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A comparative study of *Cistus ladanifer* shrublands in Extremadura (CW Spain) on the basis of woody species composition and cover

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Abstract

The ecological structure and diversity of woody species in the *Cistus ladanifer* shrubland ('jaral'), one of the most widespread Mediterranean scrub systems in the western half of the Iberian Peninsula, was studied in Extremadura (CW Spain). 57 points were sampled for presence/absence and abundance (line interception) of woody species. Several diversity indices were calculated to elucidate the role of both *C. ladanifer* and bare soil in the jaral structure. The sites were classified by agglomerative hierarchical clustering and ordinated by Principal Component Analysis (PCA). Most of the examined scrubs have diversity within the range 1–3, evenness above 0.5 and species richness between 1 and 12. Clustering and PCA distinguished three groups of scrubs: A, those with a certain Atlantic influence and highest values of diversity and total cover, in which *Lavandula stoechas* subsp. *luisieri*, *Erica umbellata* and *Halimium ocymoides* are frequent; B, the most continental scrubs, growing on moderately acid soils with *Cistus salvifolius* and *C. crispus*, and, C, those as continental as group B but on more acid soils, characterized by *Genista hirsuta*. Differential species between groups basically coincide with those used in phytosociological classifications. Diversity data, together with affinity and PCA analyses, emphasize that the ecological structure of Mediterranean shrublands is strongly influenced by humidity and the annual temperature range.

Introduction

Many studies on floristic composition, physiognomy and structure of Mediterranean shrublands, frequently including measures of diversity, are found in the literature (Specht 1969; Parsons 1976; Naveh & Whittaker 1979; Basanta *et al.* 1984; Fernández-Alés *et al.* 1984; Arroyo & Marañón 1990; see Di Castri *et al.* 1981 for a world-wide review). Diversity has also been used frequently for estimating the degradation and/or recovery of Mediterranean shrublands after perturbations (Trabaud & Lepart 1980; Basanta & García-Novo 1988; Orellana & García-Novo 1991). However, the 'jaral', a type of Mediterranean shrubland dominated by jara (*Cistus ladanifer* L.), has not been studied before for diversity values. The jaral constitutes a major part of the vegetation landscape of western Iberian Peninsula, especially in Extremadura (CW Spain), where it prevails in very strongly degraded areas with acid soils (Núñez-Olivera 1989).

Most of the descriptive information on shrublands available for the Iberian Peninsula consists of phytosociological relevés. Thus, the specific composition and phytosociological classification of the serial stages constituted by Mediterranean shrublands in Spain is reasonably well-known (Rivas-Martínez 1979). However, as far as we know, no attempt of comparison between shrubland classifications obtained by phytosociological and numerical methods was ever carried out, also as far as the jaral is concerned.

On the basis of floristic composition and cover of woody species, the purposes of the present study are 1) to analyze diversity, evenness and species richness of 57 jaral shrublands located in Extremadura, 2) to dis-

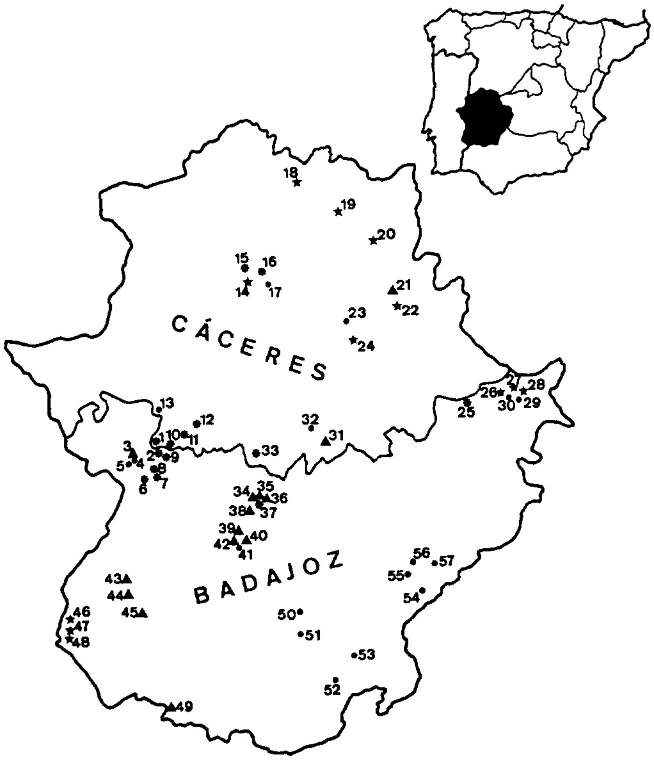

Fig. 1. Map of Extremadura showing the location of the 57 sampling points, grouped on the basis of the dendrogram of Fig. 7.
Group A, (•); Group B, (▲); Group C, (•); Undetermined localities, ★.

Table 1. Variation of α diversity with sampling size. Variances and coefficients of variation are included (n = 20).

Sampling size	α Diversity	Variance	Var. Coeff. (%)
1 × 1 m^2	0.36	0.23	133
2 × 2 m^2	0.58	0.26	88
3 × 3 m^2	0.61	0.24	80
4 × 4 m^2	0.79	0.16	50
6 × 6 m^2	0.91	0.10	35
8 × 8 m^2	0.97	0.08	29
10 × 10 m^2	0.99	0.08	28

tinguish different types of jaral by clustering analysis based on presence/absence data and by PCA based on cover data, and, 3) to compare our classification with that established by other authors using phytosociological methods.

Study area

Extremadura occupies a large part (41,602 km^2) of the central and western Iberian Peninsula (Fig. 1). The great extension, and the wide latitudinal and altitudinal ranges (280 km and 2,000 m, respectively), cause a noticeable variety of environmental conditions within the Mediterranean biogeographical region. Mean annual temperature varies between 12 °C and 18 °C (Cabezas Fernández & Escudero García 1989; Vicente Calle *et al.* 1993) and annual rainfall between 400 and 1,500 mm (Cabezas Fernández *et al.* 1986). Three bioclimatic belts are found in the region: supra-, meso- (the most extensive) and thermomediterranean (Núñez-Olivera 1989). Pre-Cambrian materials (shales and black quartzites interspersed with granites and granodiorites) dominate the substrate. Detritic Plioquaternary deposits cover depressions and some wide valleys. The variety of soils includes lithosols, regosols, luvisols and cambisols. *Cistus ladanifer* can grow on all of them.

Material and methods

Sampling 57 areas were selected for sampling, which was continued over three years. Sample sizes used in this type of study can vary considerably: 5 × 5 m^2 (Basanta & García-Novo 1988), 1 × 7 m^2 (Basanta *et al.* 1984), 8 × 10 m^2 (Díaz Pineda & González Bernáldez 1975), 10 × 10 m^2 (Juhren & Montgomery 1977; Vooková 1981), 20 × 20 m^2 (González-Bernáldez *et al.* 1975), etc. In the present work, the sample size was determined by the spectra of the α diversity (Table 1). The first four sizes differed significantly ($p < 0.01$) from the last three, so that the 6 × 6 m^2 plot was considered to yield an adequate information. Nevertheless, since the coefficient of variation was markedly smaller when using 8 × 8 and 10 × 10 m^2 plots, this last size was finally preferred. The number of samples collected at each point (3–15) depended on the total area available.

Data gathering and treatment Qualitative (presence/absence) and quantitative (cover) data were recorded in each plot, only for woody species. Species were recorded as present when the projection of above ground organs fell within the plot. Cover was measured by the line-intercept method (Floyd & Anderson 1987) using five parallel 10 m-long lines 2 m-apart in each plot. Bare soil was recorded as an additional vari-

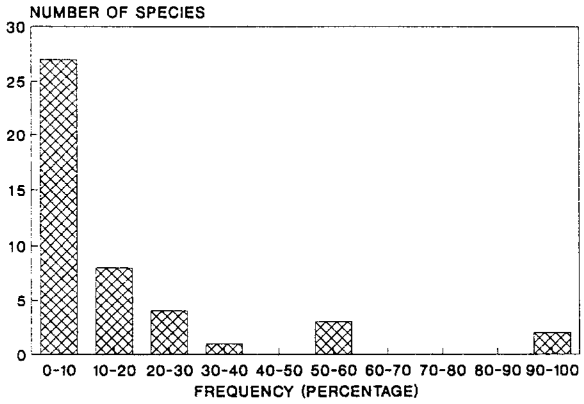

Fig. 2. Frequency distribution of the collected species.

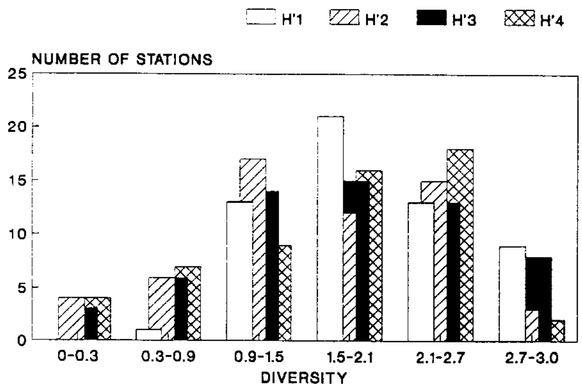

Fig. 3. Frequency distribution of diversity (H'_1 to H'_4, explanation in the text) in the sampling points.

able when no woody species existed, whether or not there was herbaceous cover (Basanta & García-Novo 1988).

Species diversity (H′, Shannon's index) and evenness ($J' = H'/H_{max}$) were calculated on the basis of cover data (Magurran 1988). Because of the importance of bare soil in the vegetation structure, diversity and evenness were calculated both with bare soil as an additional variable (H'_1 and J'_1) and without (H'_2 and J'_2). Also, species diversity was obtained after eliminating *C. ladanifer* (H'_3) and both *C. ladanifer* and bare soil (H'_4). Species richness (S) was also computed.

Starting from the presence/absence data, a similarity matrix between the 57 points was calculated using Jaccard's index (in Margalef 1982). Then an agglomerative hierarchical clustering of the points was performed using UPGMA as algorithm (Sokal & Sneath 1973) and a dendrogram was constructed. The 57 sites were ordinated by PCA using cover data (Table 2).

Student's t test was used to analyze the significant differences between the means of data sets.

Results

Diversity Primary data of presence/absence and mean cover of woody species and bare soil at the 57 sampling sites, together with values of diversity, evenness, species richness, total site cover and two climatic variables are reported in Table 2. In a plot of species frequency against number of species with each observed frequency, a hyperbolic relationship is found (Fig. 2). More than 60% of the species appear in less than 10% of the sites, while only 12 species appear in 20% or more of the sites; amongst them, only *C. ladanifer* is present in all sites.

The specific diversity of the 57 sampling sites varies between 0.00 and 3.03 (Table 2). Sites with intermediate diversity H'_1 predominate, the mode lying within the interval 1.5–2.1 (Fig. 3). If bare soil is excluded from the calculation, diversity generally decreases (H'_2: Fig. 3), except for those sites where bare soil is abundant. Eliminating *Cistus ladanifer*, diversity gives a normal distribution (H'_3: Fig. 3), with the mode within the interval 1.5–2.1, as in the case of H'_1, but a shift towards lower intervals is observed, which is more pronounced when bare soil is also eliminated (H'_4: Fig. 3). The exclusion of *C. ladanifer* generally determines a decrease in diversity (H'_3 against H'_1) in those sites with low and intermediate diversity values, and a slight increase at the sites with high diversity. This increase is due to the fact that another variable becomes dominant, either some species (*Genista hirsuta*, *Lavandula sampaiana*) or, in most cases, bare soil.

There are high positive correlations between all the calculated diversities ($p < 0.001$, Table 3), so that neither jara nor bare soil, each one separately, modify drastically the diversity values at most of the sites (those with intermediate diversities). However, the correlations when both of them are excluded (H'_4), despite their statistical significance ($p < 0.001$), are lower than any other calculated correlation.

The evenness (J'_1) is normally distributed, with the mode displaced towards high values (Fig. 4). If jara cover is excluded from the calculation (J'_2), the evenness evidently increases (Fig. 4), but also more sites with low regularity appear. There is a strong correlation between the two types of evenness and between

Table 2. Values of mean cover of woody species and bare soil, mean annual temperature, annual rainfall, diversities (H'_1 to H'_4, explanation in the text), evenness (J'_1 and J'_2, explanation in the text), species richness and total site cover in the 57 sampling points. Sampling points are arranged according to the dendrogram in Fig. 7 (group A: 1–16; group B: 43–42 and group C: 52–30).

	1	2	8	10	25	7	9	12	11	37	6	33	15	16	24	19	26	27	28	22	43	44	38	39	45	49	36	31
Cistus ladanifer	2.04	3.00	8.24	4.31	5.78	6.50	5.14	4.87	5.60	7.05	3.38	5.83	0.33	4.18	7.76	7.21	2.77	5.08	3.11	2.93	4.60	4.88	0.88	2.85	1.08	4.91	9.28	6.45
Bare soil	6.16	5.47	0.59	1.57	2.45	0.50	0.28	1.16	-	1.01	2.17	1.23	-	-	0.25	1.82	5.23	0.90	5.30	2.85	0.68	3.00	4.60	2.81	8.00	1.07	0.34	3.36
Quercus rotundifolia	-	-	-	-	-	-	-	-	-	1.16	0.22	0.54	0.17	0.08	-	-	-	-	0.56	1.40	0.53	-	-	-	0.18	1.61	0.16	-
Quercus suber	0.50	1.96	0.43	0.60	-	-	-	-	1.00	0.40	0.50	-	0.61	1.27	-	-	-	-	-	-	1.43	-	-	-	-	-	0.56	-
Quercus faginea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus pyrenaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinus pinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70	0.41	-	-	-	-	-	-	-	-	-
Pinus pinaster	-	-	-	-	-	-	-	-	-	-	-	1.51	0.91	-	-	-	0.11	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus sp.	-	-	-	-	-	-	-	-	-	-	-	-	1.42	-	-	-	-	-	-	2.75	-	-	-	-	-	-	-	-
Castanea sativa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lavandula sampaiana	-	-	-	-	-	-	-	-	-	1.04	-	2.05	-	-	-	2.79	-	-	-	-	0.33	1.04	0.73	2.14	0.10	0.13	1.51	0.17
Lavandula luisieri	1.49	0.31	2.10	4.28	1.54	1.35	3.48	1.81	3.86	2.01	0.86	1.00	-	0.51	-	-	-	-	-	1.75	-	-	-	-	-	-	-	-
Halimium ocymoides	0.05	-	0.14	-	1.49	1.63	1.88	-	2.10	-	-	0.03	0.27	3.21	0.83	0.38	-	-	-	-	-	-	-	-	-	-	-	-
Erica australis	-	-	-	0.20	0.35	2.70	2.60	1.48	2.06	1.01	-	0.94	0.81	1.51	0.38	1.86	-	3.05	-	-	-	-	-	-	-	-	-	-
Genista hirsuta	0.98	0.12	1.50	0.30	-	1.80	0.79	0.22	-	-	-	2.56	-	-	2.23	-	0.02	1.18	0.64	0.45	2.48	-	-	3.53	-	-	-	-
Cistus salvifolius	-	-	-	-	-	-	0.16	-	0.16	0.20	3.06	0.06	1.21	1.86	-	-	-	-	0.16	-	3.23	0.03	0.01	0.13	0.10	2.13	1.39	0.03
Cistus crispus	0.29	0.36	-	-	-	-	0.36	-	-	-	2.60	-	-	-	-	-	-	-	-	-	0.73	0.73	3.90	0.33	0.08	0.80	0.10	-
Phyllirea angustifolia	-	-	-	-	0.38	-	0.28	0.26	-	-	-	-	0.20	-	-	-	0.45	1.08	0.15	0.02	-	-	-	-	-	-	-	-
Rosmarinus officinalis	-	-	-	-	0.66	-	-	-	-	-	-	-	-	-	-	-	1.05	2.66	0.07	0.03	-	-	-	-	-	-	-	-
Erica umbellata	-	-	-	0.29	0.72	2.75	2.40	1.30	1.70	-	-	-	-	-	-	-	-	1.81	-	-	-	-	-	-	-	-	-	-
Ulex eriocladus	-	0.38	-	1.91	-	-	-	0.18	2.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lygos sphaerocarpa	-	-	-	-	-	-	-	-	-	-	-	-	5.10	2.57	0.87	-	-	-	-	-	-	-	-	-	-	-	-	0.20
Cytisus scoparius	-	-	0.03	-	-	-	0.20	-	0.20	-	-	0.65	-	-	-	-	-	-	-	-	0.20	-	-	-	-	-	-	-
Cistus monspeliensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.30	0.84	-	0.20	-	-	-	-
Daphne gnidium	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-	-
Halimium umbellatum	-	0.16	-	0.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	-	1.43	-	-
Genista triacanthos	-	-	2.06	-	-	2.30	0.89	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erica arborea	-	-	-	-	-	-	-	2.10	-	1.02	-	-	-	-	1.22	-	1.18	-	-	-	-	-	-	-	-	-	-	-
Thymus mastichina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus coccifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.03	-	-	-	-	-	-	-	-
Helichrysum stoechas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.05	-	-	-	-	-	-	-	-
Cistus populifolius	-	-	-	1.48	-	-	-	-	-	-	-	-	-	-	-	-	0.90	-	-	-	-	-	-	-	-	-	-	-
Cistus albidus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.23	-	-	-	-	0.55	-	-	-
Cytisus multiflorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.52	-	-	-	-	-	-	-	-	-	-	-	-
Genista tridentata	-	-	-	-	1.82	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myrtus communis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lithodora prostrata	-	-	-	-	-	-	0.62	-	0.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arbutus unedo	-	-	-	0.22	-	-	-	-	-	-	-	-	-	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-	-
Olea europaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erica scoparia	-	-	-	-	0.17	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-
Viburnum tinus	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pistacia lentiscus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelaea villosa	-	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Teucrium fruticans	-	-	-	-	-	-	-	0.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean annual temp. (°C)	16.5	16.5	16.3	16.5	15.5	16.3	16.5	16.8	16.8	16.3	16.3	15.6	16.5	16.5	16.2	13.8	15.5	15.5	15.5	15.5	16.3	16.0	16.3	16.5	15.7	15.2	16.2	16.5
Annual rainfall (cm)	72.0	71.0	65.0	72.0	86.0	60.0	70.0	75.0	73.0	55.0	60.0	65.0	59.0	70.0	70.0	140.	69.0	68.0	66.0	65.0	60.0	64.0	55.0	47.5	68.0	70.0	55.0	58.0
H'_1	1.97	2.05	2.01	2.83	2.71	2.70	3.03	2.80	2.86	2.51	2.45	2.80	2.58	2.63	1.95	2.04	2.15	2.70	1.93	2.87	2.80	1.94	1.64	2.32	1.13	2.36	1.52	1.15
H'_2	2.10	1.97	1.84	2.63	2.81	2.60	2.96	2.60	2.86	2.31	2.16	2.61	2.58	2.63	1.86	1.71	2.20	2.54	1.89	2.68	2.66	1.51	1.18	2.00	1.90	2.12	1.38	0.36
H'_3	1.58	1.65	2.23	2.73	2.47	2.67	2.99	2.86	2.80	2.62	2.19	2.88	2.46	2.45	2.27	2.05	1.78	2.62	1.49	2.68	2.74	1.77	1.33	2.00	0.72	2.34	2.07	0.57
H'_4	1.85	1.86	1.98	2.50	2.67	2.54	2.91	2.65	2.80	2.64	1.84	2.67	2.46	2.45	2.11	1.65	2.32	2.41	2.33	2.49	2.56	1.64	0.65	1.61	1.87	2.03	1.81	1.00
J'_1	0.70	0.68	0.67	0.79	0.82	0.90	0.82	0.81	0.83	0.76	0.87	0.81	0.75	0.88	0.69	0.73	0.65	0.90	0.61	0.83	0.84	0.75	0.71	0.77	0.40	0.84	0.54	0.58
J'_2	0.61	0.59	0.79	0.79	0.89	0.95	0.83	0.86	0.84	0.83	0.85	0.87	0.74	0.87	0.88	0.79	0.56	0.93	0.50	0.81	0.86	0.76	0.66	0.71	0.28	0.90	0.80	0.36
Species richness	6.00	7.00	7.00	11.0	9.00	7.00	12.0	10.0	11.0	9.00	6.00	10.0	11.0	8.00	6.00	6.00	9.00	7.00	8.00	10.0	9.00	5.00	4.00	7.00	6.00	6.00	6.00	4.00
Total site cover	5.35	3.29	14.5	14.3	12.9	19.0	18.8	12.8	19.4	14.0	10.6	15.2	11.1	15.2	13.3	12.8	6.74	15.6	5.13	11.6	14.8	7.52	5.52	9.31	2.09	11.0	13.0	6.85

Table 2. Values of mean cover of woody species and bare soil, mean annual temperature, annual rainfall, diversities (H'_1 to H'_4, explanation in the text), evenness (J'_1 and J'_2, explanation in the text), species richness and total site cover in the 57 sampling points. Sampling points are arranged according to the dendrogram in Fig. 7 (group A: 1–16; group B: 43–42 and group C: 52–30).

	34	35	3	21	40	42	52	51	41	55	53	54	5	4	13	56	50	17	32	57	23	29	30	20	14	47	48	18	46
Cistus ladanifer	4.35	0.35	7.57	5.72	2.80	4.45	6.48	5.73	8.64	5.96	6.21	7.05	7.10	4.08	5.47	7.84	6.76	4.68	7.89	5.24	8.59	4.83	5.10	5.25	8.41	7.52	7.30	6.20	6.94
Bare soil	2.15	5.04	2.35	2.64	1.40	3.16	2.77	2.14	0.96	3.51	3.81	1.28	1.35	3.51	3.14	2.21	1.61	3.12	1.99	2.83	0.99	4.47	4.18	1.55	1.40	1.83	2.70	3.80	-
Quercus rotundifolia	-	-	-	0.80	2.00	0.08	0.22	0.06	0.15	0.03	0.10	0.03	0.06	-	-	-	0.63	0.77	0.79	0.06	0.08	0.29	0.15	-	1.51	1.46	0.23	-	0.22
Quercus suber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quercus faginea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-
Quercus pyrenaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.08	-	-	-	-	-
Pinus pinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinus pinaster	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus sp.	-	-	-	-	-	1.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Castanea sativa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.53	-	-	-	-	-	-
Lavandula sampaiana	4.55	1.51	0.10	2.18	0.31	1.45	0.07	3.81	0.28	0.14	-	1.23	3.09	3.81	0.19	0.13	1.91	1.37	0.83	1.79	0.48	0.11	0.74	1.23	-	-	-	-	-
Lavandula luisieri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-
Halimium ocymoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erica australis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Genista hirsuta	-	-	-	-	-	-	0.67	1.42	1.71	1.06	0.05	5.62	0.31	0.13	2.85	0.08	1.09	0.40	-	1.46	-	0.43	0.16	-	-	-	-	-	-
Cistus salvifolius	1.20	2.75	-	-	0.53	0.68	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	-	-	-	-	-	-
Cistus crispus	-	-	-	-	0.23	-	-	-	-	-	-	-	-	-	-	-	0.01	0.13	-	-	-	-	-	-	-	-	-	-	-
Phyllirea angustifolia	-	-	-	0.56	0.49	-	-	-	-	-	-	0.05	0.04	-	-	0.10	-	-	-	-	-	-	-	-	-	-	-	-	0.50
Rosmarinus officinalis	-	-	-	0.34	2.09	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erica umbellata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ulex eriocladus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lygos sphaerocarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	1.22	0.03	0.18	0.89	-	-	-	-	-	-	-	-
Cytisus scoparius	-	-	-	-	-	-	-	-	-	-	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
Cistus monspeliensis	-	-	-	-	4.24	-	-	-	-	0.23	-	-	-	-	-	-	-	-	-	0.64	-	-	-	-	-	-	-	-	-
Daphne gnidium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	0.11	0.28	-	0.04	-	-	-	-	-	-	-
Halimium umbellatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-
Genista triacanthos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erica arborea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymus mastichina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.68	-	-	-	0.41	0.05	0.04	-	-	-	-	-
Quercus coccifera	-	-	-	0.60	0.61	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helichrysum stoechas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-
Cistus populifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cistus albidus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cytisus multiflorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.19	-	-	-	-	-	-	-	-
Genista tridentata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myrtus communis	-	-	-	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.83
Lithodora prostrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arbutus unedo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Olea europaea	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
Erica scoparia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Viburnum tinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pistacia lentiscus	-	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thymelaea villosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Teucrium fruticans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean annual temp. (°C)	16.2	16.2	16.5	16.3	16.5	16.5	14.5	15.0	16.5	15.8	14.5	15.5	16.5	16.5	16.8	16.8	16.0	16.5	16.2	16.0	16.5	15.5	15.5	15.6	16.5	16.5	16.5	14.6	16.5
Annual rainfall (cm)	55.0	55.0	65.0	68.0	47.5	47.5	57.0	58.0	47.5	57.5	48.0	57.5	63.0	63.0	78.0	57.5	53.0	70.0	60.0	57.5	70.0	66.0	68.0	90.0	69.0	62.0	60.0	103.	63.0
H'_1	1.83	1.60	0.86	2.21	2.91	2.11	1.35	1.85	1.23	1.55	1.07	1.73	1.59	1.76	1.62	1.00	1.85	2.56	1.44	2.24	1.48	1.71	1.82	1.79	1.08	1.19	0.98	0.96	1.35
H'_2	1.41	1.25	0.10	1.87	2.71	1.74	0.70	1.44	0.90	0.95	0.18	1.44	1.23	1.26	1.06	0.33	1.48	2.33	0.94	1.90	1.17	1.26	1.38	1.42	0.62	0.64	0.40	0.96	1.35
H'_3	1.38	1.42	0.25	2.21	2.72	1.89	1.11	1.52	1.52	1.22	0.27	1.36	1.49	1.27	1.17	0.81	1.96	2.54	1.64	2.17	2.04	1.31	1.52	1.42	1.00	0.99	0.20	0.00	1.85
H'_4	0.74	0.94	0.00	2.00	2.49	1.67	1.12	0.92	0.91	1.19	0.92	0.88	0.89	0.51	0.34	1.85	1.54	2.56	1.38	1.99	1.65	2.25	2.17	0.84	0.00	0.00	0.00	-	1.19
J'_1	0.92	0.80	0.54	0.79	0.81	0.75	0.58	0.80	0.53	0.60	0.54	0.62	0.53	0.76	0.81	0.39	0.66	0.81	0.56	0.75	0.57	0.54	0.57	0.77	0.68	0.75	0.62	0.96	0.52
J'_2	0.87	0.90	0.25	0.85	0.79	0.73	0.56	0.76	0.76	0.53	0.17	0.53	0.53	0.64	0.74	0.35	0.76	0.85	0.71	0.78	0.88	0.44	0.51	0.71	1.00	0.99	0.40	-	0.80
Species richness	3.00	3.00	2.00	6.00	11.0	6.00	4.00	4.00	4.00	5.00	3.00	6.00	6.00	4.00	3.00	5.00	6.00	8.00	5.00	7.00	5.00	8.00	8.00	4.00	2.00	2.00	2.00	1.00	6.00
Total site cover	10.1	4.61	7.67	9.90	13.3	8.08	7.44	11.0	10.8	7.42	6.36	14.1	10.7	8.26	8.51	8.18	10.4	9.75	9.65	9.65	11.2	6.20	6.87	10.6	9.92	8.98	7.53	6.20	10.7

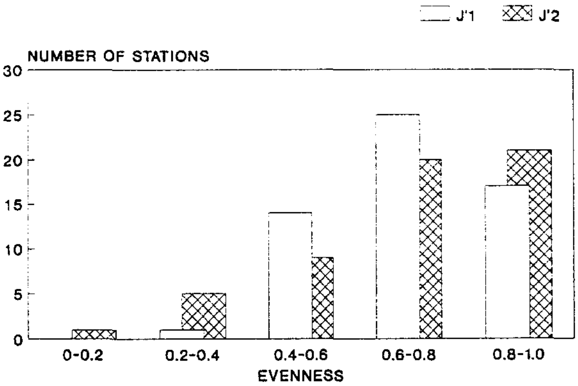

Fig. 4. Frequency distribution of evenness (J'_1 to J'_2, explanation in the text) in the sampling points.

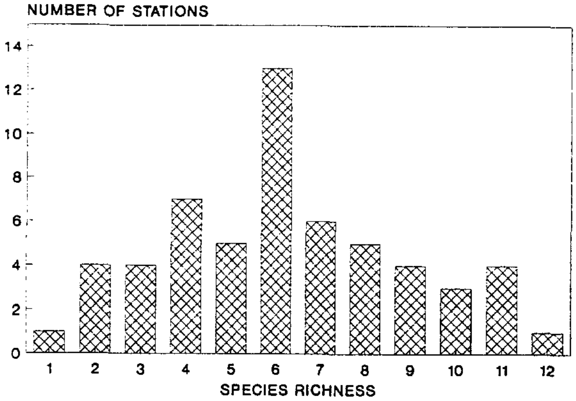

Fig. 5. Frequency distribution of species richness in the sampling points.

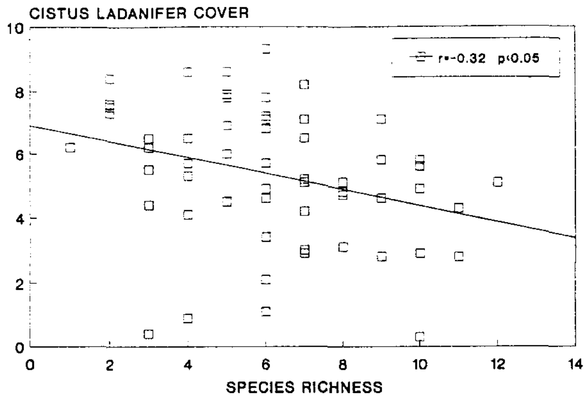

Fig. 6. Correlation between *Cistus ladanifer* cover and species richness.

Table 3. Correlation coefficients between diversity, evenness and species richness of the sampling points. Significance levels: (a) 99.9%, (b) 99%, (c) 95%.

	H'1	H'2	H'3	H'4	J'1	J'2	S
H'1	1						
H'2	0.95^a	1					
H'3	0.92^a	0.89^a	1				
H'4	0.82^a	0.84^a	0.83^a	1			
J'1	0.66^a	0.60^a	0.51^a	0.24^c	1		
J'2	0.57^a	0.57^a	0.72^a	0.30^b	0.73^a	1	
S	0.85^a	0.85^a	0.83^a	0.91^a	0.21	0.25^c	1

these and species diversity, although a markedly less significant correlation with H'_4 is found (Table 3).

Species richness, with values between 1 and 12 and a mode of 6 (Fig. 5), is closely correlated ($p < 0.001$) with species diversity (Table 3), especially when jara and bare soil are excluded. It also has a certain negative correlation (r = – 0.32, $p < 0.05$) with the abundance of jara, so that the sites with high jara cover generally have lower species richness (Fig. 6), with exceptions in slightly Atlantic scrubs, where species such as *Lavandula luisieri*, *Erica umbellata* and *E. australis* overlap with jara.

Classification and ordination Three groups of sites (A, B and C) were recognized in the dendrogram obtained from the intersite similarity matrix (Fig. 7). Group A includes sites situated at the west of the region (Fig. 1), with *Lavandula stoechas* subsp. *luisieri*, *Halimium ocymoides* and *Erica australis* as basic key species. *Quercus suber* and/or *Q. rotundifolia* constitute the tree layer when it is present, and *Ulex eriocladus*, *Genista triacanthos* and *Erica umbellata* are exclusive of this group. Mean annual rainfall of sites of group A reaches 681 mm (Table 2), significantly higher ($p < 0.01$ or $p < 0.05$) than that of groups B (582 mm) and C (607 mm). Also, there is a tendency, in sites of group A, to have a lower difference between the mean temperatures of the coldest and the hottest months than in localities of groups B and C (calculations based on Cabezas Fernández & Escudero García 1989 and Vicente Calle *et al.* 1993). This indicates a more Atlantic influence. However, mean annual temperature of group A is only slightly higher than that of group C (16.4 and 15.9 °C, respectively; $p < 0.05$) and is not significantly different from that of group B. Total cover and all diversities, including species richness, are significantly higher ($p < 0.001$) in group A than in groups B and C. Groups B and C are floristically separated from A by the presence of *Lavandula stoechas* subsp. *sampaiana* and the absence of *Halimium ocymoides*, *Erica australis*, *Ulex eriocladus* and

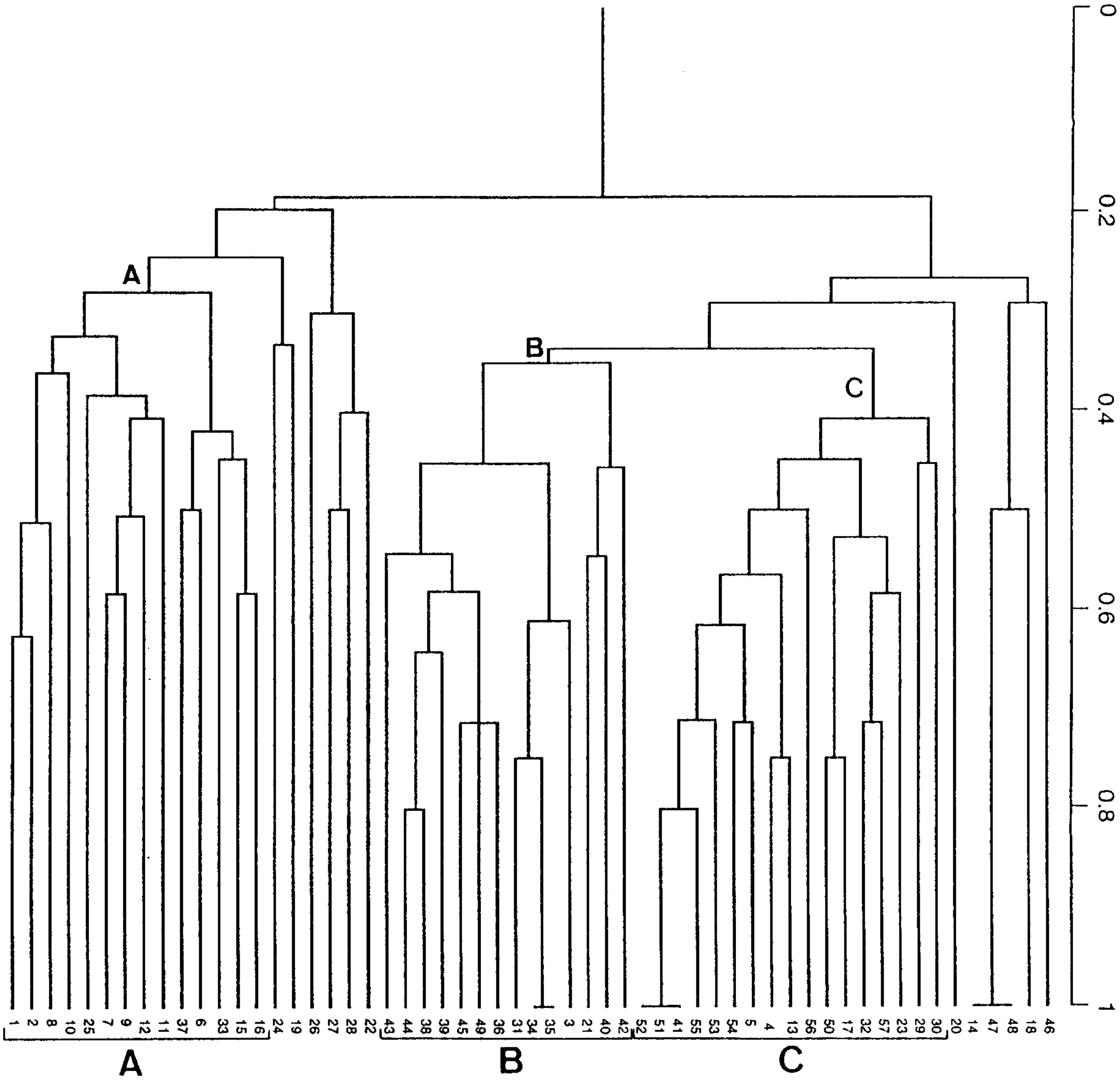

Fig. 7. Dendrogram of sampling points obtained from the matrix of intersite qualitative similarity (Jaccard's index). Letters A, B and C indicate the three groups of localities recognized.

Erica umbellata. The tree layer is constituted, when present, by *Quercus rotundifolia.* Key species to distinguish both groups are *Cistus salvifolius* and/or *C. crispus* (group B) and *Genista hirsuta* (group C). A tree layer is much more frequent in group C than in B. There are no significant differences in mean annual temperature, annual rainfall, total cover or diversity between these groups, with the exception of H'_2 ($p < 0.05$). However, a certain geographical division can be established, with group C situated more to the east (probably with more continental influence). Finally, the rest of the sites are not well-characterized. They may have diverse tree layers, either natural or reafforested, the shrub layer being intermediate between groups A and B (sites 24 to 22, Table 2) or extremely poor in species (sites 20 to 46, Table 2). The ordination of the sites obtained by the two first axes of PCA (Fig. 8) reflects cover and climate gradients. However, since cover is strongly dependent of climate, the sequence of groups A, B and C is very similar on both axes: the more Atlantic sites of group A, where total cover rises far above 100%, have positive scores, and the more

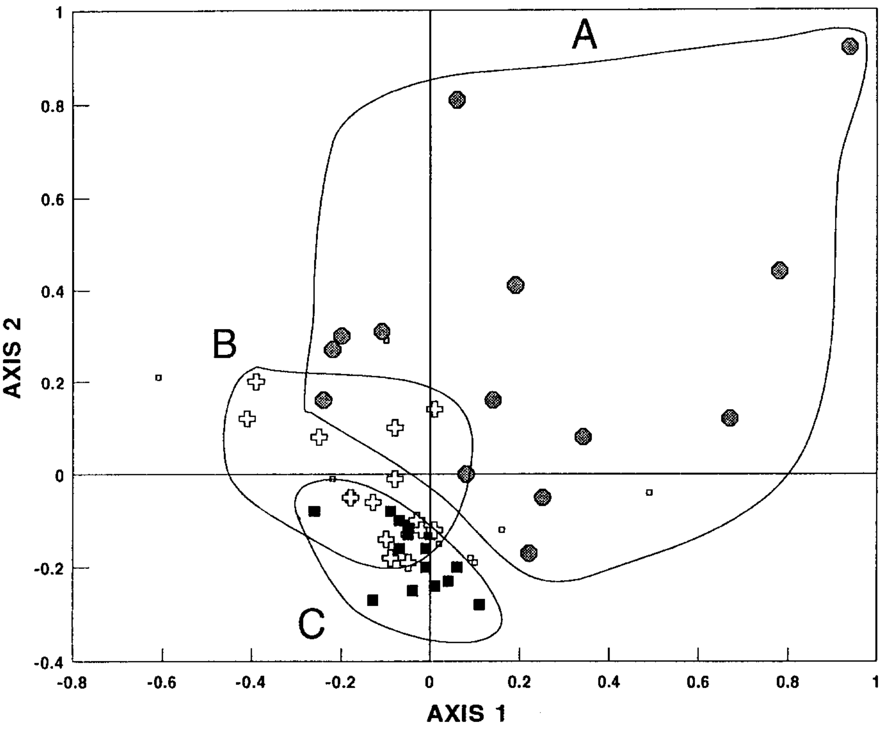

Fig. 8. Arrangement of sampling points on the first two axes of PCA. The three groups of localities recognized in the cluster analysis of Fig. 3 are indicated (A, B and C). The symbol □ represents those sites not included in any of the groups.

continental sites of groups B and C, with low shrub cover and abundant bare soil, have negative scores. The much wider dispersion of the points of group A is probably due to higher species richness, and hence to higher variability.

Discussion

Jaral scrubs extend over all the ombroclimates and bioclimatic belts of Extremadura. Despite their apparent physiognomic homogeneity, most of the scrubs studied here have a diversity of woody species within the range of 1 to 3, similar to other Mediterranean shrublands (Basanta & García-Novo 1988). At least two factors are responsible for the rather high diversity values of Mediterranean shrublands in comparison with other temperate woody communities: 1) the effect of low fertility of acid soils on the processes of competition-dominance (Marañón & Arroyo 1991); 2) the dual biogeographical origin, temperate and tropical, of the ancestors of the present shrub flora, and their subsequent diversification in an environmental mosaic (Pons 1981; Herrera 1984). The differences between the four diversity indices reveal the different weight of *Cistus ladanifer*, bare soil and the rest of the species on the structure of the jaral. The general change in diversity values when bare soil is considered as an additional variable emphasizes the importance of lack of cover in determining the shrubland structure in the Mediterranean area, where the development of a continuous and/or stratified vegetation cover is strongly limited. When bare soil is included in the calculations, the response of Mediterranean shrubland diversity to perturbations is more predictable (Basanta & García-Novo 1988) and, in other vegetation types, also the correlation between diversity and biotope variables is strongly enhanced (Martínez-Abaigar *et al.* 1991). However, we have found no significant correlation between diversity indices and the climatic variables considered. Generalized decreases in diversity have resulted when both *C. ladanifer* and bare soil (the two more frequently dominant variables) have been excluded, although Shannon's index is more sensitive to the abundance of rare species (Peet 1974). This type of diversity (H'_4) shows the weakest correlations with the rest of diversity indices except, of course, for species richness. The evenness of the shrublands is above 0.5, indicating that they are tending towards their maximum diversity. Although contradictory opinions on the use of species richness as a diversity index exist (Trabaud and Lepart 1980; Margalef 1991), we have found a very significant correlation between Shannon's indices and species richness. So, species richness is a good diversity indicator in the jaral.

Three groups of sites are clearly established by the clustering analysis, characterized by the same key species used to differentiate phytosociological associations within the classes *Calluno-Ulicetea* and *Cisto-Lavanduletea*: *Halimium ocymoides*, *Lavandula stoechas* subsp. *luisieri*, *Ulex eriocladus*, *Genista hirsuta*, *Erica umbellata* (Rivas-Martínez 1979). Shrublands of group A are more related to the former, more Atlantic class, but, within it, with those associations (*Halimium ocymoidis-Ericetum umbellatae* and *Ulici eriocladi-Ericetum umbellatae*, suballiance *Ericenion umbellatae*) less genuinely Atlantic. Shrublands of group C correspond best to the association *Genisto hirsutae-Cistetum ladaniferi* (*Cisto-Lavanduletea*), that constitutes an advanced degradation phase of *Quercus rotundifolia* or *Q. rotundifolia-Q. suber* woodlands under more continental climates (Rivas-Martínez 1979). Finally, shrublands of group B seem to be transitional between groups A and C. Probably the ultimate distinction between groups B and C is based on soil pH, since *Cistus salvifolius* and *C. monspeliensis* (group B) characterize less acid soils (5.8–6.2) than those typical of other jaral scrubs (4.8–5.8) (Núñez-Olivera 1989).

Both classification and PCA emphasize that ecological structure (diversity indices, total cover) of Mediterranean shrublands is intensely influenced by humidity and the annual range of monthly mean temperatures. In sites with a more severe drought and a wider amplitude of temperature (groups B and C), diversity and total cover are significantly lower than in more humid and milder sites (group A). Drought can have a climatic, but also an edaphic origin, because of the shallowness and sandy texture of jaral soils. This factor is of crucial importance for plants as *Cistus*, with shallow root systems (Martín Bolaños & Guinea López 1949).

In the overall family of jaral scrubs, a clear predominance of species showing the type I syndrome of Herrera (1984) is observed (species of *Cistus*, *Lavandula*, *Erica*, *Thymus*, *Rosmarinus*, *Halimium*, etc.). They are generally summer semideciduous evergreen shrubs with small seeds and large, coloured and hermaphrodite flowers. By contrast, few and generally rare species, within the genera *Quercus*, *Pistacia* or *Phyllirea*, belong to the type II. They are evergreens with sclerophyllous leaves, large seeds and small, noncoloured unisexual flowers. The postulate that type-I plants have evolved under Mediterranean conditions whereas those of type II are representative of an ancient flora (Herrera 1984) completely agrees with the outstanding morphological, phenological and ecophysiological adaptation of jaral to Mediterranean environment (Núñez-Olivera & Escudero-García 1990; Núñez-Olivera *et al.* 1993, 1994a, 1994b).

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