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Temporary ponds of eastern Poland: an initial assessment of their importance for nature conservation

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Abstract
A preliminary investigation of temporary pond water beetle and larger branchiopod crustacean assemblages was undertaken in eastern Poland in 2003 and 2004. Ponds were studied in three landscape types: floodplain, agricultural plateau and forest. Plateau and floodplain ponds were richest in species and supported most species of conservation concern. Forest landscapes, although enjoying high levels of nature conservation protection, supported the least species rich ponds with fewer rarities, although they did support a number of specialist species. Overall, the results of the study provide evidence that temporary ponds in floodplain and other low intensity agricultural landscapes support rich invertebrate assemblages of high nature conservation interest in a European context.
Keywords: *water beetles, branchiopods, landscape types, floodplain ponds, species richness*

Résumé
Etangs temporaires en Pologne orientale: une première évaluation de leur importance pour la conservation de la nature

Une recherche préliminaire a été menée en 2003 et 2004 afin d'étudier les communautés de Coléoptères aquatiques et de Crustacés Branchiopodes des étangs temporaires de la Pologne orientale. Des étangs ont été choisis dans trois types de paysages (zones alluviales, plaines agricoles et forêts). Les étangs des zones alluviales et des plaines agricoles hébergeaient la plus grande richesse spécifique et le plus grand nombre d'espèces à forte valeur de conservation. Les paysages forestiers, malgré leur degré de protection élevé, abritaient les étangs les moins riches et avec moins d'espèces rares, bien qu'on y trouvait un certain nombre d'espèces spécialisées. Globalement, les résultats de cette étude démontrent que les étangs temporaires des zones alluviales et des paysages agricoles extensifs hébergent des communautés d'invertébrés riches et avec un grand intérêt de conservation dans le contexte européen.
Mots-clés: *Coléoptères aquatiques, Branchiopodes, types de paysages, étangs des zones alluviales, richesse spécifique*

Introduction
Temporary ponds are an important and biodiverse freshwater habitat, recognised worldwide for the range of rare and endangered species they support (Collinson et al. 1995; Simovich 1998; Boix et al. 2001; Nicolet et al. 2004). In Europe, the critical importance of this waterbody type has only become recognised over the last few decades, and in most cases this recognition has come too late, with intensive agriculture and urbanisation having already eliminated large numbers of such sites from the landscape, and degraded many of those that remain (Williams et al. 1998).

In some areas of central and eastern Europe, however, high quality temporary ponds still remain relatively common, reflecting the occurrence of low intensity farming in these areas (EEA 2004a). Within the EU, parts of eastern Poland, in particular, are still

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exceptionally rich in these waterbodies, largely because agriculture here is still conducted in a relatively traditional manner. Horses are still used widely in agriculture, and there is limited implementation of techniques such as under-drainage that paved the way for the creation of the intensive arable farming which now characterises much of the lowlands of western Europe.

Over the last few years, preliminary surveys of temporary ponds in eastern Poland by the authors and colleagues have suggested that some pond plants and invertebrates rare in western Europe are quite frequent in Poland and that waterbodies in eastern Poland may support exceptional freshwater biodiversity. Populations of larger Branchiopoda (fairy shrimps, clam shrimps and tadpole shrimps), which are generally rare or declining throughout Europe (Bratton 1991; Damgaard and Olesen 1998; Eder and Hödl 2002), appear to be common. Populations of Medicinal Leech (*Hirudo medicinalis*), which is listed on the Habitats Directive, have also been recorded. The region also appears to support a rich amphibian fauna, including species that have undergone large declines in western Europe, such as the Fire-bellied Toad (*Bombina bombina*), Natterjack Toad (*Bufo calamita*) and European Tree Frog (*Hyla arborea*) (Briggs et al. 1999).

However, apart from data on amphibians and initial natural history observations of invertebrate distributions, little is known of the broader pond environment in eastern Poland. The landscape appears to sustain exceptional numbers of high quality water bodies but, as yet, little survey work has been undertaken to describe the communities they support. The objective of the present study was, therefore, to make an initial rapid assessment of the characteristics and invertebrate assemblages of temporary ponds in eastern Poland. Biological surveys focused on aquatic Coleoptera, the larger Branchiopoda and Medicinal Leech, most of which could be identified in the field.

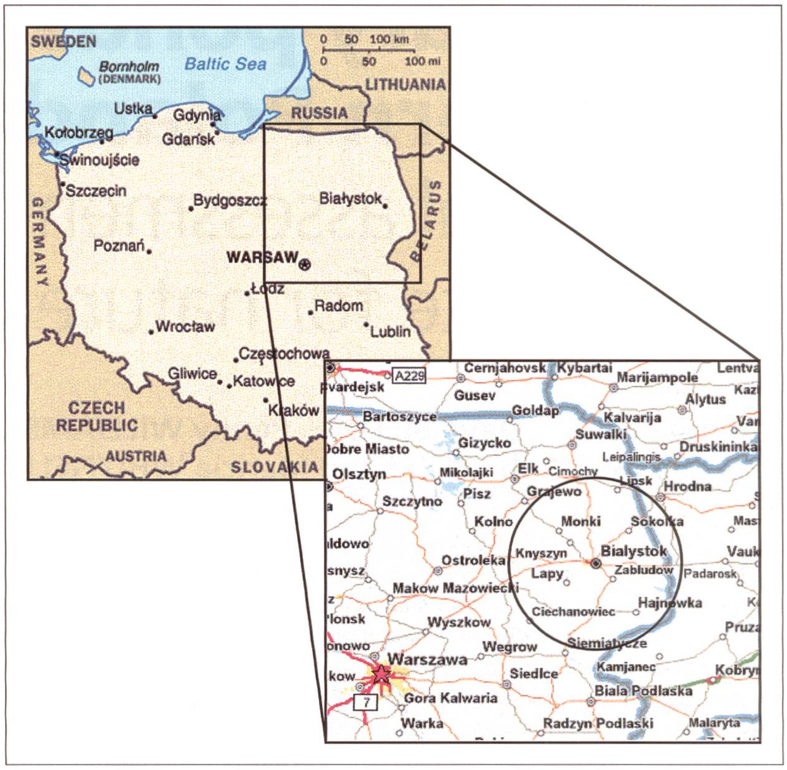


Fig. 1. Location of study area in eastern Poland.

Methods

Study area

The study was carried out in the east of Poland around the city of Bialystock (Fig. 1). Within this area the landscape was divided into three broad categories: floodplain, agricultural plateau and forest. These reflected the prevailing geomorphological, vegetation and land-use characteristics of the landscape.

Floodplain ponds were located on the floodplains of two major rivers, the Biebrza and the Narev. Ponds in the Biebrza floodplain were in an area designated as a national park, whereas those in the Narev valley were outside areas designated for nature conservation interest. Agricultural plateau ponds were located in areas of relatively high land between river valleys, predominantly used for low intensity agriculture but not generally recognised as important for nature conservation or landscape value. Forested sites were located within the Bialowieza Forest, a long-established and internationally renowned National Park and UNESCO World Heritage Site. Forest ponds included sites in the core area and in the surrounding commercially exploited forest.

In each of these areas, information obtained from local ecologists was used to identify areas where ponds typical of the landscape type were common. Field survey teams then selected ponds that covered the range of bio-morphological pond types present in each area.

Ponds typical of each landscape type are shown in Plate 1.

Survey methods

A total of 200 waterbodies were surveyed over two years, in April 2002 (n= 102) and May 2003 (n=98). At all sites a wide range of environmental variables

Plate 1: Ponds typical of floodplain, plateau and forest landscapes in eastern Poland.

(a) Pond on the floodplain of the Biebrza River supporting Lepidurus apus, Syphonophanes grubei and Cyzicus tetracerus.

(b) Pond in plateau landscape near Hajnówka supporting Lepidurus apus and Syphonophanes grubei.

(c) Pond on the edge of the Bialowieza Forest supporting Syphanophanes grubei.

was measured including: pond area, water and sediment depth, vegetation cover in the pond, composition of the pond substrate, connections to other water bodies (pond connected to ditch, stream or river: 0=no, 1=yes), surrounding landuse, amount of shade and risk of exposure to pollution. The pollution risk index was scored on a 0-10 scale (0 = no risk, 10 = severe risk) and based on a subjective assessment of the extent to which ponds were exposed to pollution from known pollutant sources such as arable farmland, urban runoff or piped inflows in the catchment of the pond.

Biologically the survey focused on water beetles, larger branchiopod crustaceans and the Medicinal leech. These taxa were selected because they could be rapidly surveyed in the field and because they make up an important proportion of the temporary pond macroinvertebrate fauna. For example, in temporary ponds in Britain, approximately 55% of the non-Dipteran macroinvertebrate species are represented by water beetles (Nicolet 2002). The larger branchiopods were selected for survey because they are under threat throughout European landscapes. The occurrence of large branchiopods (Anostraca, Notostraca and Conchostraca) and the Medicinal Leech (*Hirudo medicinalis*) was recorded at all sites (n=200) and their abundance estimated. Sites were generally searched for about 15 minutes for branchiopods and leeches, or until the species were found, whichever was the shorter. Adult water beetles (Coleoptera) were surveyed at a subset of sites (n = 115). Ponds were sampled using a standard 1 mm mesh D-framed pond net. Vigorous net sweeps were made throughout the pond and the contents of the net inspected in a white plastic tray in the field, sampling continuing until no new species were found. Most species were identified in the field but taxonomically critical specimens were returned to the laboratory for identification where necessary. All beetle sampling and identification was carried out by one of the authors (DTB).

Table 1: Kruskal-Wallis non-parametric ANOVA of between landscape differences in pond physical characteristics.

Variable	Forest	Plateau	Floodplain	Kruskall-Wallis H	df	n	P
	(mean)	(mean)	(mean)				
Pond length (m)	17.0	33.7	53.9	19.14274	2	199	p<0.001
Pond area (m)	207.8	759.5	1379.3	30.47733	2	199	p<0.001
Composition of pond bed (%):							
- bare	5.3	17.3	20.8	16.24513	2	200	p<0.001
- vegetation	31.9	70.2	72.6	41.88132	2	200	p<0.001
- leaves	62.8	12.7	6.6	111.3883	2	200	p<0.001
Underlying substrate (%):							
- mud/clay	9.5	16.3	10.5	18.16412	2	200	p<0.001
- sand	17.7	57.6	19.0	31.69808	2	200	p<0.001
- peat	72.8	26.1	69.8	52.21711	2	200	p<0.001
Average water depth (m)	0.2	0.3	0.3	16.62369	2	199	p<0.001
Shade: % waterbody overhung by trees and shrubs	61.7	8.7	3.2	120.1044	2	200	p<0.001
Pond vegetation (% cover):							
- short mixed turf	5.8	36.5	15.4	16.64868	2	200	p<0.001
- tussocks/Carex stands	24.6	41.6	13.4	21.64742	2	200	p<0.001
- moss	19.6	5.2	4.9	34.16752	2	200	p<0.001
Landuse 0-5 m from pond (% of total area):							
- deciduous woodland	71.8	16.3	4.3	91.84863	2	200	p<0.001
- coniferous woodland	28.7	0.5	0.0	56.19266	2	200	p<0.001
- non-intensive grassland	0.0	80.2	64.1	42.60895	2	200	p<0.001
- non-intensive arable	0.0	3.7	1.5	21.89776	2	200	p<0.001
- intensive arable	0.0	12.2	0.0	17.57189	2	200	p<0.001
- ponds and lakes	11.6	2.0	5.6	5.650619	2	200	p<0.001
- stream, ditches, etc.	0.4	0.9	0.8	1.061822	2	200	p<0.001
Landuse 5-25 m from pond (% of total area):							
- deciduous woodland	64.2	13.9	6.2	93.79266	2	200	p<0.001
- coniferous woodland	27.3	0.8	0.6	56.51306	2	200	p<0.001
- non-intensive grassland	0.50	67.16	56.17	77.07633	2	200	p<0.001
- non-intensive arable	0.0	13.3	1.7	45.97424	2	200	p<0.001
- intensive arable	0.0	19.9	0.0	24.85056	2	200	p<0.001
Landuse 25-100 m from pond (% of total area):							
- deciduous woodland	65.7	12.6	5.4	85.13230	2	200	p<0.001
- coniferous woodland	28.0	3.6	0.8	43.49330	2	200	p<0.001
- scrub and hedge	0.8	3.5	4.0	30.17383	2	200	p<0.001
- rank vegetation	0.0	9.1	15.5	15.35665	2	200	p<0.001
- non-intensive grassland	0.8	55.3	52.0	85.43442	2	200	p<0.001
- non-intensive arable	0.0	18.6	2.8	80.99839	2	200	p<0.001
- intensive arable	0.0	24.8	0.0	32.27627	2	200	p<0.001
Poaching intensity	0.3	0.7	0.9	32.51238	2	200	p<0.001
Pollutants (1=yes, 0=no)	0.1	0.8	0.7	58.27579	2	200	p<0.001

Analysis

Differences in the physical characteristics of ponds in the three landscape types were assessed using Kruskal-Wallace non-parametric ANOVA. Only differences significant at the p<0.001 level were considered. Biologically, ponds were classified according to their macrocrustacean and water beetle assemblages using two-way indicator species analysis, implemented as TWINSPAN. For this analysis, sites from the two floodplain locations (Biebrza river and Narev river) were combined.

Between-landscape differences in invertebrate species richness and rarity were assessed using Kruskal-Wallis non-parametric ANOVA. Post-hoc Mann-Witney U-tests were used to make pairwise comparisons of species richness in individual landscapes. Information on the status of uncommon water beetles was mainly derived from the Polish Red Data Book (Pawlowski et al. 2002) and additional sources such as Nilsson and Holmen (1995) and Sprick (2000). In some instances we also based assessments on our personal knowledge (DTB) of the status of water beetles in Europe. Where appropriate floodplain landscapes were either considered together or separately in terms of the two river valleys we investigated (Biebrza and Narev). Statistical analyses were carried out using Statistica version 6.0 (Tulsa, OK).

Relationships between assemblage composition and environmental parameters were investigated using Canonical Correspondence Analysis, implemented as CANOCO Version 4.5.

Results

Physical characteristics of ponds

Most ponds surveyed (89%) were categorised as temporary (i.e. 'sometimes dries', 'dries annually' or 'highly ephemeral'). The remaining 11% of ponds were more permanent ('rarely' or 'never' drying out). All ponds were generally very shallow (mean depth 0.2 – 0.3 m) but forest ponds were shallower than floodplain and plateau ponds (Table 1). There were significant between-landscape differences in mean pond area with forest ponds significantly smaller than those on floodplain and plateau.

Floodplain and forest ponds were mainly located on peat; plateau ponds were more often located on sands. In terms of the pond base, floodplain and plateau ponds had significantly barer substrate than forest sites and also more vegetation, reflecting the combined influence of lack of shade and the greater intensity of livestock trampling ('poaching'). As would be expected forested ponds were more shaded, had a higher proportions of leaf material covering their bases and were less well-vegetated.

The majority of the land around the forest ponds was either deciduous or coniferous woodland. Plateau and floodplain ponds were more open, with predominantly non-intensively managed grassland in their immediate surroundings. Plateau ponds were notable for a relatively high proportion (estimated 25%) of arable farmland in the zone 25-100 m around the pond. There was significantly more estimated risk of pollution in floodplain and plateau ponds than in forest ponds. Other environmental variables, such as pond marginal complexity, occurrence of connections with other waterbodies, turbidity and bank angle, did not differ between landscapes.

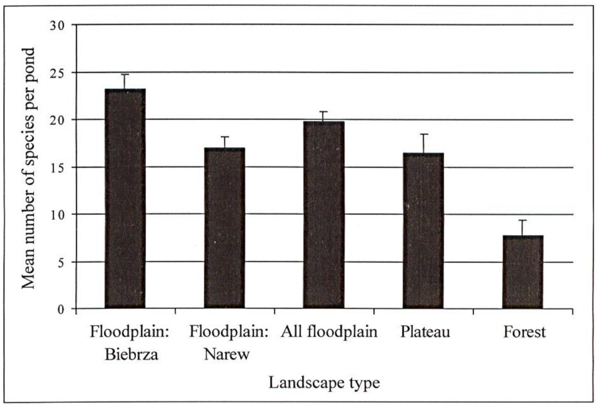


Fig. 2. Water beetle species richness in the eastern Polish landscape.

Water beetle assemblages

Water beetle species richness was significantly higher in floodplain and plateau landscapes than forest, with means (standard error shown in parentheses) of 19.8 (1.08), 16.4 (1.98) and 7.7 (1.71) species per pond, respectively (Fig. 2). Post-hoc tests indicated that water beetle species richness differed significantly between all landscapes except between the Narew floodplain and agricultural plateau (Table 2).

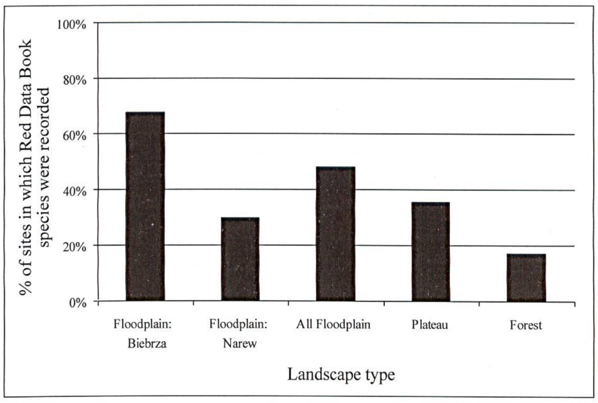


Fig. 3. Frequency of occurrence of Red Data Book water beetles in eastern Polish ponds.

Table 2: Post-hoc Mann-Whitney U-test results comparing differences in water beetle species richness in different landscape types

	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-level
Floodplain Biebrza vs Floodplain Narev	1035.5	675.5	210.5	3.259935	0.002
Floodplain Biebrza vs Plateau	981.5	614.5	208.5	3.006985	0.003
Floodplain Biebrza vs Forest	1156.0	497.0	62.0	5.491071	0.001
Floodplain Narev vs Plateau	926.5	784.5	378.5	0.645763	0.518
Floodplain Narew vs Forest	1243.5	526.5	91.5	5.208134	0.001
Plateau vs Forest	1070.5	582.5	147.5	4.126284	0.001

Overall, 19 species of rare or endangered water beetles were recorded (Table 3). Red Data Book (RDB) water beetle species richness was similar in floodplain and plateau landscapes with, respectively, means of 0.8 and 0.9 species per pond. Perhaps surprisingly, the mean frequency of RDB species was significantly lower in forest ponds (0.4 species/pond) (Kruskal-Wallis test: H (df=3, n=115) =13.88279, $p<0.01$). However, these sites did frequently support some species characteristic of shaded environments, which were rare elsewhere, such as *Ilybius neglectus* together with rare species such as *Ilybius wasastjernae*, which was recorded only in two forest ponds. Although the average number of RDB species was similar in floodplain and plateau ponds, the two main floodplain areas studied, Biebrza and Narev, differed in the number of ponds with RDB species (Fig. 3). In the Biebrza valley, 68% of ponds had RDB species. In contrast, the Narev floodplain had RDB species in only 30% of sites. In plateau ponds 36% of sites had RDB species.

Table 3: Water beetle species of conservation concern recorded in eastern Polish ponds.

Agabus biguttulus	R
Agabus pseudoclypealis	R
Bagous tubulus	R?
Bagous cf. tempestivus	R?
Bagous cf. collignensis	R?
Enochrus bicolor	PRDB-EN
Georisus crenulatus	PRDB-DD
Graphoderus bilineatus	BC
Graphoderus austriacus	R
Haliplus furcatus	PRDB-VU
Haliplus fulvicollis	PRDB-VU
Haliplus variegatus	R
Hydaticus continentalis	WD
Hydroporus elongatulus	PRDB-VU
Hydroporus glabriusculus	R
Hydroporus notatus	R
Ilybius wasastjernae	PRDB-VU
Rhantus bistriatus	WD
Spercheus emarginatus	PRDB - CR

Key

R	Taxa which are considered to be relatively rare throughout range (or at least in Central European range)
R?	Decline of most *Bagous* species has been highlighted throughout Europe (Sprick 2000).
PRDB- VU	Polish RDB Vulnerable
PRDB- EN	Polish RDB Endangered
PRDB- DD	Polish RDB Data Deficient
PRDB- CR	Polish RDB Critically Endangered
BC	Berne Convention
WD	Some evidence of decline in western European populations

Sources: Pawlowski et al. (2002), Sprick (2000).

Macrocrustacean assemblages

32% of all sites supported larger branchiopod crustaceans. Overall, floodplain and plateau ponds were equally likely to support these animals (respectively, 39% and 42% of sites) with the Biebrza floodplain ponds having the highest proportion of sites with large branchiopods (61%). The forest landscape had the smallest proportion of ponds with branchiopod crustaceans (12% - see Fig. 4). In the ponds surveyed three species of macrocrustacean were recorded in the present survey: *Lepidurus apus, Syphonophanes grubei* and *Cyzicus tetracerus*. A further species, *Triops cancriformis*, is known from some ponds in the Biebrza floodplain but was not recorded in the present study probably because all surveys were undertaken relatively early in the year.

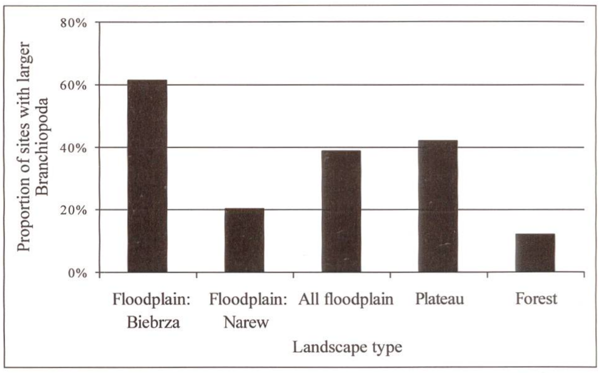


Fig. 4. Frequency of occurrence of larger Branchiopoda in eastern Polish ponds.

The Medicinal Leech

Medicinal Leech was generally rare in the study area and was recorded in only two plateau sites (4% of those surveyed).

Classification of water beetle and crustacean assemblages

TWINSPAN identified 3 main groups of sites based on the composition of beetle and crustacean assemblages (Fig. 5). The classification initially separated out predominantly forest ponds from all other sites with sites surveyed in both years of the study grouped together (TWINSPAN Group 3). No species were indicators for the forest ponds although some rare species did occur only in ponds in this landscape type (e.g. *Agabus pseudoclypealis* and *Ilybius wasastjernae*). Larger branchiopod crustaceans were rare in this end group with only one site supporting these animals.

The remaining ponds, which were predominantly floodplain and plateau sites, were divided into two groups (TWINSPAN Groups 1 and 2 in Fig. 5). Four water beetle species were identified as overall indi-

Table 4: Summary statistics for canonical correspondence analysis of waterbody assemblage data and environmental variables

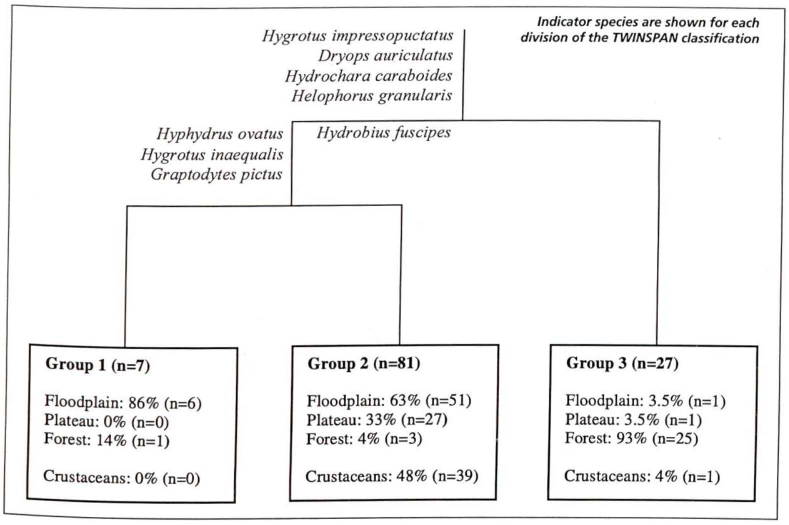
CANOCO summary statistics					
Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues:	0.241	0.186	0.169	0.126	3.690
Species-environment correlations:	0.896	0.963	0.914	0.946	
Cumulative percentage variance:					
of species data:	6.5	11.6	16.1	19.6	
of species-environment relation:	8.3	14.7	20.6	24.9	
Sum of all canonical eigenvalues					2.897

InterSet Correlations with axes				
%Cover of terrestrial plants on pond bed	0.4543	0.0134	-0.0196	-0.1043
Exposure to pollution	-0.2623	0.1072	0.0336	-0.1805
%Other substrates	0.0551	0.0324	0.2753	0.3073
%Cover of wetland plants	0.2814	0.3105	0.0319	-0.1221
Pond margin complexity	0.1465	-0.1652	0.1648	0.0583
% Substrate sand	-0.0792	0.2276	0.0018	-0.0093
% Bottom sediment comprising leaves	0.0878	0.149	0.1903	-0.001
Proportion of 5-25m zone made up by roads	0.0643	0.1444	-0.1009	0.2135
Proportion of 25-100m zone made up of rank vegetation	-0.1385	-0.132	0.0398	-0.0247

cators of these more open ponds of floodplain and plateau landscapes: *Hygrotus impressopunctatus*, *Dryops auriculatus*, *Hydrochara caraboides* and *Helophorus granularis*.

Group 1 was a small group of deeper, more permanent, floodplain ponds with a mean depth of 0.53 m, compared to mean depths of 0.17 – 0.32 m for ponds in other TWINSPAN end groups (Fig. 5). None of the sites in this group had connections to other waterbodies (ditches, streams or rivers). The group was characterised by the indicator species *Hyphydrus ovatus*, *Hygrotus inaequalis* and *Graptodytes pictus*. No larger branchiopod crustaceans were recorded in this end group.

Fig. 5. TWINSPAN classification of temporary ponds in eastern Poland.



Most sites fell into Group 2 which was composed of seasonal floodplain and plateau sites with, respectively, 51 (63%) and 27 (33%) of sites in these landscape classes. 20% of the floodplain ponds had connections to ditches, streams or rivers. This TWINSPAN end group was indicated by the occurrence of the hydrophilid beetle *Hydrobius fuscipes*. Three forest sites were also placed in this end group. Large branchiopods were present in 48% (n=39) of sites in this end group.

Environmental factors influencing pond invertebrate assemblages

CANOCO analysis also indicated that water beetle and branchiopod crustacean assemblages were broadly similar in composition in plateau and floodplain landscapes (Fig. 6). Forest assemblages were clearly differentiated from those of the more open habitats. Nine environmental variables were selected during the CCA to best explain the inertia of the species dataset (Table 4). The overall inertia (i.e. the variance in the species dispersion) was 3.690. The amount of variation explained by the selected environmental variables was 2.897. The first axis of the CCA explained 6.5% of the total inertia of the species data and together the first and second axes explained 11.6% (Table 4). Axis 1 of the biplot was dominated by the broad transition from open to forest habitats. Axis 2 was more

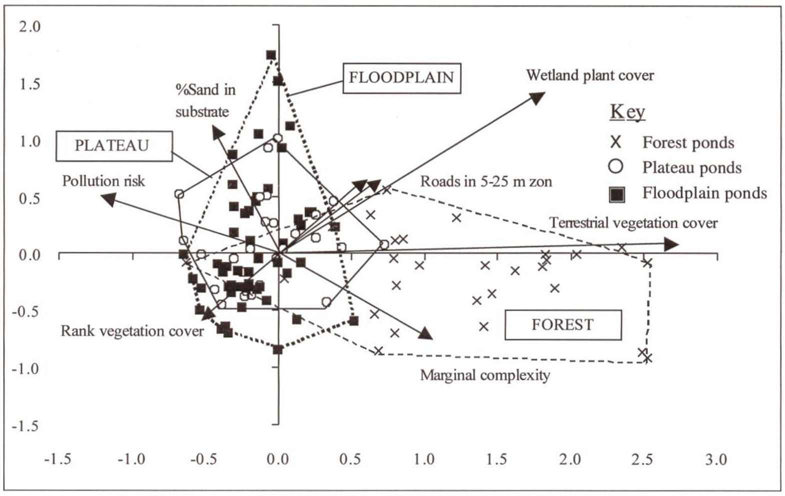


Fig. 6. CANOCO ordination biplot showing sample and environmental data from ponds in eastern Poland. Polygons enclose ponds in the three landscape types.

related to vegetation cover and substrate type in the ponds. The Monte-Carlo test of all canonical axes was significant at p = 0.002.

Discussion

Richness of fauna

Water beetles

Water beetle richness was significantly higher in floodplain and plateau landscapes than forest. This may have been due to the fact that floodplain and plateau ponds were generally larger and deeper than those of the forest and therefore able to support more species. A number of studies have shown that larger ponds sometimes support more species than shallower, more temporary ponds (reviewed in Oertli et al. 2002), although the relationship is a noisy one. Indeed, Oertli and colleagues found that in Swiss ponds, specifically for water beetles, there was no size/species richness relationship, although the ponds in their study were relatively large (mean area 8817 m^2, mean depth 1.66 m). In a study of the fauna of a series of fluctuating and temporary water bodies in southwest England, Bilton et al. (2001) found that both species richness and the proportion of predators increased with pond permanence. An alternative explanation of the water beetle richness patterns seen in the ponds of the present study is that ponds in open landscapes provided a more structurally complex environment for beetles, perhaps as a result of a more diverse and complex vegetation, than the forest ponds, which were typically open, and dominated by a substrate of dead leaves and peat.

Within the two main floodplain areas investigated the Biebrza ponds had higher species richness than those of the Narev. Two main factors probably contributed to this difference. Ponds on the Narev floodplain were generally smaller than those on the Biebrza floodplain (mean area 800 m^2 and 2077 m^2 respectively) so might again be expected to support fewer species (Oertli et al. 2002). In addition to this, ponds on part of the Narev floodplain were probably impacted by eutrophicated floodwater derived from a reservoir at the upstream end of the river valley. On the basis of vegetation characteristics and the presence of aquatic algae, floodwater from the reservoir appeared to be causing increased eutrophication of the ponds on the upper Narev floodplain.

The ponds in all landscapes supported a relatively high proportion of rare and threatened water beetle species. Overall, 37% of ponds supported one or more species listed in the Polish Red Data Book, ranging from 17% in forest to 68% on the Biebrza floodplain. There are relatively few studies analysing the frequency of occurrence of rare water beetles in ponds in different landscapes. Planula (2002) carried out a survey of pond invertebrates in a sample of 30 ponds in an intensively farmed landscape in northern Germany around Braunschweig where they found an average of 8.1 water beetle species per pond and only 0.1 rare species per pond. Similarly in a study of the invertebrate assemblages of farmed landscapes in Britain, Williams et al. (2004) found relatively low beetle richness and no Red Data Book species. In this study mean water beetle species richness across all habitats was 12.6 with 0.05 rare species per pond. In non-forested landscapes in the present study these values were 18.9 and 0.8 respectively, slightly higher than those of semi-natural temporary ponds in high nature conservation value landscapes in England and Wales (Nicolet et al. 2004), where an average of 18.1 water beetle species and 0.5 rare species per pond were recorded.

It should be noted that the three previous studies referred to above all used a standard timed hand net sampling method, with laboratory sample processing, based on the UK National Pond Survey method (Pond Action 1998). This differed from the field search sampling method used in the present study but observations made by the authors suggest that results from the two methods are broadly comparable (see McAbendroth 2004). Also in Britain, Foster and Eyre (1992) analysed large numbers of water beetle species lists from all landscape types in the country, though with an emphasis on higher quality landscapes, and generally found that the highest quality sites had 1 or more

Red Data Book species. Taken together these observations suggest that the Polish ponds support diverse beetle assemblages with many locations of potential conservation interest.

Macrocrustacea

The ponds surveyed had a high frequency of large Branchiopod crustaceans (Anostraca, Notostraca, Conchostraca). As with water beetles there are few studies with which to compare the results of the present project. In observations of ponds in a moderately intensively farmed agricultural landscape in the Avignon region of southern France we recorded fairy shrimps in only one pond in a survey of 30 sites in a 60 km x 60 km study area (Pond Conservation, unpublished data). This was equivalent to an occurrence rate of 3%, roughly 1/10th that seen in the present study. More generally, in most European states with intensive agriculture, records of larger branchiopod crustaceans are now extremely sparse. For example in Denmark, which has similar geology and soils to eastern Poland, there are probably no more than 50 sites in total which support larger branchiopods (Damgaard and Olson 1998). Similarly, in Austria, occurrences of larger Branchiopod crustaceans are largely restricted to the floodplains of the Morava and Danube rivers, being rare elsewhere (Eder et al. 1997).

Classification of ponds

The classification of ponds using TWINSPAN indicated that forest and deeper, more permanent, floodplain ponds were clearly distinguishable from seasonal ponds on both plateau and floodplain. Floodplain and plateau pond assemblages were similar to each other and formed a coherent group with subsequent splits in TWINSPAN (not shown in the analysis) dividing these sites only in terms of the year of sampling.

The indicator species identified by TWINSPAN supported this interpretation. The broad division of sites into open and forested landscapes was indicated by the occurrence of *Hygrotus impressopunctatus*, *Dryops auriculatus*, *Hydrochara caraboides* and *Helophorus granularis*, all of which are typical of shallow, well-vegetated ponds (Hansen 1987; Nilsson and Holmen 1995). In TWINSPAN Group 1 permanent floodplain ponds were indicated by the occurrence of the beetles *Hyphydrus ovatus*, *Hygrotus inaequalis* and *Graptodytes pictus*. All of these species are characteristic of larger, more permanent water bodies, particularly relatively eutrophic ones. TWINSPAN Group 2 was characterised by the presence of *Hydrobius fuscipes* which is typical of shallow, grassy ponds. No indicators were identified for the forest ponds but uncommon woodland species did occur, most notably *Agabus pseudoclypealis* and *Ilybius wasastjernae*, which have not previously been recorded in Bialowieza (Gutowski and Jaroszewich 2001).

Initial implications for the conservation of ponds in Poland

This very preliminary survey has served to highlight the importance of temporary ponds in eastern Poland. Given the threats faced by the landscape in this region, the need to protect temporary ponds in Poland is now urgent. The future of these sites and the traditional landscape in which they occur is becoming increasingly bleak as farmers increase the intensity of agricultural production to the level regarded as normal in western Europe. In this context the European Environment Agency has noted that:

> "In productive regions agricultural intensification is likely to take place, associated with biodiversity decline as previously seen in the EU" (EEA 2004b).

With respect to ponds, agricultural intensification in the west has led to pond loss rates which typically range from 50% up to 90% (Oertli et al. 2005), with many of the remaining ponds significantly impacted by diffuse and point source agricultural pollution. For example, in the United Kingdom, ponds in the ordinary farmed countryside support, on average, half the number of wetland plants that would be expected in minimally impaired ponds (Williams et al. 1998). At present, in the states which have recently joined the EU, nitrogen fertiliser applications are approximately half that of the developed EU-15 countries indicating that major increases in fertiliser use (and therefore diffuse pollution) can be expected (EEA 2004b).

Poland is currently beginning to increase agricultural intensification following its accession to the EU. At the same time, extensively farmed grasslands, which are often of very high nature conservation interest, are being abandoned (EEA 2004a). As yet most intensification has occurred in western and central Poland, but it seems inevitable that, without efforts to protect critical areas, the remaining traditional landscapes of eastern Poland, with their temporary ponds and exceptional biodiversity, will be lost in the near future. This process is likely to be exacerbated by abandonment of extensively managed grasslands which, in Poland, is most likely to occur in the biodiversity rich east.

To protect ponds in the eastern Polish landscape there is a need for information and practical action. The EEA has noted that the conservation status of high nature value farmland in central and eastern EU states is insufficiently known, although case studies (mainly relating to birds) indicate serious biodiversity declines (EEA 2004a). In the context of the present study, data about the importance and location of temporary ponds are required to enable the identification and protection of high value pond sites, complexes of ponds and the catchment areas around them. In terms of practical action there needs to be active application of the principles of sustainable agriculture through the implementation of suitable policy instruments. Data such as those generated in the present study will need to be used by national and European policy makers to promote sustainable systems, and to develop land management and nature conservation grant schemes to maintain traditional land-use practices.

Further work needed includes a more extensive survey of waterbodies in eastern Poland with transfer of data to web-based GIS systems to make these data accessible to land managers and other specialists. There also need to be more detailed studies of the ecology of temporary ponds in the study region as little is currently known of the way in which they function. Important sites should be identified as Natura 2000 sites and intermediate areas should be protected under the auspices of the Water Framework Directive (WFD). Although intended to protect all surface waters, the WFD as presently established is poorly suited to the protection of small waterbodies.

Policies to promote sustainable agriculture will increase the likelihood that high quality temporary ponds continue to exist in the Polish landscape. The main objectives of sustainable agriculture are to develop food self-reliance; to protect agricultural ecosystems (the concept of stewardship); and to sustain rural communities (MacRae 1990). At present, it seems most likely that such objectives will be achieved through the twin mechanisms in the EU of less favoured area support and agri-environment schemes (EEA 2004a). However, the social challenge of delivering sustainable farming systems is likely to be far greater than the technical challenge of defining what it should be (Firbank 2005).

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