Influence of land use on the composition of plant communities from seasonal pond ecosystems in the Guadiana Valley Natural Park (Portugal)

by Dalila ESPÍRITO SANTO and Pedro ARSÉNIO, Lisboa, Portugal

with 4 figures and 2 tables

Abstract. The aim of this work is to study the relationship between land use and different seasonal pond communities, as well as their spatial and temporal distribution in the Guadiana Valley Natural Park (Mediterranean Iberian Peninsula). A total of 104 relevés were undertaken according to the method of BRAUN-BLANQUET (1979). The relationships between species and environmental variables were studied through a canonical correlation analysis (CCA) applied to these relevés using the CANOCO program. A classification with the TWINSpan program (HILL 1979) was also made. Ten groups corresponding to the following associations were recognized: *Callitriche brutiae*-*Ranunculus peltati*, *Bolboschoenetum maritimi*, *Glyceria declinatae*-*Eleocharitetum palustris*, *Eryngium corniculati*-*Preslietum cervinae*, *Peplido erectae*-*Agrostietum salmanticae*, *Isoetes velatae*-*Juncetum pygmaei*, *Pulicaria uliginosae*-*Agrostietum salmanticae*, *Periballia laevis*-*Illecebretrum verticillati*, *Loto subbiflori*-*Chaetopogonetum fasciculati* and *Trifolium resupinatum*-*Caricetum chaetophyllae*. Both flooding period and land use were found to determine the occurrence of each of these communities. Grazing can favour the occurrence of *Isoetes* spp. communities. Soil mobilization from agricultural activities, on the other hand, is often related to the disappearance of these communities because in such circumstances no surface water accumulation occurs.

Keywords: vernal pools, ephemeral vegetation, vulnerable habitats, grazing, human disturbance.

Nomenclature: Plant species were identified through the use of the following floras: FRANCO & ROCHA AFONSO (1994, 1998, 2003), VALDÉS et al. (1987) and CASTROVIEJO et al. (1986) and through comparison with previously herborized material from the João de Carvalho e Vasconcellos Herbarium (LISI). All the names of syntaxa were checked according to RIVAS-MARTINEZ et al. (2001, 2002), after having consulted the works of AUBERT & LOISEL (1971), BALLESTEROS (1984), BRULLO & MINISALE (1998), PINTO GOMES et al. (1999), RIVAS GODAY (1956, 1964, 1970) & RIVAS-MARTÍNEZ et al. (1980) for community identification and characterization purposes.

Abbreviations: P – yearly average precipitation in mm, T – yearly average temperature in centigrade degrees (Celsius), CCA – canonical correlation analysis, CANOCO – Software for Canonical Community Ordination, TWINSpan – FORTRAN program for two-way indicator species analysis, Int. – intervention, Diss. – dissolved.

Introduction

Seasonal ponds play an important role in the food chain of the Alentejo landscape ecosystems, particularly as feeding areas for birds. These habitats are highly vulnerable, not only because of their seasonality, but also for occurring in places frequently affected by the influence of grazing and other agricultural activities. With the support of the Guadiana Valley Natural Park Authority, a floristic and ecological/syntaxonomical study was conducted on these habitats from the spring of 2001 to the spring of 2002.

The study aimed at a) a syntaxonomical classification of the pond communities, b) a better understanding of their seasonality and inter-annual variability, and c) the evaluation of how land-use changes affect these different communities both spatially and temporally.

Study area

The Guadiana Valley Natural Park is located in the south-east of the Baixo Alentejo region (Portugal) and occupies a total area of 69 500 hectares. The Guadiana river valley is one of its main natural features. It comprises numerous types of natural habitats with significant importance to nature conservation and large areas of pastures and cereal crops.

According to the Rivas-Martínez bioclimatic system (RIVAS-MARTÍNEZ et al. 1999), the Guadiana Valley ranges from the thermomediterranean to the mesomediterranean bioclimate thermotypes (CAPELO 1996). The mean annual precipitation of the area where the ponds are located is about 630 mm and the dry period (where $P < 2 T$) extends from May to September. There are no significant limitations to vegetative growth in winter, with average temperatures staying above 7.5 °C most of the time.

Two siliceous vegetation series dominate the region's natural landscape: *Pyro bourgaeanae-Querceto rotundifoliae* Sigmetum and *Poterio agrimonioidis-Querceto suberis* Sigmetum. These vegetation series occupy large areas in the south-western quadrant of the Peninsula. Land use in these areas often corresponds to the agro-sylvo-pastoral system known as *montado*.

Seasonal ponds occur within the *montado* in topographically shallow areas, ranging from 200 to 18 000 square metres, that get filled from October onwards due to autumn rain episodes. Reaching a maximum depth of 60 cm, they can stay inundated until June, or alternate between dry and submerged states as much as four times in succession (this has been observed in ponds located in recently ploughed areas). Nevertheless even these areas stay inundated or waterlogged at least until April. The dense foliage of the marginal, emergent and floating plants is one of the main characteristics of this habitat, retaining a green aspect long after all the meadows around the pond have dried up. The location of the ponds is presented in Fig. 1.

Fig. 1. Location of the studied seasonal ponds in the Guadiana Valley Natural Park.

Methods

Phytosociological relevés (104), based on the concepts of the phytosociological theory (BRAUN-BLANQUET 1979), and phytocological characterization data were sampled in 19 seasonal ponds during the spring of 2002. Field observations continued until the ponds were completely dried, with the relevés being repeated during the months of March, May and June. Both qualitative and quantitative environmental variables were measured for each pond. The qualitative variables were sample month, the usage of the pond by livestock for drinking, and the presence or absence in the vicinity of: agricultural activity generally, afforestation (distinguishing Holm Oak and *Eucalyptus*), cereal cropping, ploughing and grazing. Water depth (cm), pond area (sq metres), temperature (°C), pH, dissolved oxygen (mg/l and % of saturation) as well as conductivity (µS) and turbulence (NTL) were the quantitative variables recorded at each visit for each pond.

In addition, a soil moisture scale, ranging from 1 (dry) to 6 (waterlogged), was applied in the case of recently ploughed ponds because although there was no surface water present, soil moisture varied considerably throughout the observation period.

A TWINSpan classification (HILL 1979) was performed; the relationships between species occurrence and environmental factors were studied through canonical correlation analysis (CCA) using the CANOCO software (BRAAK & SMILAUER 1998).

Results

Syntaxonomical groups

All the relevés were classified through a TWINSpan classification analysis (Fig. 2). Ten different communities resulted from this analysis, classified into the following associations: *Callitriche brutiae*-*Ranunculetum peltati*, *Bolboschoenetum maritimi*, *Glycerio declinatae*-*Eleocharitetum palustris*, *Eryngio corniculati*-*Preslietum cervinae*, *Peplido erectae*-*Agrostietum salmanticae*, *Isoeto velatae*-*Juncetum pygmaei*, *Pulicario uliginosae*-*Agrostietum salmanticae*, *Periballio laevis*-*Illecebretum verticillati*, *Loto subbiflori*-*Chaetopogonetum fasciculati* and *Trifolio resupinati*-*Caricetum chaetophyllae*. Table 1 shows constancy values for the associations in these seasonal ponds.

Callitriche brutiae-*Ranunculetum peltati*

Group 1 in Fig. 2 and Table 1

This community, ranked into the Potametea, is usually located in the centre of the deepest ponds and is characterized by the dominance of *Ranunculus peltatus* subsp. *peltatus* var. *peltatus*. This dominance eliminates other plants due to light competition. The presence of *Callitriche brutia* is another characteristic. This association often borders on the *Peplido erectae*-*Agros-*

Fig. 2. Dendrogram obtained from a TWINSpan classification analysis on 104 relevés from the study area: Group 1, *Callitriche brutiae*-*Ranunculetum peltati*. Group 2a, *Bolboschoenetum maritimi* (May relevés). Group 2b, *Bolboschoenetum maritimae* (March relevés). Group 3, *Glycerio declinatae*-*Eleocharitetum palustris*. Group 4, *Eryngio corniculati*-*Preslietum cervinae*. Group 5a, *Peplido erectae*-*Agrostietum salmanticae* (May relevés). Group 5b, *Peplido erectae*-*Agrostietum salmanticae* (March relevés). Group 6, *Junco pygmaei*-*Isoetum velati*. Group 7, *Pulicario uliginosae*-*Agrostietum salmanticae*. Group 8, *Periballio laevis*-*Illecebrellum verticillati*. Group 9, *Loto subbiflori*-*Chaetopogonetum fasciculati*. Group 10, *Trifolio resupinati*-*Caricetum chaetophyllae*.

tietum salmanticae and *Eryngio corniculatae*-*Preslietum cervinae*. Its optimum occurs at the beginning of the inundation period.

Bolboschoenetum maritimi

Group 2 in Fig. 2 and Table 1

This community occurs in wide depressions on salty soils and is ranked into the *Phragmito-Magnocaricetea*. These large and brackish ponds are dominated by *Bolboschoenus maritimus* and are of significant value for conservation: *Juncus emmanuelis* and *Myosotis discolor* subsp. *debilis* are two of the species that occur. RIVAS-GODAY (1964) also refers to the occurrence of this community on salty sedimentary soils located upstream in the Guadiana basin. This community often borders *Isoeto-Nanojuncetea*

Table 1. Communities in seasonal ponds on the Natural Park of the Guadiana Valley: Group 1, *Callitriche brutiae*-*Ranunculetum peltati*. Group 2, *Bolboschoenetum maritimi*. Group 3, *Glyceria declinatae*-*Eleocharitetum palustris*. Group 4, *Eryngio corniculati*-*Preslietum cervinae*. Group 5, *Peplido erectae*-*Agrostietum salmanticae*. Group 6, *Junco pygmaei*-*Isoetum velati*. Group 7, *Pulicario uliginosae*-*Agrostietum salmanticae*. Group 8, *Periballio laevis*-*Illecebrellum verticillati*. Group 9, *Loto subbiflori*-*Chaetopogonetum fasciculati*. Group 0, *Junco capitati*-*Isoetum histricis*. Group 10, *Trifolium resupinati*-*Caricetum chaetophyllae*.

Group	1	2	3	4	5	6	7	8	9	0	10
N. of relevés	12	5	14	13	24	2	15	3	8	2	6
Potametea species											
<i>Ranunculus peltatus</i>	V	I	II	I	II	.	.	.	.	.	I
subsp. <i>peltatus</i>	IV	I	.	.	IV	.	.	.	.	.	I
<i>Callitriche brutia</i>	IV	I	.	.	IV	.	.	.	.	.	I
Phragmito-Magnocaricetea species											
<i>Bolboschoenus maritimus</i>	.	V	I	.	I	.	.	.	.	.	.
<i>Eleocharis palustris</i>	.	IV	V	.	III	.	.	.	IV	.	.
<i>Glyceria declinata</i>	I	IV	V	.	.	.	.	.	IV	.	IV
<i>Junco emmanuensis</i>	.	II	I	.	I	.	.	.	.	.	.
Isoeto-Littorelletea species											
<i>Baldellia</i>	.	I	I	IV	IV	IV	2	III	.	.	V
<i>ranunculoides</i>	.	.	.	.	.	.	.	.	.	.	.
<i>Junco heterophyllus</i>	I	.	.	I	.	.	I	.	.	.	.
Isoeto-Nanojuncetea species											
<i>Eryngium corniculatum</i>	I	III	III	V	IV	I	III	1	.	I	III
<i>Lythrum borysthenicum</i>	I	I	I	III	V	2	IV	2	III	I	I
<i>Isoetes setaceum</i>	I	I	I	IV	IV	.	III	.	I	I	I
<i>Isoetes velatum</i>	.	.	.	.	1	2	.	.	.	.	.
<i>Junco pygmaeus</i>	.	.	.	I	I	2	II	.	.	.	.
<i>Agrostis pourretii</i>	.	II	I	II	IV	1	V	1	.	.	.
<i>Pulicaria paludosa</i>	.	III	I	IV	IV	1	V	1	I	I	I
<i>Illecebrum verticillatum</i>	I	I	.	.	I	.	I	3	II	1	.
<i>Junco tenageia</i>	I	.	.	I	I	.	II	3	.	.	I
<i>Molineriella laevis</i>	I	.	I	II	.	.	I	1	.	.	.
subsp. <i>australis</i>	.	.	.	.	.	.	.	.	.	.	.
<i>Chaetopogon fasciculatus</i>	.	.	.	.	.	II	2	V	.	.	.
<i>Lotus subbiflorus</i>	.	.	I	II	II	I	1	2	V	1	I
<i>Isoetes histrix</i>	.	.	.	.	.	I	.	.	.	2	.
<i>Junco capitatus</i>	.	.	.	.	.	.	.	.	.	1	.
<i>Junco bufonius</i>	I	.	I	I	I	.	II	2	.	.	I
<i>Lythrum hyssopifolia</i>	.	.	I	I	II	.	II	.	.	1	II
<i>Myosotis discolor</i>	.	III	.	I	I	.	.	.	.	1	I
subsp. <i>debilis</i>	.	.	.	.	.	.	.	.	.	.	.
<i>Mentha pulegium</i>	.	.	.	I	I	.	I	.	.	2	I
<i>Marsilea batardae</i>	I	.	.	I	I	.	I	.	.	.	.
<i>Lotus conimbricensis</i>	.	.	I	I	.	.	II	.	.	.	I
<i>Chamaemelum nobile</i>	.	.	.	.	.	.	.	.	II	I	I
<i>Chamaemelum fuscatum</i>	.	.	I	.	.	.	.	I	.	.	I
<i>Eryngium galioides</i>	.	.	I	I	.	.	II	.	.	.	.
<i>Carlina racemosa</i>	.	.	.	.	I	.	II	.	I	.	.
<i>Cicendia filiformis</i>	.	.	.	.	.	.	I	.	I	.	.
<i>Exaculum pusillum</i>	.	.	.	.	.	.	I	.	I	.	.
<i>Junco hybridus</i>	I	.	.	.	.	.	.	.	.	.	.
<i>Lotus parviflorus</i>	.	.	.	.	.	.	I	.	.	.	.
<i>Ranunculus muricatus</i>	.	.	.	.	.	.	.	.	I	.	.
Mollinio-Arrhenatheretea species											
<i>Carex divisa</i>	.	.	II	.	.	.	.	.	.	1	V
<i>Rumex conglomeratus</i>	I	I	I	II	III	.	IV	.	II	.	IV
<i>Trifolium resupinatum</i>	.	I	.	.	.	.	I	1	.	.	I
<i>Phalaris caerulea</i>	.	II	I	.	.	.	.	.	.	.	III
<i>Rumex crispus</i>	.	I	.	.	.	.	.	1	.	.	.
<i>Junco inflexus</i>	.	I	.	.	.	.	.	.	.	.	.
<i>Polypogon verticillatus</i>	.	.	.	.	.	.	.	1	.	.	.
<i>Cotula coronopifolia</i>	.	.	.	.	.	.	I	.	.	.	.
Helianthemetea species											
<i>Briza minor</i>	.	.	.	.	I	.	I	.	I	.	I
<i>Leontodon longirostris</i>	.	I	.	.	.	.	I	.	I	.	.
<i>Trifolium campestre</i>	.	.	.	.	.	.	I	.	.	.	I
<i>Logfia gallica</i>	.	.	.	.	.	.	.	I	.	.	.
<i>Ornithopus pinnatus</i>	.	.	.	.	.	.	.	.	I	.	.
Other species											
<i>Polypogon maritimus</i>	.	I	I	IV	I	I	V	.	.	.	I
<i>Chamaemelum mixtum</i>	I	I	.	.	.	.	I	.	.	.	I
<i>Trifolium cernuum</i>	.	.	.	I	I	.	I	.	I	.	.
<i>Gaudinia fragilis</i>	.	.	.	.	.	.	I	.	II	I	.
<i>Lolium multiflorum</i>	.	I	.	.	.	.	I	.	.	.	I
<i>Agrostis castellana</i>	.	.	.	.	.	.	.	I	I	.	.
<i>Hypochaeris radicata</i>	.	I	.	.	.	.	.	.	.	.	.
<i>Sonchus tenerimus</i>	.	I	.	.	.	.	.	.	.	.	.
<i>Echium plantagineum</i>	.	I	.	.	.	.	.	.	.	.	.
<i>Picris echioides</i>	.	I	.	.	.	.	.	.	.	.	.
<i>Polypogon monspeliensis</i>	.	.	.	I	.	.	.	.	.	.	.
<i>Rumex pulcher</i>	.	.	.	.	.	.	.	.	I	1	.

Other species: *Narcissus bulbocodium* subsp. *bulbocodium* II in 2; *Anthemis arvensis*, *Chrysanthemum segetum*, *Coleostephus myconis*, *Lactuca serriola* and *Raphanus raphanistrum* I in 2; *Diploaxis catholica*, *Lolium rigidum* and *Trifolium glomeratum* I in 3; *Dipcadi serotinum*, *Lathyrus angulatus*, *Lotus glareosus* var. *villosus*, *Ranunculus paludosus* and *Trifolium pratense* I in 5; *Andryala integrifolia*, *Belardia trixago*, *Bromus lanceolatus*, *Crepis vesicaria* subsp. *haenseleri*, *Galactites tomentosa*, *Gastridium ventricosum*, *Lamarckia aurea*, *Parentucellia viscosa*, *Plantago lagopus*, *Reseda lutea*, *Spergularia purpurea*, *Taeniatheum caput-medusae*, *Tolpis barbata*, *Trifolium subterraneum* and *Vulpia geniculata* I in 7; *Plantago coronopus* I in 10.

communities, namely *Peplido erectae*-*Agrostietum salmanticae* and *Eryngio corniculati*-*Preslietum cervinae*. Actually, these depressions have more ecological similarity with a lake having seasonal vegetation in its edges, than with a typical seasonal pond.

The TWINSPAN classification separates the relevés of this community carried out in March from those carried out in May. This is explained by the appearance of many ruderal plants in the latter dry period relevés, colonising from the surrounding meadows.

Glycerio declinatae-*Eleocharitetum palustris*

Group 3 in Fig. 2 and Table 1

This community, also of *Phragmito*-*Magnocaricetea*, occurs only in ponds where submersion lasts from October to May/June. It is a dense, herbaceous community characterized by the dominance of *Eleocharis palustris*. It frequently colonizes the less steeply sloped margins with low energy water flows in lagoons, river weirs and small dams, as observed by NETO (2002), and borders *Molinio*-*Arrhenatheretea* communities on the land-side. In our seasonal ponds this community was always located at deeper and longer submerged areas.

Eryngio corniculati-*Preslietum cervinae*

Group 4 in Fig. 2 and Table 1

In the summer *Eryngium corniculatum* makes a dense thistle formation in the previously marshy areas, with the exception of the pond centre where *Ranunculus peltatus* dominates. The identification of this community was not easy: firstly no *Preslia cervina* occurs, probably because it either needs a longer submersion period or because collection by local people (for culinary purposes) over a long period has turned it into a rare plant. Secondly, *Eryngium corniculatum* communities in the Iberian Peninsula vary notably (MOLINA & PERTÍNEZ 2000); if the three types recognized by the above authors are accepted, all three types can be considered to exist in the ponds studied here: type a) characterized by the presence of *Isoetes setaceum* but also of *Isoetes velatum* and frequently of *Baldellia ranunculoides*, where the typical relevés of *Eryngio corniculati*-*Preslietum cervinae* are; type b) characterized by the occurrence of a large amount of *Pulicaria paludosa*; type c) characterized by a higher presence and relative abundance of *Eleocharis palustris* and *Glyceria declinata*. However, the authors consider that the heterogeneity found in this community in our study was not sufficient to justify such a division, and prefer to recognize the typical association alone. Furthermore, the authors consider that the Algarve communities should be classified into this association. In this respect we do not agree with PINTO-GOMES et al. (1999), who classified these communities into the *Preslietum*.

Peplido erectae-Agrostietum salmanticae

Group 5 in Fig. 2 and Table 1

This community is usually dominated by *Isoetes setaceum* and *Lythrum borysthenicum* (*Peplis erecta*) and sometimes also by *Agrostis pourretii*. The TWINSpan classification separates the relevés of March from those carried out in May, once more due to the invasion by ruderal species from the surroundings. MOLINA (2005) includes all the Iberian communities with *Isoetes setaceum* in the *Peplido hispidulae-Isoetetum delilei*. However, in contrast to the relevés analyzed by the above-referred author, in the ponds of the current study species such as *Myosotis sicula*, *Lythrum thymifolia* and *Sisymbrella aspera* were consistently missing. The *Peplido erectae-Agrostietum salmanticae* was described by RIVAS-GODAY (1964), who characterized this community as a pre-Isoetion association. The presence in our study of *Polypogon maritimus* and *Eryngium galioides*, besides *Agrostis pourretii*, leads us to believe this is the proper community classification. Additionally, *Isoetes setaceum* is the differential plant of *Pulicario paludosae-Agrostietum salmanticae*, and its dominant presence reinforces the belief that this association should be affiliated in the Isoetion and not in the *Agrostion salmanticae* alliance as RIVAS-MARTÍNEZ et al. (2001, 2002) considered.

Junco pygmaei-Isoetetum velati

Group 6 in Fig. 2 and Table 1

This community is dominated by *Isoetes velatum* subsp. *velatum* and also by *Junco pygmaeus*. *Isoetes velatum* is the species that, of its genus, needs the longest submersion period. The optimum of this community is achieved at the end of spring. Contact communities are *Peplido erectae-Agrostietum salmanticae* and *Glycerio declinatae-Eleocharitetum palustris* in spring and *Eryngio corniculati-Preslietum cervinae* and *Pulicario uliginosae-Agrostietum salmanticae* at the beginning of summer. This behaviour is also described by MOLINA (2005).

Pulicario uliginosae-Agrostietum salmanticae

Group 7 in Fig. 2 and Table 1

This is a community of annual grasses occurring in shallow, temporarily inundated or waterlogged plains. This community often occurs in silty to silt-loamy soils, replacing the *Loto subbiflori-Chaetopogonetum fasciculati* community by the end of spring. This interpretation was also adopted in other studies on the seasonal ponds of the Algarve (PINTO-GOMES et al. 1999). Following MOLINA & CASADO (1997), this association includes all the communities of the Iberian-atlantic pastures dominated by *Agrostis pourretii*, including the ones classified into *Peplido erectae-Agrostietum salmanticae*. In the studied ponds the difference between the two communities is made by the characteristic absence or presence of *Isoetes setaceum*, revealing a shorter or longer submersion period respectively.

Periballio laevis-*Illecebretrum verticillati*

Group 8 in Fig. 2 and Table 1

This community typically occurs in the larger ponds. It is characterized by the dominance of *Illecebrum verticillatum* in early spring and of *Molinia laevis* subsp. *australis* afterwards. Due to the absence of *Spergularia rubra* and *Spergularia capillacea*, our stands differ from the *Periballio-Illecebretrum spergularietosum*, so far only recorded in northern Portuguese mountain areas (JANSEN & SEQUEIRA 1999). Contact communities include the *Pulicario uliginosae*-*Agrostietum salmanticae* and the *Loto subbiflori*-*Chaetopogonetum fasciculati*.

Loto subbiflori-*Chaetopogonetum fasciculati*

Group 9 in Fig. 2 and Table 1

This community is characterized by the presence of *Lotus subbiflorus* and *Cicendia filiformis* amongst other species in winter and at the beginning of spring. Later in spring, and in early summer, *Chaetopogon fasciculatus* is dominating there. It occupies the pond edges, being especially vulnerable to the invasion of plants from the surrounding communities with which it contacts. In years such as 2001, a particularly wet year (the total annual precipitation of the hydrological year of 2000/01 in the studied region was 769 mm, according to IM (2004)), the presence of this association may go unnoticed. This community's absence, probably as a result of the excessive rainfall, was also noted in other seasonal pond ecosystems within the Iberian Peninsula (RIVAS-MARTÍNEZ et al. 1980; PINTO-GOMES et al. 1999).

Trifolio resupinati-*Caricetum chaetophyllae*

Group 10 in Fig. 2 and Table 1

The *Trifolio resupinati*-*Caricetum chaetophyllae*, classified into the *Molinio-Arrhenatheretea*, occurs in grazed areas and frequently contacts with the *Loto subbiflori*-*Chaetopogonetum fasciculati* community, characterized by the usual presence of *Carex divisa* (*Carex chaetophylla*).

Junco capitati-*Isoetetum histricis*

Group 0 in Table 1

This community was observed *in situ* during the 2001 survey but was not easily recognized in 2002. *Isoetes histrix* is, of all the identified *Isoetes*, the one occurring in the most marginal position in the ponds. As noted by other authors (RUDNER & DEIL 1999) in other south-western Iberian Peninsula seasonal ponds, it is the first one to disappear. Because of its ephemeral character and water needs, we believe that this association should be affiliated to the *Cicendion*, and not to the *Preslion cervinae* alliance as considered by RIVAS-MARTÍNEZ et al. (2001, 2002). As MOLINA (2005) also describes, it grows on briefly flooded soils, and is usually found in contact with annual dry grasslands of *Helianthemetea*.

Ordination by Canonical Correspondence Analysis (CCA)

The aim of this analysis was to isolate the most interesting features of floristic composition and physiognomy along this component of the successional process. The ordination of species (Fig. 3) shows that only the gross vegetation pattern is explained in part by the variables chosen (Table 2). This is supported by the low cumulative percentage variance of species, which amounts to only 10.3 % for the first two canonical axes. Moreover, of this variance, only 33.1 % can be explained by environmental variables. Random variation coming from disturbance is probably the most significant underlying reason.

By analysis of the canonical coefficients and correlations of environmental variables with axes, the variables with greater contributions to each axis were determined. Axis 1 describes a humidity (or water level) sequence between the habitats which are flooded for a longer period (communities of *Ranunculus peltatus*, *Eleocharis palustris*, *Eryngium corniculatum* and *Isoetes velatum* subsp. *velatum* on the left half of the diagram) and the habitats which are flooded for a shorter period (communities of *Chaetopogon fasciculatus* and *Molinieriella laevis* subsp. *australis*, on the right side of the diagram). The variables related with quality of water naturally are related with itself; the "June" variable is also related with humidity. In this month, relevés have been made only in wet conditions. Axis 2 mainly sepa-

Fig. 3. CCA-ordination diagram of the species identified in the relevés.

Table 2. Summary of ordination results of CCA (output of CANOCO).

Axes	1	2	3	4	Total inertia
Eigenvalues	.413	.340	.269	.225	7.302
Species-environment correlations	.920	.912	.906	.867	
Cumulative percentage variance					
of species data	5.7	10.3	14.0	17.1	
of species-environment relation	18.1	33.1	44.9	54.8	
Sum of all unconstrained eigenvalues					7.302
Sum of all canonical eigenvalues					2.277

rates the *Bolbochoenus maritimus* community due to its different floristic composition, which is associated with the larger dimensions of the pool.

Discussion and conclusions

The observed seasonal ponds can thus be classified into two distinct types: 1) ponds only with vegetation of Isoeto-Nanojuncetea and Potametea; 2) ponds with vegetation of Isoeto-Nanojuncetea, Potametea and Phragmito-Magnocaricetea.

Fig. 4. Model of the seasonal and spatial distribution of the Isoeto-Nanojuncetea vegetation in a non disturbed pond in the study area.

The first seasonal pond type consists of *microgeosigmeta* presenting simultaneously some, if not all, of the alliances of the Isoetetalia (Fig. 4). The submersion period for each *microsigmetum* determines its presence/absence, as well as the prevailing land use (grazing, cattle type, agriculture, forestry). Thus the same seasonal pond can sustain different vegetation communities from one year to the next as well as different successional paths in distinct years. Nevertheless, consistent patterns can be recognized in the transition of species composition from the beginning of the growing season towards its end, as also observed by RUDNER (2005) in the south-western Iberian Peninsula. *Eryngium corniculatum* and *Isoetes* spp. are the dominant species in these ecosystems. Several species of *Isoetes* can coexist in the same pond positioning themselves along a gradient of water depth: from the deeper to the shallower water levels one can recognize *Isoetes velatum* subsp. *velatum*, *Isoetes setaceum* and *Isoetes histrix*, each corresponding to the alliances *Menthion cervinae*, *Isoetion* and *Cicendion* (or *Agrostion pourretii*) respectively. By the end of winter, small plants of precocious budding occur in these ponds, namely: *Cicendia filiformis*, *Illecebrum verticillatum*, *Isoetes histrix*, *Isolepis pseudosetacea*, *Lotus subbiflorus*, *Juncus capitatus*, *Juncus pygmaeus*, *Radiola linoides* (*Cicendion* characteristic plants). In spring, as the water level lowers itself, *Isoetes setaceum* and *Lythrum borysthenticum* (*Isoetion* characteristic plants) reach their ecological optimum. By the end of spring *Eryngium corniculatum*, *Eryngium galiodes*, *Isoetes velatum* subsp. *velatum*, *Mentha pulegium*, *Lythrum hyssopifolium* and *Marsilea batardae* reach their maximum development (*Menthion cervinae* characteristic plants). In the beginning of summer the grasses *Agrostis pourretii*, *Molineriella laevis* subsp. *australis* or *Chaetopogon fasciculatus* (*Agrostion pourretii* characteristic plants) dominate.

The second seasonal pond type corresponds to the largest ponds with a submersion period longer than 6 months. These ponds often experience eutrophication problems, revealed by the presence of *Glyceria declinata*.

Surrounding both seasonal pond types, communities favoured by grazing, such as those dominated by *Trifolium resupinatum* and *Carex divisa*, can occur.

Thus, a well-conserved seasonal pond ecosystem is constituted by a *microgeosigmetum* whose evolution, both in space and time, follows a double gradient of temperature and soil moisture. The simultaneous presence of *Isoetes* spp., *Juncus* spp. (dwarf species only), *Eryngium* spp. and *Lythrum* spp., may serve as an indicator of well-conserved seasonal ponds. The absence of the previous taxa and the dominance of larger annual plants such as *Agrostis pourretii*, *Pulicaria paludosa* and *Mentha pulegium* are indicators of ecosystem degradation.

The occurrence of either an above average annual rainfall or the absence of soil mobilization can lead to the occurrence of ephemeral communities previously unknown from that location. As DEIL (2005) also notes, in the south-western Iberian Peninsula seed bank composition and distinct germination conditions can explain some year-to-year fluctuations in the eco-

phases of seasonal ponds, triggered by the submersion period and soil temperatures during the amphibic phase.

Generally these communities contact with vegetation of *Molinio-Arrhenatheretea*, and also of *Plantaginetalia majoris*, in the case of grazed areas. In ponds surrounded by cultivated areas, *Stellarietea mediae* characteristic plants are bound to appear, mixing with the existing seasonal pond flora. The same thing happens with *Helianthemetea guttati* characteristic plants when the ponds are surrounded by natural pastures.

Indiscriminate ploughing, the deepening of ponds for livestock drinking, cattle trampling, eutrophication, afforestation and drainage by canals constitute serious threats to the subsistence of seasonal ponds. Therefore the authors suggest that seasonal ponds located in cultivated or forested areas should be protected by a buffer zone from the impacts of ploughing and eutrophication from agricultural fertilizers. The ones located in cattle grazed areas should be fenced along the outside edges of the *Agrostion pourretii* communities in order to preserve the ponds' integrity and structure.

Extensive sheep grazing appears to have no negative repercussions on these ecosystems, however increasing stocking density may endanger the natural turnover capability of the seasonal communities as well as favour the arrival of ruderal plants, thus disturbing the successional evolution of the referred communities.

The ephemeral communities (*Cicendion* and/or *Agrostion pourretii*), created by brief submersion periods occurring occasionally on pond edges, neither add to nor diminish the conservation status of a seasonal pond.

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Addresses of the authors:

Dalila ESPÍRITO SANTO, Coordinator Researcher, Departamento de Protecção de Plantas e de Fitoecologia, Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal. E-mail: dalilaesanto@isa.utl.pt

Pedro ARSÉNIO, Landscape Architect, Secção Autónoma de Arquitectura Paisagista, Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal. E-mail: arseniop@isa.utl.pt