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Socioeconomic, physiognomic, and climatic factors determining the distribution pattern of roe deer *Capreolus capreolus* in Spain

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In Spain, the highest density of roe deer *Capreolus capreolus* (Linnaeus, 1758) is found in the northern mountains, whereas towards the south, populations are fragmented into isolated nucleii. In order to analyse the distribution patterns of this species in Spain and its variation during the last five years, a multivariate analysis of the influences of several socioeconomic, physiognomic and climatic factors was performed. This species prefers to inhabit damper and colder areas. Its distribution also reflects changes in human population; roe deer are associated with areas of zero growth or an actual decline in population density. An active management is essential to the conservation of the southern populations due to their geographic isolation and the low populational density of each nucleus.

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Introduction

Little data exists on the distribution of *Cervidae* in Spain (Cabrera 1914, Niethammer 1963, Whitehead 1972); the most recently published information is by Braza *et al.* (1989). These authors emphasize the existence of two distinct nucleii of roe deer populations: those living in the Eurosiberian region, reaching a high density and spreading, and those from the Mediterranean region, more vulnerable because of their isolation and low density. For this reason the density values are very variable, ranging between 18 individuals/100 ha in the Cantabrian Mountains and 2 individuals/100 ha in several areas of the Southern Sierras (Delibes *et al.* 1991, Saenz de Buruaga *et al.* 1991, Sáez-Royuela and Tellería 1991).

In this study, we have analysed the distribution pattern of roe deer in Spain and its variation during the last five years. We evaluated the socioeconomic, physiognomic and climatic factors affecting it.

Material and methods

A questionnaire was distributed (first in 1987 and again in 1992) to various regional and municipal offices throughout Spain, and included the following questions: (1) how many and which municipalities have roe deer populations, (2) origin of these groups: autochthonous or introduced, and (3) current status: increasing, decreasing or stable. A preliminary distribution map was published in a Spanish journal (Braza *et al.* 1989) and the collaboration of interested readers was requested. In 1993 the definitive map, shown in this article, was elaborated.

In this paper the distribution in each province is given as the percentage of surface occupied by the municipalities with roe deer populations, compared to the total surface area of the province (Table 1).

The distribution pattern of roe deer was researched in relation to the following socioeconomic, physiognomic and climatic factors: SER – percentage of inhabitants working in service sector (data from 1988), IND – percentage of inhabitants working in industry (data from 1988), AGR – percentage of inhabitants working in agriculture and livestock farming (data from 1988), DEN – density of human population stated as inhabitants per km^2 (data from 1991), CEN – relative intercensus variation (according to census of 1981 and 1991), GAM – number of game licences per 1000 inhabitants (data from 1988), PAS – percentage of surface area without agricultural use but with pasture (data from 1989), WPA – percentage of surface area without agricultural use and without pasture (data from 1989), UNP – percentage of unproductive surface area, such as rocky places or quarries (data from 1989), FOR – percentage of surface area with forest (data from 1989), ALT – altitude: (1) greater part of the provincial surface between 0 and 200 m a.s.l., (2) between 201 and 600 m, (3) between 601 and 1,000 m, (4) between 1,001 and 2,000 m and, (5) over 2,000 m, HER – percentage of provincial surface area under herbaceous cultivation (data from 1989), TRE – percentage of provincial surface area under tree and shrub cultivation (data from 1989), SHE – head of sheep per 1,000 inhabitants (data from 1989), GOA – head of goats per 1,000 inhabitants (data from 1989), RAI – annual average rainfall, SUN – sunlight hours per year, MAX – average maximum annual temperature, MIN – average minimum annual temperature.

The socioeconomic and physiognomic data were obtained from the Statistical Yearbook published by "Instituto Nacional de Estadística de España". The climatological data are averages of between 15 and 30 years, depending on the province, published by "Instituto Nacional de Meteorología de España"

Table 1. Surface occupied by the municipalities with roe deer populations as a percentage of the total surface area of the province.

Province	%	Province	%	Province	%
Alava	25.0	Cuenca	5.4	Palencia	45.7
Albacete	0.0	Gerona	4.1	Pontevedra	5.6
Alicante	0.0	Granada	0.0	La Rioja	63.6
Almería	0.0	Guadalajara	5.8	Salamanca	3.8
Asturias	100.0	Guipúzcoa	5.9	Segovia	8.6
Avila	1.5	Huelva	0.0	Sevilla	0.0
Badajoz	1.6	Huesca	26.7	Soria	100.0
Barcelona	1.6	Jaén	1.8	Tarragona	0.0
Burgos	76.7	León	62.9	Teruel	3.0
Cáceres	11.8	Lérida	9.1	Toledo	11.5
Cádiz	39.4	Lugo	100.0	Valencia	0.0
Cantabria	100.0	Madrid	13.6	Valladolid	1.4
Castellón	0.0	Málaga	17.5	Vizcaya	15.0
Ciudad Real	27.2	Murcia	0.0	Zamora	22.2
Córdoba	0.0	Navarra	26.1	Zaragoza	9.0
La Corua	24.3	Orense	65.0		

(Turmet 92. Ministerio de Obras Públicas y Transportes, 1992). The statistical analysis was undertaken using the program Statview 512+ (Feldman *et al.* 1988).

Results

Nowadays in Spain (Fig. 1) the roe deer inhabits the Pyrenees, the Cantabrian Mountains and the northern part of the Iberian Mountains, spreading through

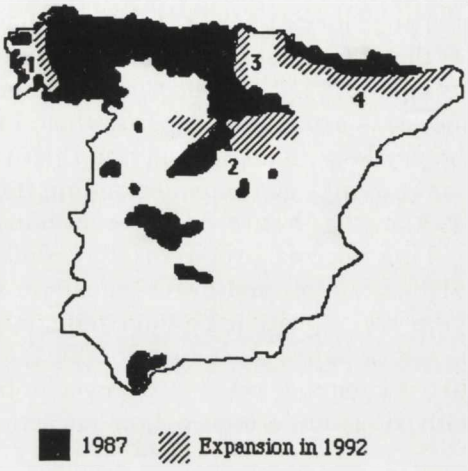

Fig. 1. Distribution pattern of roe deer in Spain. Numbers respresent the principal zones of natural dispersal (see text).

Table 2. Comparison of factors between provinces with and without roe deer, and with strong (more than 25% of surface area) or weak (less than 25% area) presence of the species. Student t-test (With/Without df: 45; More/Less than 25% df: 34). * $0.01 < p < 0.05$, ** $p < 0.001$.

Factor	With roe deer		Without roe deer			More 25%		Less 25%		
	$\bar{x}$	SD	$\bar{x}$	SD	t	$\bar{x}$	SD	$\bar{x}$	SD	t
SER	49.83	7.57	53.68	5.08	−1.58	46.57	6.73	51.90	7.47	*−2.17
IND	30.45	9.12	29.59	7.01	0.29	31.48	9.65	29.80	8.93	0.53
AGR	19.72	12.08	16.73	6.39	0.78	21.95	13.46	18.30	11.22	0.88
DEN	105.72	159.07	92.87	63.90	0.26	54.22	40.86	138.49	195.57	−1.58
CEN	0.12	5.01	7.00	4.25	**−4.11	−0.47	5.72	0.50	4.61	−0.56
GAM	43.01	15.14	42.94	10.65	0.01	45.45	11.23	41.46	17.26	0.77
PAS	38.74	13.34	32.17	8.59	1.53	42.97	11.67	36.05	13.88	1.55
WPA	18.89	13.75	16.00	7.92	0.66	17.39	10.46	19.84	15.64	−0.51
UNP	6.98	3.60	6.63	3.66	0.29	6.58	2.69	7.24	4.11	−0.53
FOR	48.13	15.73	46.16	11.94	0.38	48.87	15.43	47.66	16.27	0.22
ALT	2.64	0.80	2.27	0.90	1.29	2.71	0.83	2.59	0.80	0.45
HER	22.44	12.63	16.92	13.62	1.25	22.97	12.52	22.10	12.99	0.20
TRE	5.50	7.83	19.75	9.04	**−5.09	3.40	5.01	6.85	9.05	−1.30
SHE	428.07	259.06	343.24	150.14	1.03	343.40	240.21	481.95	261.37	−1.60
GOA	73.54	99.81	116.01	70.51	−1.31	49.56	47.28	88.81	120.80	−1.16
RAI	669.13	356.00	429.39	120.52	*2.18	716.59	297.06	638.92	392.60	0.63
SUN	2404.73	94.66	2708.92	08.82	*−2.44	2285.44	25.54	2408.73	63.28	−1.47
MAX	18.58	2.11	22.38	1.58	**−5.50	17.69	1.90	19.15	2.08	*−2.11
MIN	8.20	2.65	11.44	2.07	**−3.71	7.69	2.87	8.52	2.51	−0.91

the Central Mountains down to Gredos. Towards the south this continuous distribution breaks down, and the roe deer is present only in scattered isolated populations in the Toledo Mountains, Sierra Morena and Cádiz and Málaga ranges (southern limit of the species worldwide distribution). All of the present populations are autochthonous except those in the Catalan part of the Pyrenees and in some other small areas (Salamanca, Cáceres and Navarra). The roe deer is absent in both the Canary and Balearic Islands.

The principal zones of range expansion (Fig. 1) for this species in Spain are: (1) Sierra de Los Ancares, from where the roe deer is colonizing the eastern part of Galicia; (2) Sierras de Cameros, Demanda and Picos de Urbión, from where the species is expanding into the whole Iberian Mountains on the one hand, and into the northern plateau along the Duero River on the other; (3) Eastern spurs of the Cantabrian Mountains, expanding into the western part of the Basque Country; (4) Along the entire Pyrenees, colonizing from north to south.

This species preferentially inhabits those areas characterized by damper (higher rainfall and lower sunshine) and colder (lower values of average annual temperature, both maximum and minimum) weather (Table 2). The provinces with no roe presence have a greater surface area under tree and shrub cultivation. Its distribution also reflects changes in human population, roe deer being associated with areas of zero growth or an actual decline in population density. The same

Table 3. Principal components analysis. Orthogonal transformation Varimax. Factor scores below 0.25 are represented as 0.00. F – Factor of transformation.

Factor	F1	F2	F3	F4	F5
MAXimum temperature	**0.90**	0.00	0.00	0.00	0.00
MINimum temperature	**0.85**	−0.26	0.25	0.00	0.00
TREe and shrub	**0.76**	0.00	0.00	0.00	0.00
CENsus variation	**0.74**	0.00	0.00	0.00	0.00
ALTitude	**−0.57**	0.42	0.00	0.00	0.34
GOAts / 1000 inhabitants	**0.56**	0.29	0.00	0.00	0.31
RAInfall	0.00	**−0.84**	0.00	0.00	0.00
FORestal	0.00	**−0.77**	0.00	0.00	0.41
Without **PA**sture	0.00	**−0.77**	0.00	0.34	0.00
SUNlight hours / year	0.49	**0.69**	0.00	0.00	0.00
SHEep / 1000 inhabitants	−0.31	**0.61**	−0.29	0.29	0.00
DENsity of populaton	0.00	0.00	**0.84**	0.00	0.00
GAMe licences / 1000 inhabitants	0.00	0.00	**−0.82**	0.00	0.33
UNProductive surface	0.00	0.00	**0.79**	0.00	0.00
SERvices, % of inhabitants	0.38	0.50	**0.66**	0.00	0.00
INDustry, % of inhabitants	0.00	0.00	0.00	**0.92**	0.00
AGRiculture, % of inhabitants	0.00	0.00	−0.51	**−0.77**	0.00
HERbaceous cultivation	0.00	0.42	0.00	0.00	**−0.82**
PASture	0.00	0.00	0.00	0.42	**0.59**
Proportionate variance contributions	0.27	0.26	0.21	0.14	0.11

table illustrates the differences between provinces with strong (more than 25% of its surface area) and weak (less than 25%) roe deer presence; the only significant variations are in factors SER and MAX.

A principal components analysis was done (Table 3) with the nineteen parameters used; the scores of the different provinces in each emerging factor were used as new variables. A multiple regression analysis between the roe deer distribution area and the new variables reflects a significant relation (R^2 = 0.38; Adj. R^2 = 0.30; ANOVA: df = 5,46, F = 4.92, p = 0.0013). Results of simple regressions analyses are shown in Table 4. Two of the factors (1 and 4) are significantly related to the provincial surface area occupied by roe deer populations. Factor 1 indicates provinces with high human density, low altitude, abundance of tree and shrub crops as well as goat husbandry, and is characterized by a hot climate; this definition applies well to the coastal regions in southern and eastern Spain. Factor 4 defines those provinces with an industrial economy as opposed to the predominantly farming ones. A high score on both factors implies a low presence of roe deer.

Table 4. Simple regressions analyses results. Roe deer distribution area *versus* each factor. ANOVA (df = 1,46).

	R^2	Adj. R^2	F-test	p
Factor 1	0.21	0.19	11.65	**0.0014**
Factor 2	0.07	0.05	3.40	0.0719
Factor 3	3.78×10^{-4}	−0.02	0.02	0.8969
Factor 4	0.09	0.07	4.45	**0.0404**
Factor 5	0.01	−0.01	0.40	0.5320

Discussion

The low density of roe populations in southern Spain in contrast to that in northern Spain and central Europe may be explained by the peculiar productive conditions in the Mediterranean region, where rainfall acts as a limiting factor on vegetative activity and consequently on the carrying capacity of many herbivore species (Mooney 1981).

In France, Gaillard *et al.* (1993) found out that in an area with a mild climate and a high density of roe deer, mortality of juveniles as well as changes in reproductive parameters, e.g. onset of breeding amongst the young, was related to population density. In contrast, in populations with low density living in regions with an extreme climate, mortality showed no relationship to density and survival was dependent on the severity of winter.

Due to the low density in Mediterranean Spain, a high influence of density-independent factors on population dynamics could be expected; the critical barrier

maintaining the populations below their potential growth is the long period of summer drought. Climate does seem to have a strong influence on roe deer distribution, which is much more concentrated in colder areas with a high level of rainfall, typical of the north of the Peninsula; whereas in the south, the progressive dryness limits the roe deer to mountains, where the height effect compensates for the latitude effect, provoking wet conditions (Sáez-Royuela and Tellería 1984, 1991). Therefore the conservation of roe deer in the southern mountains is not a consequence of human pressure in the lowlands, but rather of the climatic characteristics of the habitats.

The roe deer in southern Spain are very vulnerable to human pressure, since they live in uncertain environments and are subjected to density-independent mortality. Nowadays, roe deer thrive in places with a traditional agricultural use where the human drift from the land has permitted an increase of wild ungulates populations (Tellería and Sáez-Royuela 1984). It is necessary to point out that human presence in the countryside does not seem to limit the development of roe deer populations. The opportunistic behaviour of the species allows it to exploit the rural environment modified as a result of human activities, and a balanced anthropological influence on the habitats would be of help for the conservation of this cervid. Moreover, the progressive extinction of the wolf *Canis lupus* from most of Spain in the forties (Valverde 1971) also contributed to the expansion of the big herbivores that constitute a key element of this carnivores diet.

As a result, conservation activities should be different in the north than in the south of Spain. While general conservation of the environment could be enough to ensure a fine state of health in the northern populations, in the south, due to geographic isolation and the low population density each nucleus has reached, active management is essential. Despite the fact that an unique subspecies of roe deer has been recognized in Europe (Corbet 1978), the isolated populations in the Mediterranean area could be considered an ecotype (Aragón 1993), and its preservation must be a priority task in biodiversity conservation.

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