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The vegetation of temporary ponds with Isoetes in the Iberian Peninsula

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with 2 figures and 1 table

Abstract. This study examines the floristical composition and the distribution pattern of the ephemeral quillwort swards found in the Iberian Peninsula. A systematic review based initially on 120 phytosociological relevés and using numerical analyses with classification (Euclidean distance and UPGMA and MISSQ) and ordination (principal component analysis – PCA) was carried out. Four groups corresponding to the following associations were recognized: Junco pygmaei-Isoetetum velati, Peplido hispidulae-Isoetetum delilei, Junco capitati-Isoetetum histricis, Isoetetum durieui. The study supports previous assumptions that, on the local scale within the Iberian Peninsula, temporary-pond plant-communities show greater diversity in western territories thus following the same pattern that occurs on the regional scale of the Mediterranean basin.

Keywords: isoetid vegetation, numerical ordination, vernal pools, Western Mediterranean.

Nomenclature: the taxa names of vascular plants are given according to Castroviejo et al. (1986–2003) or Tutin et al. (1964–1980). Syntaxonomical nomenclature is according to Rivas-Martínez et al. (2001).

Abbrevations: MISSQ – minimization of the increase of error sum of squares, UPGMA – unweighted pair-group method, IP – Iberian Peninsula, PCA – principal component analysis, VP – vernal pool.

Introduction

Mediterranean temporary ponds are among the most original types of habitats in Europe (Council Directive, 92/43/EEC, 1992). These ecosystems are known in other parts of the world as vernal pools (VPs) (Barbour & Major 1977, Keeley & Zedler 1998). VP plant-communities are dominated by therophytes and ephemeral geophytes, which are highly specialized to withstand periods of flooding alternating with desiccation. The climatic factors contributing to the formation of VPs are present in Mediterranean climate regions such as the Mediterranean Basin, California, Chile, South Africa, and Australia where vegetation belonging to these habitats has been described (Braun-Blanquet 1935, Rivas Goday 1971, Holland & Jain 1977, Hill et al. 1996, Bliss et al. 1998, Brullo & Minissale 1998, San Martín et al. 1998). Within the Mediterranean Basin, VPs occupy a larger area and show a more diverse flora in the western parts.

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One of the types of Mediterranean VP plant-communities that has attracted most attention from the point of view of biodiversity and conservation is the freshwater oligotrophic temporary ponds characterized by *Isoetes* (MEDAIL et al. 1996, 1998). These habitats occur from Portugal to the Near East, where they are found on non-calcareous substrates, which considerably reduces their potential area, particularly in the Eastern Mediterranean (QUEZEL 1998). This work focuses on vernal pool *Isoetes*-based vegetation in order to gain more information about its niche and sociological context. This work continues the floristical and chorological isoetid vegetation revision of the Iberian Peninsula (IP) (MOLINA et al. 1999). Furthermore, an attempt is made to find support for the hypothesis that in the IP the patterns of regional diversity are repeated at a local level: that is to say that the greatest diversity in pond plant-communities is found in the west. The present paper also provides an answer to this hypothesis.

Data and methods

A set of 120 relevés, made using field-survey methods according to BRAUN-BLANQUET (1979) was considered. They were made by different authors in the Iberian Mediterranean territories (Appendix 1). The abundance/dominance values of the 6-grade scale of Braun-Blanquet in the compiled raw table were transformed into a 0–9 ordinal scale according to VAN DER MAAREL (1979).

For data classification, the resemblance matrix between relevés was calculated using the Euclidean distance. The samples were grouped by means of both the unweighted pair-group method using arithmetic averages (UPGMA) and the minimum increase of error sum of squares (MISSQ) method (SYN-TAX 5.0, PODANI 1993). Relevé groups were distinguished by comparing the two dendrograms obtained. Clusters composed of the same relevés in the two dendrograms were considered. The basis for the final classification of the communities was 4 groups made up of 89 relevés. In the next step, constancy values for species in the 4 relevés groups were calculated, and diagnostic species for community types were distinguished in the conventional way. On the basis of diagnostic species, syntaxa were recognized and the syntaxonomical classification of communities was established. Principal Components analysis (PCA, CANOCO program, ter BRAAK & ŠMILAUER 1998) was used to identify patterns of ecological variation between the groups of relevés determined by numerical classification.

Results

Syntaxonomical groups

Table 1 shows constancy values for the four ephemeral *Isoetes* type-communities recognized in the Iberian Peninsula. These are adscribed to the following associations: Junco pygmaei-Isoetetum velati, Peplido hispidulae-Isoetetum delilei, Junco capitati-Isoetetum histricis, Isoetetum durieui.

Junco pygmaei-Isoetetum velati
Group 1 in Table 1 and Fig. 1a

Group 1 is characterized floristically by a high constancy of *Isoetes velatum* subsp. *velatum* and *Juncus pygmaeus*. It is worth noting the presence in this group of such Iberian endemisms as *Ranunculus longipes* and *Eryngium galioides*. It grows on well-drained, moderately acid soils with a high degree of saturation which are temporarily flooded by water with a low mineral content, and which are sensitive to eutrophization (MOLINA et al. 2002). It is often found in contact with annual grasslands of *Agrostis pourreti* on dryer soils (RUÍZ TÉLLEZ 1986, MOLINA ABRIL & CASADO ÁLVARO 1997) and with Mediterranean swards of *Eryngium corniculatum* or with the helophytic grasslands of *Glyceria declinata* on moister soils (MOLINA ABRIL & PERTÍÑEZ 2000).

The association Junco pygmaei-Isoetetum velati has been widely cited in the south-western quadrant of the IP. This Mediterranean Iberian-Atlantic association has a number of differential species, as well as a different phenology when compared to other vicariant associations described in the north of the IP: Isoeto-Cicendietum Br.-Bl. 1967 and Isoetetum velatae Bellot 1951 (RIVAS GODAY 1971). Other vicarious syntaxa described in the Mediterranen basin are: Myosotido siculae-Isoetetum velatae Pottier-Alapetite 1952 (Algeria, Tunisia), Buillardio vaillantii-Isoetetum velatae Poirion & Barbero 1965 (SE France), Lythro borysthenici-Ranunculetum rodiei isoetetosum velatae Barbero 1965 (SE France), Romuleo-Isoetetum velatae Brullo & Furnari 1996 (Libya) and Archidio-Isoetetum velatae Brullo & Minissale 1997 (Sicily, Italy).

Peplido hispidulae-Isoetetum delilei
Group 2 in Table 1 and Fig. 1b

Group 2 is characterized by a high constancy of *Isoetes setaceum* and of the tall terophyte *Pulicaria paludosa*. There is a high frequency in the community of helophytic taxa such as *Scirpus maritimus* or *Eleocharis palustris*. Compared with the French localities where the association Peplido hispidulae-Isoetetum setaceae was described, the Iberian communities include both a common (*Myosotis sicula*, *Sisymbrella aspera*) as well as their own (*Antinoria agrostidea*) Atlantic-Mediterranean element. This group forms part of habitats with a prolonged period of flooding and which are also capable of withstanding some eutrophization.

Table 1. Communities in temporary ponds with *Isoetes* on the Iberian Peninsula: Group 1, Junco pygmaei-Isoetetum velati. Group 2, Peplido hispidulae-Isoetetum delilei. Group 3, Junco capitati-Isoetetum histricis. Group 4, Isoetetum durieui.

Group	**1**	**2**	**3**	**4**
N. of relevés	**55**	**8**	**8**	**18**
Isoeto-Nanojuncetea species				
Isoetes velatum subsp. *velatum*	V	I	.	.
Isoetes setaceum	I	V	.	.
Isoetes histrix	I	.	V	.
Isoetes durieui	.	.	.	V
Juncus bufonius	III	I	IV	V
Lythrum borysthenicum	III	I	.	I
Mentha pulegium	II	I	.	II
Juncus capitatus	I	.	V	IV
Scirpus cernuus	I	.	IV	I
Scirpus setaceus	I	.	II	IV
Cicendia filiformis	I	.	II	I
Pulicaria paludosa	II	IV	.	.
Antinoria agrostidea	II	II	.	.
Myosotis sicula	II	II	.	.
Illecebrum verticillatum	I	I	.	.
Lythrum thymifolia	I	I	.	.
Sisymbrella aspera	I	I	.	.
Lythrum portula	I	.	II	.
Juncus pygmaeus	V	.	.	II
Juncus tenageia	II	.	.	III
Lotus angustissimus	I	.	.	IV
Centaurium maritimum	I	.	.	II
Exaculum pusillum	I	.	.	I
Radiola linoides	.	.	IV	I
Hypericum humifusum	.	.	II	II
Preslia cervina	III	.	.	.
Ranunculus longipes	II	.	.	.
Agrostis pourretii	I	.	.	.
Crassula vaillantii	I	.	.	.
Damasonium alisma	I	.	.	.
Eryngium corniculatum	I	.	.	.
Eryngium galioides	I	.	.	.
Hordeum geniculatum	I	.	.	.
Marsilea strigosa	I	.	.	.
Myosurus minimus	I	.	.	.
Ranunculus lateriflorus	I	.	.	.
Ranunculus nodiflorus	I	.	.	.
Scirpus pseudosetaceus	I	.	.	.

Group	**1**	**2**	**3**	**4**
N. of relevés	**55**	**8**	**8**	**18**
Solenopsis laurentia	.	.	IV	.
Centunculus minimus	.	.	.	IV
Lythrum hyssopifolia	.	.	.	IV
Lotus parviflorus	.	.	.	I
Magnocarici-Phragmitetea species				
Eleocharis palustris	II	IV	.	.
Scirpus maritimus	I	IV	.	.
Glyceria declinata	I	II	.	.
Littorelletea species				
Baldellia ranunculoides	III	I	.	.
Helianthemetea species				
Briza minor	I	.	III	IV
Rumex bucephalophorus	I	.	.	II
Moenchia erecta	I	.	.	I
Anthoxanthum ovatum	.	.	IV	I
Logfia gallica	.	.	II	II
Xolantha guttata	.	.	II	II
Ornithopus pinnatus	.	.	II	II
Tolpis barbata	.	.	II	I
Trifolium campestre	.	.	I	IV
Aira caryophyllea subsp. *uniaristata*	.	.	IV	.
Aira elegantissima	.	.	.	IV
Other species				
Lotus hispidus	I	.	III	I
Ranunculus saniculifolius	I	III	.	.
Cynodon dactylon	I	.	.	II
Hypochaeris radicata	I	.	.	II
Montia fontana	I	.	.	II
Trifolium glomeratum	I	.	.	II
Linum bienne	I	.	.	II
Leontodon taraxacoides	I	.	.	II
Carex flacca	I	.	.	I
Senecio vulgaris	I	.	.	I
Plantago coronopus	I	.	.	I
Agrostis castellana	+	.	.	II
Polypogon maritimus	.	III	II	.
Spiranthes aestivalis	.	.	I	II
Parentucellia viscosa	.	.	I	II
Gastridium ventricosum	.	.	II	II

Table 1 (cont.)

Other Magnocarici-Phragmitetea species: *Alisma lanceolatum* I in 1, *Juncus articulatus* III and *Apium nodiflorum* I in 4. **Other Littorelletea species:** *Elatine hexandra* and *Eleocharis multicaulis* I in 1, *Anagallis crassifolia* II in 3. **Other Helianthemetea species:** *Anthoxanthum aristatum*, *Molineriella laevis*, *Ornithopus perpusillus* and *Trifolium strictum* I in 1; *Vulpia myuros*, *Aira cupaniana*, *Hypochaeris glabra* III in 4; *Briza maxima*, *Galium divaricatum*, *Linum trigynum* and *Odontites lutea* II in 4; *Aira caryophyllea* subsp. *caryophyllea*, *Aira caryophyllea* subsp. *multiculmis*, *Aira tenorii*, *Asterolinon linum-stellatum*, *Cerastium semidecandrum* and *Trifolium arvense* I in 4. Other species: *Apera spica-venti*, *Chamaemelum fuscatum*, *Callitriche brutia*, *Callitriche truncata*, *Carum verticillatum*, *Carex hirta*, *Chamaemelum nobile*, *Corrigiola litoralis*, *Herniaria glabra*, *Poa annua*, *Poa infirma*, *Pulicaria vulgaris*, *Ranunculus flammula*, *Rumex acetosella* subsp. *angiocarpus*, *Stellaria alsine* and *Trifolium micranthum* I in 1; *Callitriche stagnalis* II in 2; *Carex vulpina*, *Myriophyllum alterniflorum* and *Rumex pulcher* I in 2; *Filago gallica* and *Pinguicula lusitanica* II in 3; *Anagallis arvensis* and *Serapias lingua* IV in 4; *Cynosurus echinatus*, *Gaudinia fragilis* and *Sagina apetala* III in 4; *Bromus hordeaceus*, *Calluna vulgaris*, *Carex punctata*, *Danthonia decumbens*, *Erica scoparia*, *Holcus lanatus*, *Myrtus communis*, *Plantago lanceolata*, *Sagina subulata*, *Scilla autumnalis*, *Scirpus holoschoenus*, *Sedum sediforme*, *Sherardia arvensis*, *Sporobolus indicus*, *Trifolium angustifolium*, *Trifolium ligusticum* and *Leontodon longirostris* II in 4; *Allium sphaerocephalon*, *Blackstonia perfoliata*, *Centaurium erythraea*, *Cerastium glomeratum*, *Cistus monspeliensis*, *Cistus salviifolius*, *Crassula tillaea*, *Dittrichia viscosa*, *Euphorbia exigua*, *Geranium dissectum*, *Geranium molle*, *Iris lutescens*, *Lavandula stoechas*, *Ornithopus compressus*, *Plantago lagopus*, *Polypogon monspeliensis*, *Prunella laciniata*, *Samolus valerandi*, *Selaginella denticulata*, *Trifolium dubium*, *Trifolium resupinatum* and *Vulpia ciliata* I in 4.

Junco capitati-Isoetetum histricis
Group 3 in Table 1 and Fig. 1c

This group is characterized by *Isoetes histrix* with a high constancy of small annual plants from the Isoeto-Nanojuncetea class (*Juncus capitatus*, *Scirpus cernuus*, *Radiola linoides*, *Solenopsis laurentia*), together with annual plants from the Helianthemetea class (*Aira caryophyllea* subsp. *uniaristata*, *Anthoxanthum ovatum*, *Briza minor*). It grows on soils which are briefly flooded, and may occupy flushes, shallow depressions in the land or a peripheral position in the VP hydrosere. This group may be found in contact with annual dry grasslands of Helianthemetalia (Rivas Goday 1971, Rudner et al. 1999).

The communities of the south-western quadrant of the Iberian Peninsula studied here have been ascribed to the association of Junco capitati-Isoetetum histricis, although SW Iberian communities with *Isoetes histrix* have been assigned to different associations (Laurentio-Juncetum tingitani Rivas Goday & Borja in Rivas Goday 1968, Isoeto histricis-Radioletum linoidis Chevassut & Quézel 1956 – described from Algeria –). Other close associations described in the Mediterranean basin are: Laurentio-Anthoceretum dichotomi Br.-Bl. 1936 (Morocco), Serapio-Isoetetum histricis Pedrotti 1962 (Italy) and Serapio-Oenanthetum lachenalii histricetosum Barbero 1967 (SE France).

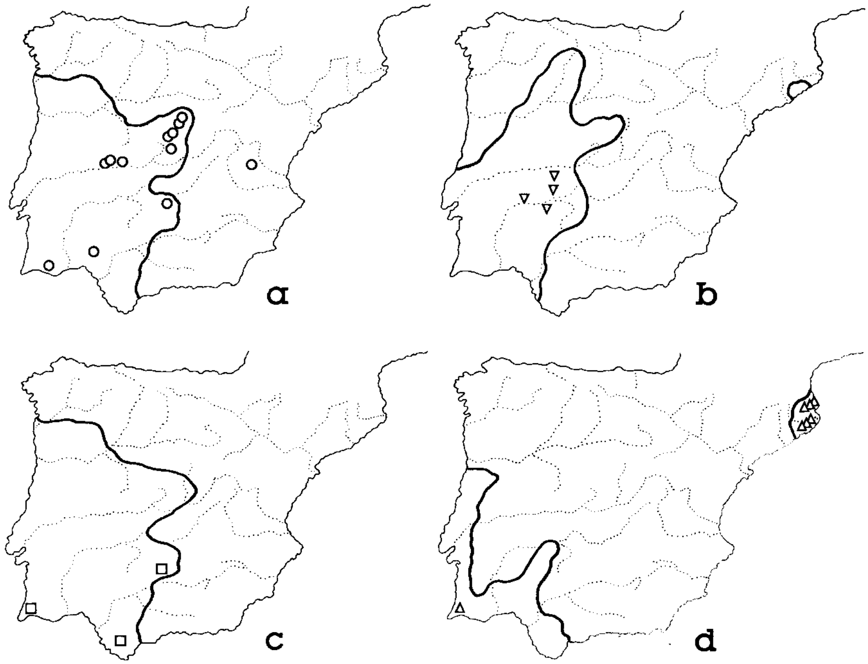

Fig. 1. Distribution of temporary pond plant-communities with *Isoetes* in the Iberian Peninsula. Samples: Circles, Junco pygmaei-Isoetetum velati (a); Triangles down, Peplido hispidulae-Isoetetum deleilei (b); Squares, Junco capitati-Isoetetum histricis (c); Triangles up, Isoetetum durieui (d). The overall distribution of each community is delimited by lines according to the Iberian distribution of *Isoetes* species (PRADA 1983).

Isoetetum durieui
Group 3 in Table 1 and Fig. 1d

This is characterized by the presence of *Isoetes durieui* and by a high constancy of certain Isoeto-Nanojuncetea characteristic species such as *Juncus capitatus*. Within the companion species of Helianthemetea some differential taxa may exist between the NE communities (e.g. *Aira elegantissima*, Table 1) and the SW communities (e.g. *Anthoxanthum aristatum* subsp. *macranthum*, see RUDNER et al. 1999). The association Isoetetum durieui is found in small depressions in the land, on the banks of intermittent streams and in other areas where water is available most of the year but not in summer (BALLESTEROS 1984, FRANQUESA 1995).

Isoetetum durieui has been cited in the north-eastern quadrant of the Iberian Peninsula as well as in the south-western corner of the Iberian Peninsula. Other close syntaxa described in the Mediterranean basin are: Isoeto histricis-Radioletum linoidis Chevassut & Quezel 1956 isoetetosum durieui (Algeria), Isoeto-Nasturtietum Barbero 1965

(SE France), Isoeto-Ranunculetum parviflori Brullo, Di Martino & Marcenò 1977 (Pantelleria, Italy) and Radiolo-Isoetetum durieui Brullo & Minissale 1997 (Minorca, Spain).

Ordination of the Isoetes vegetation

The ordination diagram obtained using PCA (Fig. 2) illustrates two main gradients. Axis 1 describes an altitudinal sequence between the amphibian habitats, which are flooded for a longer period (communities of *I. velatum* subsp. *velatum* and *I. setaceum* on the left half of the diagram) and the semi-terrestrial habitats, flooded for a shorter period (communities of *I. durieui* and *I. histrix* on the right side of the diagram). Axis 2 mainly separates the *Isoetes setaceum* community due to its different floristic composition, which could be attributed to the more eutrophic conditions supported by this community.

Discussion

The group of *Isoetes*-based ephemeral vegetation contains 42 taxa characteristic to Isoeto-Nanojuncetea. This figure correspond to approximately 45 % of those species characteristic to the class which are present on the Iberian Peninsula (Rivas-Martínez et al. 2002). From a phytogeographical viewpoint, they include the endemic element (*Eryngium galiodes*, *Ranunculus longipes*), the western Mediterranean element (*Isoetes velatum* subsp. *velatum*, *Isoetes setaceum*, *Exaculum pusillum*, *Agrostis pourretii*), the Atlantic-Mediterranean element (*Isoetes histrix*, *Myosotis sicula*, *Sisymbrella aspera*) and the Mediterranean element (*Isoetes durieui*, *Lythrum thymifolia*).

Soil type and topography are implicated as main factors determining the vegetation of vernal pools (Holland & Dains 1990). The fact that the *Isoetes* communities are only found on non-calcareous soils explains that the first PCA axis was primarily related to the period of submersion: longer in the *Isoetes velatum* and *I. setaceum* communities and shorter in the *I. histrix* and *I. durieui* communities.

The distribution of the four *Isoetes* species overlaps in the IP, occurring mainly in the western Mediterranean half, and to a lesser degree in the north-eastern Mediterranean quadrant (Prada 1983). The distribution of these communities provided by this work indicates that the western Mediterranean part of the peninsula, with four communities of *Isoetes*, shows a greater phytocenotic richness than the north-eastern quadrant of the Peninsula, which has only one. This distribution pattern can be explained by a combination of ecological factors in the Mediterranean Western territories of the Iberian Peninsula: Mediterranean climate with an Atlantic influence and siliceous soils. The amount of rainfall in western Mediterranean areas increases continuously from summer to spring (spring > winter > autumn > summer), in contrast to the Eastern Mediterranean basin where the Mediterranean rhythm of rainfall interrupts the filling from precipitation in win-

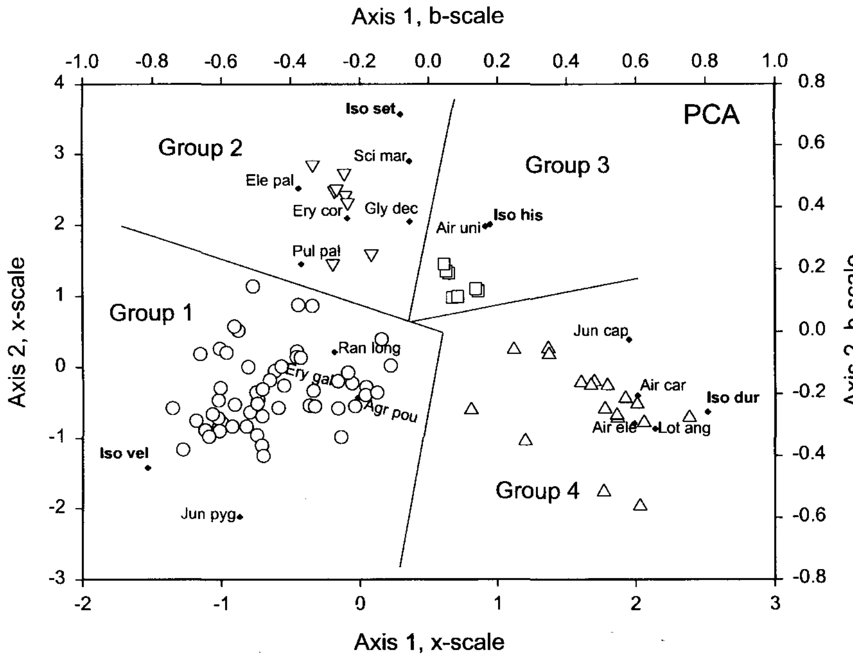

Fig. 2. PCA-ordination diagram of the *Isoetes*-based vegetation (89 relevés). The x-scale applies to sites, the b-scale to species. Samples: Symbols correspond to those in Fig. 1. Plants: *Air car - Aira caryophyllea* subsp. *caryophyllea*, *Air ele – Aira elegantissima*, *Air uni – Aira caryophyllea* subsp. *uniaristata*, *Agr pou – Agrostis pourretii*, *Ele pal – Eleocharis palustris*, *Ery gal – Eryngium galioides*, *Ery cor – Eryngium corniculatum*, *Gly dec – Glyceria declinata*, *Iso dur – Isoetes durieui*, *Iso his – Isoetes histrix*, *Iso set – Isoetes setaceum*, *Iso vel – Isoetes velatum* subsp. *velatum*, *Jun cap – Juncus capitatus*, *Jun pyg – Juncus pygameus*, *Lot ang – Lotus angustissimus*, *Pul pal – Pulicaria paludosa*, *Ran lon – Ranunculus longipes*, *Sci mar – Scirpus maritimus*.

ter and thus the efficiency of water storage (autumn > winter > spring > summer). Moreover, the greater extension of siliceous soils in the western part of the peninsula, and its characteristic orography (with basins running from east to west) appears to have favored the isolation of the basins and the formation of an endemic Iberian-Atlantic element.

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