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# Distribution patterns of the small mammals (Insectivora and Rodentia) in a transitional zone between the Eurosiberian and the Mediterranean regions

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## Abstract

**Aim** To determine, by means of quantitative analyses, the distribution patterns of the insectivores and rodents in Catalonia using physiographical regions as Operative Geographical Units (OGUs).

**Location** Catalonia (north-eastern Iberian Peninsula).

**Methods** Based on the presence/absence of twenty-five small mammals in thirteen physiographical regions, which were used as OGUs, the following aspects were studied: (a) identification of biotic boundaries; (b) determination of chorological association of species; (c) climatic characterization of the biotic regions and the chorotypes. Groups of biotic regions and species were established, and their statistical significance was tested. The possible effect of several climatic factors on these groupings was studied using discriminant analyses.

**Results** A significant biotic boundary was found to separate the central and eastern Pyrenees from the remaining physiographical regions. The climatic variables that defined this boundary were related to the severity and the availability of environmental energy. Four chorotypes were identified. One chorotype was constituted by Pyrenean or Pre-Pyrenean species, an association determined by their mid-European requirements; another chorotype was formed by Eurosiberian species, but showed a variable degree of tolerance to Mediterranean conditions; a third chorotype included species with a wide distribution that are Mediterranean, anthropic, generalist or have very specific habitats; and finally the fourth chorotype was constituted by a strictly Mediterranean species. The climatic factors that accounted for the distribution of these chorotypes were the mean July temperature and the mean annual precipitation.

**Main conclusions** We conclude that the axial zone of the Pyrenees, except the coastal portion, determines two biotic regions in Catalonia. As for the classification of species, using quantitative techniques for the first time, we offer a new biogeographicalal configuration for the small mammals in this temperate-Mediterranean transition.

**Keywords**
Insectivora, Rodentia, biotic regions, chorotypes, Catalonia, Iberian Peninsula.

## Resumen

**Objetivo** Determinar mediante análisis cuantitativos los patrones de distribución de los insectívoros y roedores en Cataluña usando regiones fisiográficas como Unidades Geográficas Operativas (OGUs).

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**Localización** Cataluña (noreste de la península Ibérica).

**Métodos** A partir de la presencia/ausencia de 25 especies en 13 regiones fisiográficas, usadas como OGUs, se estudiaron los siguientes aspectos: (a) identificación de las fronteras bióticas; (b) determinación de las asociaciones corológicas de especies; (c) caracterización climática de las regiones bióticas y de los corotipos. Se establecieron grupos de regiones bióticas y de especies, evaluándose su significación estadística. El posible efecto de diversos factores climáticos en estas agrupaciones se estudió mediante análisis discriminantes.

**Resultados** Se detectó una frontera biótica significativa que separa los Pirineos Centrales y Orientales del resto de regiones fisiográficas. Las variables climáticas que definen esta frontera estuvieron relacionadas con la severidad y disponibilidad de energía ambiental. Se detectaron cuatro corotipos. Uno estuvo constituido por especies pirenaicas o prepirenaicas, asociación que vino determinada por sus requerimientos medioeuropeos; otro corotipo estuvo integrado también por especies eurosiberianas pero que muestran un grado variable de tolerancia a las condiciones mediterráneas; un tercer corotipo incluyó especies de distribución amplia que son mediterráneas, antrópicas, generalistas o bien que requieren hábitats muy específicos; y finalmente un cuarto corotipo estuvo constituido por una especie de requerimientos mediterráneos estrictos. Los factores climáticos que determinaron la distribución de estos corotipos fueron: la temperatura media en julio y la precipitación anual media.

**Conclusiones principales** Concluimos que la zona axial de los Pirineos, exceptuando la porción costera, determina la existencia de dos regiones bióticas en Cataluña. Respecto a la clasificación de las especies, mediante el uso por primera vez de técnicas cuantitativas ofrecemos una nueva configuración biogeográfica para los micromamíferos en esta transición climática templado-mediterránea.

**Palabras clave**
Insectívoros, roedores, regiones bióticas, corotipos, Cataluña, península Ibérica.

## INTRODUCTION

The Iberian Peninsula is a microcontinent where both Mediterranean and Eurosiberian floristic and vegetation regions occur (Rivas-Martínez, 1987). These two dominant elements are in part determined by the Iberian climate, which ranges from the wetter and temperate conditions of the Eurosiberian region in the North to the xeric and warmer conditions in the southernmost areas of the Mediterranean region. Catalonia is located in north-eastern Iberia and widely reflects the noticeable bioclimatic, physiographical and phytogeographical diversity of this Peninsula. In physiographical terms Catalonia shows wide variations, ranging from the Alpine belt of the Pyrenees and the humid Atlantic zone of the Aran Valley (north-western Catalonia) to the coastal regions with humid or maritime Mediterranean climates, and the eastern end of the great plain of the Ebro river with a subarid continental Mediterranean climate (for details see Bolòs, 1985). From a phytogeographical viewpoint, Bolòs (1985) and Nuet *et al.* (1991) indicate three main regions in Catalonia: the Mediterranean region, which is characteristic of the lowlands and occurs over large areas of the territory, the Eurosiberian region, which extends over most of the Pyrenees, Pre-Pyrenees and the coastal range of mountains, and the Boreoalpine region, which only occurs in the highest altitudes of the Pyrenees and the Montseny mountains. It is these characteristics that make Catalonia an interesting territory in which to identify biogeographical patterns in animal taxa with a wide distribution throughout the Palaearctic region (see e.g. Llorente *et al.*, 1995). In this way, small mammal species (Insectivora and Rodentia) of Catalonia have been grouped in several studies (Sans-Coma, 1974; Claramunt *et al.*, 1975; Gosálbez, 1976, 1987; Gosálbez *et al.*, 1985), though always on the basis of visual analysis of the geographical distributions. Nevertheless, as reported by several authors, such as Jardine (1972), Birks (1987), Real *et al.* (1992), Vargas (1993), and Márquez *et al.* (1997), the best method for establishing groups of species is based on quantitative analyses in order to avoid basic subjective errors and to produce consistent results. Specifically, the main aim of the quantitative analysis of the presence/absence of several taxa in a number of areas (Birks, 1987) is to detect repeatable biogeographical patterns within the data in the form of biotic elements (groups of taxa with similar distributions) and biotic regions (groups of areas with similar biotas). Several quantitative methods of classification used in defining boundaries between ordered locations can be found in the literature (see McCoy *et al.*, 1986; references therein). The method outlined by McCoy *et al.* (1986) is an extension of the probabilistic similarity techniques (Crick, 1980) used to develop a matrix-analysis method of placing boundaries between the biotas of ordered locations. This technique, complemented by a significant test of the resulting groups according to the approach of Real *et al.* (1992), constitutes an objective method for measuring the statistical significance of groups obtained from a numerical classification (see Márquez *et al.*, 1997). As for insectivores and rodents, it has been applied to determine certain aspects of their distribution in the Iberian Peninsula (Palomo *et al.*, 1994; Real *et al.*, 1996).

The main aim of this paper is to determine by means of quantitative analyses the distribution patterns of the insectivores and rodents in Catalonia, using physiographical regions as Operative Geographical Unities (OGUs; Crovello, 1981). Specifically, the goals of the study are: (a) to identify significant biotic regions; (b) to determine possible groupings of species with similar distribution patterns (chorotypes); (c) to characterize climatically the biotic regions and the chorotypes. In order to reach points a and b, the method of McCoy *et al.* (1986), complemented with the modifications of Real *et al.* (1992), was used; discriminant analyses were undertaken to reach goal c.

## MATERIALS AND METHODS

### Study area

The study area corresponds to Catalonia (Spain), which is located in the north-east of the Iberian Peninsula, between 0°10′ E (Tossal del Rei) and 3°19′ E (Cap de Creus), and between 42°51′ N (Mont Ombrè) and 40°31′ N (els Campets). It covers an area of 31,930 km$^2$, which is limited by the Pyrenees in the North, and the Mediterranean sea in the East; its western border does not correspond to any natural unit. For analytical purposes, Catalonia was divided into thirteen physiographical regions (adapted from Bolòs, 1985), which are defined by geological, climatic, and vegetational characteristics, and used as OGUs (Fig. 1).

### Classification of physiographical regions and species

Information on the distribution of twenty-five small mammal species in Catalonia (nine insectivores and sixteen rodents; see Appendix I) was obtained from Gosálbez *et al.* (1985) complemented with further records, published between 1986 and 1996 (Arrizabalaga *et al.*, 1986; Gil *et al.*, 1986; Real & Bros, 1987; Ventura, 1988; Ventura & Gosálbez, 1988; Boada, 1990; Aguilar *et al.*, 1992; Torre & Tella, 1994; Real *et al.*, 1995; Ruiz-Romero, 1995a, 1995b), and with own new data recorded after 1985 (unpublished). Of the small mammals in Catalonia, four species were not considered for analysis because of the unreliability of information concerning their distribution (*Galemys pyrenaicus*, *Neomys anomalus*, *Crocidura suaveolens*, and *Apodemus flavicollis*; moreover, *Myocastor coypus* was also not considered because it is an allochthonous not acclimated species (Ruiz-Olmo, 1995) and *Marmota marmota* because it is a reintroduced species that

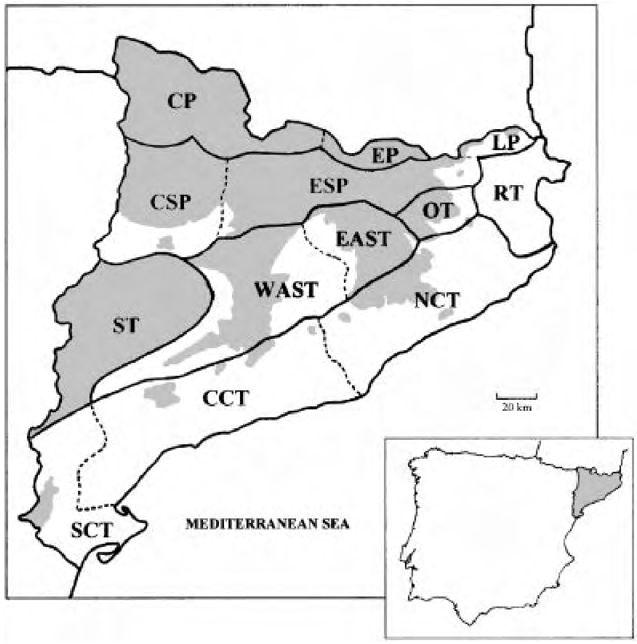


**Figure 1** Physiographical regions of Catalonia. CCT, central Catalanidic territory; CP, central Pyrenees; CSP, central segment of the southern Pre-Pyrenees; EAST, eastern Auso-Segarric territory; EP, eastern Pyrenees; ESP, eastern segment of the southern Pre-Pyrenees; LP, littoral Pyrenees; NCT, northern Catalanidic territory; OT, Olositanic territory; RT, Ruscinic territory; SCT, southern Catalanidic territory; ST, Sicoric territory; WAST, western Auso-Segarric territory. Dashes indicate Eurosiberian biogeographical region.

is still spreading in Catalonia (for details see García-Ferré *et al.*, 1995).

The presence/absence matrix for the species in the thirteen OGUs was constructed. The Baroni-Urbani and Buser's similarity index (for details see Baroni-Urbani & Buser, 1976) was applied to this matrix in order to classify both physiographical regions (Q-mode) and species (R-mode). The methodological advantages of this index in biogeographical studies are underlined by Vargas (1993). From the indices obtained, two similarity matrices were constructed: one for the classification of geographical areas and the other for the determination of chorotypes. The unweighted pair-group method using arithmetic averages (UPGMA) was used in the classification (for details see Márquez *et al.*, 1997), displaying the results as a dendogram.

In order to determine the significance of the similarities in both matrices the probability table in Baroni-Urbani & Buser (1976) was used. The similarity values were transformed into three classes identified by '+', '–' and '0' signs, if the values were significantly higher or lower than expected at random or without any significant difference, respectively. The transformed values were ordered as matrices of significant similarities.

Following the McCoy *et al.* (1986) method and the approach by Real *et al.* (1992), for each node of the dendrogram the presence of strong or weak significant segregations between species or physiographical regions separated by the

**Table 1** Average of the climatic variables for each physiographical region used in stepwise discriminant analyses.

| Regions | PE | AWD | MAP | MJAP | MJUP | MAT | MJAT | MJUT | RT | HS |
|---|---|---|---|---|---|---|---|---|---|---|
| CP | 591.3946 | 11.8023 | 951.9748 | 56.1319 | 76.0354 | 6.4034 | – 0.7908 | 15.4206 | 15.1841 | 4.1765 |
| EP | 682.2202 | 1.8027 | 1098.2320 | 41.4375 | 114.4922 | 7.7003 | 0.4413 | 15.9500 | 14.6166 | 3.7500 |
| LP | 783.5000 | 106.0244 | 850.1853 | 43.9884 | 40.3583 | 13.8496 | 5.1747 | 21.8566 | 16.4023 | 0.7143 |
| CSP | 682.2202 | 86.8848 | 711.6217 | 42.6367 | 47.6967 | 11.2291 | 2.4204 | 20.7243 | 18.5034 | 3.5556 |
| ESP | 643.9017 | 28.9210 | 918.8883 | 36.0536 | 77.3681 | 10.1235 | 1.7684 | 18.3238 | 16.5054 | 2.5455 |
| OT | 736.4333 | 44.9918 | 963.5646 | 39.0117 | 71.7514 | 12.8355 | 4.3135 | 20.4523 | 16.3021 | 1.6667 |
| ST | 806.8818 | 395.0526 | 418.2113 | 25.7552 | 15.9910 | 14.0129 | 4.7852 | 24.4622 | 20.0065 | 0.7500 |
| WAST | 743.8363 | 188.7164 | 575.8646 | 29.0061 | 28.1861 | 12.7804 | 4.0349 | 22.3981 | 18.5531 | 1.5455 |
| EAST | 664.0278 | 67.7999 | 770.3279 | 29.8653 | 55.8841 | 11.8700 | 3.0442 | 21.2575 | 18.0613 | 2.4000 |
| RT | 783.5000 | 192.3737 | 683.1784 | 37.9618 | 27.1359 | 14.7517 | 7.2019 | 22.8721 | 15.6532 | 0.0000 |
| SCT | 799.6331 | 287.1936 | 570.5792 | 36.4612 | 16.9476 | 15.2215 | 7.1036 | 23.2785 | 15.6306 | 0.0000 |
| CCT | 783.5673 | 253.5525 | 583.8348 | 33.5369 | 19.6652 | 14.5959 | 6.8736 | 22.9100 | 16.2259 | 0.2500 |
| NCT | 767.9795 | 149.5702 | 753.0527 | 42.1914 | 33.2716 | 14.1212 | 6.4230 | 22.4858 | 16.0342 | 0.3929 |

node was tested. At each node of the dendrogram a submatrix, which only included the physiographical regions or species involved in the node, was established from the matrix of significant similarities. This submatrix was divided into three zones: zones A and B, which corresponded to each group of regions or species separated by the node; and zone A*B, which corresponded to the intersection between both zones. From the number of pluses and minuses in each zone, parameters DW, DW(A*A), DW(B*B), and DS were computed. DW is a measure of the efficiency of a boundary to separate two groups of physiographical regions or species, whose fauna or geographical distribution, respectively, is similar within but not between each group. DW can be separated into parameters, DW(A*A) and DW(B*B). These parameters measure the extent to which the similarities higher than expected (+) tend to be in zones A and B, but not in A*B, i.e. they measure the internal homogeneity in zones A and B. DS is another measure of the efficiency of a boundary, giving a measure of whether the similarities lower than expected (–) tend to be located in A*B, but not in A or B. The statistical significance of each node of the dendrogram was assessed by a *G*-test of independence (following the application of Yates' correction) of the distribution of the signs '+', '–' and '0' in the zones A, B and A*B of the submatrix. This test gives parameter GW, for weak segregation, and GS, for strong segregation (for details see McCoy *et al.*, 1986).

### Relationships between the biotic regions and chorotypes with climatic variables

In order to determine a possible climatic characterization of the biotic regions and the chorotypes the following variables were considered: potential evapotranspiration (PE), annual water deficit (AWD; corresponding to the addition of the monthly differences between the potential and real evapotranspiration), mean annual precipitation (MAP), mean January precipitation (MJAP), mean July precipitation (MJUP), mean annual temperature (MAT), mean January temperature (MJAT), mean July temperature (MJUT), difference between the mean temperatures of January and July (RT), and number of months in which mean minima temperatures were < 0 (HS). The values of most of these variables were taken from the Atlas climàtic de Catalunya (Clavero *et al.*, 1996), except those corresponding to HS, which were taken from the Atlas fitoclimático de España (Allue, 1990). For each variable, the averages for each physiographical region were calculated (Table 1) and the normality test of Kolmogorov-Smirnov-Lilliefors was applied.

The inclusion of each OGU to each biotic region and the presence of each chorotype to each OGU were coded as binary variables. Further, the possible dependence of the biotic regions and chorotypes to any combination of climatic variables considered was determined by stepwise discriminant analyses (Norusis, 1997).

## RESULTS AND DISCUSSION

### Biogeographical regions

From the presence/absence of each species in the thirteen physiographical regions considered (Table 2), a similarity matrix was obtained, from which a significant similarity matrix (Table 3) and its corresponding dendrogram were produced. The method outlined by McCoy *et al.* (1986) revealed two Operative Biogeographical Units (OBUs; see Doadrio, 1988): a Pyrenean zone, which included two physiographical regions (CP and EP), and a larger zone that comprised the remaining regions (Fig. 2). Both OBUs were separated by a weak boundary (DW > 0 and GW was significant; see Table 4), which was characterized by the following discriminant function: $y = 4.2685*MAT-2.0339*MJAT-0.0488*PE-8.5922$. This function classified all OGUs correctly.

Since the configuration and limits of biogeographical regions are strongly related to the type of OGUs considered (see e.g. Palomo *et al.*, 1994; Real *et al.*, 1996), our results are only one way of identifying biogeographical units. Thus when using physiographical regions as OGUs, the Q-mode analysis revealed the existence of a geographical pattern,

**Table 2** Presence (1) or absence (0) of each small mammal species considered in each physiographical region.

| | Physiographical regions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | CP | EP | LP | CSP | ESP | OT | ST | WAST | EAST | RT | SCT | CCT | NCT |
| *Erinaceus europaeus* | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Atelerix algirus* | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| *Talpa europaea* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| *Sorex minutus* | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| *Sorex araneus* | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| *Sorex coronatus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Neomys fodiens* | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Crocidura russula* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Suncus etruscus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Sciurus vulgaris* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Glis glis* | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Eliomys quercinus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Apodemus sylvaticus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Rattus rattus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Rattus norvegicus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Mus musculus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Mus spretus* | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Clethrionomys glareolus* | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| *Arvicola terrestris* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Arvicola sapidus* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Chionomys nivalis* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Microtus gerbei* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Microtus duodecimcostatus* | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Microtus arvalis* | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Microtus agrestris* | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |

**Table 3** Matrix of significant similarities for the physiographical regions of Catalonia. +, Values significantly higher than expected at random, $P < 0.05$; –, values significantly lower than expected at random, $P < 0.05$; 0, values not different from those expected at random.

| | SCT | CCT | LP | RT | CSP | NCT | EAST | OT | WAST | ESP | CP | EP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ST | + | + | + | + | + | + | + | + | + | + | 0 | 0 |
| SCT | | + | + | + | + | + | + | + | + | + | 0 | 0 |
| CCT | | | + | + | + | + | + | + | + | + | 0 | 0 |
| LP | | | | + | + | + | + | + | + | + | 0 | 0 |
| RT | | | | | + | + | + | + | + | + | 0 | 0 |
| CSP | | | | | | + | + | + | + | + | 0 | + |
| NCT | | | | | | | + | + | + | + | 0 | + |
| EAST | | | | | | | | + | + | + | + | + |
| OT | | | | | | | | | + | + | + | + |
| WAST | | | | | | | | | | + | 0 | + |
| ESP | | | | | | | | | | | + | + |
| CP | | | | | | | | | | | | + |

with Catalonia divided only by a weak frontier; the axial zone of the Pyrenees, with the exception of the coastal portion, remains well defined respect to the other regions. The selection of the mean annual tempertaure, the mean January temperature, and the potential evapotranspiration by our discriminant function indicates that the severity and the availability of environmental energy (*sensu* Real *et al.*, 1996) leads to the biotic division of Catalonia for small mammals. This agrees with the general results obtained by Real *et al.* (1996), in which these variables, together with the global solar radiation and the mean July temperature, are climatic factors that define the biotic boundaries corresponding to the biogeographical regions for the insectivores of the Iberian Peninsula. Nevertheless, it should be borne in mind that, as these authors indicate, the variable that best defines this energy depends on the kind of OGUs considered.

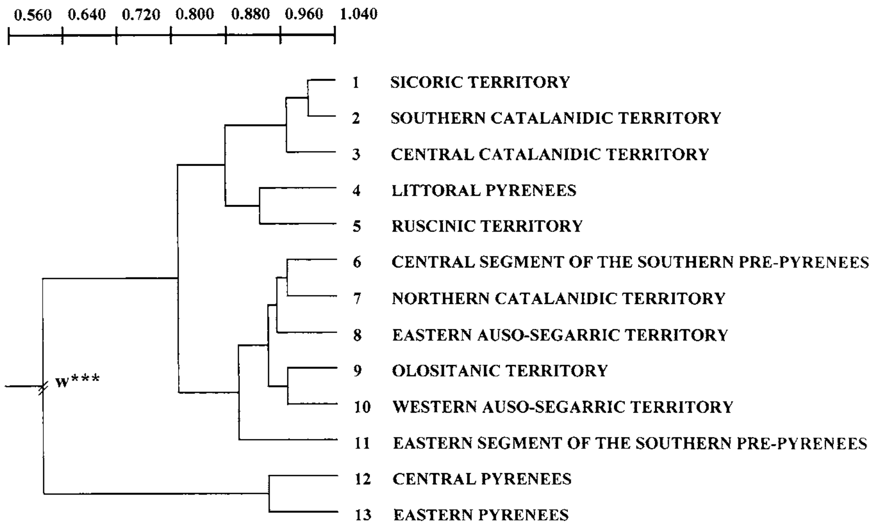


**Figure 2** Classification dendrogram of the thirteen physiographical regions of Catalonia according to their similarity in the small mammal fauna. w, Weak segregation; $***P < 0.001$.

**Table 4** Significant segregations between the physiographical regions and the species on the dendrogram's fork. GW and GS indicate weak segregation and strong segregation between the groups, respectively. $*P \leq 0.05$; $**P \leq 0.01$; $***P \leq 0.001$. DW(A*A) and DW(B*B) quantify the internal homogeneity of each group analysed. DW and DS quantify the value of each boundary.

| | Groups set up by UPGMA | | | Weak boundary | | | | | Strong boundary | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | Group B | Coefficient | DW(A*A) | DW(B*B) | DW | GW | P | DS | GS | P |
| Regions | 1–11 | 12–13 | 0.63 | 0.366 | 0.366 | 0.537 | 35.721 | *** | −0.341 | 0 | n.s. |
| Chorotypes | 1–4 | 5–6 | 0.744 | 0.307 | 0.307 | 0.507 | 3.068 | *n.s.* | −0.400 | 0 | n.s. |
| | 7–11 | 12 | 0.772 | 0.261 | −0.446 | 0.131 | 1.885 | *n.s.* | −0.446 | 0 | n.s. |
| | 7–12 | 13–24 | 0.635 | 0.424 | 0.476 | 0.565 | 98.131 | *** | −0.231 | 0 | n.s. |
| | 7–24 | 25 | 0.494 | 0.445 | −0.091 | 0.222 | 17.803 | *** | −0.091 | 0 | n.s. |
| | 1–6 | 7–25 | 0.222 | 0.591 | 0.501 | 0.546 | 129.554 | *** | 0.494 | 166.370 | *** |

## Chorotypes

The dendrogram constructed from the species similarity matrix is shown in Fig. 3. From the similarity values obtained between each pair of species, a matrix of significant similarities (Table 5) was obtained. The following chorotypes were distinguished (see Figs 3, 4): chorotype I was constituted by six species and its distribution included physiographical regions CP, EP, and ESP; chorotype II included six species and its distribution included all physiographical regions except SCT and ST; chorotype III contained twelve species and was distributed throughout all Catalonia; chorotype IV was constituted by one species, which was distributed in regions SCT, CCT, NCT, RT, ST, CSP and WAST. Chorotype I was separated from the other three by a strong boundary, but only weak boundaries separates chorotypes II, III and IV from each other (Table 4).

In order to characterize chorotypes 1, 2, and 4 climatically the following discriminant functions were obtained, respectively: $y = 0.7747*\text{MJUT-}16.2324$; $y = 0.0061*\text{MAP-}4.6806$; $y = 0.0089*\text{MAP-}6.7640$. The functions for chorotypes 1 and 4 classified all their respective OGUs correctly, while that for chorotype 2 classified 84.62% of its OGUs.

In the most recent study reviewing the distribution of small mammal fauna in Catalonia (Gosálbez *et al.*, 1985) four main groups of species were established through visual analysis of the distribution areas: mid-European, Mediterranean, anthropic, and species with particular habitat requirements. Only the former was divided into subgroups, which were defined as follows: species that occur exclusively in the western Pyrenees, species with a wider distribution throughout the Pyrenees, and species uniformly distributed in the Pyrenees, part of the Pre-Pyrenees and in the humid eastern region of Catalonia (in our study this region mainly corresponds to the Olositanic territory, part of the eastern segment of the southern Pre-Pyrenees, and part of the northern Catalanidic territory; see Fig. 1).

Our R-mode analysis revealed that the species considered are not distributed independently of each other and that there are four distribution patterns. Three of these chorotypes are formed by several species while one includes only one species. It its worth mentioning that these species associations could be exclusively interpreted in terms of the influence of climatic factors, since these are the only ones taken into account for analysis.

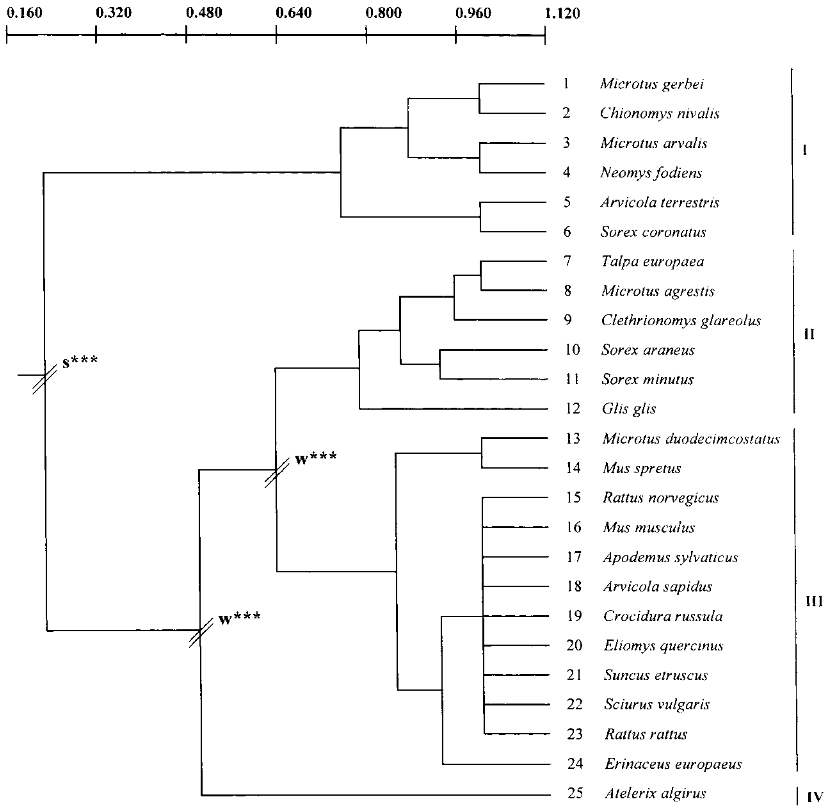


**Figure 3** Classification dendogram of the twenty-five species of small mammals according to distributional similarities in the thirteen physiographical regions of Catalonia. I-IV, Chorotypes; w, weak segregation; s, strong segregation; $^{***}P < 0.001$.

**Table 5** Matrix of significant similarities for the small mammal species from Catalonia. +, Values significantly higher than expexected at random, $P \leq 0.05$; –, values significantly lower than expected at random, $P \leq 0.05$; 0, values not different from those expected at random.

| | *C. nivalis* | *M. arvalis* | *N. fodiens* | *A. terrestris* | *S. coronatus* | *T. europaea* | *M. agrestris* | *C. glareolus* | *S. araneus* | *S. minutus* | *G. glis* | *M. duodecimcostatus* | *M. spretus* | *R. norvegicus* | *M. musculus* | *A. sylvaticus* | *A. sapidus* | *C. russula* | *E. quercinus* | *S. etruscus* | *S. vulgaris* | *R. rattus* | *E. europaeus* | *A. algirus* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *M. gerbei* | + | + | + | + | + | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | 0 | – |
| *C. nivalis* | | + | + | + | + | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | 0 | – |
| *M. arvalis* | | | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | 0 | – |
| *N. fodiens* | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | 0 | – |
| *A. terrestris* | | | | | + | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. coronatus* | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. europaea* | | | | | | | + | + | + | + | 0 | 0 | 0 | + | + | + | + | + | + | + | + | + | 0 | 0 |
| *M. agrestris* | | | | | | | | + | + | + | 0 | 0 | 0 | + | + | + | + | + | + | + | + | + | 0 | 0 |
| *C. glareolus* | | | | | | | | | + | + | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. araneus* | | | | | | | | | | + | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *S. minutus* | | | | | | | | | | | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *G. glis* | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *M. duodecimcostatus* | | | | | | | | | | | | | + | + | + | + | + | + | + | + | + | + | + | + |
| *M. spretus* | | | | | | | | | | | | | | + | + | + | + | + | + | + | + | + | + | + |
| *R. norvegicus* | | | | | | | | | | | | | | | + | + | + | + | + | + | + | + | + | 0 |
| *M. musculus* | | | | | | | | | | | | | | | | + | + | + | + | + | + | + | + | 0 |
| *A. sylvaticus* | | | | | | | | | | | | | | | | | + | + | + | + | + | + | + | 0 |
| *A. sapidus* | | | | | | | | | | | | | | | | | | + | + | + | + | + | + | 0 |
| *C. russula* | | | | | | | | | | | | | | | | | | | + | + | + | + | + | 0 |
| *E. quercinus* | | | | | | | | | | | | | | | | | | | | + | + | + | + | 0 |
| *S. etruscus* | | | | | | | | | | | | | | | | | | | | | + | + | + | 0 |
| *S. vulgaris* | | | | | | | | | | | | | | | | | | | | | | + | + | 0 |
| *R. rattus* | | | | | | | | | | | | | | | | | | | | | | | + | 0 |
| *E. europaeus* | | | | | | | | | | | | | | | | | | | | | | | | 0 |

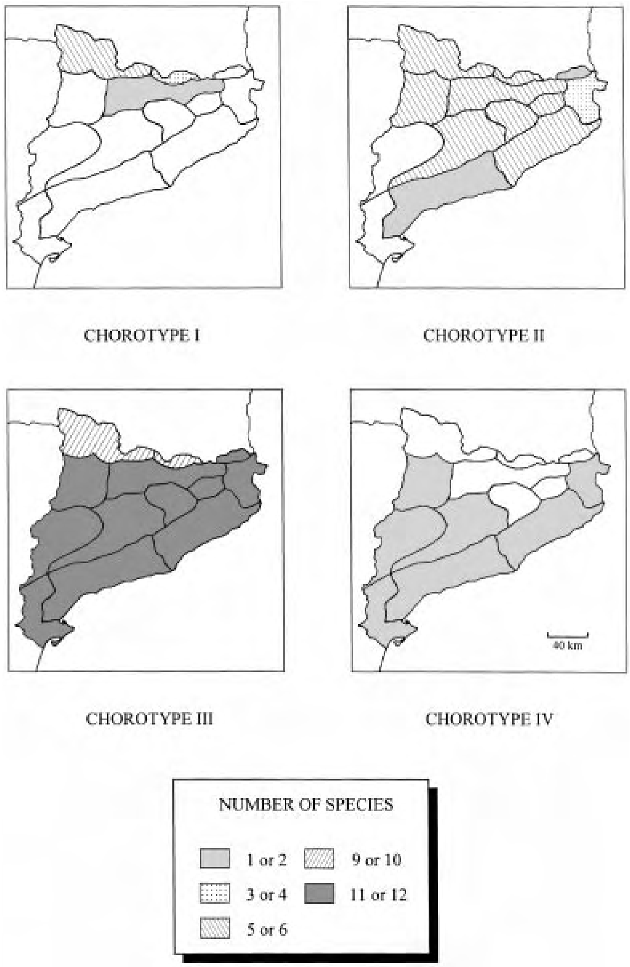


**Figure 4** Distribution of the four chorotypes obtained in Catalonia. In all the occupied physiographical regions the hatchings indicate the number of species from the chorotype that appear in each region.

The discriminant function showed that the mean temperature in July is the only climatic variable that accounts for the distribution of chorotype I. The coefficients of the function revealed that the species of this chorotype are characteristic of zones with relatively low temperatures during summer; these species occur in the Pyrenees and, in some cases (*Neomys fodiens* and *Microtus arvalis*), in the eastern segment of the southern Pre-Pyrenees, but always in areas with annual mean temperatures below 10–12 °C. In fact, insectivores and rodents of chorotype I are mid-European species that occur in zones with cold axeric and axeromeric bioclimates. Their absence in southern areas of Catalonia with suitable habitats, such as the Eurosiberian bioclimatic strata from the northern Catalanidic territory (e.g. Montseny mountains) and the zones with moderate Atlantic characteristics from the Olositanic territory, might be related in several cases to historical factors rather than ecoclimatic ones (see e.g. Torre *et al.*, 1996).

In the study by Gosálbez *et al.* (1985), all the species in our chorotype I, together with *Sorex minutus*, *Sorex araneus*, *Clethrionomys glareolus*, and *Microtus agrestis* were included in the same group. In our analysis, these latter four species were grouped together with *Talpa europaea* and *Glis glis* in chorotype II. According to the discriminant function obtained, mean annual precipitation is the only factor that affects its distribution, i.e. relatively high precipitations determine the presence of the species of this chorotype. They also have mid-European requirements and apppear in zones with annual precipitations above 600 mm. In comparison with chorotype I, these species show a wider geographical distribution in Catalonia extending, in general, into southern and eastern physiographical regions. Thus, for example, within chorotype II *T. europaea*, *C. glareolus*, and *M. agrestis* are the most tolerant to Mediterranean conditions and therefore they appeared associated in the dendogram; in fact, they occur from the Pyrenees to coastal zones from the Ruscinic and the northern Catalanidic regions.

In the quantitative analysis by Real *et al.* (1996) of the biogeography of the insectivores in the Iberian Peninsula, *S. coronatus*, *S. minutus*, *N. anomalus*, *N. fodiens*, *T. europaea*, and *G. pyrenaicus* formed a northern chorotype defined by its tendency to occupy highland areas close to the coast. This group includes the insectivores of our chorotypes I and II, and reflects the mid-European character of these species. Nevertheless, in the study by Real *et al.* (1996) *S. araneus* was included in another chorotype together with *Atelerix algirus*. According to these authors, this grouping is conditioned by several macroenvironmental factors, such as penetration ways, climatic stability and habitat heterogeneity. Nevertheless, in phytogeographical terms, while *S. araneus* is a mid-European species, *A. algirus* is from northern Africa (see Holz & Niethammer, 1990), and in Catalonia it only occurs in typical Mediterranean environments (Gosálbez & López-Fuster, 1985). In contrast to the results by Real *et al.* (1996), our classification analysis shows that the phytogeographical influence, indirectly represented by climatic factors, mainly accounts for the separation of these two insectivores in different chorotypes. Thus, *A. algirus* was significantly separated from the remaining species, and constituted the only representative of chorotype IV; it mainly occurs in environments with annual precipitations below 600 mm (see Ruiz-Romero, 1995b). Specifically, our discriminant analysis corroborates the dependence of the species on dry habitats since the relatively low mean annual precipitation is the only climatic variable that accounts for its distribution.

The other insectivores and rodents considered were grouped in the same chorotype because of their wide distributions. Thus, chorotype III includes, on the one hand, Mediterranean species, such as *Suncus etruscus*, *Crocidura russula*, *Mus spretus*, and *Microtus duodecimcostatus*, which are not so strict in their requirements as *A. algirus* and therefore penetrate areas with a mid-European influence, but always in zones with moderate temperature (mean annual temperatures above 5 °C) and humidity conditions (annual precipitation below 1000 mm). On the other hand, this chorotype includes anthropic (*Rattus rattus*, *Rattus norvegicus*, and *Mus musculus*), generalist (*Erinaceus europeus*, *Eliomys quercinus*, and *Apodemus sylvaticus*), and species with particular habitat requirements, such as *Sciurus vulgaris*, which occurs only in relatively dense and homogeneous woodlands, and *Arvicola sapidus* that appears in well vegetated banks of rivers, ponds, canals and drainage ditches. Our results are consistent with the study by Real *et al*. (1996), in which *E. europaeus*, *Talpa occidentalis* (not present in Catalonia), *S. etruscus* and *C. russula* were grouped in a chorotype defined by its most generalist distribution and characterized by their tendency to occupy northern and montane areas close to the coast.

In conclusion, using the physiographical regions in Catalonia as OGUs, we have applied a classification method to them and the small mammal species, and then tested the significance of the resulting groups. This allows the distinction of biotic regions and groups of species that occur together more frequently than expected at random from which are just product of the cluster analysis. Discriminant analyses allowed us to interpret the biotic regions and the chorotypes in terms of the climatic factors that determine them. Nevertheless, although the results obtained constitute the first quantitative approach to the biogeography of the insectivores and rodents in Catalonia, further studies that use other types of OGUs and other environmental variables are needed to determine all the causes of the distribution of these mammals in this temperate-Mediterranean climatic transition.

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**Appendix I** Nomenclature authorities for all species names mentioned in this paper. (*): species used for analyses in this paper.

O. Insectivora
- *Erinaceus europaeus* L., 1758*
- *Atelerix algirus* (Lereboullet, 1840)*
- *Talpa europaea* L., 1758*
- *Talpa occidentalis* Cabrera, 1907
- *Galemys pyrenaicus* (Geoffroy, 1811)
- *Sorex minutus* L., 1766*
- *Sorex araneus* L., 1758*
- *Sorex coronatus* Millet, 1828*
- *Neomys fodiens* (Pennant, 1771)*
- *Neomys anomalus* Cabrera, 1907
- *Crocidura suaveolens* (Pallas, 1811)
- *Crocidura russula* (Hermann, 1780)*
- *Suncus etruscus* (Savi, 1822)*

O. Rodentia
- *Sciurus vulgaris* L., 1758*
- *Marmota marmota* (L., 1758)*
- *Glis glis* (L., 1766)*
- *Eliomys quercinus* (L., 1766)*
- *Apodemus flavicollis* (Melchior, 1834)
- *Apodemus sylvaticus* (L., 1758)*
- *Rattus rattus* (L., 1758)*
- *Rattus norvegicus* (Berkenhout, 1769)*
- *Mus musculus* Rutty, 1772*
- *Mus spretus* Lataste, 1883*
- *Clethrionomys glareolus* (Schreber, 1780)*
- *Arvicola terrestris* (L., 1758)*
- *Arvicola sapidus* Miller, 1908*
- *Chionomys nivalis* (Martins, 1842)*
- *Microtus gerbei* (Gerbe, 1879)*
- *Microtus duodecimcostatus* (de Sélys-Longchamps, 1839)*
- *Microtus arvalis* (Pallas, 1779)*
- *Microtus agrestis* (L., 1761)*
- *Myocastor coypus* (Molina, 1782)

## BIOSKETCHES

**Maria A. Sans-Fuentes** is a graduate of the University of Barcelona. After focusing her interests on several aspects of the taxonomy and biogeography of Iberian small mammals, she is currently completing her PhD on cytogenetics of *Mus musculus*.

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