EDICIONES COMPLUTENSE

Mediterranean Botany
ISSN-e: 2603-9109

ARTICLES

A Floristic-ecological classification of gorse scrub communities with *Echinospartum ibericum* (Fabaceae) in the Iberian Peninsula

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https://doi.org/10.5209/mbot.92111 Received: 14 October 2023 / Accepted: 29 September 2025 / Published online: 29 January 2026

Abstract. We analysed 194 phytosociological relevés from *Echinospartum ibericum* scrub communities across the Iberian Peninsula. Classification and ordination of the relevés were performed using multivariate statistical analyses, yielding 13 groups comprising nine syntaxa (associations or subassociations), three variants, and one transitional unit. For each community, we documented the distribution, bioclimatic characteristics, diagnostic species, and phytosociological class affinities of the participating flora. Relevés taken at higher altitudes were enriched in species of Junipero-Pinetea, whereas those from lower altitudes were enriched in species of the class Cytisetea. However, of the 12 communities identified, Cytisetea scopario-striati species predominated in eight, Festucetea indigestae in two, Calluno-Ulicetea and Junipero-Pinetea in one. A syntaxonomic scheme is presented in accordance with these results.
Keywords: vegetation classification, pulvinate scrub, hierarchical cluster analysis (HCA), non-metric multidimensional scaling (NMDS).

How to cite: Pulgar, I. & Herrera, J.M. 2026. A Floristic-ecological classification of gorse scrub communities with Echinospartum ibericum (Fabaceae) in the Iberian Peninsula. Mediterr. Bot. 47(1), e92111. https://doi.org/10.5029/mbot.92111

Introduction

Echinospartum (Spach) Fourr. —commonly known as 'cambrión', 'friar's cushion', among other names— is a genus of gorse-like shrubs comprising five species, four of which are endemic to the Iberian Peninsula and one (*E. horridum*) shared between France and Spain. Two species grow on calcareous substrates (*E. horridum* and *E. boissieri*), whereas the remaining three (*E. algibicum*, *E. barnadesii* and *E. ibericum*) occur on siliceous soils in the western half of the Iberian Peninsula (Talavera, 1999). According to Aparicio et al. (2002), the three species on siliceous substrates may have arisen through population isolation following the cold phases of the Quaternary. All species inhabit xeric environments owing to the scarcity of soil within the crevices of large rocky outcrops, where they root. Such environments are widespread in Iberian mountains of Mediterranean and sub-Mediterranean type, where communities containing members of the genus are particularly localised. This study focuses on communities containing *E. ibericum* Rivas Mart., Sánchez-Mata & Sancho, the species with the largest distribution area—from Sierra Morena to Galicia—mainly on granite and quartzite substrates. Within its distribution area, it occupies elevations of 700–2200 m asl (Talavera, 1999). As a woody shrub, the species can be classified as a nanophanerophyte or a chamaephyte, often forming pulvinate growth in high-mountain environments. Following the biogeographical framework of Rivas-Martínez *et al*. (2017a), it is endemic to the Western Iberian Mediterranean Province, with incursions into the Eurosiberian Region. These communities are of high conservation interest, as they form part of habitat type 4090 under the Habitats Directive 92/43/EEC, are rich in endemic species of the siliceous rocky areas of the western Iberian Peninsula, and are mostly located within protected areas of the Natura 2000 network.

Previous syntaxonomic treatments

Communities dominated by *E. ibericum* have been studied for decades across mountainous areas of the Iberian Peninsula. Considering the Iberian *Echinospartum* communities as a whole, Rivas-Martínez *et al*. (2001) proposed a classification reflecting an altitudinal gradient. Subsequently, new syntaxa have been described (Cano *et al*., 2007; Vicente-Orellana & Galán de Mera, 2008;

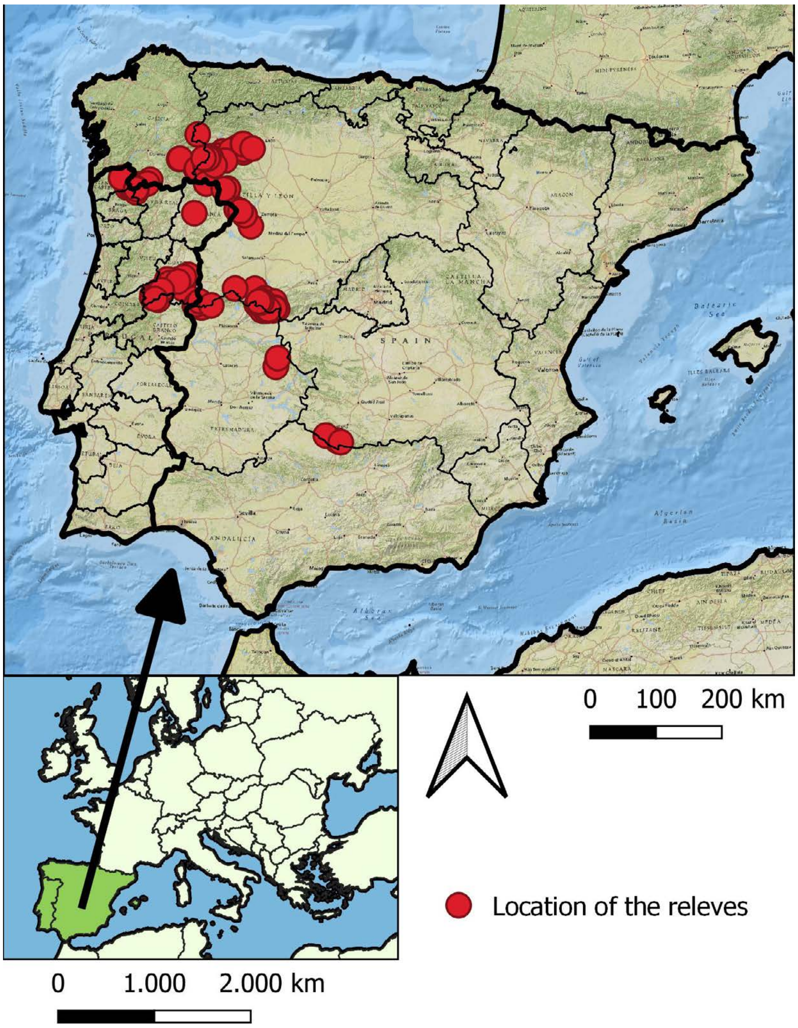

Figure 1. Distribution map of the *Echinospartum ibericum* relevés analysed.

González de Paz *et al*., 2012) and partial revisions of the *E. ibericum* and *E. barnadesii* communities have been made (Costa *et al*., 2003; Gavilán *et al*., 2011; Amor & Ávila, 2012). In this study, we provide new relevés from the north-western limit of the species' distribution and, together with those of González de Paz (2012) and Honrado (2003), incorporate them into the published dataset, with the aim of characterising *E. ibericum* communities using a phytosociological approach. Specifically, our objectives are: (1) to characterise *E. ibericum* communities from floristic and bioclimatic perspectives; and (2) to provide an updated syntaxonomic scheme for these communities, based on the European vegetation synthesis by Mucina *et al*. (2016).

Material and methods

Data sources and management

The study comprised 194 relevés containing *E. ibericum*, which were conducted according to the Braun-Blanquet methodology (Braun-Blanquet, 1979; Figure 1). The dataset covered the western Iberian Peninsula, extending from Sierra Morena to Galicia and northern Portugal. Of these, 177 relevés were compiled from the literature (Table S1), and 17 were unpublished relevés from the north-western end of the species' distribution (Serra do Xurés) (Table 1). Only the relevés from the original tables of the syntaxa that included *E. ibericum* were incorporated into the analysis, as it is beyond the scope of this study to characterise biotopes without the occurrence of this species. At the taxonomic level, this study followed the nomenclature of *Flora Iberica* (Castroviejo *et al*., 1986–2021), not recognising the intraspecific taxa of *E. ibericum* (Talavera, 1999). Using the WorldClim database (Fick & Hijmans, 2017), with a spatial resolution of 1 km^2, the following bioclimatic indices were calculated for each relevé: thermicity index (It), annual ombrothermic index (Io), and continentality index (Ic); these indices were used to establish the bioclimatic units (Rivas-Martínez *et al*., 2017b). Relevés that lacked 1 × 1 km grid-square references were located as accurately as possible on the basis of the reported altitude and the descriptions provided in the published sources. Relevés located within the same grid-square were assigned the same mean values for each index.

Data analysis

The main vegetation types were identified through hierarchical cluster analysis (HCA) and non-metric multidimensional scaling (NMDS) ordination.

To conduct the HCA, vegetation cover values were transformed to the combined scale (van der Maarel, 1979). We then calculated the Hellinger distance matrix based on the species data (Legendre & Legendre, 2003; Borcard *et al*., 2011), which down-weights high abundances relative to low ones and avoids similarities arising from joint absences. We used this matrix to obtain floristic relationships between relevés and subsequently performed hierarchical clustering using Ward's minimum variance method (Ward, 1963).

The optimal number of clusters was determined using three separate analyses. The first analysis compared the dissimilarity matrix with the binary matrices of the successive partitions (Borcard *et al*., 2018). This technique compared the original dissimilarity matrix with binary matrices calculated by cutting the dendrogram at various levels. The second analysis calculated the average silhouette widths (Rousseeuw, 1987). Silhouette width is a measure of the degree to which an object belongs to its group, based on the average difference between that object and all objects in its own group, compared to the same measure calculated for the next-closest group. At each fusion level, the average silhouette width can be used as a measure of the quality of the partition (Rousseeuw quality index). The third method used was the species fidelity analysis (Borcard *et al*., 2018), which forms groups based on a set of diagnostic species, that is, species that are significantly more frequent and abundant in a specific group of sites. Specifically, the best partition maximises both (i) the sum of the indicator values and (ii) the proportion of clusters with significant indicator species. In this study, we used the IndVal index (Dufrêne & Legendre, 1997) with a significance threshold of $p \leq 0.01$.

Once the optimal number of clusters was established, a synoptic table analysis was carried out. Diagnostic species were defined as those with IndVal ≥ 0.4 and $p \leq 0.01$, using the extension developed by De Cáceres *et al*. (2010b), which identifies indicator species for individual site groups and combinations of site groups. Constant species were defined as those that occur in ≥ 50% of a cluster's relevés, and dominant species as those with cover > 25% in more than 50% of the relevés.

To visualize the relationships between the main groups of relevés, an NMDS ordination was carried out using the Hellinger distance in three dimensions ($k = 3$). Environmental variables were passively represented by vectors that maximised the linear correlation between each explanatory variable and the NMDS axes.

Spearman's rho correlation coefficient was used to evaluate pairwise correlations between bioclimatic indices and altitude. An affinity analysis of the groups for specific phytosociological classes was carried out. For this, the species present in each relevé were assigned to the corresponding phytosociological class using the catalogue of Rivas-Martínez *et al*. (2011). The percentages of phytosociological classes in each group were calculated by summing, for each relevé, the number of species assigned to each class.

Statistical analyses were performed with the 'vegan' (Oksanen *et al*., 2018) and 'indicspecies' (De Cáceres & Jansen, 2016) packages using the R software environment (R Core Team, 2018).

Results

Multivariate analysis-HCA

Across 194 phytosociological relevés, 189 vascular plant species were recorded. *E. ibericum* had a mean cover of 41%. The most frequent species co-occurring with *E. ibericum* (> 25% of relevés) were *Festuca yvesii* subsp. *summilusitana* (48%), *Avenella flexuosa* (37%), *Cytisus oromediterraneus* (36%), *Sedum brevifolium* (32%), *Helictochloa marginata* (29%) and *Erica arborea* (26%).

The HCA of the *E. ibericum* communities is shown in Figure 2. The analyses indicated 13 clusters from both the comparison of the dissimilarity matrix with binary matrices of successive partitions and the species-fidelity analysis, and 14 clusters from the average silhouette-width criterion.

After examining the two partitions from floristic and biogeographical perspectives, a 13-cluster solution was selected. This partition appears to reflect an altitudinal division into three main branches: clusters 1–6 at low-altitude sites (680–1600 m asl), clusters 7–10 at high-altitude sites (1637–2390 m asl), and clusters 11–13 at intermediate-altitude sites between the other two branches (1069–1640 m asl).

The 13 clusters exhibit distinctive floristic compositions with characteristic diagnostic species (exclusive or shared among clusters), as shown in the synoptic table (Table S2), together with constant and dominant species.

Physiognomically, all clusters, except 6, 9 and 11, are dominated by *E. ibericum*. Clusters 6 and 11 lack dominant species, whereas cluster 9 has *Juniperus communis* subsp. *alpina* as the sole dominant.

Multivariate analysis-NMDS

The NMDS (Figure 3) yielded a three-dimensional solution (final stress = 0.17) with linear and non-metric goodness-of-fit values of $R^2 = 0.795$ and 0.969, respectively. The 13 clusters detected by HCA were arranged along the main axes. Clusters 1–6 were opposed to clusters 7–10 along axis 1, while clusters 1 and 8–10 were separated from clusters 4–6 and 11–12 along axis 2. Axis 3 separated clusters 2, 3, 8, 9, and 12 from clusters 1 and 11.

The species with the highest positive correlations (> 0.4) with axis 1 were *Cytisus oromediterraneus*, *Avenella flexuosa*, *Neoschischkinia truncatula* subsp. *truncatula*, and *Arrhenatherum elatius*, whereas *Helictochloa marginata*, *Cytisus multiflorus*, *Neoschischkinia truncatula* subsp. *durieui*, *Genista hystrix*, and *Pterospartum tridentatum* showed the highest negative correlations. On axis 2, *Festuca yvesii* subsp. *summilusitana* and *Sedum brevifolium* showed strong positive correlations (> 0.4), while no species showed a negative correlation on this axis. On axis 3, *Genista hystrix* and *Juniperus communis* subsp. *alpina* showed the highest positive correlations, whereas *Sedum brevifolium* showed the highest negative correlation.

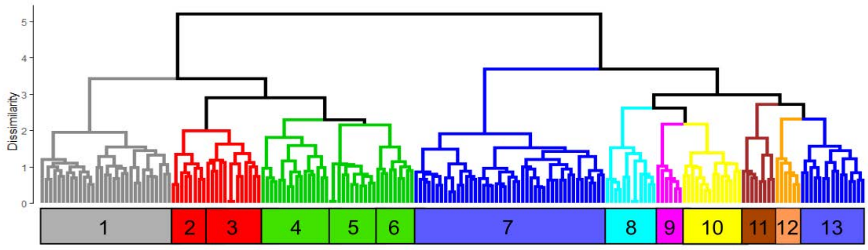

Figure 2. Hierarchical clustering (Hellinger distance and Ward's minimum variance method) of *Echinospartum iberici* communities. The colours denote the different associations, and the numbers indicate the clusters (k = 13). Grey, *Festuco summilusitanae-Echinospartetum* (1); red, *Genisto hystricis-Echinospartetum* (2), *Genisto hystricis-Echinospartetum* var. *Dianthus laricifolius* subsp. *merino* (3); green, *Echinospartetum* var. *Erica arborea* (4), *Echinospartetum* (5), *Echinospartetum* var. *Halimium lasianthum* subsp. *alyssoides* (6); dark_blue, *Cytiso oromediterranei-Echinospartetum* (7), *Cytiso oromediterranei-Echinospartetum* (transitional unit) (13); light blue, *Teucrio salviastri-Echinospartetum* (8); pink, *Genisto sanabrensis-Juniperetum alpinae* subass. *echinospartetosum* (9); yellow, *Armerio ciliatae-Echinospartetum* (10); brown, *Genisto cinerascentis-Adenocarpetum argyrophylli* subass. *echinospartetosum* (11); orange, *Cytiso oromediterranei-Genistetum cinerascentis* var. *E. ibericum* (12).

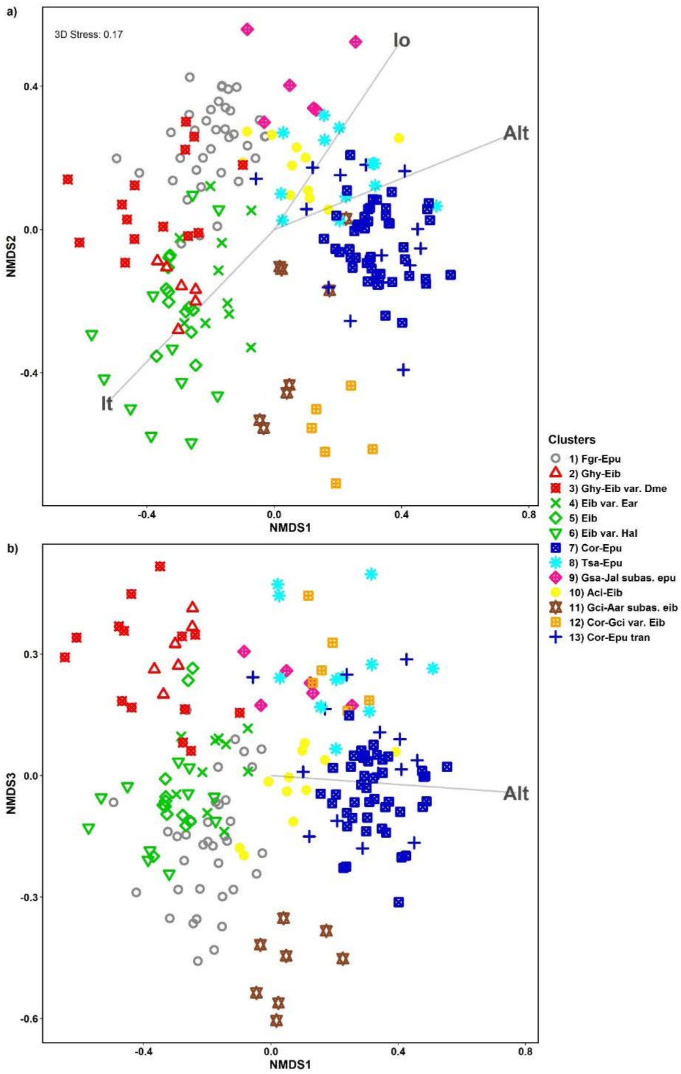

Figure 3. Non-metric multidimensional scaling (NMDS; Hellinger distance). A, axes 1 and 2; b, axes 2 and 3. Grey lines denote vectors of environmental variables. Bioclimatic indices: It, thermicity index; Io, ombrothermic index; Ic, continentality index; Alt, elevation. Syntaxon: Fsu-Eib, *Festuco summilusitanae-Echinospartetum*; Ghy-Eib, *Genisto hystricis-Echinospartetum*; Ghy-Eib var. Dme, *Genisto hystricis-Echinospartetum* var. *Dianthus merinoi*; Eib var. Ear, *Echinospartetum* var. *Erica arborea*; Eib, *Echinospartetum iberici*; Eib var. Hal, *Echinospartetum* var. *Halimium alyssoides*; Cor-Epu, *Cytiso oromediterranei-Echinospartetum*; Tsa-Epu, *Teucrio salviastri-Echinospartetum*; Gsa-Jal subas. epu, *Genisto sanabrensis-Juniperetum alpinae* subas. *echinospartetosum*; Aci-Eib, *Armerio ciliatae-Echinospartetum*; Gci-Aar subas. eib, *Genisto cinerascentis-Adenocarpetum argyrophylli* subas. *echinospartetosum*; Cor-Gci var. Eib, *Cytiso oromediterranei-Genistetum cinerascentis* var. *E. ibericum*; Cor-Epu tran, *Cytiso oromediterranei-Echinospartetum* (transitional unit).

Environmental factors

As shown by the vectors of environmental variables superimposed on the NMDS ordination (Figure 3; correlations > 0.4), axis 1 is positively correlated with altitude (Alt) and the annual ombrothermic index (Io) and negatively correlated with the thermicity index (It). Both Io and It are strongly correlated with Alt and partially correlated with the continentality index (Ic) (Figure S1). Clusters 7–10 comprise relevés taken at higher-altitude sites, whereas clusters 1–6 comprise those taken at lower-altitude sites. A similar pattern is also evident for Io. Axis 1 can be interpreted as a gradient of increasing Io and decreasing It. Axis 2 is positively correlated with Io and negatively with Ic and It. Clusters 11–12 comprise relevés with high Ic and It and low Io, whereas clusters 8–10 comprise relevés with low Ic and It and high Io. This axis can be interpreted as a gradient of increasing Io and decreasing Ic and It. Finally, axis 3 shows no significant correlations with the bioclimatic variables and does not reflect any gradient in the bioclimatic variables considered.

Syntaxonomic analysis

The proportional representation of diagnostic species belonging to phytosociological classes or subordinate syntaxa (Rivas-Martínez *et al*., 2011; Figure 4) shows that all clusters include species of the class Cytisetea scopario-striati, which is the dominant class in all clusters except clusters 1, 9, 10, and 12. In cluster 1, species of the class Calluno-Ulicetea predominate (19%); in cluster 9, those of the class Junipero-Pinetea predominate (30.6%); and in clusters 10 and 12, species of the class Festucetea indigestae predominate slightly (24.7% and 22.9%, respectively). In the remaining clusters, species of the class Cytisetea have the highest proportional representation, with the highest proportion (48.3%) in cluster 5.

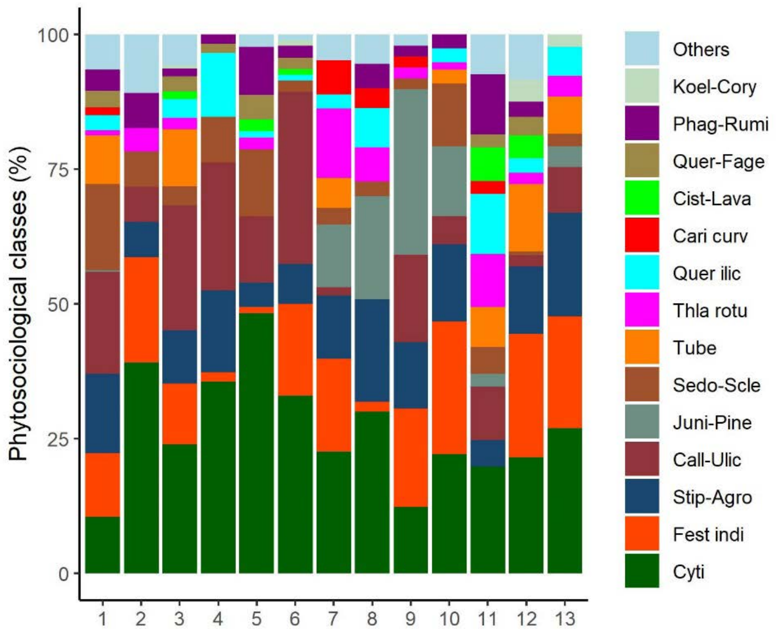

Figure 4. Percentage of phytosociological classes in each of the 13 clusters. Values are weighted by species frequency within clusters. Phytosociological classes: Koel-Cory, Koelerio-Corynephoretea canescentis; Phag-Rumi, Phagnalo-Rumicetea; Quer-Fage, Querco-Fagetea sylvaticae; Cist-Lava, Cisto-Lavanduletea; Cari curv, Caricetea curvulae; Quer ilic, Quercetea ilicis; Thla rotu, Thlaspietea rotundifolii; Tube, Tuberarietea; Sedo-Scle, Sedo-Scleranthetea; Juni-Pine, Junipero-Pinetea; Call-Ulic, Calluno-Ulicetea; Stip-Agro, Stipo giganteae-Agrostietea castellanae; Fest indi, Festucetea indigestae; Cyti, Cytisetea.

Plant community description

On the basis of the statistical analyses presented above and the details provided in the synoptic table (Table S2), nine associations are recognised (clusters 1–13; Figure 2). Three variants (clusters 3, 4 and 6) and one transitional unit (cluster 13) were identified within these nine associations. In cases where two clusters were merged into a single group, the values of diagnostic, constant and dominant species, as well as the syntaxonomy and bioclimatology, were recalculated.

Festuco summilusitanae-Echinospartetum iberici Costa Ten., Morla & Sáinz-Ollero 1993 nom. corr. (cluster 1)

[*Festuco graniticolae-Echinospartetum lusitanici*, Costa Ten., Morla & Sáinz-Ollero, in *Lazaroa* 13: 144, T. 1. 1993 (art. 43).] Taxonomic corrections: *Echinospartum ibericum* subsp. *pulviniformis* (Rivas Mart.) Rivas Mart. 1987 in *Lazaroa* 7: 111, should be *Echinospartum ibericum* Rivas Mart., Sánchez-Mata & Sancho; and *Festuca graniticola* Kerguélen & Morla 1985 in *An. Jard. Bot. Madrid* 42(1): 156, should be *Festuca yvesii* subsp. *summilusitana* (Franco & Rocha Afonso) Mart.-Sagarra & Devesa in *Acta Bot. Malac.* 46 (2021).

E. ibericum thorny gorse scrubs occur in the Supratemperate sub-Mediterranean belt of the NW of the Iberian Peninsula (Galicia, W Zamora, N of Portugal).

Table 1. New relevés (New-Rel) contributing to *Echinospartum ibericum* communities.
Species not ordering according to any syntaxonomical unit.

Altitude (1=10 m asl)	120	102	143	132	132	127	96	123	107	151	153	153	154	153	117	135	102
Cover (%)	40	20	30	30	50	30	60	60	60	40	40	60	30	30	50	30	30
Orientation	S	E	-	SE	-	W	SE	S	E	S	S-SE	SE	S	SE	S-SW	S-SE	S
Area (m^2)	10	8	5	10	6	50	6	10	60	10	14	2	8	10	90	20	20
Inclination (%)	5	<5	-	<5	-	<5	5	5	20	<5	5	<5	5	45	5	<5	5
N. species	13	15	10	9	9	10	10	13	17	9	11	3	8	11	19	8	14
Relevé N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Echinospartum ibericum	2	3	3	3	3	3	2	3	4	2	3	3	3	2	3	2	3
Sedum brevifolium	1	+	2	1	2	2	2	2	3	3	2	.	2	1	1	1	1
Festuca yvesii subsp. *summilusitana*	2	1	3	3	2	.	2	3	3	2	2	2	3	2	.	1	.
Pterospartum tridentatum	2	1	.	.	+	.	+	.	.	+	2	2	1	1	1	1	1
Neoschischkinia truncatula subsp. *durieui*	+	1	1	1	1	1	1	.	.	1	.	.	2	.	2	1	.
Thymus caespititius	.	1	2	1	.	2	.	2	.	+	1	.	1	r	.	1	.
Helictochloa marginata	.	1	1	.	1	.	.	1	r	+	1	.	.	1	+	.	1
Ornithogalum concinnum	+	+	+	.	r	+	1	+	r	.	.	.	.	.	1	.	.
Silene acutifolia	1	.	.	1	+	.	.	r	1	.	.	.	.	.	.	.	.
Erica umbellata	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	1	1
Minuartia recurva	.	.	.	.	.	.	.	r	.	2	+	.	+	1	.	.	.
Hypochaeris radicata	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	r	+
Dianthus langeanus	1	.	.	.	.	.	2	.	2	.	.	.	.	.	1	.	.
Logfia minima	.	+	.	.	.	r		.	r	.	.	.	.	.	.	.	1
Micropyrum tenellum	.	+	.	.	.	.	1	.	1	.	.	.	.	.	r	.	.
Jasione sessiliflora	r	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	2
Phalacrocarpum oppositifolium subsp. *hoffmannseggii*	1	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.
Sedum hirsutum	1	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.
Solidago virgaurea	.	.	.	1	.	.	.	.	.	r	.	.	.	.	.	.	1
Armeria humilis subsp. *humilis*	.	.	.	.	+	.	.	.	.	.	r	.	1	.	.	.	.
Holcus gayanus	.	.	.	.	.	.	.	.	1	.		.	.	r	1	.	.
Spergula morisonii	.	.	.	.	.	.	.	.		.	r	.	.	r	r	.	.
Erica arborea	+	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Narcissus bulbocodium	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis curtisii	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Calluna vulgaris	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Rumex angiocarpus	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+
Molineriella laevis	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.
Halimium umbellatum subsp. *umbellatum*	.	.	.	.	.	2		.	2	.	.	.	.	.	.	.	.
Conopodium majus	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
Allium sphaerocephalon	.	.	.	.	.	.	.	r	+	.	.	.	.	.	.	.	.

Other species: *Scilla monophyllos* + in 2; *Allium ericetorum* and *Hyacinthoides paivae* r in 3; *Sedum pruinatum* +, *Arenaria querioides* 1 in 6; *Festuca paniculata* s.l. +, *Centaurea langei* subsp. *geresensis* r in 8; *Carex binervis* +, *Tulipa sylvestris* subsp. *australis* r in 11; 14*: Erica australis* and *Sedum anglicum* 1 in 14; *Anthoxanthum ovatum* subsp. *Aristatum*, *Avenella flexuosa*, *Sedum arenarium* and *Festuca elegans* +, *Coincya monensis* subsp. *cheiranthos* and *Luzula lactea* r, *Plantago holosteum* 1 in 15; *Festuca* sp. 2, *Anarrhinum bellidifolium* 1 in 17.

Localities: from Spain (Ourense province): 2: Lobios, Serra de Santa Eufemia, 29TNG7032; 3: Lobios, Serra do Xurés, 29TNG8031; 4, 5: Lobios, Serra do Xurés, c. Pión de Paredes, 29TNG7832; 6: Muiños, Serra do Xurés, 29TNG8336; 7: Lobios, Serra de Santa Eufemia, 29TNG7033; 8: Lobios, Serra de Santa Eufemia, Cruz do Touro, 29TNG6930; 9: Baltar, between Tosende and Covas, 29TNG9944; 14: Lobios, Serra do Xurés, Pico da Nevosa, 29TNG7931; 15: Calvos de Randín, 29TNG9538; 17: Lobios, Serra de Santa Eufemia 29TNG7031.

From Portugal: 1: Minho. Serra Amarela. 29TNG7031; Tras-os-Montes, Serra do Gerês: 10: 29TNG7930; 11: 29TNG7830; 12: 29TNG7830; 13: 29TNG7830; 16: Emcosta do Sol and Cabezos de Moudelo, 29TNG7529.

Exclusive diagnostic species: Not present.
Shared diagnostic species: *Festuca yvesii* subsp. *summilusitana*, *Helictochloa marginata*, *Neoschischkinia truncatula* subsp. *durieui*, *Sedum brevifolium*, *Pterospartum tridentatum* and *Ornithogalum concinnum*.
Constant species: *Sedum brevifolium*, *Festuca yvesii* subsp. *summilusitana*, *Neoschischkinia truncatula* subsp. *durieui*, *Helictochloa marginata* and *Pterospartum tridentatum*.
Dominant species: *Echinospartum ibericum* (mean cover = 35%).
Syntaxonomy: This association is dominated by species of Calluno-Ulicetea (19%), followed by those of Stipo giganteae-Agrostietea castellanae (14.9%), Festucetea indigestae (11.8%), and Cytisetea (10.5%).
Synchorology: This association is distributed in the NW of the Iberian Peninsula (Galicia, W Zamora, N of Portugal), with an altitudinal range of 960–1600 m asl North Lusitania Sierran Sector (Peneda and Xurés Sierras District), Lusitanian Douro Sector (Chaves-Verín and Bragança Districts), Bierzo and Sanabria Sector (Queixa Sierran District and W of Zamora-Sanabria District).
Bioclimatology: Supratemperate sub-Mediterranean bioclimatic belt, with an ombrotype ranging from upper subhumid to lower hyperhumid and continentality from pronounced semihyperoceanic to pronounced euoceanic.

Genisto hystricis-Echinospartetum iberici Navarro & Valle 1983 corr. Rivas-Martínez 2011 (clusters 2 and 3)

E. ibericum gorse scrubs with *Genista hystrix* occur in the upper Mesomediterranean and lower Supramediterranean belts of the NW of the Iberian Peninsula (Zamora, E and NE Bragança).

Genisto hystricis-Echinospartetum iberici F. Navarro & C. Valle 1983 corr. Rivas-Martínez 2011 (Typical) (cluster 2)

E. ibericum thorny gorse scrubs of the upper Mesomediterranean belt of the Bierzo and Sanabria Sector (Maragatería, Zamora-Sanabria Districts), located below 810 m asl
Exclusive diagnostic species: *Leucanthemopsis pulverulenta*.
Shared diagnostic species: *Genista hystrix*, *Digitalis thapsi*, *Neoschischkinia truncatula* subsp. *durieui* and *Ornithogalum concinnum*.
Constant species: *Genista hystrix*, *Leucanthemopsis pulverulenta*, *Ornithogalum concinnum*, *Cytisus scoparius*, *Neoschischkinia truncatula* subsp. *durieui*, *Stipa gigantea* and *Genista florida*.
Dominant species: *Echinospartum ibericum* (mean cover = 58%).
Syntaxonomy: Association in which species of Cytisetea (39.1%) and Festucetea indigestae (19.6%) dominate.
Synchorology: Association distributed in the province of Zamora, with an altitudinal range of 700–810 m asl Bierzo and Sanabria Sector (Maragatería, Cabrera-Montes de León, and Zamora-Sanabria Districts).
Bioclimatology: Upper Mesomediterranean to lower Supramediterranean bioclimatic belts, with a lower subhumid ombrotype and a marked euoceanic level of continentality.

Genisto hystricis-Echinospartetum iberici var. with ***Dianthus laricifolius*** subsp. ***merinoi*** (cluster 3)
E. ibericum gorse scrubs occur above 870 m asl at the boundary between the Bierzo and Sanabria Sector (Zamora-Sanabria District) and Salamanca Sector (High Salamanca District).
Exclusive diagnostic species: *Dianthus laricifolius* subsp. *merinoi*.
Shared diagnostic species: *Genista hystrix*, *Helictochloa marginata* and *Pterospartum tridentatum*.
Constant species: *Genista hystrix*, *Helictochloa marginata* and *Pterospartum tridentatum*.
Dominant species: *Echinospartum ibericum* (mean cover = 31%).
Syntaxonomy: Variant in which species of Cytisetea (23.9%) and Calluno-Ulicetea (23.2%) dominate, followed at a distance by those of Festucetea indigestae (11.3%), Tuberarietea (10.6%) and Stipo giganteae-Agrostietea castellanae (9.9%).
Synchorology: Variant located in the province of Zamora, with an altitudinal range of 870–1370 m asl Bierzo and Sanabria Sector (Zamora-Sanabria District) and Salamanca Sector (NE High Salamanca District).
Bioclimatology: Supramediterranean bioclimatic belt with a lower subhumid to upper humid ombrotype and continentality ranging from attenuated semihyperoceanic to pronounced euoceanic.

Echinospartetum iberici Rivas-Martínez 1974 corr. Rivas-Martínez & Sánchez-Mata 2002 (clusters 4–6)

E. ibericum gorse scrubs occur in the Supratemperate sub-Mediterranean and Supramediterranean belts of the CW of the Iberian Peninsula. Our results indicate the presence of two variants:

Echinospartetum iberici (Typical) (cluster 5)

Exclusive diagnostic species: Not present.
Shared diagnostic species: *Cytisus multiflorus* and *Helictochloa marginata*.
Constant species: *Cytisus multiflorus*, *Genista cinerascens*, *Digitalis thapsi* and *Neoschischkinia truncatula* subsp. *durieui*.
Dominant species: *Echinospartum ibericum* (mean cover = 55%).
Syntaxonomy: Association dominated by species of Cytisetea (48.3%), followed by Calluno-Ulicetea (12.4%).
Synchorology: This association is widely distributed in the CW Iberian Peninsula, with an altitudinal range of 680–980 m asl Salamanca Sector (High Salamanca District), Lusitano-Duriense Sector (Beira Norte District), and Montemuro and Estrela Sierras Sector (Estrela Sierran and Guarda Districts).
Bioclimatology: Supratemperate sub-Mediterranean and Supramediterranean bioclimatic belts, with a lower subhumid to lower humid ombrotype and continentality from attenuated semihyperoceanic to attenuated euoceanic.

Echinospartetum iberici var. with ***Halimium lasianthum*** subsp. ***alyssoides*** (cluster 6)

Exclusive diagnostic species: Not present.

Shared diagnostic species: *Cytisus multiflorus* and *Helictochloa marginata*.
Constant species: *Cytisus multiflorus*, *Halimium lasianthum* subsp. *alyssoides*, *Arenaria querioides* and *Helictochloa marginata*.
Dominant species: Not present.
Syntaxonomy: Variant in which species of Cytisetea dominate (33%), followed by Calluno-Ulicetea (31.9%).
Synchorology: Variant based on relevés from the Sierra de Gata, with an altitudinal range of 850–1320 m asl Salamanca Sector (High Salamanca District).
Bioclimatology: Supratemperate sub-Mediterranean and Supramediterranean bioclimatic belts, with a lower subhumid to lower humid ombrotype and continentality from attenuated semihyperoceanic to attenuated euoceanic.

Echinospartetum iberici var. with ***Erica arborea*** (cluster 4)

Exclusive diagnostic species: Not present.
Shared diagnostic species: *Halimium lasianthum* subsp. *alyssoides*, *Helictochloa marginata*, *Neoschischkinia truncatula* subsp. *durieui* and *Pteridium aquilinum*.
Constant species: *Halimium lasianthum* subsp. *alyssoides*, *Helictochloa marginata* and *Erica arborea*.
Dominant species: *Echinospartum ibericum* (mean cover = 60%).
Syntaxonomy: Variant dominated by species of Cytisetea (35.6%), followed by Calluno-Ulicetea (23.7%) and Stipo giganteae-Agrostietea castellanae (15.3%).
Synchorology: Variant based on relevés from the Serra da Estrela, with an altitudinal range of 1050–1600 m asl Montemuro and Estrela Sierra Sector (Estrela Sierra and Guarda Districts).
Bioclimatology: Supratemperate sub-Mediterranean bioclimatic belt, with an ombrotype ranging from upper subhumid to lower hyperhumid and continentality ranging from attenuated semihyperoceanic to pronounced euoceanic.

Cytiso oromediterranei-Echinospartetum pulviniformis Rivas-Martínez *et al.* 1987 (clusters 7 and 13)

“Piorno serrano” (*Cytisus oromediterraneus*) brooms with *E. ibericum* in the Oromediterranean and upper Supramediterranean belts of the Central Range. The association comprises two clusters: cluster 7 corresponds to the typical association and occurs in the Oromediterranean belt from the W of the Sierra de Gredos to the Peña de Francia, and cluster 13, which groups the communities of the upper Supramediterranean belt of these same mountains, including the highest altitude relevés from the Sierra de Gata.
Exclusive diagnostic species: Not present.
Shared diagnostic species: *Cytisus oromediterraneus*, *Avenella flexuosa*, *Neoschischkinia truncatula* subsp. *truncatula*, *Festuca yvesii* subsp. *summilusitana* and *Arrhenatherum elatius*.
Constant species: *Avenella flexuosa*, *Cytisus oromediterraneus*, *Neoschischkinia truncatula* subsp. *truncatula* and *Festuca yvesii* subsp. *summilusitana*.
Dominant species: *Echinospartum ibericum* (mean cover = 49%).
Syntaxonomy: Association dominated by species of Cytisetea (23.6%), with a substantial contribution from those of *Festucetea indigestae* (18.1%) and, to a lesser extent, Stipo giganteae–Agrostietea castellanae (13.5%), Thlaspietea rotundifolii (10.7%) and Junipero-Pinetea (9.7%).
Synchorology: This association occurs in the highest areas of the mountain ranges of Tormantos, Gata, Peña de Francia, Béjar, and W Gredos (cluster 7: 1650–2390 m asl; cluster 13: 1320–1640 m asl). Béjar and Gredos Sierras Sector (Tormantos Sierran and Béjar Sierran Districts) and Salamanca Sector (Batuecas and Malcata Sierran District).
Bioclimatology: Orotemperate sub-Mediterranean, upper Supratemperate sub-Mediterranean, and upper Supramediterranean bioclimatic belts, with a lower subhumid to lower hyperhumid ombrotype and continentality from attenuated semihyperoceanic to attenuated euoceanic.

Teucrio salviastri-Echinospartetum pulviniformis Rivas-Martínez 1974 corr. 1981 (cluster 8)

Gorse scrubs with *E. ibericum* and *Teucrium salviastrum* in the sub-Mediterranean Supra-Orotemperate belts on the summits of the Serra da Estrela (Portugal).
Exclusive diagnostic species: *Phalacrocarpum oppositifolium* subsp. *oppositifolium* and *Teucrium salviastrum*.
Shared diagnostic species: *Juniperus communis* subsp. *alpina*, *Cytisus oromediterraneus*, *Avenella flexuosa* and *Festuca yvesii* subsp. *summilusitana*.
Constant species: *Phalacrocarpum oppositifolium* subsp. *oppositifolium*, *Juniperus communis* subsp. *alpina*, *Teucrium salviastrum*, *Avenella flexuosa* and *Erica arborea*.
Dominant species: *Echinospartum ibericum* (mean cover = 31%).
Syntaxonomy: Association dominated by species of the class Cytisetea (30%), with a large contribution from the classes Junipero-Pinetea (19.1%) and Stipo giganteae-Agrostietea castellanae (19.1%).
Synchorology: Exclusive to the Serra da Estrela, with an altitudinal range of 1650–1970 m asl Montemuro and Estrela Sierra Sector (Estrela Sierran District).
Bioclimatology: Sub-Mediterranean Supra-Orotemperate bioclimatic belts, with a lower humid to lower hyperhumid ombrotype and a markedly attenuated semihyperoceanic level of continentality.

Genisto sanabrensis-Juniperetum alpinae F. Prieto 1983, corr. Rivas-Martínez 2011 ***echinospartetosum iberici*** Penas *et al.* 1990 (cluster 9)

Juniper thickets with *Genista sanabrensis* and *E. ibericum* in the sub-Mediterranean Orotemperate belt of the Bierzo and Sanabria Sector.
Exclusive diagnostic species: *Genista sanabrensis*.
Shared diagnostic species: *Juniperus communis* subsp. *alpina*, *Avenella flexuosa*, *Festuca yvesii* subsp. *summilusitana* and *Pterospartum tridentatum*.
Constant species: *Genista sanabrensis*, *Juniperus communis* subsp. *alpina*, *Festuca yvesii* subsp. *summilusitana*, *Pterospartum tridentatum* and *Avenella flexuosa*.

Dominant species: *Juniperus communis* subsp. *alpina* (mean cover = 42%).
Syntaxonomy: Association dominated by species of Junipero-Pinetea (30.6%), followed by Festucetea indigestae (18.4%), Calluno-Ulicetea (16.6%) and Cytisetea (12.2%).
Synchorology: Subassociation that develops at the intersection among the Segundera, Cabrera, and Eixe mountain ranges (1830–1870 m asl). Bierzo and Sanabria Sector (Cabrera and Montes de León District).
Bioclimatology: Lower Orotemperate belt, with an upper humid to lower hyperhumid ombrotype and an attenuated semihyperoceanic level of continentality.

Armerio ciliatae-Echinospartetum iberici González de Paz 2012 (cluster 10)

E. ibericum gorse scrubs with *Armeria ciliata* in the sub-Mediterranean Supra-Orotemperate belts in the Sierra de La Cabrera (Zamora).
Exclusive diagnostic species: *Armeria ciliata*.
Shared diagnostic species: *Cytisus oromediterraneus*, *Avenella flexuosa*, *Festuca yvesii* subsp. *summilusitana*, *Neoschischkinia truncatula* subsp. *durieui* and *Sedum brevifolium*.
Constant species: *Armeria ciliata*, *Festuca yvesii* subsp. *summilusitana*, *Sedum brevifolium* and *Avenella flexuosa*.
Dominant species: *Echinospartum ibericum* (mean cover = 60%).
Syntaxonomy: Species of Festucetea indigestae (24.7%) and Cytisetea (22.1%) dominate in this association.
Synchorology: This association is exclusive to the Sierra de La Cabrera (Zamora), with an altitudinal range of 1637–1940 m asl Bierzo and Sanabria Sector (Zamora-Sanabria District).
Bioclimatology: Sub-Mediterranean Supra-Orotemperate bioclimatic belts, with a lower humid to lower hyperhumid ombrotype and continentality ranging from marked semihyperoceanic to marked euoceanic.

Genisto cinerascentis-Adenocarpetum argyrophylli Vicente-Orellana & Galán 2008 subass. ***echinospartetosum iberici*** Vicente-Orellana & Galán 2008 (cluster 11)

Brooms of *Genista cinerascens* with *Adenocarpus argyrophyllus* and *E. ibericum* in the Supramediterranean belt of the southern half of the Iberian Peninsula (Cáceres, Toledo, and Ciudad Real).
Exclusive diagnostic species: *Adenocarpus argyrophyllus*, *Dianthus lusitanicus*, *Halimium ocymoides* and *Quercus rotundifolia*.
Shared diagnostic species: *Sedum brevifolium* and *Arrhenatherum elatius*.
Constant species: *Dianthus lusitanicus*, *Adenocarpus argyrophyllus*, *Arrhenatherum elatius*, *Halimium ocymoides*, *Juniperus oxycedrus* subsp. *badia* (lagunae), *Quercus rotundifolia* and *Sedum brevifolium*.
Dominant species: Not present.
Syntaxonomy: In this association, species of Cytisetea dominate (19.8%), followed by Quercetea ilicis (11.1%) and Phagnalo-Rumicetea (11.1%).
Synchorology: Subassociation distributed throughout the mountain ranges of Las Villuercas, Madrona, and Montes de Toledo, with an altitudinal range of 1,069–1,590 m asl Oretano Sector (Villuercas Sierran and Eastern Montes of Toledo Districts) and Mariánica Range Sector (East Mariánica District).
Bioclimatology: Supramediterranean bioclimatic belt, with a lower dry to upper subhumid ombrotype and continentality from attenuated euoceanic to attenuated semicontinental.

Cytiso oromediterranei-Genistetum cinerascentis Rivas-Martínez 1970 var. with ***Echinospartum ibericum*** Sardinero 2004 (cluster 12)

Cytisus oromediterraneus and *Genista cinerascens* brooms with *E. ibericum* in the Supramediterranean belt of the Sistema Central.
Exclusive diagnostic species: *Euphorbia oxyphylla*, *Thymus zygis*, *Corynephorus canescens*, *Lavandula pedunculata*, *Cytisus scoparius*, *Adenocarpus complicatus*, *Armeria trasmontana*, *Centaurea alba*, *Genista tournefortii*, *Quercus pyrenaica* and *Festuca elegans*.
Shared diagnostic species: *Pteridium aquilinum*, *Genista cinerascens*, *Digitalis thapsi*, *Arenaria querioides*, *Neoschischkinia truncatula* subsp. *truncatula* and *Cytisus oromediterraneus*.
Constant species: *Cytisus oromediterraneus*, *Corynephorus canescens*, *Genista cinerascens*, *Lavandula pedunculata*, *Cytisus scoparius*, *Euphorbia oxyphylla*, *Thymus zygis*, *Quercus pyrenaica*, *Festuca elegans*, *Adenocarpus complicatus*, *Armeria trasmontana*, *Centaurea alba*, *Genista tournefortii*, *Digitalis thapsi*, *Arenaria querioides*, *Neoschischkinia truncatula* subsp. *truncatula*, *Agrostis castellana* and *Jasione sessiliflora*.
Dominant species: *Echinospartum ibericum* (mean cover = 36%).
Syntaxonomy: Association in which species of Festucetea indigestae (22.9%) and Cytisetea (21.5%) dominate, followed at a distance by Stipo giganteae-Agrostietea castellanae (12.5%) and Tuberarietea species (12.5%).
Synchorology: This association is found in the provinces of Salamanca and Ávila, at 1300–1450 m asl Béjar and Gredos Sierra Sector (Tormantos Sierran and Béjar Sierran Districts).
Bioclimatology: Lower and middle Supramediterranean bioclimatic belt, under a lower-upper subhumid ombrotype and a pronounced euoceanic level of continentality.

Discussion

This study, which covers the entire range of *E. ibericum*, presents communities that are well defined by their generally endemic, exclusive diagnostic species, while others lack such exclusive diagnostic species in the mountain systems they inhabit. However, the latter are well defined by a particular composition of shared diagnostic species. Currently, vegetation classification is based on so-called exclusive diagnostic species (Barkman, 1989; Chytrý, 2002), but by focusing on these alone, some communities are overlooked. In these cases, the question arises whether only exclusive diagnostic species should be used as the sole criterion for defining vegetation communities, or whether other criteria such as structure/physiognomy and ecology (Ewald, 2003; Willner, 2006; Chiarucci, 2007), as well as cover and distribution, should be taken into account. In this study, an integrative view was used to categorise the different plant communities, distinguishing those with a shared set of diagnostic species and a characteristic distribution range.

As can be seen in Figure 1, there are groups of relevés that follow each other altitudinally and in a W–E direction in the NW and C mountains of the Iberian Peninsula. Rivas-Martínez *et al.* (2001) proposed a classification into two different phytosociological classes: those located at higher altitudes are included in Junipero-Pinetea and those at basal and middle altitudes in Cytisetea scopario-striati. Subsequently, and after the description of new syntaxa, different authors carried out studies on the classification of these communities (Costa *et al*., 2003; Gavilán *et al*., 2011; Rivas-Martínez *et al*., 2011; Amor & Ávila, 2012) in which the division into two classes was maintained, although there were discrepancies in the number of accepted syntaxa.

Our analyses identify nine syntaxa with three new variants, which, albeit with some discrepancies, are largely congruent with the described associations but less consistent with their syntaxonomic placement. The greatest controversy surrounds the supratemperate–supramediterranean communities of the NW Iberian Peninsula, which have been grouped according to a synthetic criterion in a single association (*Echinospartetum iberici*) (Rivas-Martínez, 2001; Costa *et al.*, 2003; Gavilán *et al.*, 2011; Amor & Ávila, 2012) or treated by maintaining the associations *Festuco summilusitanae-Echinospartetum iberici* and *Genisto hystricis-Echinospartetum iberici* as syntaxa independent of the former (Rivas-Martínez, 2011). Our results support the independence of the three associations. The bioclimatic parameters of the areas of occurrence differ significantly from one area to another, as reflected in the species present in each area, which include diagnostic species and constant species. Although *Festuco summilusitanae-Echinospartetum iberici* lacks exclusive differential species, it exhibits shared diagnostic taxa and a constant floristic composition that clearly distinguishes it from the other two associations (including *Festuca yvesii* subsp. *summilusitana* and *Sedum brevifolium*). *Genisto hystricis-Echinospartetum iberici* is characterised by diagnostic and constant species such as *Genista hystrix* and *Leucanthemopsis pulverulenta*, whereas *Echinospartetum iberici* is defined by *Cytisus multiflorus* and *Halimium lasianthum* subsp. *alyssoides*. Our results also confirm the status of *Armerio ciliatae-Echinospartetum iberici* as an independent association, which has not previously been included in any review.

For the *Echinospartetum iberici* association, we propose two new high-altitude variants. The typical association (cluster 5) consists of the *Echinospartum* thickets with *Cytisus multiflorus* located below 1320 m asl It brings together the relevés that occupy the most basal position and present the greatest similarity with the *typus* relevé of the association. Cluster 6 groups the communities located in the adjacent higher altitudinal band (var. with *Halimium lasianthum* subsp. *alyssoides*), which, to date, has only been sampled in the Sierra de Gata. Both variants share the diagnostic species *Cytisus multiflorus* and *Helictochloa marginata*. At higher altitudes and in western Eurosiberian areas (Serra da Estrela *sensu lato*), these communities incorporate *Erica arborea*, while *Cytisus multiflorus* disappears, in response to a decrease in It and an increase in Io; we recognise these communities as the var. with *Erica arborea* (cluster 4).

We also propose a northern high-altitude variant for *Genisto hystricis-Echinospartetum iberici*. The typical association (cluster 2), located at very low altitude within the *E. ibericum* communities, is rich in elements of the class *Cytisetea* (*Cytisus scoparius*, *Genista florida*); with increasing altitude these species are partly replaced by species of the class Calluno-Ulicetea (*Pterospartum tridentatum*). This pattern may reflect, at least in part, variation in Io and It—with increasing Io and decreasing It along the altitudinal gradient—although other, unmeasured environmental or historical factors may also contribute. The presence of endemic taxa of the class *Festucetea indigestae* contributes to the characterisation of these communities, which we recognise as the var. with *Dianthus laricifolius* subsp. *merinoi* (cluster 3).

Another discrepancy with respect to previous analyses is the grouping of cluster 7 (*Cytiso oromediterranei-Echinospartetum pulviniformis*) with cluster 13, which groups together the relevés located altitudinally below them (*Genisto cinerascentis-Cytisetum oromediterranei* var. with *Echinospartum pulviniforme* sensu Sardinero, 2004) and those located in the highest areas of the Sierra de Gata with a northern aspect. This grouping is due to the loss, in the relevés of cluster 13, of the large group of constant and diagnostic species exclusive to the association *Genisto cinerascentis-Cytisetum oromediterranei* var. with *E. ibericum* (cluster 12) (Table S2). As confirmed by other authors (Amor & Ávila, 2012), in our analysis the relevés of *Echinosparto iberici-Juniperetum lagunae* (Cano *et al*., 2007) are clearly integrated with those of *Genisto cinerascentis-Adenocarpetum argyrophylli* subass. *echinospartetosum iberici* (cluster 11).

The remaining associations *Genisto sanabrensis-Juniperetum alpinae* subass. *echinospartetosum iberici* (cluster 9) and *Teucrio salviastri-Echinospartetum pulviniformis* (cluster 8) remain independent syntaxa as in previous ordinations.

The analysis of syntaxa membership in phytosociological classes, according to the flora participating in each association, does not fully fit into traditional syntaxonomy. The inclusion of the associations of the sub-Mediterranean Orotemperate belt in Junipero-Pinetea is doubtful based on the presence of the participating flora. *Genisto sanabrensis-Juniperetum alpinae* subass. *echinospartetosum iberici* is the only one with a majority cover of species of this class, which also have a notable influence on the associations *Cytiso oromediterranei-Echinospartetum pulviniformis* (11.7%, cluster 7), *Teucrio salviastri-Echinospartetum pulviniformis* (20%, cluster 8) and *Armerio ciliatae-Echinospartetum iberici* (13%, cluster 10). In the first two clusters (clusters

7 and 8), Cytisetea species dominate, while in *Armerio ciliatae-Echinospartetum iberici* species of the class Festucetea indigestae dominate (24.7%), although almost to the same extent as the Cytisetea species (22.1%). Although in all three cases there is a clear influence of *Junipero-Pinetea* species, in none of them do they have a majority presence, and the linkage of these communities with the syntaxa of the classes Cytisetea and Festucetea indigestae remains to be studied. Without the influence of *Junipero-Pinetea* species, in the ass. *Genisto cinerascentis-Cytisetum oromediterranei* var. with *E. ibericum* (cluster 12), species of the class *Festucetea* also dominate (22.9%), although almost to the same extent as the Cytisetea species (21.5%). Finally, in *Festuco summilusitanae-Echinospartetum iberici* (cluster 1), the dominance belongs to the species of the class Calluno-Ulicetea, with *Helictochloa marginata* and *Pterospartum tridentatum* as constant species and the frequent presence of *Erica umbellata*, which leaves open the possibility of placing this association within the *Ericion umbellatae* alliance of the class Calluno-Ulicetea.

Conclusions

Although *Echinospartum* gorse scrubs are species-poor owing to their development in extensive rocky montane environments, changes in their characteristic floristic composition were observed, thereby allowing the identification of 13 groups linked to 9 associations. All groups had exclusive and/or shared diagnostic species, together with constant species that characterised each syntaxon. The succession of syntaxa along the west-east (W-E) and altitudinal gradients responded to the climatic variables analysed and was consistent with the biogeographical pattern.

The floristic composition of the communities does not support the inclusion of some syntaxa in the classes Cytisetea scopario-striati and Junipero-Pinetea. In communities located in the Supramediterranean belt, species of the class Cytisetea predominate. With increasing altitude into the sub-Mediterranean Orotemperate belt, the communities become richer in species characteristic of the class Junipero-Pinetea, although these are statistically dominant only in ass. *Genisto sanabrensis-Juniperetum alpinae* subass. *echinospartetosum iberici*. Communities further north and west incorporate the highest proportion of Calluno-Ulicetea species, which are dominant in *Festuco summilusitanae-Echinospartetum iberici*, whereas those in the southern half of the Iberian Peninsula are richest in species of the class Cisto-Lavanduletea. An increase in Calluno-Ulicetea species is also observed in continental mountains with rising altitude. In all groups, acidic rock environments facilitate the establishment of small chamaephytes and hemicryptophytes of the classes Stipo giganteae-Agrostietea castellanae and Festucetea indigestae, indicating their close dynamic relationship with the vegetation analysed.

The syntaxa recognised in this study are summarised in the following syntaxonomic scheme, following Mucina *et al.* (2016):

CYTISETEA SCOPARIO-STRIATI Rivas-Mart. 1974
- *Cytisetalia scopario-striati* Rivas-Mart. 1974
  - *Genistion floridae* Rivas-Mart. 1974
    - *Cytiso oromediterranei-Genistetum cinerascentis* Rivas-Mart. 1970, corr. Rivas-Mart. & Cantó 1987
      - Variant with *Echinospartum ibericum* Sardinero 2004
    - *Genisto cinerascentis-Adenocarpetum argyrophylli* Vicente-Orellana & Galán 2008
      - subass. *echinospartetosum iberici* Vicente-Orellana & Galán 2008
  - *Cytision multiflori* Rivas-Mart. 1974
    - *Festuco summilusitanae-Echinospartetum iberici* Costa Ten., Morla & Sáinz 1993, corr. Pulgar & Herrera*(1)
    - *Genisto hystricis-Echinospartetum iberici* F. Navarro & C. Valle 1983, corr. Rivas-Mart. 2011 (typicum)
      - Variant with *Dianthus laricifolius* subsp. *merinoi*
    - *Echinospartetum iberici* Rivas-Mart. 1974 corr. Rivas-Mart. & Sánchez-Mata 2002 (typicum)
      - Variant with *Erica arborea*
      - Variant with *Halimium lasianthum* subsp. *alyssoides*
    - *Armerio ciliatae-Echinospartetum iberici* González de Paz 2012*(2)

JUNIPERO-PINETEA SYLVESTRIS Rivas-Mart. 1965 nom. invers. propos
- *Juniperetalia hemisphaericae* Rivas-Mart. et J.A. Molina in Rivas-Mart. et al. 1999
  - *Cytision oromediterranei* Tx. in Tx. et Oberd. 1958, corr. Rivas-Mart. 1987
    - *Genisto sanabrensis-Juniperetum alpinae* F. Prieto 1983, corr. Rivas-Mart. 2011
      - subass. *echinospartetosum iberici* Penas *et al.* 1990
    - *Cytiso oromediterranei-Echinospartetum pulviniformis* Rivas-Mart. et al. 1987*(3)
    - *Teucrio salviastri-Echinospartetum pulviniformis* Rivas-Mart. 1974 corr. 1981*(3)

*With high percentage of constant or dominant species of classes: (1) Calluno-Ulicetea; (2) Festucetea indigestae; (3) Cytisetea scopario-striati.

See text for explanations.

Authorship

I.P. and J.M.H.: Sampling, Data curation, Data Analyses, Draft writing, Editing and Final correction.

Conflict of interest

None.

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Supplementary material

Figure S1. Pairwise correlation plots for all combinations of bioclimatic indices.

Table S1. Syntaxa, authors, and origin of analysed relevés.

Table S2. Synoptic table of species constancy (%) by cluster.