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Craniometrical characteristics of *Neomys fodiens* (Pennant, 1771) (*Mammalia, Insectivora*) from the northeastern Iberian Peninsula

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The aim of this paper was to establish the craniometrical features of *Neomys fodiens* (Pennant, 1771) from the northeastern Iberian Peninsula (Catalonia). The variability in 22 skull and mandible measurements in a series of forty eight specimens was studied. Fifty seven specimens from Navarre were used for comparison. The specimens from Catalonia display smaller skull sizes than those from Navarre (*N. f. niethammeri*) and should be assigned to the nominal subspecies, *N. f. fodiens*. The greatest differences between both samples are observed in dental measurements and for the rostral region. A discriminant function was established. The variables selected according to their discriminant power were HC and PGW. This function enables us to obtain a 94.4% correct discrimination between both samples. The differentiation in *N. fodiens* in the Iberian Peninsula is discussed and attributed to historical and ecological factors.

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Introduction

Despite Miller's mention (1912) of the possible presence of *Neomys fodiens* in the Iberian Peninsula, the first precise reference to the species belongs to Cabrera (1914), who mentions it in the Pyrenees of Huesca. According to Ellerman and Morrison-Scott (1951), the Iberian individuals correspond to the nominal subspecies, *N. f. fodiens* (Pennant, 1771).

Later on, Bühler (1963) describes a new subspecies, *N. f. niethammeri*, (Terra Typica: Ramales de la Victoria, Santander), characterised by its larger skull size towards *N. f. fodiens*. Heim de Balsac and de Beaufort (1969), Vericad (1970) and Pemán (1983) refer the individuals from the Picos de Europa, Navarre and the Basque Country, respectively, to this subspecies. However, Nores *et al.* (1982) argued about the subspecific validity of *N. f. niethammeri*.

Other studies have reported certain features about the distribution and morphology of *N. fodiens* in the Iberian Peninsula (Sánchez-Canals 1977, Nores 1979). Data

on the populations from the northeast of this area are limited to those provided by Sans-Coma and Margalef (1981), based on two specimens.

In this paper the craniometrical characteristics of *N. fodiens* from Catalonia are given, to determine its taxonomical status and provide more in-depth knowledge of this species in Spain.

Material and methods

Forty eight individuals (23 males, 22 females, 3?) from the northeastern Iberian Peninsula (Catalonia) were analysed. They were captured in the following locations (U.T.M. 10×10 km): Lérida: Bausén (31TCH14), Bossost (31TCH13), Les Bordes (31TCH13), Aubert (31TCH13), Viella (31TCH13), Salardú (31TCH23); Girona: Espinavell (31TDG59), Setcases (31TDG49). Fifty seven individuals (28 males, 29 females) from Quinto Real (30TXN26), Navarre, were used for comparison.

The following 22 measurements were taken (Fig. 1): CIL: condyle-incisor length; CBL: condyle-basal length; RL: rostral length; SCL: skull case length; SBL: staphylion-basion length; USDi: length of the upper dental series; USD: length of the upper dental series without incisor; P^4M^3 : P^4M^3 length; OW: infraorbital width; IOW: interorbital width; ZW: zygomatic width; PGW: postglenoid width; SCW: skull case width; SCH: skull case height; IAL: incisor-angle length; ANL: angular length; ARL: articular length; CL: coronoid length; CH: coronoid height; LDSi: length of the lower dental series; CM_3 : CM_3 length; M_1M_3 : M_1M_3 length.

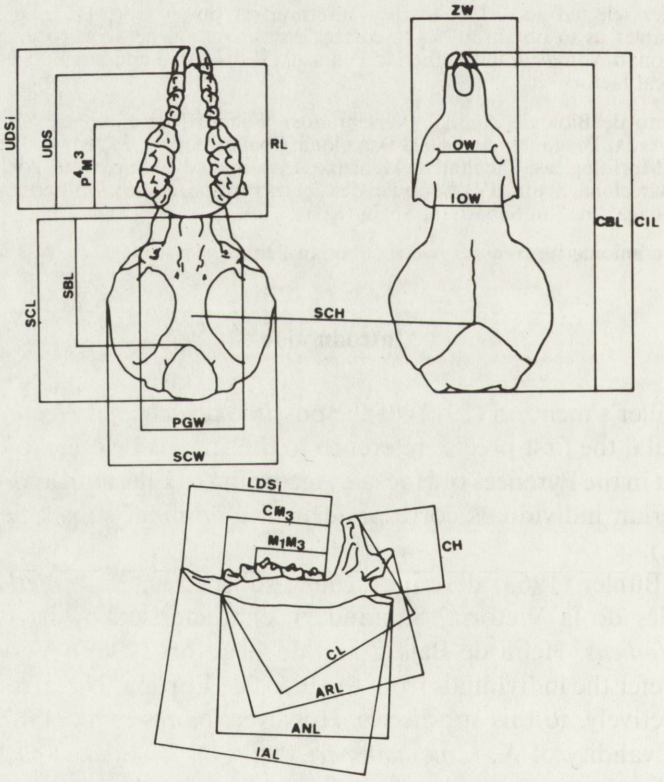

Fig. 1. Cranial and mandibular parameters measured in *Neomys fodiens*.

The specific identification of the individuals was carried out from the morphological characteristics of the mandible and the discriminant formula established by Bühler (1964).

For the statistical analysis, the normality of variables and homogeneity of variances was presumed. The differences between sample mean values were evaluated using d and t Student statistics (Parker 1976, Sokal and Rohlf 1979). Discriminant-function analysis was used to define similarities or dissimilarities between samples (Jennrich and Sampson, 1983). The data were processed on an IBM 3083/XE01 computer in the University of Barcelona Computer Centre.

Results

The specimens from Catalonia display smaller skull and mandible sizes than those from Navarre (Table 1). Statistical comparison of the sample means points to significant differences in all the parameters analysed, except for SCL, SBL and SCW. The significance level for all variables was $p<0.001$, except for SCH ($p<0.02$). The differences in total skull length are mainly due to the elongation of the rostral region in the individuals from Navarre.

To complete these observations, a discriminant function was established sequentially (Jennrich and Sampson 1983), using all the parameters analysed. The variables selected according to their discriminant power were CH and PGW. Subsequently, the individuals were classified for each population group (Catalonia, Navarre) according to the canonical coefficient of each variable. The results obtained are as follows:

Group	Correct percentage	Catalonia group	Navarre group
Catalonia	91.7	33	3
Navarre	96.2	2	51
Total	94.4	35	54

As can be seen, the total percentage of discrimination is 94.4%. The distribution of individuals from each group on the canonical axis is represented in Fig. 2, using only those specimens with complete skull and mandible measurements. The discriminant function is: $d=-2.71951$ PGW -4.33769 CH $+40.20525$.

The discrimination criterion is geometrical: the canonical coordinates have been taken from individual averages for each group (Navarre: $k_1=-0.94747$; Catalonia:

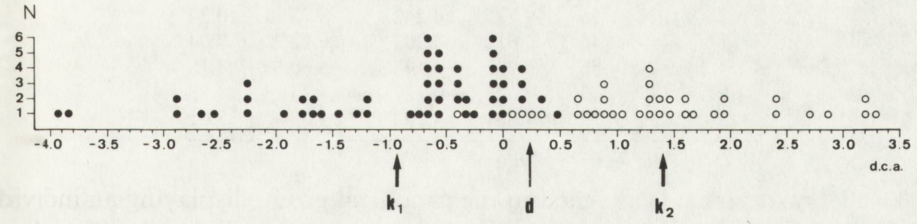

Fig. 2. Distribution of the specimens of *Neomys fodiens* from Navarre (●) and Catalonia (○) in the discriminant canonical axis (d. c. a.). The discriminant function is: $d=-2.71951$ PGW $-$ 4.33769 CH + 40.20525. k_1, k_2: canonical variables evaluated over the averages of each group; $d=k_1+k_2/2$.

Table 1. Measurements (in mm) of *Neomys fodiens* from Catalonia (C) and Navarre (N).

Variable		n	$\bar{x}$	SD	min	max
CIL	C	22	21.850	0.645	20.00	22.84
	N	55	22.525	0.411	21.67	23.32
CBL	C	22	21.007	0.554	19.61	22.03
	N	55	21.505	0.475	20.47	22.51
RL	C	39	10.225	0.422	9.24	10.91
	N	55	10.643	0.278	9.65	11.37
SCL	C	23	10.907	0.458	9.82	11.82
	N	56	11.092	0.227	10.54	11.54
SBL	C	19	8.661	0.267	8.16	9.05
	N	56	8.691	0.221	8.06	9.09
USDi	C	38	10.234	0.337	9.46	10.94
	N	54	10.709	0.200	10.26	11.19
USD	C	38	8.647	0.272	8.15	9.28
	N	55	9.033	0.192	8.40	9.41
P^4M^3	C	38	5.608	0.119	5.26	5.94
	N	57	5.916	0.122	5.64	6.19
OW	C	39	3.342	0.109	3.10	3.59
	N	55	3.483	0.133	3.13	3.86
IOW	C	37	4.540	0.097	4.30	4.73
	N	55	4.674	0.163	4.34	5.11
ZW	C	38	6.757	0.246	6.30	7.34
	N	56	7.003	0.237	6.42	7.50
PGW	C	37	6.246	0.171	5.78	6.57
	N	55	6.553	0.163	6.16	7.03
SCW	C	22	10.820	0.194	10.52	11.13
	N	56	10.863	0.247	10.21	11.30
SCH	C	29	5.675	0.207	5.23	6.17
	N	56	5.772	0.161	5.41	6.19
IAL	C	39	14.045	0.452	13.07	14.98
	N	55	14.514	0.319	13.58	15.13
ANL	C	39	11.232	0.342	10.63	11.84
	N	56	11.555	0.300	10.61	12.18
ARL	C	40	11.432	0.319	10.85	11.96
	N	55	11.869	0.284	11.11	12.49
CL	C	40	9.910	0.342	9.19	10.59
	N	56	10.457	0.332	9.76	11.22
CH	C	40	5.056	0.163	4.73	5.48
	N	56	5.388	0.172	5.10	5.89
LDSi	C	40	9.396	0.323	8.74	10.02
	N	55	9.775	0.242	8.73	10.24
CM_3	C	40	6.617	0.202	6.22	7.04
	N	56	6.902	0.142	6.60	7.18
M_1M_3	C	40	4.623	0.137	4.34	4.93
	N	56	4.831	0.102	4.60	5.01

$k_2 = 1.39488$). A specimen is assigned to the canonical group displaying an individual value closer to the mean value for the group. Because the canonical variable is adjusted so that variances among the groups are equal, when the function is evaluated for the inclusion of a new individual, if $d > 0.223\ [(k_1 + k_2)/2]$ it will be considered to belong to

the group from Catalonia and if $d<0.223$, then it will be assigned to the group from Navarre.

The function obtained was applied to the individual measurements of the specimens from the Basque Country studied by Pemán (1983) (n = 57). Except for two cases, these individuals display values of d included in the group from Navarre (n = 55, 96.49%), showing a mean value (k) of -1.18824.

Discussion

The results obtained agree with the morphometrical variation observed in *N. fodiens* in the Iberian Peninsula (Sánchez-Canals 1977, Nores 1979, Nores *et al.* 1982, Pemán 1983).

According to bibliographical data (Miller 1912, Cabrera 1914, Buchalczyk and Raczyński 1961, Bühler 1963, Pieper 1966, Rempe and Bühler 1966, Saint-Girons, 1973), the individuals from Catalonia should be assigned to the nominal subspecies, *N. f. fodiens*, whereas the specimens from Navarre fit the range values for *N. f. niethammeri*. These results corroborate the existence of at least two morphotypes of *N. fodiens* in the Iberian Peninsula. One morphotype is distributed in Navarre, the Basque Country and Eastern Asturias and has been considered *N. f. niethammeri*. The other morphotype, with smaller skull sizes, offers a scattered distribution, occupying the northern extremes of the Peninsula (Galicia-Western Asturias and Eastern Pyrenees) (Fig. 3). According to data in the literature, these latter individuals should be assigned to the nominal subspecies, *N.f.fodiens*. Nevertheless, this subspecific differentiation could be questioned.

If the craniometrical and morphological characteristics are considered, the

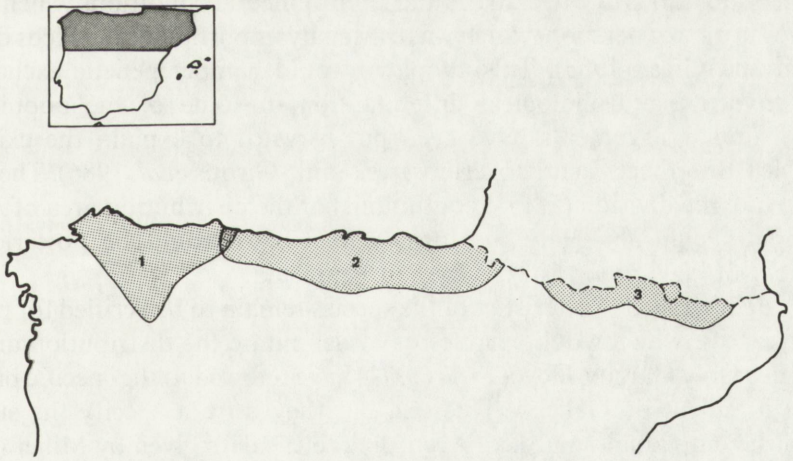

Fig. 3. Geographical distribution of *Neomys fodiens* in the Iberian Peninsula. 1, 3: *N. f. fodiens*; 2: *N. f. niethammeri*. Data from Vericad (1970), Sans-Coma and Margalef (1981), Nores *et al.* (1982), Pemán (1983), Gosálbez *et al.* (1985), González and Román (1988) and own data.

separation of these forms into two subspecific categories seems to be correct. The existence of a cline, as Nores *et al.* (1982) point out, does not seem clear. The results obtained, together with the bibliographical data, show that the size differences in the species do not fit a geoclinal variation. In general, a gradual size variation is not observed from one end of the Iberian distribution area of the species to the other. The individuals of *N. f. niethammeri*, which are larger, occupy an intermediate geographical position between the occidental (Galicia-Western Asturias) and the oriental (Catalonia) populations, both attributed to *N. f. fodiens* (Fig. 3). Nevertheless, according to Nores *et al.* (1982), the areas of *niethammeri* and *fodiens* overlap in Asturias (Fig.3), although these authors do not describe the intergrade zone. This overlap is not in agreement with the definition for subspecies given by Mayr (1969) and therefore the taxonomical status of the species in this area remains to be solved.

The larger skull sizes of *niethammmeri* could be a result of a subspeciation process. As Thorpe (1987) points out this process can be motivated, in general, by ecological and historical factors. As regards the former, Nores *et al.* (1982) mention that the area occupied by *N. f. niethammeri* has a calcareous substrate. Therefore, because rivers with these characteristics are richer in nutrients, individuals with a more developed masticator apparatus could have been selected, as they would be in a better position to capture larger prey. In this sense, the greatest differences (larger *d* or *t* statistical values) between *N. f. fodiens* and *N. f. niethammeri* correspond to parameters connected with mastication (UDSi, UDS, P^4M^3, ARL, LDSi, M_1M_3).

Because *N. fodiens* is a species which is strictly linked with aquatic environments, the genetic flux between populations may be reduced, thus providing an opportunity for genetic drift and natural selection.

From a historical point of view, allopatry may have appeared among the Cantabrian populations due to climatic and environmental conditions which appeared during the Wurmian glaciation, which was especially important in the Picos de Europa (Nussbaum and Gigax 1953). This allopatry would hamper genetic exchange, and therefore, favour a morphological differentation in some of the populations of *N. fodiens*. Similar arguments have been put forward to explain the existence of morphological differences in other vertebrates (Saint-Girons *et al.* 1986). These factors would motivate the division (at first continuous) of the distribution area of *N. fodiens* in the Iberian Peninsula. Here the form *niethammeri* would be posterior to the establishment of *N. f. fodiens* in the Iberian Peninsula.

The existence and characteristics of the species remain to be verified for part of the Western Pyrenees, which would enables us to delimitate the distribution area of the Iberian forms. Only Garzón-Heydt *et al.* (1971) have referred to the specific presence of *N. fodiens* in Sallent de Gállego (Huesca), but they do not specify the subspecific category of the individuals analysed. According to the data given by Miller (1912) for the French Pyrenees, they may belong to the subspecies *N. f. fodiens*.

The possibility that the populations of *niethammeri* may represent a different species could be raised. From a biometrical and morphological point of view,

differences between *niethammeri* and *fodiens* are more conspicuous than those between *N. fodiens fodiens* and *N. anomalus* (M. J. Lopez-Fuster, unpub.) Genetic, biochemical and ecological studies could establish the exact taxonomical status of *N. fodiens* populations in the Iberian Peninsula.

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