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Plant diversity and conservation value of continental temporary pools

Balázs A. Lukács[1,*], Gábor Sramkó[2], Attila Molnár V.[3]

[1]Department of Tisza research, Balaton Limnological Institute, Centre for Ecological Research, H-4026 Debrecen, Bem tér. 18/C.
[2]MTA-ELTE-MTM Ecology Research Group, H-1117 Budapest, Pázmány Péter s. 1/C.
[3]Department of Botany, University of Debrecen, H-4032 Debrecen, Egyetem tér 1.

*Corresponding author:
Email: lukacs.balazs@okologia.mta.hu; Phone: +3630-545-9845

Abstract
Temporary pools are unusual habitats because they share features of aquatic and terrestrial ecosystems. They are habitats of community interests according to the Natura 2000 network (Natura code: 3130 and 3170), and can be found in several climatic regions where they harbours various wetland habitats. Whereas Mediterranean temporary pools are well studied, only a few papers deal with their continental counterparts probably because they are mainly found on arable fields often displaying decades-lasting dormancy. This study aims at filling this gap in our knowledge by evaluating plant species composition, habitat types and diversity of temporary pools in continental climate. We analysed data from 185 phytosociological relevés (79 historical and 106 contemporary data) from different types of waterlogged arable fields, including rice paddy fields, from the Pannonian Ecoregion. We found significant differentiations of rice paddy fields from 'other' waterlogged arable fields according to PCA, TWINSPAN and Generalized Least Square Model. Diversity partitioning of species abundance data showed that these habitats have a very high alpha (Species number, Simpson and Shannon) and beta diversity, which means that all the sites have high importance in habitat conservation. We found many vascular plants listed in IUCN and national red lists among the indicator and characteristic species of continental temporary pools. Our results demonstrate the conservation importance of continental temporary pools in relation to habitat and biodiversity management and conservation planning.

Keywords: agriculture; additive diversity partitioning; Isoëto-Nanojuncetea; *Elatine*; habitat types; *Lindernia procumbens*; temporary ponds; vascular plants.

Abbreviations: AIC – Akaike's Information Criterion; AF – arable fields; CTP – continental temporary pool; GLS – Generalized Least Square Model; PCA – Principal Components Analysis; RPF – rice paddy fields; TWINSPAN – Two Way Indicator Species Analysis

1. Introduction

Temporary pools (vernal pools) are small and shallow wetlands characterised by mostly annual amphibious plants (Pinto-Cruz et al., 2009). Temporary pools are widespread on a global scale; they can be found in the Mediterranean (Zacharias and Zamparas 2010; Grillas et al., 2004), in the tropics (Bambaradeniya et al., 2004) and in continental climate as well. In Europe they are considered to be habitats of Community Interest and harbour many endangered and red list species. Seasonal wetlands in Europe, especially in the Mediterranean, encompass a wide range of vegetation and community type richness that include annual and perennial vegetation (Deil, 2005; Pinto-Cruz et al., 2009). The general ecology (Zacharias and Zamparas, 2010; Pinto-Cruz et al., 2011; Bagella and Caria, 2012), threatening factors (Rhazi et al., 2001), conservational aspects (Rhazi et al., 2004; Pinto-Cruz et al., 2009), and diversity of Mediterranean temporary pools are well understood and intensively investigated. It is currently recognised as one of the most interesting habitats in the Mediterranean bioclimatic region, which maintain numerous extremely rare and isolated taxa (Médail, 2004).

Under continental climatic conditions, temporary wetlands are very shallow water bodies, which appear in floodplains of rivers or any kind of water-saturated or submerged places where astatic water conditions (i.e. temporal overdominance of water) can easily arise; such conditions normally occur on arable fields (Deil, 2005). Temporary pools on arable fields have different names in the literature: "farmland ponds" (Giora et al., 2010), "segetal fields with inland water" (Csiky and Oláh, 2006), "vernal pools on soils with bad water balance" (Pál et al., 2006), "ephemeral mudflat vegetation" (Bissels et al., 2005), and dwarf plant communities (Deil, 2005); or named according to a phytosociological taxon name (Nanocyperion; Isoëto-Nanojuncetea vegetation; Ellenberg, 1988). Mediterranean temporary pools and temporary pools on arable fields have many similar characters: floods, precipitation growth, lifts of ground water in winter, at spring or sometimes at the beginning of summer are the major factors that determine the formation of these habitats (Zacharias and Zamparas 2010). Hence, similar to Mediterranean temporary pools, we propose here to classify temporary wetlands in continental climate into a common habitat type to be called to Continental temporary pools (CTP).

Similarly to Mediterranean temporary pools, CTPs have a largely autonomous hydrology, inundated and dry periods are alternating, and usually occupy small pools, we should rather refer to them as depressions, which are flooded for a sufficiently long period to allow for the development of hydromorphic soils and aquatic or amphibious plant communities (Bagella and Caria, 2012). If they persist until mid-summer for an adequate period, special vegetation dominated by amphibious plant communities will develop. Drying in summer eliminate more common aquatic plants and helophyte communities, which are characteristic elements of more permanent waters (Zacharias and Zamparas, 2010). CTPs are likely to appear in the former floodplain of rivers, which are cut from direct floods due to river regulation, but situated in lower reliefs. A major difference between Mediterranean and continental temporary pools is that CTPs mostly (but not exclusively) develops in waterlogged arable fields. Soil management and plant protection is nearly impossible in these temporary pools during inundation, wherefore very special vegetation develops (Albrecht, 1999; Baumann and Täuber, 1999; Täuber, 2000; Täuber and Petersen, 2000). Most of them appears random and can reappear after decades of dormancy (Popiela, 2005).

The appearance of waterlogged arable fields is connected to mere chance or haphazard; it often happens that fields are not covered by water for decades, but in some years significant floods appear because of high precipitation. According to Hoffmann et al. (2000), the vegetation of CTPs needs special climatic variables such as high precipitation in the previous year, relatively cool spring, and relatively warm and wet summer days. The species connected to CTPs have well-adapted to long-lasting dormancy. They have long-term persistent seed bank, high plasticity in germinations, and high vegetative plasticity of adults (Poschlod et al., 1999). Seeds are viable for decades or even more than one hundred years (Deil, 2005) and many of the species of CTPs have a persistent seed bank and produce enormous number of seeds (Bissels et al., 2005). Rare and endangered species that are apparently absent in the vegetation for decades can be recorded in the seed bank (Poschlod, 1993).

Freshwaters in general are among the most diverse and yet threatened components of global biodiversity (Dudgeon et al., 2006). Within an agricultural landscape, freshwater ponds are proved to be biodiversity hotspots (Davies et al., 2008; Thiere et al., 2008), and their conservation of continental freshwater flora and fauna requires urgent information on the ecological quality of its habitat (Oertli et al., 2005). Agricultural fields have replaced natural floodplain habitats in the Pannonian Ecoregion (i.e. the central European plain region stretching from southern Czech Republic to central Serbia mainly including present day territory of Hungary) after large-scale river regulations; therefore, freshwater biodiversity became isolated and endangered. Because of the present intensive agricultural land use, medium and small sized ponds and marshes are less frequent in the former floodplain along river valleys; hence, freshwater diversity can only survive in other habitat-types occupying small endorheic basins and depressions. Nonetheless, they appear seasonally, and temporary pools represent characteristic and important freshwater habitat-type in this agricultural landscape. CTPs are highly vulnerable due to their shallow water, small surface area, and the intensive agricultural and hydrographical modifications of its habitat.

Our work intends to objectively assess the conservational value of CTPs. One of the most influential approaches for assessing the conservation value of different habitat types to depict landscape diversity, and therefore linking patterns in biological diversity to landscape level environmental heterogeneity, is additive partitioning of species diversity (Veech et al., 2002; Erős, 2007). Briefly, additive diversity partitioning allows the decomposition of total (gamma) diversity into its local, within-habitat/community (alpha) and between-habitat/community (beta) components at a hierarchical scale and for a variety of measures of species diversity (e.g. number of species, Shannon diversity).

The aims of our study are: (i) to identify temporary pond types according to their vegetation composition; (ii) to define plant community diversity in terms of floristic composition of CTPs.

2. Materials and methods

2.1. Study area

The study was carried out in the Tisza and Drava Plains which are the tributaries of the Danube and located in the Pannonian Ecoregion, in Central Europe (EEA, 2002; Figure 1). Basically this Ecoregion belongs to seven countries (Austria, Czech Republic, Hungary, Slovakia, Serbia, Ukraine and Romania), and 90% of its area is found in Hungary. The large-scale river regulations here were performed in the 19^{th} century, which redrew the hydrological features of the whole area. The landscape of the ecoregion became highly influenced by human impact, and these perturbations resulted in the severe alteration or even in the extinction of indigenous natural habitats, and development of new aquatic systems. Hundreds of new standing waters were created along rivers (e.g. oxbow-lakes), while other habitat-types became scarcer (e.g. alkali ponds), transformed, or disappeared (e.g. marshes). In spite of their highly transformed nature, the environmental conditions underpinning the original hydrological characters still exist, as it is can be seen after heavy rains or floods which unravel the shape of the former swamps, marshes, lakes and canals. Such weather conditions can create thousands of hectares of waterlogged arable fields, which vary in size between $1m^2$ to 10 hectares, and are usually waterlogged for 2–3 months.

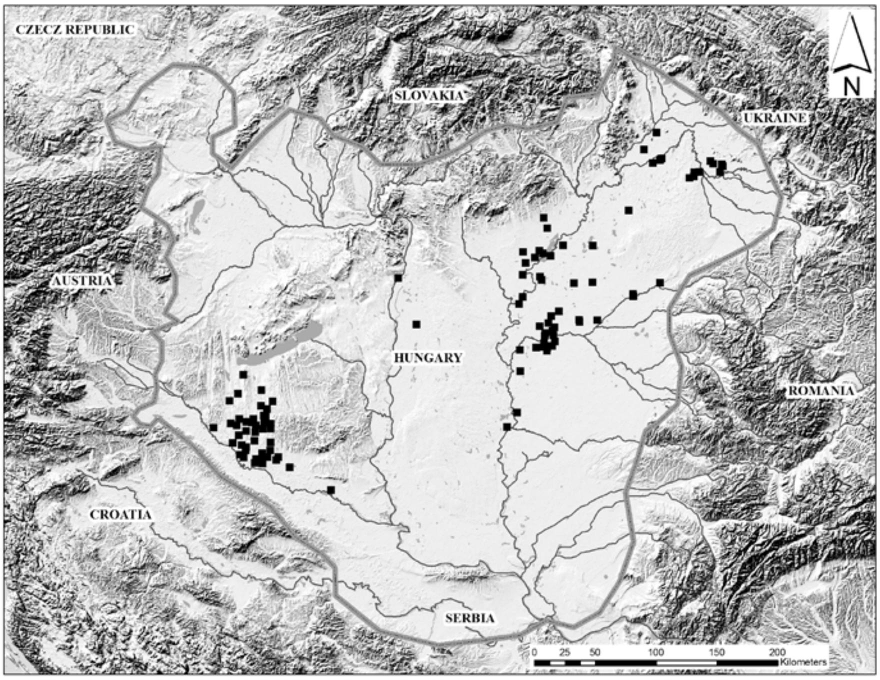

Figure 1. The 72 seasonally inundated sampling sites were located in agricultural fields in the Pannonian Ecoregion.

2.2. Data collection and data analysis

Vascular plant abundance data was collected from 17 sites with characteristic Isoëto-Nanojuncetea vegetation using 2m × 2m sized randomly arranged phytosociological relevés (Braun-Blanquet, 1951). Literature data of phytosociological relevés of the same dwarf plant communities from the Tisza and Drava Plains were also collected from 55 sites (Tímár, 1952, 1957; Ubrizsy, 1961; Pál et al., 2006). Altogether, 183 relevés in 72 seasonally inundated arable fields were included in our analyses. A-D scores of literature data were transformed into percent values (Dierschke, 1994). All sampling sites were characterized by very shallow water and different kind of human influence. They were situated in waterlogged arable fields (AF, n=143; field sampling data: 103; literature data: 40) and rice paddy fields (RPF, n=42; field sampling data: 3; literature data: 39) what we treated as 'a priori' habitat types. Vascular plants were identified to species level using the handbook of Király (2009). *Characeae* was only identified to genus level. The raw matrix was analyzed for synthetic parameters. Species constancy from abundance data and species conservational value (IUCN, 2011; Király, 2007) was assessed. Plant species were categorised into growth-form (den Hartog and Segal, 1964): hydrophyte (i.e. plants that mainly grows under water), hygrophyte (i.e. plants that mainly grows in wet or waterlogged soil), helophyte (i.e. plants that mainly grows in marshy soils) and 'other' categories (i.e. all other categories present at the site). Plant community types and indicator species were performed with Two-way indicator species analysis (TWINSPAN).

To evaluate the spatial pattern of plant species abundance, we examine the spatial autocorrelation by using Moran's index (I) as a function of spatial distance (Moran 1950). As spatial autocorrelation was found in our data set (Moran-Index = 0.57019; Z-value = 0.066, p= 0.0001) Generalized Least Square Model (GLS) was applied to define significant differences among potential plant community types. The proper measures of goodness-of-fit for the spatial model are based on the likelihood function. The use of an exponential spatial correlation was substantiated by the lower Akaike's Information Criterion (AIC) values of these models compared to models with a linear, spherical or Gaussian spatial correlation.

Moran's I was calculated using the ape package in the R Statistical Environment (Paradis et al., 2004; R Development Core Team, 2008); the GLS analysis was performed using the nlme package in R (Pinherio et al., 2012; R Development Core Team, 2008).

TWINSPAN were made with Community Analysis Package 4 (Pisces Conservation Ltd). After square root transformation Principal Components Analysis (PCA) was carried out to define pond groups and reliable species using the program CANOCO 4.5. (ter Brak and Smilauer, 2002).

We used additive partitioning (Veech, et al 2002) to examine the conservation value of habitats resulted from TWINSPAN clustering and PCA. Diversity calculations were made (i) at the relevé scale within a habitat type (i.e. alpha diversity); (ii) between relevés within a habitat type (i.e. $beta_1$ diversity); (iii) between habitat types within the ecoregion (i.e. $beta_2$ diversity), and (iv) for the whole ecoregion (i.e. total or gamma diversity).

We considered three diversity indices, ranging from those that put more weight to species richness (i.e. number of species) to those that emphasise abundance ratios (dominant versus rare species): (i) the number of species; (ii) Shannon diversity (dominant and rare species are weighted equally) and (iii) Simpson diversity (weighted toward abundant species). We quantified beta diversity among sites as the difference between total (gamma) and alpha diversity (Veech et al., 2002). Diversity calculations were made using the programme Species Diversity and Richness 4.1.2. (Pisces Conservation Ltd).

3. Results

3.1. Habitat characteristics

There were no constant species (i.e. species found in 81-100% of the relevés). Frequent species (n=6), which means that these species occurs less than 41-60% of the relevés constituted more than 30% of the overall abundance. Rare species (n=217), occurring in less than 20% of the relevés, contribute 25% of the overall abundance. Two species were found as abundant (occurrence: 61-80%) and 12 species found occasionally (occurrence: 21-40%) gives 20% and 22% of the overall abundance, respectively (Figure 2 and Table 1).

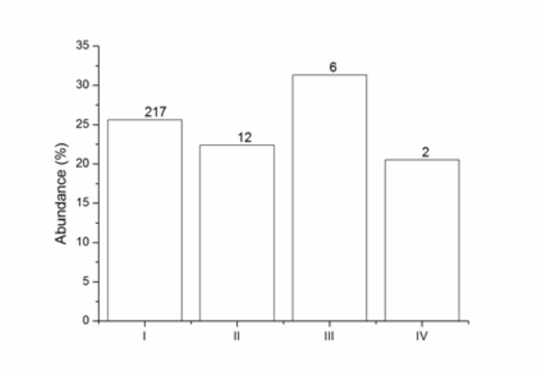

Figure 2. Mean abundances of species constancy value categories in the 183 relevés. Abbreviations: IV - abundant, III - frequent; II - occasional; I - rare. Numbers above bars refer to species number.

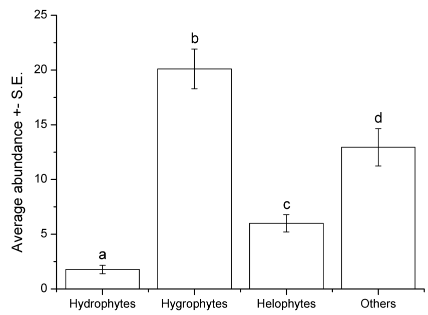

Figure 3. Average abundance of main life-form categories of the 183 relevés. Letters above bars show significant differences obtained by GLS to evaluate spatial autocorrelation.

According to the growth form spectra (Figure 3) relevés were dominated by hygrophytes (mud species). Other life form categories (arable plants, arable weeds) have also high abundance, while hydrophytes (aquatic plants) and helophytes (marsh plants) have very low abundance.

From the species list six species are categorised as near threatened, one species as endangered, three species as least concerned, and two species as data deficient according to IUCN (EU27) Red List (Table 1.). Six species are protected by national legislation in Hungary (Király, 2007).

Table 1. Red list categories (IUCN, national) and their proportion from total variance of all abundant (IV), all frequent (III), all occasional (II) and some of the rare (I) species found in the 183 relevés. Abbreviations: DD-data deficiency; EN-endangered; LC-least concern; NT-near threatened; P-Protected. Var(y): cumulative fit per species as fraction of variance of species in PCA ordination.

IUCN	IUCN (EU27)	HU	Taxa	Constancy	var(y)
			Echinochloa crus-galli	IV	22.11
LC		P	*Lindernia procumbens*	IV	20.26
			Alopecurus aequalis	III	5.78
NT	NT	P	*Elatine alsinastrum*	III	8.52
DD	NT	P	*Elatine hungarica*	III	24.85
LC	NT	P	*Elatine triandra*	III	9.00
LC			*Typha latifolia*	III	7.03
			Lythrum hysoppifolia	III	5.83
			Peplis portula	III	11.51
DD	DD		*Schoenoplectus supinus*	III	14.75
LC	NT		*Alisma gramineum*	II	1.84
LC	LC		*Alisma lanceolata*	II	7.33
			Alisma plantago-aquatica	II	2.95
			Eleocharis palustris	II	4.12
			Juncus bufonius	II	3.84
LC	LC		*Limosella aquatica*	II	2.38
			Polygonum aviculare	II	0.74
			Ranunculus sardous	II	4.77
LC			*Typha angustifolia*	II	2.18
LC	EN	P	*Elatine hydropiper*	I	0.14
LC	LC		*Eleocharis acicularis*	I	2.43
LC	NT	P	*Eleocharis carniolica*	I	0.05
LC	DD		*Eleocharis mamillata*	I	0.00
LC	NT		*Eleocharis ovata*	I	3.11

3.3. Habitat types

TWINSPAN clustering identified two habitat groups: rice paddy fields and 'other' waterlogged arable fields (Table 2). GLS showed significant differences between rice paddy fields and 'other' waterlogged arable fields ($P < 0.001$).

Table 2. Habitat types and indicator species of the 183 relevés obtained by TWINSPAN classification. Diagnostic species are highlighted by frames. The species' average covers are shown. Abbreviations: RPF, rice paddy fields; AF, arable fields.

Vegetation type	**RPF**	**AF**
Number of relevés	***128***	***42***
Alisma gramineum	6.94	0.77
Alisma lanceolata	2.82	13.60
Alisma plantago-aquatica	0.69	5.07
Alopecurus aequalis	0.14	13.10
Alopecurus pratensis	0.18	5.08
Ambrosia artemisiifolia	0.00	1.78
Bidens tripartita	0.16	3.00
Chara sp.	1.18	3.21
Cirsium arvense	0.12	0.75
Cyperus fuscus	2.16	2.09
Echinochloa crus-galli	6.63	51.34
Elatine alsinastrum	5.69	16.32
Elatine hungarica	28.78	42.03
Elatine triandra	17.10	11.16
Eleocharis acicularis	10.47	0.61
Eleocharis ovata	0.00	5.18
Eleocharis palustris	2.88	6.32
Elymus repens	5.02	5.81
Glyceria fluitans	0.45	6.07
Gypsophila muralis	0.51	0.87
Heleochloa alopecuroides	4.10	1.46
Juncus articulatus	0.06	0.93
Juncus bufonius	0.06	8.36
Juncus compressus	0.29	4.28
Lemna minor	9.45	6.69

Vegetation type	**RPF**	**AF**
Number of relevés	***128***	***42***
Limosella aquatica	2.14	3.85
Lindernia dubia	0.02	6.94
Lindernia procumbens	6.18	43.40
Lythrum hyssopifolia	0.49	9.90
Matricaria recutita	0.18	1.81
Myosurus minimus	0.00	0.81
Oenanthe aquatica	0.00	1.93
Oryza sativa	18.53	0.00
Peplis portula	2.82	24.22
Plantago major	0.59	3.01
Poa annua	0.00	0.94
Poa trivialis	0.00	0.62
Polygonum amphibium	0.00	4.33
Polygonum aviculare	1.39	1.01
Polygonum mite	0.00	0.74
Ranunculus sardous	0.27	10.34
Ranunculus sceleratus	0.12	3.74
Rorippa islandica	0.00	1.07
Rumex stenophyllus	0.18	0.90
Schoenoplectus mucronatus	0.98	0.99
Schoenoplectus supinus	10.63	27.82
Sparganium erectum	0.00	3.85
Typha angustifolia	5.92	1.99
Typha latifolia	2.39	14.37

Indicator species of rice paddy fields are *Oryza sativa, Eleocharis acicularis* and *Elatine triandra.* Characteristic species of the 'other' group are *Alisma lanceolata, Alopecurus aequalis, Echinochloa crus-galli, Elatine hungarica, Elatine alsinastrum, Lindernia procumbens, Peplis portula, Ranunculus sardous, Schoenoplectus supinus,* and *Typha latifolia*. For all the sites TWINSPAN analysis found *Oryza sativa, Elatine hungarica, Elatine triandra, Eleocharis acicularis* and *Echinochloa crus-galli* as indicator species. The PCA ordination diagram also distinguished these units (Figure 4). Sites separated along Axis 1 containing rice communities (*Oryza sativa*) from the 'others'. In the upper right quadrant of the ordination diagram a small subgroup of arable fields can be distinguished from the 'others' characterised by *Elatine hungarica*. Another subgroup can be separated in the upper left quadrant characterised by *Echinochloa crus-galli, Lindernia procumbens, Elatine triandra,* and *Elatine alsinastrum*. In the left side of the diagram another group of arable fields dominated by *Ranunculus sardous* and

Alopecurus aequalis can be distinguished. The first principal component explains 14.8% and the second principal component explains 24.2% of total variance. *Elatine hungarica, Lindernia procumbens*, *Echinochloa crus-galli, Peplis portula and Schoenoplectus supinus* were found as species that are mostly determined by sites variance in the PCA ordination (see Table 1).

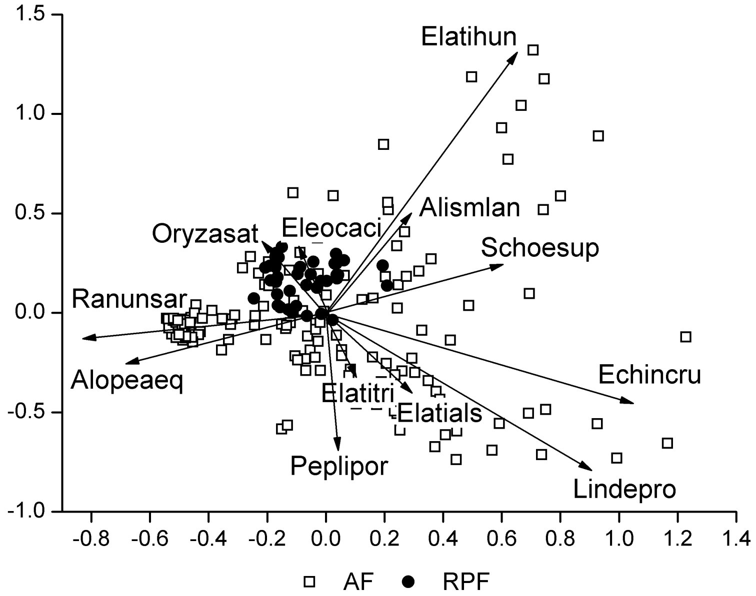

Figure 4. Ordination biplot of 183 relevés from 72 sites by principle component analysis (PCA). Each point (circles and squares) represent a relevés. Proximity between the points indicates species composition similarity. The direction and length of the arrows signify the direction and strength of a species to a group of relevés. Abbreviations: Alismlan, *Alisma lanceolata*; Alopeaeq, *Alopecurus aequalis*; Elatihun, *Elatine hungarica*; Elatitri, *Elatine triandra*; Elatials, *Elatine alsinastrum*; Eleocaci, *Eleocharis acicularis*; Schoesup, *Schoenoplectus supinus*; Echincru, *Echinochloa crus-galli*; Lindepro, *Lindernia procumbens*; Oryzasat, *Oryza sativa; Peplipor, Peplis portula; Ranunsar, Ranunculus sardous*. RPF, rice paddy fields; AF, arable fields.

3.4. Diversity partitioning

Alpha diversity of species richness was significantly lower in rice paddy fields (Figure 5). Within habitat type beta diversity (i.e. $beta_1$) was showed the same pattern. The overall within habitat type beta diversity (Total-$beta_1$= 222.16±0.7) was as high as alpha diversity of all sites (Total-alpha=239±9.06). Between habitat type diversity was relatively high ($beta_2$=93). Overall landscape scale patterns in species richness was best explained by within site diversity (alpha: 52%) followed closely by within habitat type diversity ($beta_1$: 48%), whereas between habitat type diversity ($beta_2$: 2%) was very low.

Shannon diversity of rice paddy fields and the 'other' disturbed habitats was quite similar (RPF-alpha: 3.35±0.1 SE, AF-alpha: 3.5±0.08 SE), whereas within habitat type beta diversity (i.e. $beta_1$) was found to be significantly lower in RPFs (Figure 5). Between habitat type diversity was relatively low ($beta_2$=0.15). Overall landscape scale patterns in Shannon diversity was best explained by within site diversity (alpha: 55%) followed by within habitat type beta diversity ($beta_1$: 29%) and finally between habitat type diversity ($beta_2$: 16%).

The patterns of Simpson diversity are partially similar to Shannon diversity (Figure 5). The alpha diversity of RPFs and 'other' waterlogged arable field was significantly different (RPF-alpha: 16.63±2.74 SE, AF-alpha: 16.31±1.86 SE). Within habitat type beta diversity of RPFs was significantly lower than other waterlogged arable field habitats. Between habitat type diversity was relatively high ($beta_2$=2.34). Overall landscape scale patterns in Simpson diversity was best explained by within site diversity (alpha: 56%) followed by within habitat type diversity ($beta_1$: 41%) and finally between habitat type diversity ($beta_2$: 6.5%).

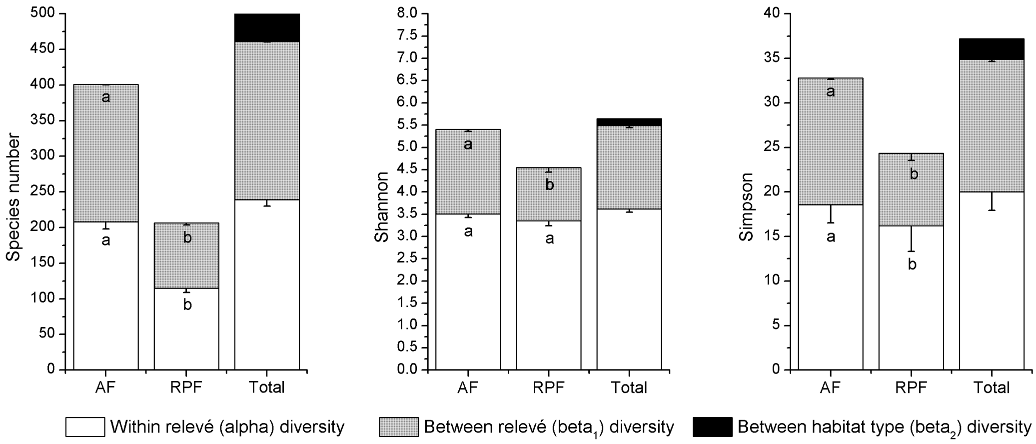

Figure 5. Additive partitioning of the number of species, Shannon and Simpson diversity, with corresponding S.E. ranges for the two habitat types resulted from TWINSPAN clustering. Abbreviations: RPF-rice paddy fields; AF-waterlogged arable fields. Letters under bars show significant differences between habitat types obtained by GLS to evaluate spatial autocorrelation.

4. Discussion

4.1. Habitat characteristics and habitat types

Temporary pools in a continental agricultural landscape are proved to be an important habitat for the conservation of freshwater biodiversity, harbouring surprisingly high number of species. In this study, we have produced the first account of the conservational importance of the vegetation of continental temporary pools. Our results emphasize that the vascular flora of CTPs is characterized by species tolerating flooded-waterlogged soils, amphibious species adapted to live either on land or in water, and aquatic plants adapted to deep water.

Habitat characteristic and habitat types of temporary pools according to floristic composition is scarcely studied in this Ecoregion, most probably due to its rarity, temporary nature, and because they are "hidden away" in agricultural environment where vegetation ecologists rarely make surveys . From syntaxonomical point of view these dwarf plant communities are belong to Isoëto-Nanojuncetea community (Popiela, 2005) and most of their literature are more or less descriptive (Tímár, 1952, 1957; Ubrizsy, 1948, 1961; Soó, 1948; Pietsch, 1973, Deil, 2005). Furthermore, communities belonging to other classes such as Potametea, Phragmitetea, and Magnocaricetea could be present at the same site, moreover, dwarf plant communities are normally replaced by Bidentetea communities as consequence of natural temporal changes (i.e. natural succession).

Habitat preferences of dwarf plant communities are different in Hungary according to literature (Csiky and Oláh, 2006) and herbarium data. These habitat differences are not mirrored in our study probably due to the large scale applied here. According to the findings of PCA ordination and TWINSPAN clustering dwarf plant communities can be divided into to two major types of habitats. This result contrasts to those carried out in Atlantic-Mediterranean region (Pinto-Cruz et al., 2009), which revealed several community types of temporary habitats. Our TWINSPAN results indicate the significant difference of rice paddy fields from 'other' waterlogged arable habitats, implying that these habitats maintain different species pool. Although RPFs create a distinct and cohesive point cloud in PCA ordination, their difference from others are evaluated here only as a subgroup, because this distinct group is surrounded by the others points. However, these could also form several subgroups, but without any kind of ecological inference. The diversity differences of these habitat types are also small. RPFs differ to some extent only in total number of species. Between habitat types Shannon diversity ($beta_2$) was minimal; between habitat type species number and Simpson diversity were relatively low. All of these results underline our view on the existence of a common habitat type.

We found that *Elatine hungarica, Elatine triandra, Eleocharis acicularis* and *Echinochloa crus-galli* are the main characteristic native species of the whole community. Although *Peplis portula, Schoenoplectus supinus, Eleocharis acicularis, Elatine triandra* and *Alisma lanceolata* may appear in both types of temporary pools, but characterise RPFs with higher appearance values.

4.2. Plant species diversity and conservation of temporary pools

The opinion about whether temporary or permanent wetlands harbour higher diversity is contrasting. Some of the studies (Nilsson and Svenson, 1995; Fairchild et al., 2003) found that temporary pools maintain higher species diversity (dytiscid, culicid and aquatic beetles), while Giora et al. (2010) found that permanent ponds possess more diverse plant and beetle communities. In addition, our study revealed a much higher plant species diversity of continental temporary pools than farmland ponds (Giora et al., 2010) or other floodplain freshwater habitats (Lukács et al., 2009; Lukács et al., 2011). Nonetheless, these findings must be interpreted as an important but not significant characteristic of these habitats, because our sampling clearly preferred ponds with characteristic Isoëto-Nanojuncetea vegetation and in general.

The IUCN Red List of Threatened Species is the most comprehensive resource detailing the global conservation status of plants and animals. In addition to be a source of essential information to guide conservation efforts focused on species, it is also one of the most useful tools for identifying sites for conservation importance. Moreover, Red List data can also be used to guide management of natural resources at multiple scales (Rodrigues et al., 2006), e.g. in Environmental Impact Assessments, National Biodiversity Strategies and Action Plans (Meynell, 2005). Continental temporary pools with characteristic Isoëto-Nanojuncetea vegetation are of major conservational importance because, despite their small size, they provide habitat for many rare and endangered species. Many of the characteristic and indicator species (*Elatine triandra, Elatine alsinastrum, Schoenoplectus supinus* and *Alisma gramineum*) are listed on IUCN and national red lists. Additionally, *Lindernia procumbens,* protected by IUCN and Bern convention, and *Elatine hungarica,* endemic to the Pannonian Ecoregion and listed by IUCN, were both found as characteristic species of waterlogged arable fields emphasising the need for their habitat protection. Another reason for their protection is the alarming rate of elimination or degradation of these habitats. The Pannonian Ecoregion situated mostly in the former floodplain of large rivers (Danube, Tisza, Körös, Maros, Drava) which are regulated to gain arable fields. Agricultural work is responsible for both the generation and abolishment of these habitats. The major environmental factors maintaining these habitats are continuous human disturbance by ploughing and somehow regular water-logging, which create hectares of open surfaces. If these ploughed fields are water-logged by heavy rains or floods, optimal circumstances can be established and temporary pool vegetation may arise. But local and regional scale drainage of arable fields, which is the interests of agriculture, can seriously endanger these habitats as it can cause searing before the characteristic plant community could develop.

The results of species richness, Shannon and Simpson diversity calculations have indicated similar alpha diversity between habitats, which argues for their overall uniformity in this respect. But these habitats also have a very high between relevé ($beta_1$) diversity, which means that these sites are different from each other in species composition. Overall, the conservation message from these results can be drawn as: because of the high contribution of between site ($beta_1$) diversity to total diversity, the best strategy for conserving these habitats and the inhabiting species in the Pannonian Ecoregion is to choose as many sites as possible for conservation. These results also imply the special importance of individual sites during the conservation planning of these habitats and species. However, when resources of conservation are limited, which is often the case, planning should ensure the conservation of a reasonably high portion of these habitat sites in the region.

The reasonably high number of sampling sites ensures the spatial patterns observed here to mirror faithfully the landscape-level ecology and diversity of CTPs. Our findings are in agreement with studies emphasizing the importance of wetlands found in agricultural landscapes (Davies et al., 2008), and argue against the assumption of current ideas, which emphasize the high importance of aquatic biodiversity found in large water bodies, which are in focus of Water Framework Directive (2000/60/EC). Our findings also corroborate the results to those studies (Williams et al., 2004; Oertli et al., 2005) that confirm the necessity to include agricultural freshwater habitats in the list of habitats requiring legal protection. In sum, we would like to draw attention to CTPs as habitat of community interest and habitat of many endangered species to serve reliable data which help decision makers to improve its conservation.

5. Conclusions

Our results suggest that temporary pools are valuable habitats according to their vegetation in the Pannonian Ecoregion, and under continental climatic influence. Here, in this agricultural landscape, important seasonal wetlands appear with similar conservation value and species richness as documented in Mediterranean temporary pools. The similarity between Mediterranean and Pannonian temporary pools led us to propose the term "Continental Temporary Pool" (CTP) to describe this similar habitat-type. The number of uncommon, rare and red list species (IUCN, Bern Convention and national red list) found in CTPs suggest that they are significantly contribute to gamma diversity at the ecoregional level. Their habitats have high alpha and beta diversity, which means that these habitats differ from each other according to their species composition. This information is critical in conservation planning. Some practical implication can also be drawn from our study.

- Many temporary pools in arable fields are best to left alone and not drained during their main vegetation period. This is the first management option.
- Although these habitats found to be high conservation value according to its vascular flora they are virtually unexplored from other groups of biotic elements yet. A wider range of research with other biotic elements (e.g. macrozoobenthon) is therefore recommended to assess their overall conservation value.
- Temporary pools are neglected from biodiversity assessment and monitoring schemes. International, national and local conservation strategies that aim to protect freshwater species and their assemblages need to consider temporary pools in arable fields.

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