descriptive statistics (mean = x̄, Standard Deviation = SD, Coefficient of Variation = CV) were computed. Plots were used to compare pattern of variation between sexes. Median-log Levene's test was performed to compare relative variation within sexes (Schultz, 1985). Significance of variation between sexes was assessed by Student's t-test. The average degree of sexual dimorphism was measured as the percentage difference between means: % SD = x̄ males - x̄ females / x̄ females x 100 (Rossolimo & Pavlinov, 1974).

Overall pattern of intersexual variation was examined using principal component analysis (PCA) transforming the original set of variables into a small set which defines independent pattern of variation. PCA was performed on the character correlation matrix of log transformed data to correct for difference in magnitude of character means and variances. Projection of the samples on principal component I and II was used as measure of morphometric variation.

Two group stepwise discriminant analysis was carried out in order to develop discriminant diagnostic key for sex determination. Centroids were tested for equality by one-way multivariate analysis of variance (MANOVA, Wilks' likelihood ratio method). Histograms of the individual scores allowed visual asscssmcnt of the sex of each specimen. The calculations were performed on raw data to make easy practical application.

Italian sample was compared with 19 European samples (De Marinis, 1993) to analyse the morphometric relationships among polecat populations in Europe. The geographic differences were more evident in males, probably as a consequence of a higher number of samples with more individuals throughout the species range. For this reason only data on male samples are shown. The mean value of condylobasal length was chosen to illustrate the general pattern of cranial variation in Europe, because of the data easily available from the literature. Tukey multiple range test was performed as pairwise comparison testing the means differences for each pair of local populations (Sokal & Rohlf, 1981), in order to disclose the general trend of the geographic variation in the skull morphology of polecal.

All analyses were carried out using the following packages: CSS 3B, Statgraphics 5.0.

RESULTS

INTERSEXUAL VARIATION

Descriptive statistics are given in Tab. 1. Median-log Levene's test showed no significant differences in relative variation within sexes except for rostrum (P<0.05) and bimolar width (P<0.01). Results of Student's t-test revealed highly significant differences (P<0.0001) between sexes in all measurements of polecat skull (Tab. 1). The general pattern of variation in sexual dimorphism is shown in Fig. 2. Rostrum width (1) and upper canine length **(8)** were the most dimorphic characters, followed by zygomatic (2), bimolar (6) and mastoid (4) width and mandible length (10). On average, males were 15.2% larger than females. Bivariate plot of rostrum width vs. upper canine length showed no overlapping within the observed range of variation (Fig. 3a). Despite of the marked sexual dimorphism, bivariate plots of some characters revealed overlapping between sexes (Fig. 3b).

Loadings of the 16 variables on the first three principal component accounted for 90.89% of the character variance (Tab. 2). The first principal component (PCI) can be interpreted as "skull size" since all variables are positively correlated with it, although some shape variation is necessarily involved (Gibson et al., 1976). Since PCI explained 80.46% of the total variance in ***M. putorius,*** the differences

Tab. 1 – Descriptive statistics of 16 cranial measurements of male and female of M. *putorius*. Mean (x̄), Standard Deviation (SD), Coefficient of Variation (CV), value from Student's t-test (t), value derived from median-log Levene's test (Fj with 1,46 degrees of freedom. **All** t values are statistically significant (P<0.0001); F values arc no statistically significant unless otherwise stated (* P<0.05; ** P<0.01).

	MALES (n = 31)			FEMALES (n = 17)				
VARIABLE	x̄	SD	CV	x̄	SD	CV	t	F
Rostrum Width	17.22	0.64	3.7	13.78	0.81	5.9	16.18	4.52*
Zygomatic Width	41.08	2.06	5.0	34.80	1.50	4.3	11.05	0.26
Postorbital Width	16.90	0.88	5.2	15.33	0.81	5.3	6.09	0.05
Mastoid Width	36.54	1.85	5.1	31.32	1.25	4.0	10.36	0.22
Braincase Height	24.64	0.99	4.0	22.08	0.74	3.3	9.29	0.51
Bimolar Width	25.75	0.71	2.8	22.09	1.12	5.1	13.86	11.41**
Upper Toothrow Length	24.24	0.62	2.6	21.46	0.70	3.3	14.18	0.39
Upper Canine Length	4.25	0.25	5.9	3.32	0.24	7.2	12.57	0.52
Upper Premolar Length	7.38	0.37	5.0	6.55	0.23	3.5	8.36	1.80
Mandible Length	41.96	1.99	4.7	35.77	1.14	3.2	11.77	1.55
Lower Toothrow Length	24.64	0.90	3.6	21.95	0.74	3.4	120.5	0.13
Condylobasal Length	65.96	2.73	4.1	58.60	1.59	2.7	10.19	1.72
Braincase Length	44.73	2.32	5.2	39.78	1.52	3.8	7.90	1.03
Facial Length	26.80	0.98	3.7	23.70	0.95	4.0	10.59	0.27
Upper Molar Length	6.20	0.25	4.1	5.63	0.24	4.2	7.57	0.01
Upper Molar Width	3.55	0.26	7.4	3.12	0.18	5.7	6.03	0.28

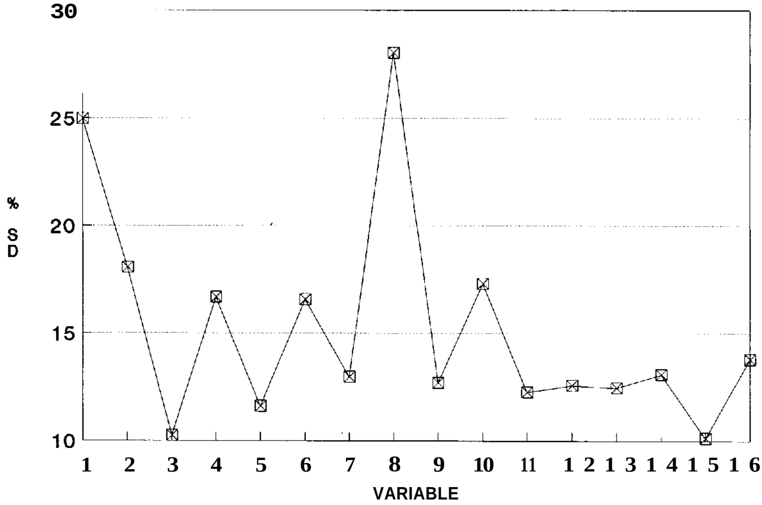

Fig. 2 – Sexual dimorphism in *M. putorius*. % SD = percentage of differences between means of males and females (x̄ male - x̄ female/ x̄ female x 100). 1 rostrum width; 2 zygomatic width; 3 postorbital width; 4 mastoid width; 5 braincase height; 6 bimolar width; 7 upper toothrow length; 8 upper canine length; 9 last upper premolar length; 10 mandible length; 11 lower toothrow length; 12 condylobasal length; 13 braincase length; 14 facial length; 15 upper molar length; 16 upper molar length.

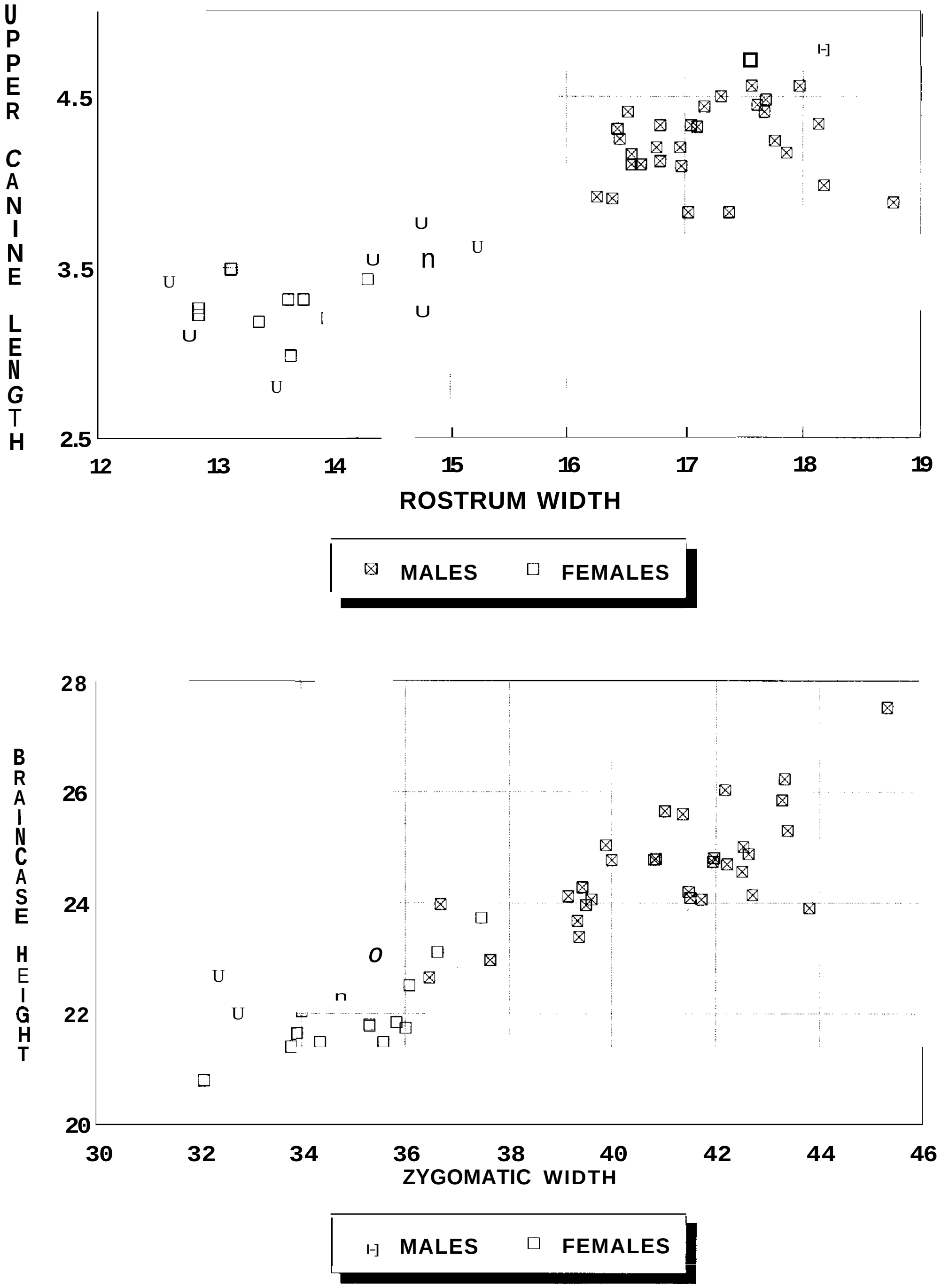

Fig. 3 – Rostrum width vs. upper canine length (a) and zygomatic width vs. braincase height (b) in male and female of *M. putorius*.

between sexes are mainly described by a general size factor. The effectiveness of PCI to separate sexes is evident when plotting PCI vs. PCII (Fig. 4). PCII and PCIII seem to include a shape factor, showing a combination of positive and negative signs. These component summarized only 10.43% of the variation with high loadings of upper molar size and upper premolar length and postorbital width.

Tab. 2 – Loadings of 16 **skull** characters on the First three principal components extracted from a correlation matrix for 31 males and 17 females of *M. putorius*.

VARIABLE	PCI	PCII	PCIII
Upper Toothrow Length	0.972	0.041	0.128
Mandible Length	0.962	0.121	0.106
Zygomatic Width	0.959	0.207	-0.038
Rostrum Width	0.953	0.087	0.064
Mastoid Width	0.944	0.218	-0.022
Condylobasal Length	0.938	0.258	0.058
Bimolar Width	0.936	-0.027	0.040
Upper Canine Length	0.929	-0.192	0.030
Facial Length	0.926	0.159	0.174
Braincase Height	0.913	0.133	-0.093
Braincase Length	0.889	0.339	-0.031
Lower Toothrow Length	0.884	-0.126	0.122
Upper Molar Length	0.796	-0.435	-0.121
Upper Premolar Length	0.786	-0.512	0.128
Postorbital Width	0.760	0.035	-0.624
Upper Molar Width	0.758	-0.554	-0.047
Eigenvalue	12.87	1.15	0.51
% Variance explained	80.46	7.20	3.23

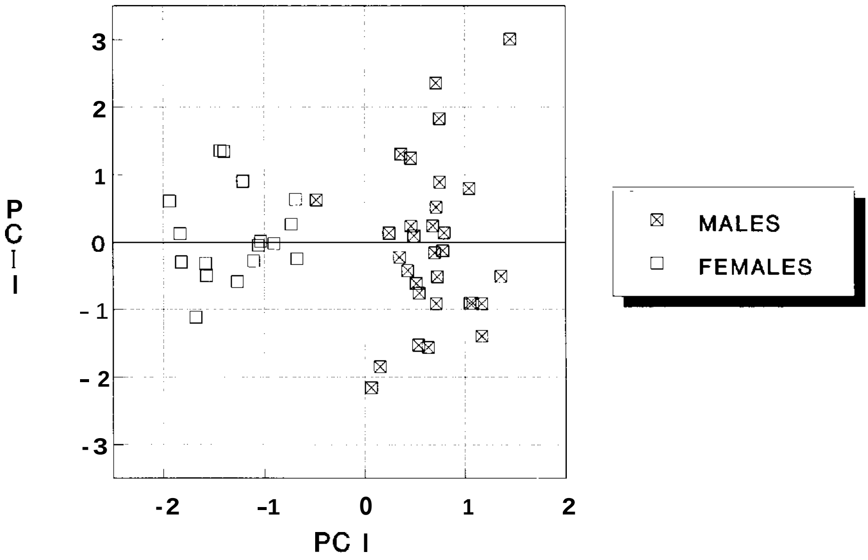

Fig. 4 – Plot of PCII vs. PCI showing the separation of sexes in *M. putorius*.

Two group stepwise discriminant analysis resulted in only a set of 2 variables out of 16 being required to separate males and females of *M. putorius*: rostrum width (RW) and upper toothrow length (UTL). The sex determination key is as follows:

$$x = -32.58 + 1.17\ (RB) + 0.58\ (UTL)$$

The key provided 100 % correct classification. The statistical evaluation of the determination by the key was F = 168.93, with 2,45 degrees of freedom, $P<0.0001$. Five specimens of unknown sex were classified as 4 males and one female using this sex determination key (Fig. 5).

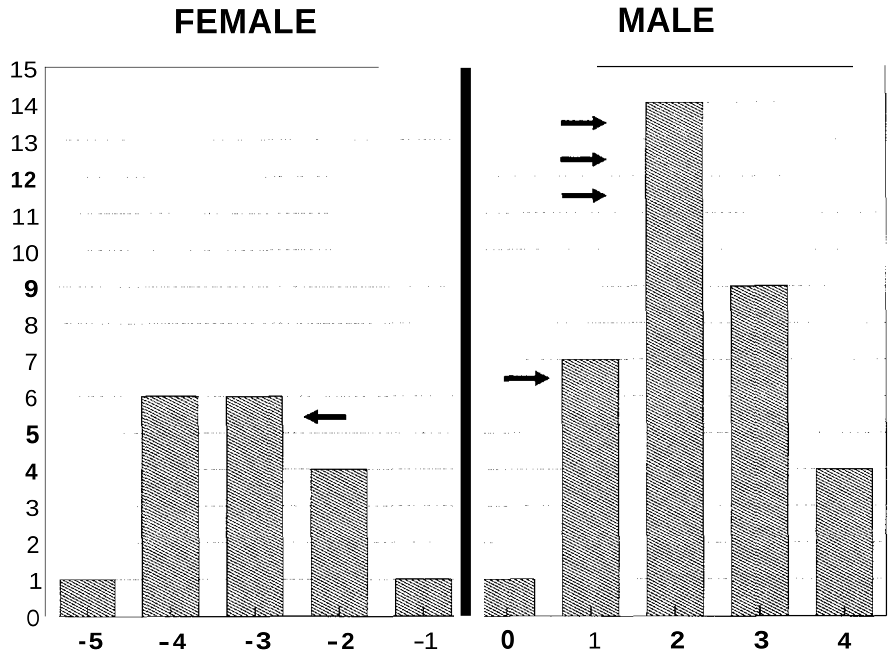

Fig. 5 – Histogram of discriminant scores of males and females of *M. putorius*. Groups centroids: 1.YY (males), -3.62 (females).

INTERPOPULATION VARIATION

The geographic variation in condylobasal length of polecat skull is presented in Fig. 6. Population means of *M. putorius* showed **a** general trend of increasing size from East to West throughout Europe. Populations from Central Europe did not fully conformed to this trend; they had the largest means, for example 70.99 mm for the Northern Germany sample.

The results of Tukey multiple range test confirmed the generally eastwestward gradual size variation in geographic samples. In Tab. 3 the results related to bimolar width are presented. There is a clear distinction between Eastern populations of *M. putorius* from one side, and Central and Western populations from the other. Among the Eastern populations there were polecats collected in Southern Finland, North-Western Russia, North-Eastern Poland, Southern Poland and Bulgaria. The Swedish group resulted more similar to the Western and Central samples.

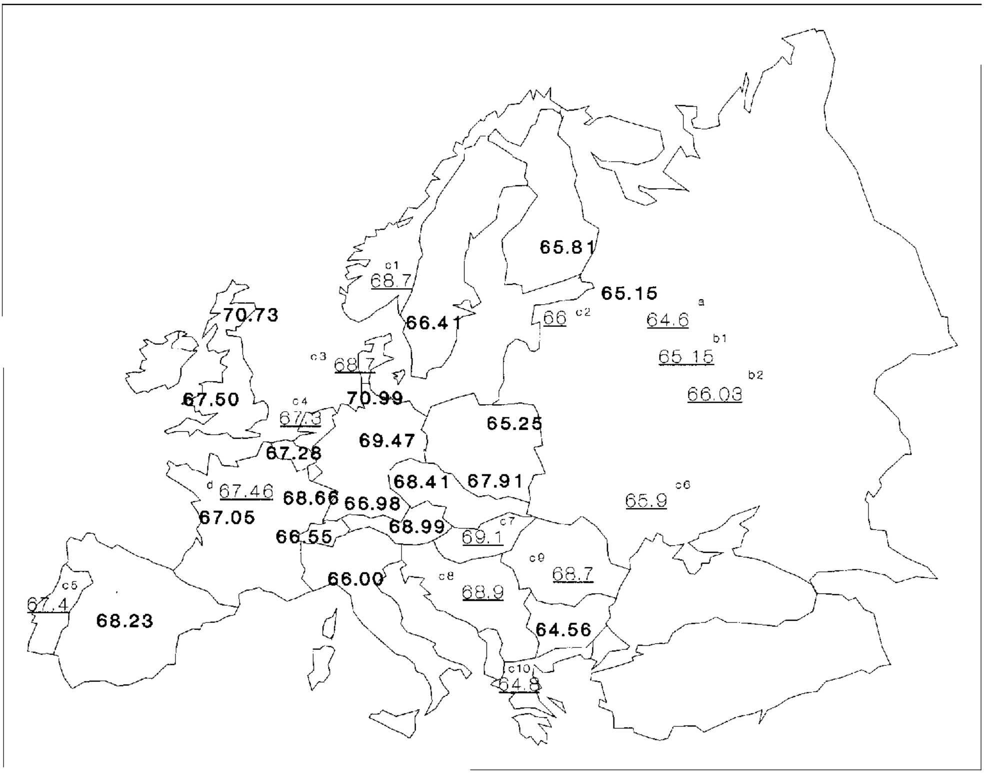

Fig. 6 – Population means of condylobasal length of *M. putorius* males. Figures in boldface from De Marinis, 1993. a = Blandford, 1987 n=33; b1= Ognev, 1962 n=2; b2= Ognev, 1962 n=14; c1 n=9; c2 n=18; c4 n=69; c5 n=4; c6 n=15; c7 n=46; c8 n=13; c9 n=36; c10 n=2; Wolsan, 1993; c3= Degerbol, 1933 n=15; d = Saint Girons, 1973 n= 21.

Tab. *3* – Results of Tukey test on bimolar width (BW) of 19 populations of polecat males.

GROUP	N	BWA AVERAGE	HOMOGENEOUS GROPUP
Bulgaria	51	23.74	*
North-Eastern Poland	31	23.95	** ***
North-Western Russia	16	24.23	***
Southern Poland	18	24.30	
Southern Finland	29	24.55	**
Southern Sweden	*55*	24.88	** ***
Wales	45	24.91	
Southern Germany	24	24.94	****
Belgium	40	25.37	****
Western Switzerland	30	25.40	****
Western France	19	25.58	**** ***
NORTH-CENTRAL ITALY	35	25.64	
Western Czechoslovakia	28	25.68	****
North-Eastern France	***26***	25.74	***
Eastern Austria	20	25.89	**** ***
Iberian peninsula	20	25.96	***
Eastern Germany	25	26.13	*
Northern Germany	21	26.80	**
Scotland	2	28.04	

DISCUSSION

The polecat shows a strong skull dimorphism. The differences between sexes are mainly described by a general size factor, as occurs in most carnivores (Ewer, 1973). Masticatory apparatus exhibits the most significant sexual dimorphism.

Data on polecat skull from Poland show a higher degree of sexual dimorphism: on average males are 20.36% larger than females (Buchalczyk & Ruprecht, 1977). More than one third of the Polish sample is composed by specimens collected in the Rzeszòw region where giants forms were often encountered, particularly among males. Data on sexual dimorphism may thus reflect this sampling bias.

The "resource partitioning model" holds that sexual dimorphism occurs to reduce intersexual food competition in Mustelidae (Brown & Lasiewski, 1972). The sexes achieved optimum but different body size correlated with ihe size of the food ingested. In polecat males a larger mastoid width together with a larger zygomatic breath, could correspond to a larger size of Jaw musculature and a more powerful neck inuscles (Randinski, I981). Furthermore the males have smaller postorbital width in relation to the size of the rest of the skull. The main part of the masticatory activity is performed by the temporalis muscle which mostly originates from the braincase-roof (Ewer, 1973). A narrower postorbital width in relation to the general size of the skull, will correspond to a large anterior part of the temporalis muscle and thus increase ihe biting force. These characters would allow the male to handle relatively larger preys. Canine size, the most dimorphic character, might reflect the typical size of the prey. Therefore the sexual dimorphism would permit a certain degree of dietary separation between sexes. According to Brugge (1977) males and females of *M. putorius* exploit different food items. Birds, rats and moles make up the bulk of the male diet while small rodents, lagomorphs and amphibians represent the most common prey in the female diet. The data do not confirm the Brown and Lasiewski theory (1972) as the smaller females do not prey on smaller animals than males. However these results are based on a reduced set of scat sample, only 15 scats for males and 26 for females. Blandford (1987) and Weber (1989) observed no dietary partitioning between sexes in polecat. At present there is no dietary evidence to suggest that sexual dimorphism in *M. putorius* is related to competition between sexes for limited food resources.

A more recent theory explains sexual dimorphism by different sex-specific pressures, taking into account the polygynous breeding system of mustelids and the lack of male parental care. Male and female size could be influenced by the differences in the reproductive roles and the seasonal energy requirements of each sex (Erlinge, 1979; Moors, 1980). Small females are favoured because they need less energy for daily maintenance and are probably more efficient in hunting small prey; so they can channel more energy into reproduction. The optimum body size of females is supposed to fall within a narrower range than that of male. This hypothesis was tested using the skull size as an indicator of body size, because of the high correlation existing between these two variables (Kalls & Harvey, 1985). According to the results of the median-log Levene's test there is no significant difference in polecat between sexes in the variability of cranial measurements.

These results seem not to confirm this supposition. Larger males are favoured by sexual selection that takes place as competition to achieve the highest reproductive success, mating with the highest number of breeding females. The relatively wider rostrum of males providing a support for the larger canine roots and the relatively wider zygomatic arches and mastoid breadth may serve a function related to intrasexual display or fighting. Observations of fighting during breeding season joined with a remarkable fat loss in polecat male show that only larger males can successfully mate (Poole, 1970; Weber, 1987).

It is important to stress that without further behavioural and ecological studies, the adaptive significance of these sexual differences cannot be fully clarified.

The pattern of size variation in ***M. putorius*** seems to follow a trend of size increase along a E-W axis. The species do not follow Bergmann's rule of increasing body size with latitude as other mustelids *M. nivalis* (Zyll de Jong, 1992), *M. erminea* (Erlinge, 1987), *Martes martes* and *M. foina* (Reig, 1992). The morphological variation is not merely associated with latitudinal changes but it is turning out to be a rather complex phenomenon, that may be controlled by different factors as life history of the species, prey size, prey diversity and the presence of sympatric species competing for similar food resources (Gittleman, 1985).

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