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HIGH MOUNTAIN PSYCHRO-XEROPHILOUS CALCICOLOUS PASTURES OF THE IBERIAN PENINSULA: *MINUARTIO-POION LIGULATAE*

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Abstract: A syntaxonomical review of the *Minuartio-Poion ligulatae* (*Festuco hystricis-Ononidetea striatae*) in the Iberian Peninsula, supported by numerical classification (complete linkage clustering) and ordination (correspondence analysis), is presented. Communities of psychro-xerophilous calcicolous plants occur in the high mountains and "parameras" of the south and central western Iberian Peninsula, areas which suffer from severe frosts. The data collected point to three large groups of communities: those of the chorological Carpetano-Ibérico-Leonesa Province; those of the Castellano-Maestrazgo-Manchega Province; and those of the Bética Province. Within the latter group, similarities and differences between the communities were analyzed and two new associations (*Herniario boissieri-Festucetum hystricis* and *Pimpinello gracilis-Festucetum nevadensis*) were described. In addition, data clearly support the existence of a humidity-xericity gradient responsible for the distinction of the communities into different syntaxonomic units.

INTRODUCTION

The calcareous high mountains of the Iberian Peninsula (reaching more than 1700 m a.s.l.) have a cold Mediterranean climate, as described by QUÉZEL (1977). Summers are dry and the high altitude provides a long duration of sunshine and ultraviolet radiation; winters are long and cold. These factors, together with frosts, which make the plants lose their leaves, cause a prolonged non-growth period. The natural landscape is a mosaic of plant communities, with low-density needle-leaved woods, thorny scrubs, grasslands (named "lastonares") and cushion-like communities (named "piornales") (MOTA 1990). Among these phytocoenoses there are psychro-xerophilous pastures (also called "tomillar-praderas" and "tomillares"), the subject of this paper.

Psychro-xerophilous pastures consist of caespitose plants, including hemicryptophytes and dwarf cushion-forming or fruticose chamaephytes. They occur on summits of mountains, on calcareous or dolomitic rocks and shallow alkaline soils undergoing severe frosts. They spread throughout SW Eurosiberian areas (under submediterranean climatic conditions) and throughout the high Mediterranean ranges of the Iberian Peninsula and northern Morocco.

RIVAS-MARTÍNEZ et al. (1991) identified this type of hemicryptophytic vegetation as belonging to a new class, the *Festuco hystricis-Ononidetea striatae*, formerly included (together with chamaephytic and nanochamaephytic Mediterranean scrubs) in the

Table 1. Number of endemic and more widespread taxa included in the plant communities under study. (1) – most of them from W Mediterranean region; (2) – two taxa from Bética Province & NW Africa. CIL – Carpetano-Iberico-Leonesa Province, CMM – Castellano-Maestrazgo-Manchega Province, B – Bética Province.

Biogeographic groups	Total taxa (*n*)	Narrow endemic	Iberian endemic	Iberian and NW African	Mediterranean (1)	Widespread
CIL + CMM + B	6	-	0	2	2	2
CIL + CMM	9	-	2	0	3	4
CMM + B	8	-	2	2	2	2
CIL	6	0	2	0	2	2
CMM	35	6	5	1	3	20
B	46	29	4	3 (2)	5	5
Total	110	35	15	8	17	35

Ononido-Rosmarinetea. The evidence provided by RIVAS-MARTÍNEZ et al. (1991) convincingly supports this classification. In addition, the *Ononido-Rosmarinetea* was not well characterized ecologically and presents a "bad common spatial structure" in the terminology of PIGNATTI et al. (1995). MUCINA (1997) accepted the *Festuco hystricis-Ononidetea striatae* in his Conspectus of classes of European vegetation, and we follow this approach.

In the Iberian Peninsula this vegetation type is included in the *Minuartio-Poion ligulatae* O. BOLÒS 1962, one of the three alliances of the *Festuco hystricis-Poetalia ligulatae* RIVAS GODAY et RIVAS-MARTÍNEZ 1963. This vegetation type occurs in continental areas and especially in the high Iberian mountains (Fig. 1), such as the calcareous part of the Sierra of El Moncayo, the Celtibérico-Alcarreñas ranges in the central-western Iberian Peninsula, and the mountains of the SE Iberian Peninsula (they are even found in certain places in the Atlas Mts. of Morocco).

The aim of this paper is to review syntaxonomically by means of multivariate classification and ordination the communities of psychro-xerophilous plants in the Iberian Peninsula. Similar studies are being carried out in Europe and in the Iberian Peninsula (e.g. MOTA et al. 1991, 1993, LOIDI & FERNÁNDEZ-GONZÁLEZ 1994, ESCUDERO & PAJARÓN 1994, LOIDI et al. 1996, 1999, MOLINA et al. 1999, etc.), contributing to the European Vegetation Survey (RODWELL et al. 1995, 1997). Likewise, these studies provide the information necessary to implement projects aimed at the conservation of habitats and species, such as the Natura 2000 Network (RIVAS-MARTÍNEZ et al. 1996).

From a taxonomical point of view, the plant communities under study are extremely rich and include a large number of endemic species (50 endemic taxa of 110, see Tab. 1). It has already been observed that high mountains promote plant endemism (e.g. VALENTINE 1972, KRUCKERBERG & RABINOWITZ 1985, DOMÍNGUEZ et al. 1996, etc.), and these orophilous plants are a good example of this pattern (BLANCA 1993, SAINZ OLLERO 1983). Included are a number of species which, due to their restricted distribution, habitats or populations, should be protected (GÓMEZ et al. 1995).

METHODS

This study uses a total of 172 phytosociological relevés carried out in field surveys following the guidelines of BRAUN-BLANQUET (1932). The relevés of each of the nine

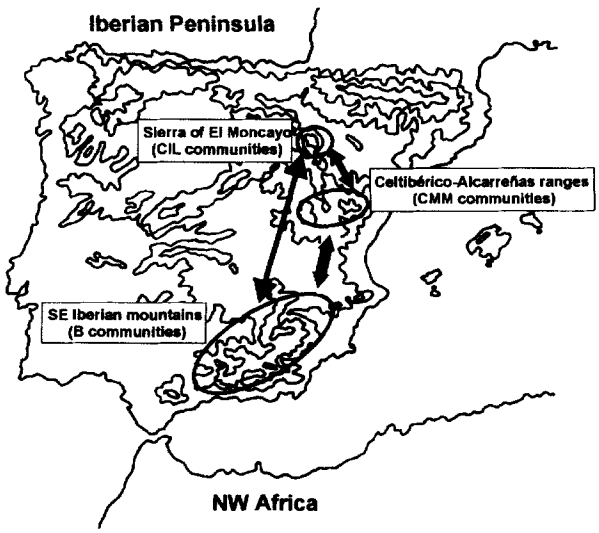

Fig. 1. Distribution of the *Minuartio-Poion ligulatae* communities on the Iberian Peninsula. The thickness of the arrows indicates the greater or smaller biogeographic affinities between the high mountains under study.

associations already published by FONT QUER (1954), RIVAS GODAY & BORJA (1961), LÓPEZ (1976), MARTÍNEZ PARRAS et al. (1987), PÉREZ RAYA (1987), NAVARRO (1989) and GÓMEZ et al. (1995) have been used. The relevés of some communities have not yet been published (MOTA 1990, PEÑAS 1997). A synthetic table of the alliance has been made, with all relevés, using the records of presence in each community, as expressed on the Braun-Blanquet scale modified by GÉHU & RIVAS-MARTÍNEZ (1981). The new syntaxa were named according to the Code of Phytosociological Nomenclature (WEBER et al. 2000).

The relationships between communities have been revealed by means of the ordination and classification of relevés. Ordination was performed by correspondence analysis (CA) and classification by complete linkage clustering (CLC), based on Jaccard's similarity index. Both CA and CLC have been carried out using the SYN-TAX 5.02 package (PODANI 1995). Cover estimates in phytosociological data have been transformed according to WESTHOFF & VAN DER MAAREL (1973) and VAN DER MAAREL (1979). The species with constancy lower than 5% were excluded from the analysis. The relevés include 144 taxa, 110 of which are diagnostic taxa of the associations, subassociations, variants and high-rank syntaxa.

Nomenclature follows RIVAS-MARTÍNEZ (1995, 1996) for bioclimatic terms, RIVAS-MARTÍNEZ (1987), RIVAS-MARTÍNEZ et al. (1997) for biogeographic terms, and Flora Iberica vol. II–VIII (CASTROVIEJO et al. 1990–2000) and Flora europaea (TUTIN et al. 1964–1980, and 1993) for plant taxonomy, except: *Carduncellus arenosus* subsp. *pseudomitissimus* RIVAS GODAY et RIVAS MART., *Carthamus monspelliensium* (L.) ALL., *Centaurea mariana* NYMAN, *Erodium cheilanthifolium* BOISS., *Erysimum baeticum* subsp. *bastetanum* BLANCA et M.C. MORALES, *Koeleria crassipes* subsp. *nevadensis* (HACK.) ROMERO ZARCO, *Koeleria vallesiana* subsp. *humilis* BRAUN-BLANQ., *Plantago subulata* subsp. *granatense* (WILLK.) MALAG., *Potentilla tabernaemontani* ASCH., *Serratula nudicaulis* subsp. *albarracensis* PAU, *Seseli montanum* subsp. *granatensis* (WILLK.) PARDO, *Teucrium*

expansum PAU, *Teucrium leonis* SENNEN, *Thymus serpyllum* subsp. *zapateri* (PAU) RIVAS GODAY et BORJA, *Thymus serpylloides* subsp. *gadorensis* (PAU) JALAS.

The following abbreviations are used throughout the paper: CLC – complete linkage clustering, CA – correspondence analysis, CIL – Carpetano-Iberico-Leonesa Province, CMM – Castellano-Maestrazgo-Manchega Province, B – Bética Province.

RESULTS

Total data set

Published data and our own unpublished relevés were summarized in two phytosociological tables. One of them comprises 172 relevés (can be provided upon request and can be found on the www pages of Folia Geobotanica) and the other is a synthetic table (Tab. 2).

The relevés were ordinated using correspondence analysis (Fig. 2). There are different biogeographic groups of relevés: those of the Carpetano-Iberico-Leonesa (CIL) area (from the calcareous part of El Moncayo massif), those of the Castellano-Maestrazgo-Manchega (CMM) ranges, and those of the Bética Province (B).

Synthetic Tab. 2 served as the basis for a CLC analysis (Fig. 3), where these biogeographic groups were separated. We take them as two large geographic groups, such as that of the SE Iberian Peninsula (B) and that of the Central and Western Iberian Peninsula (CIL+CMM). We have carried out subsequent ordinations and classifications, keeping the relevés of the C and W Iberian Peninsula (CIL and CMM) separate from those of the SE Iberian Peninsula (B).

Communities of the Central and Western Iberian Peninsula

Fig. 4 shows the CA of the synthetic table for the communities from the C and W Iberian Peninsula. In these areas four associations (author citations see Appendix) belonging to two biogeographical units were recorded (see Fig. 1 and Tab. 2):

(a) Carpetano-Ibérico-Leonesa (CIL) communities: (1 and 2) *Androsaco villosae-Festucetum hystricis*, with two subassociations, *festucetosum hystricis*, as a typical one, and *ononidetosum striatae* of depressions with deeper soils (NAVARRO 1989).

(b) Castellano-Maestrazgo-Manchega (CMM) communities: (3) *Festucetum hystricis* variant *typicum*, (4) *Festucetum hystricis* variant with *Artemisia pedemontana* (syn. *Paronychio-Artemisietum pedemontanae*) and (5) *Astragalo austriaci-Ononidetum cenisiae*.

Communities of the SE Iberian Peninsula

Fig. 5, which records both the syntaxa already described and the unpublished syntaxa, shows the CA of the Bética Province communities (author citations see Appendix) using the data of the synthetic table (Tab. 2): (6) *Erodio daucoidis-Saxifragetum erioblastae*, (7) *Coronillo minimae-Astragaletum nummularioidis*, (8) *Seselio grantensis-Festucetum hystricis* (syn. *Senecioni boissieri-Festucetum hystricis*), (9) *Achilleo odoratae-Astragaletum tremolsiani*, (10) *Herniario boissieri-Festucetum hystricis*, (11) *Pimpinello gracilis-Festucetum nevadense*, (12a) *Seselio granatensis-Festucetum hystricis* variant *typicum*, (12b) *Seselio granatensis-Festucetum hystricis* variant with *Centaurea boissieri* subsp. *prostrata*, (12c) *Seselio granatensis-Festucetum hystricis* variant with *Centaurea mariana*, (12d) *Seselio granatensis-Festucetum hystricis* variant with *Erodium daucoides*.

Table 2. Synoptic table of the *Minuartio-Poion ligulatae* alliance. 1 – *Androsaco-Festucetum hystricis festucetosum hystricis*, 2 – *Androsaco-Festucetum hystricis ononidetosum striatae*, 3 – *Festucetum hystricis* variant *typicum*, 4 – *Festucetum hystricis* variant with *Artemisia pedemontana* (syn. *Paronychio-Artemisietum pedemontanae*), 5 – *Astragalo-Ononidetum cenisiae*, 6 – *Erodio-Saxifragetum erioblastae*, 7 – *Coronillo-Astragaletum nummularioidis*, 8 – *Seselio-Festucetum hystricis senecionetosum boissieri* (syn. *Senecioni-Festucetum hystricis*), 9 – *Achilleo-Astragaletum tremolsiani*, 10 – *Herniario-Festucetum hystricis*, 11 – *Pimpinello-Festucetum nevadensis*, 12a – *Seselio-Festucetum hystricis* variant *typicum*, 12b – *Seselio-Festucetum hystricis* variant with *Centaurea boissieri* subsp. *prostrata*, 12c – *Seselio-Festucetum hystricis* variant with *Centaurea mariana*, 12d – *Seselio-Festucetum hystricis* variant with *Erodium daucoides*. Biogeographic groups: CIL – Carpetano-Iberico-Leonesa Province; CMM – Castellano-Maestrazgo-Manchega Province and B – Bética Province. Sources of relevé groups: A , B – NAVARRO (1989); C – FONT QUER (1954); D, F – LÓPEZ (1976); E, G, H, I- RIVAS GODAY & BORJA (1961); J, K – PÉREZ RAYA (1987); L, M, N – GÓMEZ et al. (1995); O, P, S – PEÑAS (1997); Q – MARTÍNEZ PARRAS et al. (1987); R, T, U, V, W – MOTA (1990).

Syntaxon	1	2	3			4		5		6	7		8	9	10	11	12a			12b	12c	12d	12a
Number of relevés	7	4	14	11	13	3	2	4	6	9	4	12	10	11	10	7	10	11	5	7	5	3	4
Relevé plot group	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Biogeographic groups	CIL		CMM														B						
Character and differential species of the *Minuartio-Poion ligulatae* and higher units																							
Festuca hystrix	V	V	V	V	V	5	5	III	V	V	IV	IV	V	.	V	.	V	V	V	V	V	2	II
Helianthemum oelandicum subsp. *incanum*	V	V	II	V	IV	5	5	III	IV		III	III	IV	.	.	I	IV	IV	II	II	III	4	.
Poa ligulata	III	.	V	V	V	.	5	.	V	IV	V	V	II	.	+	II	IV	V	IV	V	IV	4	V
Koeleria vallesiana	V	IV	III	V	V	4	5	V	IV	.	.	.	.	.	.	.	II	.	.	.	.	.	.
Coronilla minima subsp. *minima*	III	III	+	III	+	.	3	.	I	.	V	IV		.	.	.	II	.	.	.	.	.	.
Arenaria grandiflora subsp. *grandiflora*	IV	III	.	I	.	.	.	.	.	IV	.	.	III	II	.	.	.	.	.	.	.	.	.
Differential CIL and CMM species																							
Seseli montanum subsp. *montanum*	I	V	+	I	II	.	.	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fumana procumbens	IV	II	I	III	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Teucrium expansum	V	IV	.	.	.	2	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia kapela subsp. *serpyllifolia*	V	III	.	I	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex humilis	V	V	.	I	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria erinacea	V	V	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Teucrium chamaedrys	.	III	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Avenula bromoides	.	I	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ononis striata	.	V	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential CMM and B species																							
Anthyllis vulneraria s.l.	.	.	+	.	.	.	.	.	.	.	.	I	III	.	II	.	.	+	III	I	I	2	II
Dianthus pungens subsp. *brachyanthus*	.	.	+	IV	.	.	5	.	.	.	III	I	.	V	III	.	II	II	.	.	III	.	.
Achillea odorata	.	.	II	IV	II	4	3	.	I	.	.	III	.	.	.	.	+	.	.	.	I	.	.
Ononis cristata	.	.	.	I	III	.	.	IV	V	.	V	II	.	.	.	.	I	.	.	.	.	.	.

Syntaxon	1	2	3			4		5		6	7		8	9	10	11	12a			12b	12c	12d	12a
Number of relevés	7	4	14	11	13	3	2	4	6	9	4	12	10	11	10	7	10	11	5	7	5	3	4
Relevé plot group	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Biogeographic groups	CIL		CMM							B													
Silene legionensis	.	.	II	II	.	.	.	.	.	.	.	II	.	.	.	I	.	II	.	II	.	.	.
Scabiosa turolensis	.	.	.	.	.	.	.	V	.	.	.	.	.	.	I	.	+	.	.	.	.	.	.
Euphorbia nicaeensis subsp. *nicaeensis*	.	.	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	.	.	.	.
Sideritis glacialis	.	.	.	.	.	.	3	.	.	.	.	.	+	.	.	.	.	.	.	.	.	4	.
Androsaco-Festucetum hystricis																							
Androsace villosa	IV	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thymus praecox subsp. *praecox*	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Iberis saxatilis s.l.	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Anthyllis montana	V	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carduncellus arenosus subsp. *pseudomitissimus*	.	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Narcissus requienii	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential CMM species																							
Astragalus incanus subsp. *incanus*	.	.	+	II	IV	4	3	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla cinerea	.	.	II	+	II	.	5	IV	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium pilosella	.	.	II	III	IV	.	.	IV	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carthamus monspeliensium	.	.	.	.	V	.	5	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cirsium acaule subsp. *acaule*	.	.	.	.	IV	.	.	IV	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium arvense	.	.	.	.	II	.	.	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polygala calcarea	.	.	.	.	II	.	.	II	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Galium indubedae	.	.	.	.	II	.	.	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippocrepis comosa	.	.	.	.	II	.	.	III	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Minuartia funkii	.	.	I	.	.	.	5	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festuca indigesta subsp. *aragonensis*	.	.	.	.	II	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carduncellus monspelliensium	.	.	.	II	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago maritima subsp. *serpentina*	.	.	.	.	II	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Linum suffruticosum subsp. *salsoloides*	.	.	.	+.	I	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paronychia capitata subsp. *capitata*	.	.	+	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Festucetum hystricis* variant *typicum																							
Potentilla tabernaemontani (incl. *P. verna*)	.	.	II	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asperula cynanchica	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Merendera pyrenaica	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Globularia vulgaris	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Armeria trachyphylla	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hormathophylla lapeyrousiana	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
***Festucetum hystricis* variant with *Artemisia pedemontana* (syn. *Paronychio-Artemisietum pedemontanae*)**																							
Artemisia pedemontana	.	.	.	.	.	5	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Teucrium gnaphalodes	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Astragalo-Ononidetum cenisiae																							
Astragalus austriacus	.	.	.	.	.	.	.	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arenaria obtusifolia subsp. *ciliaris*	.	.	.	.	.	.	.	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arrhenatherum elatius subsp. *bulbosum*	.	.	.	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Serratula nudicaulis subsp. *albarracinensis*	.	.	.	.	.	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prunella grandiflora subsp. *grandiflora*	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Prunella laciniata	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salvia pratensis	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Seseli nanum	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Allium senescens subsp. *senescens*	.	.	.	.	.	.	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alyssum montanum	.	.	.	.	.	.	.		III	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gentiana cruciata subsp. *cruciata*	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pimpinella saxifraga	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential B species																							
Seseli montanum subsp. *granatensis*	.	.	.	.	.	.	.	.	.	.	.	II	IV	.	.	III	V	V	V	.	III	.	II
Arenaria armerina subsp. *armerina*	.	.	.	.	.	.	.	.	.	.	.	II	.	II	III	II	II	.	.	III	IV	.	II
Koeleria vallesiana subsp. *humilis*	.	.	.	.	.	.	.	.	.	.	.	V	.	IV	.	.	.	IV	.	III	III	2	III
Plantago subulata subsp. *granatense*	.	.	.	.	.	.	.	.	.	.	.	III	.	V	IV	II	II	.	.	.	.	.	.
Arenaria tetraquetra subsp. *murcica*	.	.	.	.	.	.	.	.	.	.	.	II	V	.	.	.	.	V	.	II	III	.	.
Astragalus incanus subsp. *nummularioides*	.	.	.	.	.	.	.	.	.	.	V	V	.	III	.	.	.	+	.	.	I	.	.
Helianthemum cinereum subsp. *rotundifolium*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	+	II	V	III	.	.	.
Festuca nevadensis	.	.	.	.	.	.	.	.	.	.	IV	III	.	V	.	V	.	.	.	.	.	.	.
Pimpinella tragium subsp. *lithophylla*	.	.	.	.	.	.	.	.	.	III	III	II	III	.	.	.	.	.	.	.	.	.	.
Alyssum serpyllifolium	.	.	.	.	.	.	.	.	.	.	IV	.	.	.	.	.	.	+	.	.	III	.	II
Hieracium pilosella subsp. *tricholepium*	.	.	.	.	.	.	.	.	.	.	.	II	.	.	II	III	+	.	.	.	.	.	.
Thymelaea granatensis	.	.	.	.	.	.	.	.	.	.	.	II	.	.	.	.	I	II	.	II	.	.	.
Astragalus vesicarius	.	.	.	.	.	.	.	.	.	.	III	I	.	.	.	.	.	.	.	.	I	4	.
Poa bulbosa	.	.	.	.	.	.	.	.	.	I	.	I	.	+	.	.	.	.	.	.	.	.	V
Erodium daucoides	.	.	.	.	.	.	.	.	.	IV	.	.	.	+	.	.	.	.	.	.	.	5	.
Potentilla reuteri	.	.	.	.	.	.	.	.	.	.	.	II	.	IV	.	.	+	.	.	.	.	.	.

Syntaxon	1	2	3			4		5		6	7		8	9	10	11	12a			12b	12c	12d	12a
Number of relevés	7	4	14	11	13	3	2	4	6	9	4	12	10	11	10	7	10	11	5	7	5	3	4
Relevé plot group	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Biogeographic groups	CIL		CMM							B													
Cirsium acaule subsp. *gregarium*												+		III			+						
Paronychia kapela subsp. *baetica*													II					II		II			
Genista pseudopilosa												II				II		+					
Festuca indigesta subsp. *hackeliana*											V				II								
Senecio boissieri											II		V										
Koeleria crassipes subsp. *nevadensis*											V						+						
Centaurea boissieri subsp. *jaennensis*												III						V					
Corynephorus canescens										I					III								
Erodium cazorlanum																		II		IV			
Paronychia aretioides																			I		II		
Teucrium webbianum																I				I			
Leontodon boryi													+									2	
Erodio-Saxifragetum erioblastae																							
Saxifraga erioblasta										V													
Erysimum nevadense										II													
Coronillo-Astragaletum nummularioidis																							
Arenaria armerina subsp. *caesia*											IV												
Seselio-Festucetum hystricis senecionetosum boissieri (syn. ***Senecioni-Festucetum hystricis***)																							
Galium pyrenaicum													IV										
Achilleo-Astragaletum tremolsiani																							
Astragalus tremolsianus														V									
Astragalus bourgeanus														II									
Herniario-Festucetum hystricis																							
Koeleria caudata															V								
Herniaria boissieri subsp. *boissieri*															III								
Armeria villosa subsp. *bernisii*															II								
Erysimum baeticum subsp. *bastetanum*															I								
Pimpinello-Festucetum nevadensis																							
Pimpinella gracilis																III							

Seselio-Festucetum hystricis festucetosum hystricis																										
Armeria bourgaei s.l.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	.	.	.	.			
Hippocrepis squamata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	.	.	.			
Centaurea boissieri subsp. *prostrata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	.	.	.			
Centaurea mariana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	V	.	.			
Erodium petraeum subsp. *valentinum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	.	.			
Helianthemum cinereum subsp. *guadiccianum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II	.	.			
Erodium cheilanthifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III			
Other species																										
Jurinea humilis	.	.	II	.	.	.	3	.	.	.	V	III	III	II	II	.	II	II	I	I	III	4	III			
Erinacea anthyllis subsp. *anthyllis*	V	I	.	.	.	.	5	.	.	.	.	I	III	.	III	.	I	II	.	III	II	2	.			
Eryngium campestre	.	.	IV	III	III	4	.	.	.	.	.	.	.	.	II	.	.	.	.	.	.	.	.			
Galium verum	+	.	.	.	.	.	.	IV	II	.	.	.	.	.	.	II	.	.	.	.	.	.	.			
Helianthemum appeninum subsp. *suffruticosum*	.	.	II	.	.	.	.	.	.	.	.	.	.	.	II	.	II	.	.	.	.	.	.			
Festuca trichophylla	.	.	.	.	IV	.	.	IV	III	.	.	.	.	.	.	III	.	.	.	.	.	.	.			
Bromus erectus subsp. *erectus*	.	.	.	.	.	.	.	V	II	.	.	.	.	.	.	III	.	.	.	.	.	.	.			
Odontites longiflora	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I	.	.	.			
Other CIL & CMM species																										
Arenaria serpyllifolia	II	.	III	.	II	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Other CMM species																										
Thymus serpyllum subsp. *zapateri*	.	.	III	.	V	.	5	V	V	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Petrorhagia prolifera	.	.	.	.	II	.	3	II	II	.	.	.	.	.	.	.										
Hornungia petraea	.	.	III	.	.	.	3	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Ononis pusilla subsp. *pusilla*	.	.	II	.	III	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Thymus bracteatus	.	.	.	V	.	4	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Cerastium gracile	.	.	.	.	II	.	5	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Campanula glomerata s.l.	.	.	.	.	II	.	.	III	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Erigeron acer subsp. *acer*	.	.	.	.	II	.	.	V	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Carex halleriana	.	.	.	.	II	.	.	IV	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Lotus corniculatus s.l.	.	.	.	.	IV	.	.	III	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Avenula pratensis	.	.	.	.	.	.	3	V	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Androsace maxima	.	.	IV	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Alyssum alyssoides	.	.	III	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Marrubium supinum	.	.	.	.	II	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Veronica verna	.	.	IV	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			
Cerastium brachypetalum subsp. *brachypetalum*	.	.	III	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.			

Syntaxon	1	2	3			4		5		6	7		8	9	10	11	12a			12b	12c	12d	12a
Number of relevés	7	4	14	11	13	3	2	4	6	9	4	12	10	11	10	7	10	11	5	7	5	3	4
Relevé plot group	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Biogeographic groups	CIL		CMM							B													
Senecio minutus	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Buglossoides arvensis subsp. *gasparinii*	.	.	II	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Other B species																							
Draba hispanica subsp. *hispanica*	.	.	.	.	.	.	.	.	.	III	III	I	II	.	.	.	I	IV	.	IV	II	2	.
Thymus serpylloides subsp. *gadorensis*	.	.	.	.	.	.	.	.	.	.	IV	I	.	.	V	.	.	III	V	III	II	.	.
Sedum amplexicaule subsp. *tenuifolium*	.	.	.	.	.	.	.	.	.	.	.	II	.	II	III	.	.	+	.	.	.	4	II
Centaurea boissieri subsp. *boissieri*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV	III	I	.	.	.	I	.	II
Lotus glareosus var. *villosus*	.	.	.	.	.	.	.	.	.	.	.	III	.	IV	.	II	.	.	.	.	.	.	.
Teucrium leonis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III	.	II	.	.	.
Ononis spinosa subsp. *australis*	.	.	.	.	.	.	.	.	.	.	.	.	.	V	.	.	.	.	.	.	.	.	.

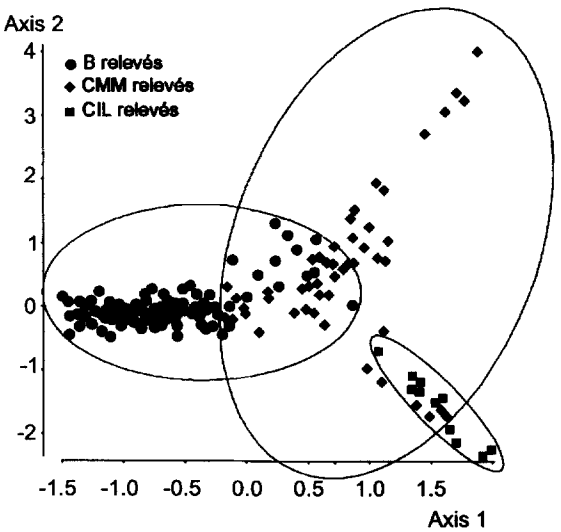

Fig. 2. CA-ordination of the *Minuartio-Poion ligulatae* relevés.

DISCUSSION

Total data set

If the Iberian communities of the *Minuartio-Poion ligulatae* are taken as a whole, three large groups with different associations can be distinguished (Figs. 2 and 3). These three groups correspond to the three biogeographical divisions: the Castellano-Maestrazgo-Manchega communities (CMM), the Carpetano--Ibérico-Leonesa (CIL) and the Bética (B).

Fig. 2 with respect to axis 1 shows the location of a large number of relevés of the C and W Iberian Peninsula (CMM) between those of the SE (B) and those of the north (CIL), reflecting their latitudinal situation in the Iberian Peninsula. This latitudinal situation is a continentality gradient (ALLUE 1990), since the communities with a less continental character are on the left side of the CA. In every chorological province a number of endemic taxa define the communities and biogeographically distinguish one from the other.

Communities of the Central and Western Iberian Peninsula

Among the communities of the C and W Iberian Peninsula, a distinction can be made between those from the CIL Province and those from the CMM, as shown in Fig. 4.

It can be observed that those belonging to the *Androsaco-Festucetum hystricis* are clearly different from the rest, because of diagnostic species such as *Androsace villosa*, *Anthyllis montana*, *Iberis saxatilis* s.l., *Ononis striata* and *Carduncellus arenosus* subsp. *pseudomitissimus* (NAVARRO 1989). In the CA of the communities, those of the Moncayense communities (*Androsaco-Festucetum hystricis*) have been plotted with negative values with respect to axis 2, clearly distinct from the rest of CW Iberian Peninsula.

The *Festucetum hystricis* is a widely distributed community in the CMM Province, probably due to its lack of exclusive taxa. A detailed study to revise its biogeographical distribution would be useful. There is no clear distinction between the *Paronychio--Artemisietum pedemontanae* and the former association because they overlap in most of the locations (Fig. 4). The main difference between these associations is the presence of *Artemisia pedemontana* in the latter (and *Teucrium gnaphalodes* to a much lesser extent). Both are abundant in certain spots, especially in cattle-raising areas (RIVAS GODAY & BORJA 1961). Given this fact, we propose that the *Paronychio-Artemisietum pedemontanae* be considered as an ecological variant of the *Festucetum hystricis* (see Appendix).

Astragalo-Ononidetum cenisiae was recorded where the climate conditions are not so extreme and variable as those affecting the previous communities, and is composed of palatable grass species (RIVAS GODAY & BORJA 1961). For this reason it includes a large

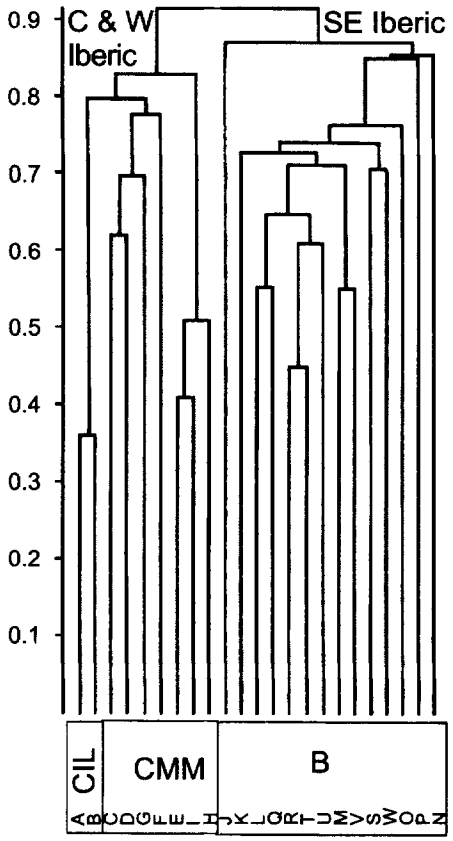

Fig. 3. CLC-classification of the *Minuartio-Poion ligulatae* communities, using the synthetic values of Tab. 2 (see Tab. 2 and Appendix for nomenclature of the communities).

number of taxa of the *Festuco-Ononidetea*, and is most weakly linked to the *Festuco-Poetalia ligulatae*. From a syntaxonomic point of view it can be considered as a transitional association towards the communities of this class (*Festuco-Ononidetea strictae*).

The CA (Fig. 4) reveals a humidity--xericity gradient along axis 2 where humidity increases from positive to negative values. This is clearly revealed by both the distribution of *Astragalo--Ononidetum cenisiae*, which tends to occur under milder conditions, and the distribution of *Androsaco-Festucetum hystricis*, which, although normally found in dry environments, also occurs in a northern massif (El Moncayo), with higher rainfall than the ranges of the C and W Iberian Peninsula.

Communities of the South eastern Iberian Peninsula

Syntaxonomic diversity is enormous in the SE Iberian Peninsula, because of the broad distribution of the alliance over the whole chorological Bética Province where there are many isolated areas of high altitude. In the ordination (CA) of the groups of relevés (Fig. 5) the clear definition of some associations is apparent, because of their floristic and ecologic peculiarities (e.g. *Coronillo-Astragaletum nummularioidis* and *Erodio-Saxifragetum erioblastae* (LOSA et al. 1986, PÉREZ RAYA 1987)).

Two groups of unpublished relevés (10 and 11) are so clearly differentiated from the rest (see Tab. 2) that, as PEÑAS (1997) suggested, we consider them as two new associations. They can be described and discussed as follows:

Herniario boissieri-Festucetum hystricis ass. nov., includes xerophilous perennial pastures occurring in the Sierra de Los Filabres (Filábrico Subsector from the Nevadense Sector of the Bética Province). It is found in the upper supramediterranean and oromediterrranean thermotypes, on siliceous soils (Nevado-Filábride geological complex) with high pH (DÍAZ 1987). Together with species such as *Festuca hystrix*, the endemic taxa *Herniaria boissieri*, *Armeria villosa* subsp. *bernisii* or *Erysimum baeticum* subsp. *bastetanum*, and other hemicryptophytes such as *Poa ligulata*, *Koeleria caudata*, *Festuca indigesta* subsp. *hackeliana*, *Dianthus pungens* subsp. *brachyanthus*, are found. The siliceous soil and the biogeographical area in which these species occur could lead to the inclusion of this

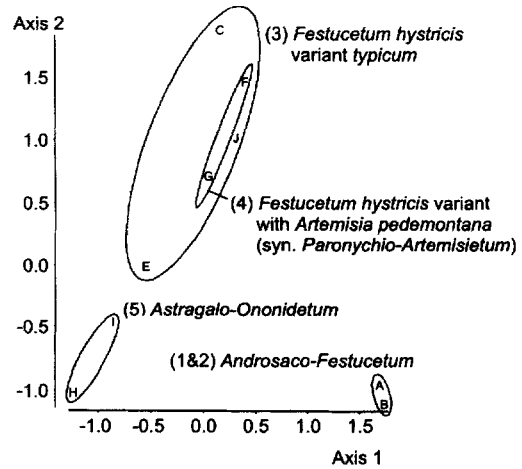

Fig. 4. CA-ordination of the C and W Iberian Peninsula communities, using the synthetic values of Tab. 2 (see Tab. 2 and Appendix for nomenclature of the communities). (Axes 1 and 2 account for almost 25% of the variance, axes 1–5 for 40%).

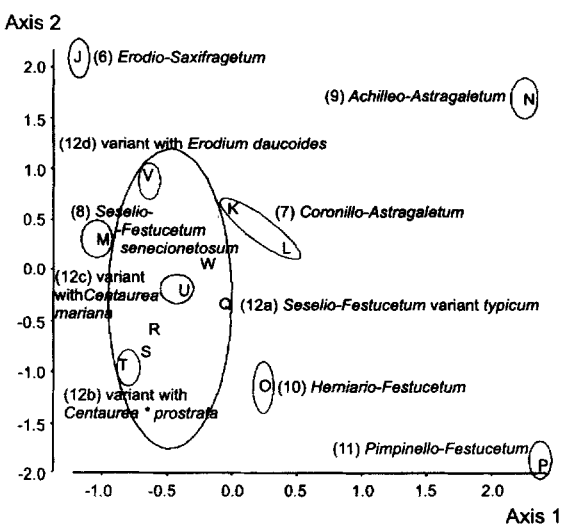

Fig. 5. CA-ordination of the communities of the SE Iberian Peninsula, using the synthetic values of Table 2 (see Tab. 2 and Appendix for nomenclature of the communities). (Axes 1 and 2 account for 30% of the variance, axes 1–5 for 57%).

community in the *Sedo-Scleranthetea*. However, only *Corynephorus canescens* is present as a character species from the *Sedo-Scleranthetea*, and many of the character species belong to the *Minuartio-Poion ligulatae*.

Pimpinello gracilis-Festucetum nevadensis ass. nov., is a community with *Festuca nevadensis* as the dominant species. It flourishes in places shaded by pine trees or cliffs and always on soils with a considerable amount of organic matter. The association is confined to the Bética Province. It has been found in the Sierras of Baza and El Pozo-Cazorla; in certain spots it has also been found in Los Filabres, under reafforested pines. *Festuca nevadensis* and *Pimpinella gracilis* are the taxa which characterize the association. We include it in the *Minuartio-Poion ligulatae* (*Festuco--Ononidetea striatae*) because of the presence of many of its species and others from higher syntaxonomical units: *Seseli montanum* subsp. *granatensis*, *Poa ligulata*, *Silene legionensis*, *Plantago subulata* subsp. *granatense*, *Helianthemum oelandicum* subsp. *incanum*, *Genista pseudopilosa*, etc.

The *Seselio-Festucetum hystricis*, like the *Festucetum hystricis* in the C and W Iberian Peninsula, presents scattered relevés in the CA (Fig. 5). It occurs in a large biogeographical area and abundantly in all the high areas of the Bética Province. The variant with *Centaurea mariana*, although restricted to a limited biogeographical area (Serrano-Mariense Subsector of the Guadiciano-Baztetano Sector) and with several endemic taxa absent in other variants, is not well defined in the CA. It is preferable not to consider it as a different association, since the rest of its species do not render conclusive results in the multivariate analysis. The variant with *Centaurea boissieri* subsp. *prostrata* is slightly differentiated from the rest due to its floristic definition, a more northern location in the Bética Province and its

preference of continental climate conditions. The variant with *Erodium daucoides* is so close to the *Erodio-Saxifragetum erioblastae* association that it can be considered as the transition between the latter and the *Seselio-Festucetum hystricis* in its typical variant.

Although the characteristic endemic flora of the *Senecioni boissieri-Festucetum hystricis* is of interest in itself, the ordination given in Fig. 5 suggests that *Senecioni-Festucetum* could be considered as a subassociation of the *Seselio-Festucetum hystricis* (see Appendix).

A review of the Bética communities in the CA (Fig. 5) leads to a clear distinction between them, particularly considering their position with respect to axis 1. This axis defines a gradient of humidity-xericity, the highest positive values indicating the wettest conditions.

As shown in Fig. 5, communities such as *Achilleo-Astragaletum tremolsiani* and *Pimpinello-Festucetum nevadensis* are plotted to the right, since they occur in depressed areas where snow tends to remain, producing soil moisture and little or no frosts. The latter two communities are dominated by *Festuca nevadensis* and show a less abundant and frequently present *Festuco-Poetalia* taxa and total absence of *Festuca hystrix*. Although *Festuca nevadensis* communities are the most closely related to the Bética associations of the *Festuco-Brometea* and *Nardetea strictae* (RIVAS GODAY & MAYOR 1966, PEÑAS 1997), which leads us to consider them as transitional towards these classes; some authors (GÓMEZ et al. 1995, MOTA 1990) have stressed the taxonomic proximity of the pastures of *Festuca nevadensis* to the communities of the *Minuartio-Poion ligulatae*. Likewise, the *Coronillo-Astragaletum nummularioidis* shows the presence of more mesophytic plants; this association has an ecological and syntaxonomical role similar to that of the *Astragalo-Ononidetum cenisiae* in the CMM ranges.

Other associations are plotted on the left side of the axis 1 (Fig. 5), that is, with negative values. This is the case of the *Erodio-Saxifragetum erioblastae* and the *Seselio-Festucetum hystricis senecionetosum boissieri* and, closely related to them, the variants with *Erodium daucoides* and *Centaurea boissieri* subsp. *prostrata* of the *Seselio-Festucetum hystricis*; they all occur on peaks and areas rather exposed to the wind and frost with low humidity (PÉREZ RAYA 1987, SÁNCHEZ GÓMEZ et al. 1994, GÓMEZ et al. 1995). From a floristic point of view, they are close to the rupicolous *Thlaspietea rotundifolii* and *Asplenietea trichomanis*, which justifies considering them as transitional communities towards these classes.

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APPENDIX

Syntaxonomic scheme of the *Minuartio-Poion ligulatae* syntaxa (numbers of syntaxa used in Tab. 2 and Figs. 4, 5).

Festuco hystricis-Ononidetea striatae RIVAS-MARTÍNEZ, DÍAZ, FERNÁNDEZ PRIETO, LOIDI et PEÑAS 1991

Festuco hystricis-Poetalia ligulatae RIVAS GODAY et RIVAS-MARTÍNEZ 1963.

Minuartio-Poion ligulatae O. BOLÒS 1962

Androsaco villosae-Festucetum hystricis NAVARRO 1989

subass. *festucetosum hystricis* NAVARRO 1989 (1)

subass. *ononidetosum striatae* NAVARRO 1989 (2)

Festucetum hystricis FONT QUER 1954 (syn. *Poo-Festucetum hystricis* (FONT QUER 1954) RIVAS GODAY et BORJA 1961)

variant *typicum* (3)

variant with *Artemisia pedemontana* (syn. *Paronychio-Artemisietum pedemontanae* (RIVAS GODAY et BORJA 1961) RIVAS GODAY et RIVAS-MARTÍNEZ 1963) (4)

Astragalo austriaci-Ononidetum cenisiae RIVAS GODAY et BORJA 1961 (5)

Erodio daucoidis-Saxifragetum erioblastae PÉREZ RAYA et LOSA in PÉREZ RAYA 1987 (6)

Coronillo minimae-Astragaletum nummularioidis PÉREZ RAYA 1987 (7)

Seselio granatensis-Festucetum hystricis MARTÍNEZ PARRAS, PEINADO et ALCARAZ 1987

subass. *senecionetosum boissieri* (MOTA ex GÓMEZ, F.VALLE et MOTA 1995) PEÑAS, CABELLO, F. VALLE et MOTA, comb. nov. (syn. *Senecioni boissieri-Festucetum hystricis* MOTA ex GÓMEZ, F.VALLE et MOTA 1995) (8)

subass. *festucetosum hystricis* MARTÍNEZ PARRAS, PEINADO et ALCARAZ 1987

variant *typicum* (12a)

variant with *Centaurea boissieri* subsp. *prostrata* (12b)

variant with *Centaurea mariana* (12c)

variant with *Erodium daucoides* (12d)

Achilleo odoratae-Astragaletum tremolsiani MOTA ex GÓMEZ, F.VALLE et MOTA 1995 (9)

Herniario boissieri-Festucetum hystricis PEÑAS, CABELLO, F. VALLE et MOTA **ass. nov.** (10)

Holotypus. Locality: Granada (Baza), near Cerro de Alflares, 30SWG2622; altitude 1850 m, area 25 m^2 (other relevés can be provided upon request). Diagnostic taxa of the association and higher units: *Festuca hystrix* 3, *Herniaria boissieri* subsp. *boissieri* 1, *Armeria villosa* subsp. *bernisii* 1, *Koeleria caudata* 1, *Plantago subulata* subsp. *granatense* +, *Helianthemum cinereum* subsp. *rotundifolium* 1, *Corynephorus canescens* 2, *Anthyllis vulneraria* subsp. *argyrophylla* 1. Other taxa: *Thymus serpylloides* subsp. *gadorensis* 2, *Sedum amplexicaule* subsp. *tenuifolium* 1, *Helianthemum appeninum* subsp. *suffruticosum* 1, *Centaurea boissieri* +, *Helichrysum italicum* subsp. *serotinum* +, *Eryngium campestre* +, *Teucrium similatum* +, *Teucrium lerrouxi* +.

Pimpinello gracilis-Festucetum nevadensis PEÑAS, CABELLO, F. VALLE et MOTA **ass. nov** (11)

Holotypus. Locality: Jaén, Sierra de Segura, Llanos de Hernánpelea; altitude 1780 m, area 4 m^2, aspect W, inclination 10° (other relevés can be provided upon request). Diagnostic taxa of the association and higher units: *Festuca nevadensis* 5, *Pimpinella gracilis* 1, *Arenaria armerina* subsp. *armerina* +, *Poa ligulata* +, *Silene legionensis* 2. Other taxa: *Arrhenatherum baeticum* 2, *Festuca elegans* 1, *Avenula arundana* +.