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Vegetation dynamics on exposed pond bottoms in the Českobudějovická basin (Czech Republic)

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with 4 figures and 5 tables

Abstract. The vegetation dynamics on the exposed bottoms of fishponds and storage ponds in the Českobudějovická basin (South Bohemia, Czech Republic) were studied. In 2001–2002, a total of 42 permanent plots in 19 storage ponds and 7 plots in 2 nursery fishponds were established. Phytosociological relevés were recorded using the Braun-Blanquet method and stored in the Czech National Phytosociological Database in TURBO(VEG). 445 relevés from autumn 2001 and the vegetation period of 2002 were analysed using the DCA and CCA methods from the package CANOCO, STATISTICA software and JUICE 6.1 software. Species lists exported from TURBO(VEG) served as a general description of species richness. This study attempts to explain the relationship of vegetation cover and floristic spectrum on the one hand to abiotic factors and management on the other hand. The CCA analysis detected moisture and the week in which the data were recorded to be the most important variables. These factors influence the basic vegetation structure and species composition; however, they explain only 2.5 % of the variability. Both factors are partly given by the type of summer drying of the pond, i.e., by the management. According to the type of summer drying and vegetation phase we distinguished spring ponds (the storage ponds and nursery fishponds) and summer ponds. The nursery fishponds are only shortly dried in April–June. Therefore, annual species with extremely short live cycles occur there, e.g., *Coleanthus subtilis*. Thermophilous species, germinating in May and June, and plants with longer life cycles are eliminated. The spring storage ponds are dried from December or early spring throughout the whole vegetation period. They are characterized by many perennial species, e.g., *Juncus articulatus* and *Equisetum palustre*. In the summer storage ponds, dry mostly for 2–4 months in summer and early autumn, thermophilous annual species, such as *Lindernia dubia*, are found.

Besides summer drying, other management practices are used in the storage ponds, e.g., herbicide spraying, mowing, liming, etc. These practices can exclude some species from the total species spectrum and can have positive influence on the development of other species. For example herbicides and mowing reduce total cover and competition from some perennial species, which supports the survival of annuals in the vegetation. The diversity of the storage ponds' environments was considerably higher than that of the fishponds, and this was reflected in the species richness. In 17 relevés from fishponds, a total of 24 plant species were found; in 17 comparable relevés from storage ponds, 64 species were recorded.

Keywords: fishpond management, Isoëto-Nanojuncetea, moisture gradient, ordination, South Bohemia, seasonal changes, storage ponds.

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Introduction

South Bohemia is the region with the highest concentration of fishponds in Europe. Most of them were constructed in the 15^{th}–16^{th} century for breeding of common carp; this type of use has been maintained until the present (Andreska 1997). Fish farming is an important part of the agriculture of the Czech Republic. Recent fishpond management distinguishes various types of ponds in accordance with different criteria (cf. Čítek et al. 1993). According to the age of the fish, there are two types of fishponds: nursery ponds for the breeding of young fish to 1–2 years of age and main fishponds for the production of marketable fish. The main ponds are usually fished out in autumn. Before transport to the consumer, it is necessary to put the fish into clear water storage ponds; this process contributes to higher meat quality. The storage ponds are interconnected into a storage pond system. Each fish farm has one or more storage pond systems.

Because of the different types of use, the individual pond types have to be managed in different ways. The management of fishponds includes manuring with organic manure (dung, compost etc.), liming, feeding the fishstock and summer drying of the fishpond. The last management practice is the oldest method of increasing fishpond production. It is based on leaving the whole fishpond (full summer drying) or its margins (partial s.d.) without water. The summer drying of the pond continues throughout all or part of the vegetation period, usually from spring to the end of May or June. Summer drying of fishponds enables quick mineralisation of organic nutrients in the muddy substrate by oxygen activity and the development of vegetation cover. For economical reasons the use of summer drying has been strongly limited in recent decades. In nursery ponds only partial and reduced summer drying is currently maintained.

Storage ponds serve for the storage of a large number of fish in a relatively small space. To eliminate surviving of fish parasites and diseases, summer drying and liming of storage ponds is widely used. Before filling the storage ponds, the vegetation is mown and raked out. Recently, some fish farms have begun to use herbicides to retard vegetation growth or to eliminate its development at all because of the labour involved in mowing. However, the vegetation cover on the pond bottom has a positive influence on the health of the stored fish.

Various management practices and types of use, and their different intensity and timing, together with the natural characteristics of the ponds cause great diversity in pond vegetation. Even the fishponds or the storage ponds of one system can differ considerably in their species spectrum and the percentage cover of individual species. This aspect, together with the rapid development of vegetation on exposed pond bottoms and its limited duration, can help to explain why the vegetation dynamics of exposed pond bottoms have scarcely been studied in the past.

The aim of this study is to show the major gradients in the species composition of the vegetation of exposed pond bottoms. The following questions will be addressed: (1) Which environmental factors or management practices have an essential influence on the species composition? (2) What are the differences in species spectrum on the exposed bottoms of nursery fishponds and storage ponds? (3) How are the individual species and the vegetation cover affected by "catastrophic events", e. g., flooding and herbicide spraying? (4) What changes in vegetation structure and species composition can be observed during one vegetation period, and how can they be explained?

Study area

The investigated area is situated in the southern part of the Czech Republic, in the Českobudějovická basin. For the current study, we chose the storage ponds of the Hluboká Fish Farm and two fishponds located nearby. They are situated in the southeast part of the Českobudějovická basin, near the town of Hluboká nad Vltavou (Fig. 1).

Environmental conditions

The Českobudějovická basin is a plain (from 370 to 450 m a.s.l.) surrounded by hilly country. The investigated area is located in the lowest part of this plain. It is made up of terraces and alluvial deposits, partially from the airborne sand from the river valleys of the Vltava and Otava rivers (Demek 1965).

Fig. 1. Location of the study area in the Czech Republic. The black dot represents the town of Hluboká nad Vltavou and includes all three study sites – the storage pond system of the Hluboká Fish Farm and the Podhradský rybník and Pěnský rybník fishponds.

From the geological point of view, it is a freshwater basin created by unstabilised sediments of the Mesozoic Era and Tertiary Period, non calcareous clays, sands and gravels, with local sandstones and conglomerates. Soils include pseudo-clays and clays in the plain. The Českobudějovická basin belongs to the most continental part of the Czech Republic. The highest and lowest temperatures were + 40 °C and – 42.2 °C. Mean annual temperature in České Budějovice (9 km south from Hluboká nad Vltavou) is 7.8 °C, the sum of annual precipitation is 620 mm (Culek 1996). The area belongs to the catchment basin of the Vltava River.

The Českobudějovická basin is a typical example of a cultural landscape. It is a mosaic of arable land, grasslands and forests. Numerous fishponds are characteristic; the largest one, Bezdrev, is 433 ha in size.

Investigated localities

1. Storage pond system of the Hluboká Fish Farm

Nowadays the storage pond system of the Hluboká Fish Farm includes 48 regularly used storage ponds. Storage ponds are oblong. Through the middle, in the long direction, a small, usually permanent stream flows. The walls of storage ponds are mostly built of stones or concrete panels. Rarely, the walls are not stabilized and are grassy or clay. All storage ponds are numbered.

The storage pond system is connected by canals to the Munický rybník fishpond and uses its water.

2. The Podhradský rybník fishpond

The Podhradský rybník fishpond is situated near the Hluboká Fish Farm. Two main roads create a border in the southern and eastern parts of the pond and the rest of the border is created by the edge of the town of Hluboká. Local sewerage flows into the pond there. Therefore, the pond is very rich in nutrients. The most common species of the pond margins is *Phalaris arundinacea*, followed by *Typha latifolia*. Large *Carex* beds occur locally. In general, the vegetation creates only a narrow line with broad areas.

3. The Pěnský rybník fishpond

The Pěnský rybník fishpond lies in the forest about 2.5 km northwest of the church in the centre of the town of Hluboká nad Vltavou. The banks are surrounded by forest and narrowly lined with reeds. This fishpond is also rich in nutrients but less so than the previous one.

Both fishponds are nursery fishponds for fingerling of the common carp.

Methods

Data sampling

1. Period of data recording
Data were gathered from the storage ponds of the Hluboká Fish Farm in 2001 (12–14th September) and 2002 (5th March to 17th October); and from the Podhradský rybník and Pěnský rybník fishponds from 30th April to 28th May, 2002.

In 2001, data were collected from one observation. In this year, we could not recognize all of the treatments that had occurred on the sampling plots, because there was no evidence of them. Therefore, we recorded only current treatments. In 2002, data were recorded at regular two-week intervals. Data recording was interrupted or stopped when the plots in ponds were under water. Therefore, a different number of records exists for each storage pond or fishpond.

2. Selection of storage ponds and fishponds
The sampling plots were established in storage ponds and fishponds. We established 42 plots in the 19 storage ponds. In 2001, we recorded data from 29 plots in 13 storage ponds. The next year, we added 13 plots in 6 more storage ponds. We selected storage ponds which were without water in the autumn of 2001 and during the first data recording in the spring of 2002. Additional criteria for selection were different substrates, kinds of stored fish, types of storage pond walls, size of storage ponds and types of vegetation within the storage ponds.

The Podhradský rybník and Pěnský rybník fishponds were dried for a brief period in 2002. Therefore, they were selected for observations. We established 4 plots on the Podhradský rybník and 3 plots on the Pěnský rybník fishponds.

3. Definition of sampling plots
In selected storage ponds, we fixed two stable points on a diagonal. Between them, we marked a line which followed the moisture gradient and substrate type. Along this line, we randomly placed uniform sampling plots, 1 × 1 m. All plot measurements are reproducible.

The sampling plots (1 × 1 m) on the Podhradský rybník and Pěnský rybník fishponds were placed in different types of habitats. Plots were marked with pegs.

4. Recording relevés and environmental factors for plots
On each sampling plot, we recorded phytosociological relevés using the modified Braun-Blanquet scale (van der Maarel 1979). Each phytosociological relevé contained total cover, herb layer and moss plus algae layer (E, E_1, E_0). Only living plants were recorded. Recorded environmental factors were type of substrate, moisture, mowing, flooding, type of walls, size, kind of stored fish, liming, and chemical treatment. The herbicide Roundup

was used as a chemical treatment on some of the plots. Its active ingredient is glyphosate-IPA 480 g/l-IPA 360 g/l glyphosate A-fosfonomethylglycin.

Nomenclature of taxa and syntaxa

The nomenclature of all recorded taxa follows the Central European species list included in TURBO(VEG) (Hennekens 1995). Species not included in the TURBO(VEG) species list are: *Bolboschoenus laticarpus*, probably stable hybrid of *Bolboschoenus yagara* (Ohwi) Y. C. Yang & M. Zhan and *B. koschewnikowii* (Kots) A. E. Kozhevnikov (cf. Hroudová et al. 2001), and *Lindernia dubia* (L.) Pennell.

The nomenclature of syntaxa is according to Moravec et al. (1995).

Notes on problematic taxa

Some taxonomically complicated or difficult to determine taxa, esp. juveniles, occurred in the sampling plots. Notes were written in each relevé in TURBO(VEG) regarding uncertain determination of species. For the purposes of the analysis, it was necessary to simplify the species list and to combine some taxa of vascular plants (Tab. 1).

In autumn 2001, bryophytes were collected from sampling plots and determined afterwards. According to this determination, we were able to record mosses directly on plots in 2002 at the genus level. In autumn 2002, we again collected mosses for precise determination. On several plots mosses disappeared before collecting. In these cases, we had only uncertainly determined species without microscopic verification. Some species were without important characteristic features; therefore we determined them only to the genus level. For the purposes of the analysis, we simplified the list of recorded bryophytes and combined some taxa (Tab. 2).

A detailed determination of algae was not made. We recorded only species easily determinable in the field.

Data analysis

The phytosociological relevés were stored in the Czech National Phytosociological Database in TURBO(VEG) (Hennekens 1995, Hennekens & Schaminée 2001, Chytrý & Rafajová 2003). Relevés without at least one recorded species (observations shortly after the exposure of the sampling plot) were excluded from further analysis. Two storage ponds with plots established in September of 2001 were flooded nearly the entire vegetation period of 2002 and development of vegetation was interrupted in an early phase. All relevés from these plots were also excluded from analysis. A total of 445 relevés from fishponds and storage ponds were included in the analysis.

1. Species lists exported from TURBO(VEG) for individual groups of relevés were used as a basic description of species richness (Results, part 1).

Tab. 1. Problematic taxa – vascular plants.

Determined taxa	Turboveg database	Taxa used for analysis	Notes on determination
Agrostis & *Alopecurus*	*Agrostis stolonifera, Alopecurus aequalis* & *A. geniculatus*	the group *Agrostis-Alopecurus*	exact determination of sterile specimens is difficult; in some plots several species occur together
Achillea	*A. millefolium* agg.	*A. millefolium* agg.	exact determination of sterile specimens is impossible
Atriplex	*Atriplex* sp. juv. & *A. prostrata*	*A. prostrata*	only one species of the genera confirmed
Bidens	*Bidens* sp. juv., *B. cernuus*, *B. frondosus*, *B. radiatus* & *B. tripartitus*	*Bidens* sp. juv., *B. cernuus*, *B. frondosus*, *B. radiatus* & *B. tripartitus*	most individuals were determined to species level
Bolboschoenus	*B. maritimus* agg.	*B. maritimus* agg.	exact determination of sterile specimens is impossible; one collection of a full grown plant was determined as *B. laticarpus* (outside of the plots)
Elatine	*Elatine* sp., *E. triandra* & *E. hydropiper*	*Elatine* sp., *E. triandra* & *E. hydropiper*	most individuals were determined to species level
Eleocharis	*E. palustris* agg.	*E. palustris* agg.	*Eleocharis palustris* agg. includes *E. palustris* subsp. *palustris* and probably *E. palustris* subsp. *vulgaris*; exact determination of the species in the field is impossible
Epilobium	*Epilobium* sp. (ster.), *E. ciliatum*, *E. hirsutum*, *E. roseum* & *E. tetragonum*	*Epilobium* sp. (ster.), *E. ciliatum*, *E. hirsutum*, *E. roseum* & *E. tetragonum*	exact determination of sterile specimens is impossible; many individuals were determined to species level
Equisetum	*E. arvense*	*E. arvense*	many individuals looked like the very rare hybrid *E.* × *littorale*; they were included with *E. arvense*, because of its ecological and morphological plasticity
Galeopsis	*Galeopsis* sp.	*Galeopsis* sp.	occurred in the storage ponds only in the juvenile stage

Tab. 1. (cont.)

Determined taxa	Turboveg database	Taxa used for analysis	Notes on determination
Chenopodium	*Chenopodium* sp. juv., *C. album* agg. & *C. ficifolium*	*Chenopodium album* agg. & *C. ficifolium*	the individual species of the *C. album* agg. were not determined except *C. ficifolium*; juvenile specimens determined as *Chenopodium* sp. were included in *C. album* agg.
Lemna	*L. minor*	*L. minor*	it was impossible to distinguish the cover of *L. minor* and *L. gibba* separately on the water surface; for this reason we created a group *Lemna minor* that includes both species
Myosotis	*M. palustris* agg. & *M. laxa* subsp. *caespitosa*	*M. palustris* agg. & *M. laxa* subsp. *caespitosa*	from the *M. palustris* agg. only *M. laxa* subsp. *caespitosa* was precisely determined
Potentilla	*Potentilla* sp. juv., *P. anserina*, *P. reptans* & *P. supina*	*Potentilla* sp. juv., *P. anserina*, *P. reptans* & *P. supina*	most individuals were determined to species level
Salix	*Salix* sp. juv. and approximately determined *S. fragilis, S. triandra* & *S. cinerea* agg. (= *S. caprea, S. cinerea*)	*Salix* sp. juv.	
Sonchus	*Sonchus* sp. juv., *S. asper* & *S. oleraceus*	*Sonchus* sp. juv., *S. asper* & *S. oleraceus*	most individuals were determined to species level
Spergularia	*S. echinosperma*	*S. echinosperma*	transitional types between *S. echinosperma* and *S. rubra* were observed; ecologically closer *S. echinosperma*
Taraxacum	*T.* sect. *Ruderalia*	*T.* sect. *Ruderalia*	the individual species of the *T.* sect. *Ruderalia* were not determined
Trifolium	*Trifolium* sp. juv. & *T. hybridum*	*T. hybridum*	genus contains only one recorded species; all records were grouped for analyses
Typha	*Typha* sp. juv. & *T. latifolia*	*T. latifolia*	genus contains only one recorded species; all records were grouped for analyses
Verbascum	*Verbascum* sp.	*Verbascum* sp.	occurred in the storage ponds only in the juvenile stage

Tab. 2. Problematic taxa – mosses and algae.

Determined taxa	Turboveg database	Taxa used for analysis	Notes on determination
Pohlia	*Pohlia* sp.	*Pohlia* sp.	only determination to genus level was possible
Bryum	*Bryum* sp., *B. argenteum*, *B. klinggraeffii* & *B. rubens*	*Bryum* sp., *B. argenteum*, *B. klinggraeffii* & *B. rubens*	in data analysis the group of plants determined only to genus level was separated from the confidently determined species
Physcomitrium	*Physcomitrium* sp., *P. eurystomum* & *P. pyriforme*	*Physcomitrium* sp., *P. eurystomum* & *P. pyriforme*	in data analysis the group of plants determined only to genus level was separated from the confidently determined species
Amblystegium	*Amblystegium* sp. & *A. humile*	*A. humile*	*A. humile* was the only determined species; all records were entered as *A. humile*
Brachythecium	*B. rivulare*, *B. rutabulum* & *B. mildeanum*	*Brachythecium* sp.	this genus occurred in the storage ponds only rarely; all the species were placed in one group *Brachythecium* sp.
Riccia	*Riccia* sp., *R. cavernosa* & *R. fluitans*	*Riccia* sp., *R. cavernosa* & *R. fluitans*	all records were kept separate in the analyses
Algae	*Nostoc commune*, *Botrydium granulatum*	*Nostoc commune*, *Botrydium granulatum*	other algae were not determined, but their total cover was estimated; all algae included in the E_0 layer
Charophyta	*Chara* sp.	*Chara* sp.	macrophytic alga from Charophyta occurred in one of the plots; it was not exactly determined

These lists served to compare the species richness of storage ponds and fishponds and the representation of chosen systematic and biological groups. We excerpted data from TURBO(VEG) and floristic lists for each storage pond (which also includes the area outside the sampling plots) and defined groups of characteristic species for storage ponds and fishponds. The database of TURBO(VEG) and field records were used to characterize vegetation. Random selection of relevés (Results, part 1) was made by a function included in TURBO(VEG).

2. We excerpted data about the cover of each layer and the number of species from the TURBO(VEG) database. Changes in cover and species number are displayed on the graph (Fig. 2) made by STATISTICA 6.0 sofware (StatSoft 2001). All plots from fisponds and storage ponds were analysed together.

3. Species with higher than 25 % cover were selected from the TURBO-(VEG) database. These species were defined as dominants. For each species was counted the number of relevés where it occurred as a dominant.

4. We distinguished two main types of ponds according to the type of summer drying, spring and summer ponds. The spring ponds included storage ponds and nursery fishponds. Nursery fishponds in our study were exposed from the end of March/beginning of April to the middle of May/end of May. The spring storage ponds were exposed from December/beginning of April to the middle of September/end of October. The summer ponds, which included only storage ponds, were exposed (a) from December/beginning of April to the end of March/middle of April, and then flooded for 1–3 months (some of these ponds were flooded and exposed 2 × during the vegetation period), (b) from July to September/October. In the group of summer storage ponds, we also included a storage pond exposed from early spring to the middle of September, but with vegetation development interrupted by the storage of fish between the middle of June and the middle of July. For the data from storage ponds from 2001, the classification for 2002 was used, because the cycle of flood and exposure is usually similar for each pond every year.

We divided the relevés into two groups according to the type of pond. Using the JUICE 6.1 program (Tichý 2002), we produced a synoptic table and determined diagnostic species for each group of relevés, using the phi coefficient as a fidelity measure (Sokal & Rohlf 1995, Chytrý et al. 2002). Species with phi > 0.15 were considered diagnostic and ranked by decreasing value of phi in the synoptic table.

5. Variables in CCA

For individual variables and their explanation see Tables 3 and 4.

To moderate the influence of the most abundant species, all species data were square root transformed. These data were first subjected to detrended correspondence analysis (DCA) using the CANOCO 4.5 package (ter Braak & Šmilauer 2002, Lepš & Šmilauer 2003), in order to assess the overall variation patterns in species composition. First, the effects of the environmental variables on species composition were tested by the Monte Carlo permutation test in CCA. Numbers of ponds with plots were characterised as a series of dummy variables, and in the analysis they were used as covariables.

Tab. 3. Explanation of variables in CCA – categorial variables.

Variables / scale	0	1	Notes
liming	no	yes	
gravel	no	yes	substrate contains more than 20 % gravel more than 1 cm in diameter
high water	no	yes	flooded in August 2002
fish D	no	yes	"destructive" fish = influence vegetation and pond substrate (common carp, white amur, breeding pike-perch; they dig in the muddy bottom, etc.)
fish N	no	yes	"non-destructive" fish = does not influence vegetation and pond substrate (bream, marketable pike-perch, pike, sheath fish, fingerling of all fish species)

Tab. 4. Explanation of variables in CCA – numerical variables.

Variables/ scale	0	1	2	3	4	Notes
mud	pure sand	up to 1 cm	1–3 cm	3–10 cm	more than 10 cm	
moisture	drying plot	usually moist	water-logged	shallowly flooded; to 5 cm	flooded; more than 5 cm	
Roundup	no	after first application	after second application	–	–	
mowing	no	after first cutting	after second cutting	–	–	
week	–	–	–	–	–	numbers of the weeks according to the calendar

The variation in species composition explained by the two most significant variables, moisture and week, was partitioned using a series of partial CCAs. The ratio of particular canonical eigenvalues to the sum of all eigenvalues (total inertia) was used to measure the proportion of explained variation (Borcard et al. 1992). For the two partial CCAs in which a single explanatory variable was used, we listed scores along the 1st CCA axis for species with the highest fit in the analysis. The order of scores of these species reflects the vegetation change along the gradient of moisture and week, after cancelling out the effects of the other variables.

Results

1. Species richness and vegetation characteristics of fishponds and storage ponds in 2001–200

Plant communities of exposed pond bottoms are traditionally considered to be a species poor vegetation type. However, large differences in species richness among the individual types of ponds can be found.

We analysed 428 relevés from storage ponds (September 2001 to October 2002) and 17 relevés from nursery fishponds (end of April to end of May 2002). The dataset for storage ponds includes a total of 126 plant species: 106 vascular plant species, 17 moss species and 3 algae species (only determined species were included). In the nursery fishponds, 24 plant species were found: 22 vascular plant species, 1 moss species, and 1 alga species.

We possesed 57 relevés from storage ponds from the same period as that in which the sampling plots on the fishponds were studied. These 57 relevés contained 88 species (78 vascular plants, 7 mosses, 3 algae). The number of comparable relevés from storage ponds (57) and fishponds (17) was highly disproportioned. Therefore, we made a random selection of 17 relevés from storage ponds (see Methods, Data analysis, part 1). These relevés contained 64 species, including 56 vascular plants, 5 mosses and 3 algae species. Most of the species recorded on fishponds were also found on the plots in storage ponds. There are 9 species which occurred in fishponds and were not documented in storage pond plots in the spring. Five species, *Chenopodium glaucum*, *Elatine triandra*, *Epilobium hirsutum*, *Phalaris arundinacea* (juv.) and *Coleanthus subtilis*, were never found in the relevés from storage ponds. The first four species occur rarely in storage ponds; therefore they were not recorded in the plots. *Coleanthus subtilis* does not colonize the exposed bottoms of storage ponds of the Hluboká Fish Farm. This is probably caused by liming and the different quality of substrate in the storage ponds and in the fishponds (cf. Pietsch 1985, Lampe 1996, Filípková 2001). We have found this to hold true in fishponds and storage ponds throughout the whole Czech Republic.

The vegetation of the storage ponds contains more species than that of the fishponds. In the relevés in storage ponds, 52 annual species and 45 perennial species were represented. An additional 9 vascular plant species represent the seedlings of trees and hydrophytes. In some plots, there are even perennial dominants: *Alisma plantago-aquatica, Leersia oryzoides, Agrostis stolonifera*, etc. In the plots from fishponds, annual species prevailed (20 recorded species), and only 2 juveniles of perennial species were recorded.

The spectrum of therophytes in the storage ponds included groups of species which were absent or occurred only rarely in fishponds: (1) species of nutrient poor substrates, esp. wet sands, in the past frequent on fishpond margins, e. g., *Isolepis setacea*, *Cyperus flavescens*, *Tillaea aquatica* and *Gypsophila muralis*; (2) species with marginal occurrence in the region, e. g., *Cyperus fuscus*, *C. michelianus*, *Lindernia dubia* and *L. procumbens*; (3)

species with a life cycle of 2 months or longer, e.g., *Eleocharis ovata* and *Carex bohemica*. They are frequent in the main ponds but rare in the nursery ponds; (4) ruderal and weed species with affinity to terrestrial vegetation types, e.g., *Geranium pusillum*, *Capsella bursa-pastoris*, *Conyza canadensis*, *Arabidopsis thaliana*, *Stellaria media*, etc.

Similarly, the species richness in the bryophyte flora is much higher in the storage ponds than in the fishponds. In the fishponds, only *Physcomitrium* sp. was found. Ephemeral bryophytes, e.g., *Physcomitrium pyriforme*, *P. eurystomum*, *Physcomitrella patens* and *Riccia cavernosa*, colonize the storage ponds with a short phase of summer drying. In the storage ponds dried from spring to autumn, perennial mosses are frequent. They are represented by different ecological groups of mosses: species of springs and swampy areas (e.g., *Drepanocladus aduncus* and *Leptodictyum riparium*), wet grasslands (*Amblystegium humile*, *Brachythecium rutabulum* and *Climatium dendroides*) and ruderal places (*Bryum argenteum* and *Ceratodon purpureus*).

From the phytosociological point of view, the stands in the investigated fishponds belong to the class Isoëto-Nanojuncetea, alliance Eleocharition ovatae. On the deep pond mud, communities of the Bidentetea tripartitae class occurred. The diversity of vegetation types in the storage ponds is higher. Only a few of the stands can be ranked into described vegetation units. The stands of the Isoëto-Nanojuncetea and Bidentetea classes are the most frequent. In the storage ponds with deep mud which are permanently wet or shallowly flooded, communities of Lemnetea, Potametea and Phragmito-Magnocaricetea (esp. alliance Oenanthion aquaticae) occurred. A substantial part of the stands in the storage ponds is represented by mosaics of the mentioned vegetation units. Additionally, the vegetation includes many wet grassland species, e.g., *Potentilla anserina*, *Taraxacum* sect. *Ruderalia*, *Plantago lanceolata* and *Rumex crispus*, ranked into the alliance Agropyro-Rumicion crispi.

2. Changes in vegetation cover and species richness during one vegetation period

The general trend of the changes in vegetation cover and species richness is displayed in a graph (Fig. 2).

(1) Early spring

There is little change in all variables in the first weeks of observation (beginning of March to middle of April). Higher temperatures from the middle of April led to a noticeable increase in vegetation cover and species number by the end of the month.

(2) Period after herbicide spraying in May to June

Between the middle of May and the middle of June, the individual storage ponds were sprayed with herbicide. The spraying effect was visible after 1–2 weeks as an intensive dying off of the plant biomass. Nevertheless,

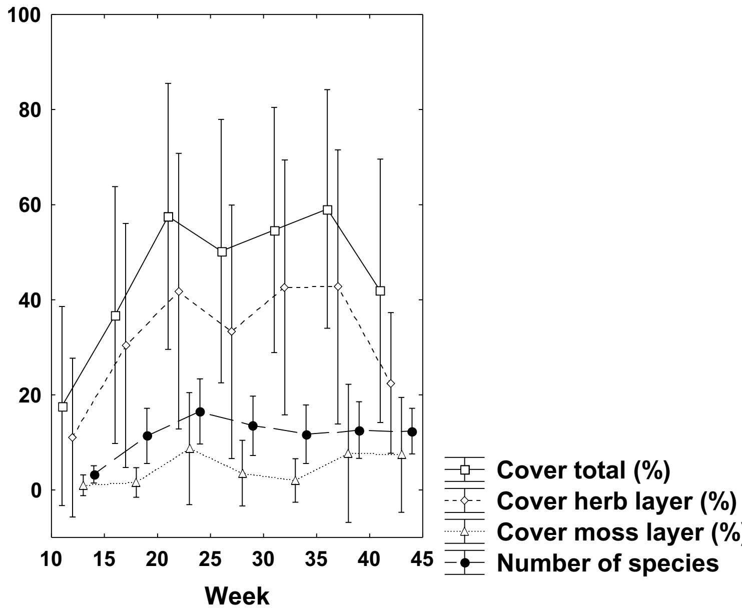

Fig. 2. Seasonal changes in vegetation cover and in species richness. Error bars represent standard deviation from the mean.

there were always individual plants which were only partly affected by herbicide and quickly regenerated. Additionally, we observed some species that were resistant to herbicide, e.g., *Tillaea aquatica* and *Equisetum palustre*. Even apparently dead individuals of some perennials, such as *Butomus umbellatus*, *Leersia oryzoides* and *Juncus articulatus* can regenerate from underground organs. *Lindernia dubia* and *Cyperus fuscus*, the typical annuals of exposed pond bottoms, regerminate from the seed bank. In the warm and wet summer of 2002, the regeneration of vegetation cover after spraying was very rapid. A total of 16 sampling plots were sprayed, and the herb layer in 13 of them reestablished the original cover value in a period of 2–8 weeks. Because the spraying was carried out over a period of 4 weeks, the mean decrease in total and herb layer cover on the graph is negligible. However, in individual cases, it reached about 50–80 % in 2 weeks. Similarly, the decrease in species number was very intensive in some plots, but most species appeared again, except the ruderal species (*Chenopodium album* agg., *Cirsium arvense*, *Tripleurospermum inodorum*, etc.). Probably these species cannot establish a long-term seed bank in the storage ponds, and they are imported repeatedly from the surroundings or with the fish. On the other hand, *Lindernia procumbens* and *Cyperus flavescens* appeared as new species in the plots after spraying at the end of June. This is due to their high temperature requirement for germination (Lampe 1996). These facts are visible in the graph (Fig. 2) by the small decrease in species richness after the application of herbicide. This decrease continues slowly during the period of herb layer regeneration. It is connected with other factors, e.g., high cover values of the regenerated stands, herbivorous insects or the extremely wet weather in July and August of 2002. These conditions were especially unsuitable for juveniles and species which do not respond well to competition.

The curve of the cover of moss and algae layers in the summer period follows the curve of the species number. There was a visible decrease in the mean cover value between the 25th and 30th weeks. We did not observe direct damage to the moss and algae biomass after the application of herbicide, but there a thick layer of dead plants which could limit the development of the E_0 layer, often existed. The later continuous decrease is related to competition from the connected herb layer.

(3) Period after the flooding in August

In August of 2002, there were a series of flooding in southern Bohemia. The storage pond system in Hluboká was flooded during the 10th–13th August (the 33rd week). The first data sampling after the flooding was carried out during the 21st–24th August (the 34th week). We found that the stands in individual storage ponds were affected in different ways, in accordance with their phenological stage, species composition, etc. In some plots, the herb layer cover increased or was only retarded (storage ponds exposed shortly before the flooding while still in an initial or vegetative stage of succession). In other plots a decrease of 50–80 % in the herb layer was observed. The herb layer died off slowly after the flooding. The graph (Fig. 2) shows a visible decrease in the total cover and herb layer cover after the 40th week, but additional factors also influenced vegetation cover. Some storage ponds were sprayed with herbicides 2 weeks before the flooding. In the end of summer and the beginning of autumn, stands in spring storage ponds (see Methods, part 4) are in a late phenological phase. Many individuals from the annual species die off naturally during this time. After the flooding (at the end of August) the storage ponds were mown and prepared for the storage of fish. Herbicide spraying, flooding, mowing and the end of the vegetation period for some species selectively impacted the storage ponds: (1) the spraying affected all plant species sensitive to herbicides; (2) the flooding affected mainly plants with rough surface of leaves (e.g., *Leersia oryzoides*, *Echinochloa crus-galli*) which could not assimilate because of a fine layer of mud covering their vegetative organs; (3) the mowing eliminated a substantial portion of the biomass of tall plants; (4) low temperatures at the end of the vegetation period prevented the massive regeneration of thermophilous annuals from seeds (e.g., *Echinochloa crus-galli*, *Cyperus flavescens* and *Lindernia dubia*).

The influence of various management practices on individual storage ponds is different because structure and species composition are highly variable. Although species number in individual plots decreased considerably after the flooding and management treatments, total species richness was maintained (Fig. 2). Most species had reduced cover in September and

October, but the vegetation period was not completely finished until the storage ponds were filled with water.

The mean cover value of the E_0 layer at the end of the vegetation period probably increased as a result of the decreasing herb layer cover, especially after the removal of the mown biomass. In some cases, it disappeared under the layer of mud deposited by the flooding.

3. Dominant species and their dynamics

A total of 428 relevés from storage ponds were analysed. From this dataset, only 109 relevés contained a dominant. For comparison, 17 relevés from fishponds were analysed. Twelve relevés contained dominant species.

A total of 15 dominant species were established in relevés from storage ponds. Six of them were represented in at least 5 relevés: *Leersia oryzoides* (26 relevés), *Agrostis-Alopecurus* (23), *Lindernia dubia* (19), *Echinochloa crus-galli* (8), *Juncus articulatus* (6) and *Lemna minor* (5). Dominance of individual species can change greatly during the vegetation period. The dominance changes for six of the most frequent species for each month of research are displayed in the graph (Fig. 3). Only a few plots had dominant

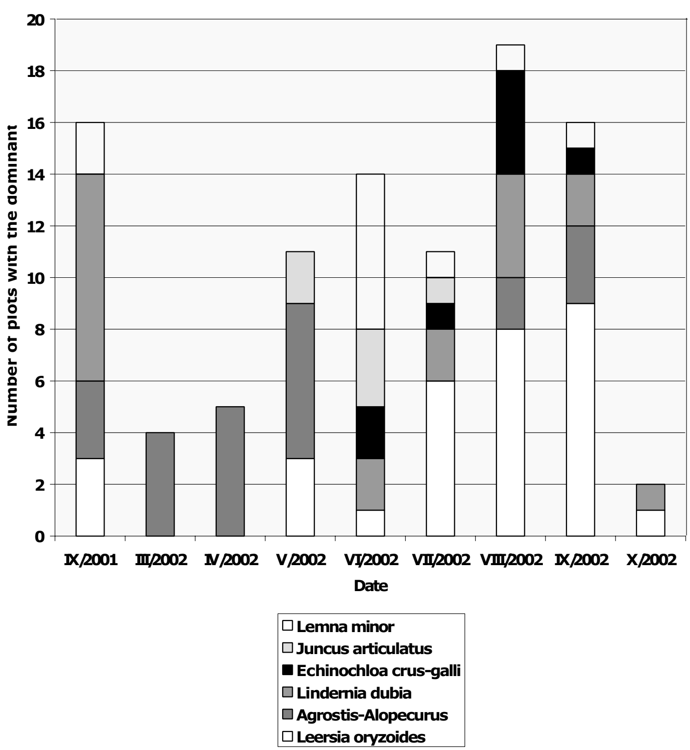

Fig. 3. Seasonal dynamics of selected dominants in storage ponds.

species in the early spring. This generally corresponds with the low herb layer cover during this period (Fig. 2). The only dominant during this period was *Agrostis-Alopecurus*, which can survive the winter with assimilating leaves. These grass species predominated in storage ponds exposed in December 2001 or in the first months of 2002. *Juncus articulatus* also has similar requirements. However, we found it among dominants later in May. For perennial species, their cover at the end of the vegetation period is very important. In 2001, there was no plot dominated by *Juncus articulatus*; its cover did not exceed 5 %. In the same plots in 2002, the cover of *Juncus articulatus* reached 30 %.

Other perennial species, e.g., *Leersia oryzoides* and *Alisma plantago-aquatica*, survive the winter period as rhizomes. Especially *Leersia* created aboveground biomass very slowly in the spring months. At the beginning of May, *Leersia oryzoides* had low cover, 5 % in plots. Later in the season, in the same plots, it reached a cover of > 50 %. The dominants among the annual species also create their biomass mainly in the summer. The earliest annual dominant is *Juncus bufonius*, predominating in some relevés recorded in May. The other annual species, mainly *Lindernia dubia* and *Echinochloa crus-galli*, reached a cover of > 25 % in June and later. It is visible on the graph (Fig. 3) that *Agrostis-Alopecurus* and *Juncus articulatus* ceased to dominate in June and August. This was due to spraying. Some storage ponds dominated by *Agrostis-Alopecurus* were used for the storage of fish in summer. *Echinochloa crus-galli* was not found as a dominant in 2001. All relevés in which *Echinochloa* predominated were recorded in storage ponds observed in 2002. A comparison of the spectra of dominants in September of 2001 and 2002 shows noticeable differences in the number of plots dominated by *Lindernia dubia* and by *Leersia oryzoides*. These cases cannot be clearly explained because data is lacking from part of the vegetation period of 2001 and the number of compared relevés is small. It could be caused by climatic factors, especially by the extremely wet summer and flooding in 2002, but also by other factors, including population fluctuation.

The spectrum of dominants on the nursery fishponds (usually exposed 2–3 months) is restricted to several species with extremely short life cycles or with the ability to finish their life cycles in shallow water. In relevés from the Podhradský rybník and Pěnský rybník fishponds, three species with more than 25 % cover occurred: *Coleanthus subtilis* (9 relevés), *Callitriche palustris* (2) and *Elatine triandra* (1). Our experiences show that *Coleanthus subtilis*, due to its life cycle of 5–7 weeks (Hejný 1969, Lampe 1996), is best adapted to the conditions of nursery fishponds. On the main fishponds, which are dry in summer, *Coleanthus* is quickly overgrown by taller annual plants (*Bidens* spp., *Persicaria* spp.), which negatively influence its vitality; the *Coleanthus* plants are usually thin, with a poor inflorescence.

4. Species composition in ponds based on the type of summer drying

There are two main types of summer drying. We distinguished between spring and summer ponds. The spring ponds are exposed at least from spring to the middle of May, frequently during the whole vegetation period. The development of vegetation is concentrated in spring and early summer. Intensive development of vegetation on summer ponds is not possible earlier than July (for details see Methods, Data analysis).

We divided the relevés into two groups according to pond type. We obtained 231 relevés for spring and 214 relevés for summer ponds. The group of spring ponds includes the data from storage ponds and nursery fishponds. The group of summer ponds is restricted only to storage ponds. Table 5 shows differences in species composition between these two groups of relevés.

The following groups of species are characteristic for spring ponds: (1) Perennial herbs or mosses surviving the winter with assimilation organs (*Equisetum palustre*, *Juncus articulatus*, *Amblystegium humile*) or creating new ones in early spring (*Alisma plantago-aquatica*, *Juncus compressus*). According to our observations, these plants need more time for full development, e.g. the vascular plants reach maturity in 4–5 months. Therefore the group is restricted to storage ponds with a long dry period. (2) Annual species germinating in early spring. *Coleanthus subtilis* needs extreme fluctuations between daytime and nighttime temperatures for germination (Lampe 1996, Pietsch 1999). Therefore, germination is concentrated in spring and autumn (Hejný 1969). *Persicaria hydropiper*, *P. minor*, and *Ranunculus sceleratus* can germinate throughout the vegetation period. We found the first juveniles of these species on our plots between the middle and the end of April. (3) Annual species not appearing on the plots before May–June. The occurrence of these species in spring plots is probably more connected with moisture and type of substrate than with their phenology. *Potamogeton pusillus* and *Chara* sp. as hydrophytes colonize only shallow flooded plots. *Sagina procumbens*, *Tillaea aquatica* and *Nostoc commune* occurred mainly on moist sand or sand with a thin layer of clay mud. These conditions occur rarely in the summer ponds. The spring ponds are probably more suitable for the growth of *Tillaea aquatica* due to a longer dry period. In comparison with other therophytes of exposed pond bottoms, the development of this species is slow and its life cycle can continue until October.

Juveniles of *Sonchus* sp. and *Epilobium* sp. were present in spring ponds. In most relevés, they were determined only to genus (for details see Methods). Excerption of complete data for both genera (TURBO(VEG)) shows that species of *Sonchus* and *Epilobium* prevail in spring storage ponds. In the summer storage ponds and fishponds, they occur only rarely. An important fact is that the spring storage ponds are “more terrestrial” on their margins than the summer storage ponds and fishponds. These conditions are suitable for ruderal species, e.g. *Capsella bursa-pastoris*, *Conyza canadensis*, *Galinsoga quadriradiata* and *Geranium pusillum*. Other factors, such as type of substrate, should not be overlooked.

Tab. 5. Differences in species composition between storage ponds with different types of summer drying. Column 1 – plots from spring ponds, column 2 – plots from summer ponds. The numbers in the columns are frequencies in %. Species are ranked according their phi coefficients. Species with phi coefficients higher than 0.15 are shown in bold and italics. Number of stars reflects the importance of the species (***: phi > 0.3; **: 0.2 < phi < 0.3; *: 0.15 < phi < 0.2). "Other species" with frequencies lower than 20 % in all of the columns were deleted.

	1	2
Number of plots	231	214
species associated with spring ponds		
Amblystegium humile	***49****	1
Juncus articulatus	***35*****	10
Equisetum palustre	***39****	14
Alisma plantago-aquatica	***66****	39
Tillaea aquatica	***15****	1
Persicaria minor	***25****	7
Potamogeton pusillus	***10****	•
Sagina procumbens	***15****	3
Juncus compressus	***8****	•
Coleanthus subtilis	***7****	•
Persicaria hydropiper	***42****	24
Ranunculus sceleratus	***12****	2
Sonchus sp.	***6****	•
Epilobium sp.	***26****	12
Chara sp.	***5****	•
Nostoc commune	***26****	14
species associated with summer ponds		
Bolboschoenus maritimus	19	***44****
Lindernia procumbens	2	***14****
Lindernia dubia	33	***52****
Bidens tripartitus	4	***14****
Limosella aquatica	6	***17****
Lythrum salicaria	4	***15****
Peplis portula	12	26*
Persicaria lapathifolia	21	***37****
Potentilla anserina	•	***5****
Eleocharis ovata	10	***22****
Spergularia echinosperma	•	***5****
other species		
Leersia oryzoides	67	59
Eleocharis acicularis	48	44
Echinochloa crus-galli	45	49
Agrostis-Alopecurus	43	41
Callitriche palustris	40	36
Juncus bufonius	31	29
Rorippa palustris	31	39
Cyperus fuscus	29	43
Lemna minor	28	26
Spirodela polyrhiza	22	21
Gnaphalium uliginosum	21	23
Eleocharis palustris	19	22
Plantago major ssp. *intermedia*	15	26

There are also species associated with summer ponds (Tab. 5). In this group are species developing in high summer temperatures, *Bolboschoenus maritimus* among perennials, and *Lindernia dubia* and *L. procumbens* (cf. Lampe 1996) among annuals. On the plots in spring ponds, they rarely appeared earlier than the end of May. The same applies to *Eleocharis ovata* and *Peplis portula*, although they are not included among the thermophilous species of exposed pond bottoms (cf. Lampe 1996).

The apparent affinity of most species associated with summer ponds to later exposure of the substrate can be interpreted as the influence of substrate and moisture. The bottoms of most summer ponds are covered with a layer of mud after the drainage of the pond. The mud stays wet for several weeks. The plots in sandy summer ponds were often shallowly (0.5 – 1 cm) flooded during the vegetation period. These conditions are optimal for the development of *Eleocharis ovata*, *Lindernia procumbens*, *L. dubia*, *Peplis portula*, *Limosella aquatica* (cf. Lampe 1996), *Spergularia echinosperma* and *Bolboschoenus maritimus*. Our observations from spring plots with such conditions also show that the competition of perennial species, especially *Leersia oryzoides*, can restrict the development of some annuals.

The affinity of some species, e. g., *Persicaria lapathifolia*, is hard to interpret. Detailed knowledge of local conditions, and a plant biology, is necessary. Some species, *Potentilla anserina*, for example, originates in the vegetation on the walls or banks of the pond.

In the group of "other species" (Tab. 5) *Leersia oryzoides* among perennials and *Echinochloa crus-galli* and *Cyperus fuscus* among annuals for example are without significant affinity for any type of pond. The synoptic table (Tab. 5) includes only frequencies and does not take cover into account. For example, *Leersia oryzoides* attain only small cover in summer ponds, while in the spring ponds it is often a dominant of the stands. The same applies to the group of species developing in early spring, e. g., *Agrostis-Alopecurus*, *Juncus bufonius* and *Eleocharis acicularis*. All these species occurred with considerably lower cover in the summer ponds than in the spring ponds. *Callitriche palustris* and *Rorippa palustris* are examples of indifferent species – they occurred in all types of ponds with similar frequency and cover.

5. Influence of environmental conditions and management on vegetation dynamics within a vegetation period

Result of the detrended correspondence analysis (DCA) is presented in Fig. 4. The most important gradient can be explained as seasonal changes in the vegetation of exposed pond bottoms; the second most important gradient corresponds with moisture. The result of DCA in particular corresponds with our field observations. Groups of species with affinity to one or more interconnected factors are visible in the ordination diagram (Fig. 4). For example, we consider the complex of species *Lemna minor, Spirodela polyrhiza, Leersia oryzoides,* and *Alisma plantago-aquatica* to be indicators of wet muddy or shallowly flooded plots. On the opposite side

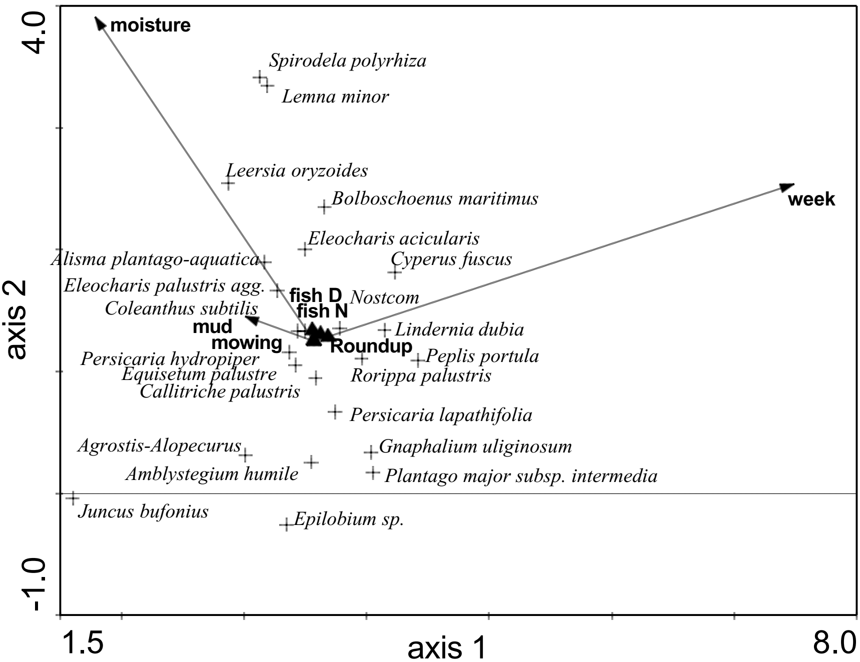

Fig. 4. Ordination diagram of species and environmental variables from DCA analysis. Only the species with the highest weight in analysis are displayed.
Abbreviation: *Nostcom* = *Nostoc commune*.

of the diagram, there are species which were recorded mainly in plots with slightly moist, mainly sandy substrates (*Gnaphalium uliginosum*, *Persicaria lapathifolia*, *Plantago major* subsp. *intermedia*). Closely related to the spring period are *Juncus bufonius* and *Agrostis-Alopecurus*; they colonize moist to wet clay mud or sands. By contrast, the group *Peplis portula*, *Cyperus fuscus* and *Lindernia dubia* represent thermophilous species which develop in the summer.

Permutation tests in the canonical correspondence analysis (CCA) showed that the effects of each of the measured variables on species composition were significant. The most significant variables were moisture and the week during which the data were recorded. These variables can explain only 1.4 % and 1.1 % (together 2.5 %) of the total variation of species composition. The other environmental variables in descending order of influence were kind of fish, liming, Roundup, gravel, mud, flooding, and mowing.

The results of partial CCAs for moisture and the week showed the influence of these two factors without the effects of other variables. The following species (listed from highest to lowest moisture demands) showed a positive correlation to moisture: *Potamogeton pusillus*, *Spirodela polyrhiza*, *Lemna minor*, *Bidens cernua*, *Bolboschoenus maritimus*, *Leersia ory-*

zoides, etc. The high negative correlation to moisture was indicated for the ruderal species: *Sonchus* sp., *Chenopodium polyspermum* and *Atriplex prostrata*, but also for *Drepanocladus aduncus*, *Cyperus michelianus* and *Carex bohemica* which are considered to be species with a high moisture requirement. Firstly, these species grew on a sandy substrate with changing moisture in our plots, so they were probably dried out at the time data was recorded. Secondly, the species *Cyperus michelianus* and *Carex bohemica* need the highest moisture in the germination period, but later they can survive in drier conditions (cf. Lampe 1996).

The following species (listed from week 10 to week 24) showed a positive correlation to the factor "week": *Conyza canadensis*, *Sonchus oleraceus*, *Epilobium ciliatum*, *Lindernia procumbens*, *L. dubia*, *Cyperus fuscus*, etc. A high negative correlation to the same factor was indicated for: *Atriplex prostrata*, *Tripleurospermum inodorum*, *Agrostis-Alopecurus*, *Juncus bufonius*, *Epilobium* sp., etc.

Discussion

1. State of knowledge of vegetation dynamics on exposed pond bottoms

The vegetation of annual hygrophilous plants on exposed pond bottoms attracted the attention of European botanists at the end of the 19th and in the first decades of the 20th century (e.g. Domin 1904, Bojko 1932, Braun-Blanquet & Moor 1935, Klika 1935, Moor 1936, 1937, Oberdorfer 1936, Libbert 1938, Ambrož 1939, Folföldy 1942). One of the most characteristic traits of this vegetation type is very rapid colonization of newly opened niches on exposed substrata. Large changes in the structure and species composition of stands on exposed pond bottoms over the span of a few weeks make vegetation dynamics research more difficult. Therefore most authors dealt with phytosociology of plant communities on exposed pond bottoms (e.g. Korneck 1960, Pietsch 1963, Philippi 1968, 1984, 1985, Pietsch & Müller-Stoll 1968, 1974, Vicherek 1972, Hejný & Husák 1978, Hejný 1997, Popiela 1997, etc.). There are only sporadic studies of selected aspects of the vegetation dynamics on the exposed bottoms of cut backwaters (Bagi 1987) or fishponds (Hroudová 1981, Prach et al. 1987, Bauer & Poschlod 1994, Poschlod 1996). Research usually took place during one vegetation period. The intervals between individual observations were always longer than the two weeks used in our project, usually four to five weeks up to a few months. The number of plots was also considerably lower than in our case. Additionally, the vegetation of storage ponds which is an essential part of our research was poorly studied compared to other types of exposed wet substrata. Only a few papers mentioning the flora and vegetation of storage ponds exist (Míchal & Kurka 1991, Chán 1999, Hejný 1999, Šumberová 2003). The only work on the dynamics and other ecological aspects of vegetation in storage ponds is the diploma thesis of Filípková (2001). However, the author studied only 6 exposed storage ponds, and she did not collect her data on fixed sampling plots. We found no literature data of comparable extent and sampled in a similar fashion as ours. Therefore, the interpretation of specific features of the vegetation dynamics on exposed pond bottoms and prediction of its further trends were made mainly on the basis of our direct observations and earlier field experiences, the well-known biological characteristics of the species (Hejný 1960, 1969, Lampe 1996) and information from fish farmers about the management treatments on fishponds and storage ponds.

2. Appropriateness of the chosen methodology and its problems

During vegetation sampling, some problems occurred which could influence the quality of the data. To maintain the intervals between observations, data were recorded in any weather. Bad light conditions probably sometimes led to the overlooking of some miniature plants, especially juveniles or mosses. Additionally, some algae and mosses can be nearly invisible in dry weather.

We did not step into sampling plots during the vegetation period, but we could not exclude fish farmers, who had to provide common management, especially in storage ponds. Some of the plots were trampled or gritted with sand when the rugged surface of the bottom was levelled out. Trampling was frequent in any period of succession, and its influence was different according to the type of substrate. This factor was not included in the analyses. The gritting of sand was represented in the analysis by the change of substrate.

There are other important factors which were not recorded because of time demands or the absence of technical equipment (e.g. chemical characteristics of the substrate, temperature and precipitation curves). There were also factors difficult to measure or detect, such as the density of the seed bank, transport of seeds with fish and fish farming equipment, the life history of each pond (i.e. exact data about summer and winter drying, liming, removal of mud, and other management practices in the past), etc. This is probably the reason why the two most important variables in CCA analysis, moisture and week of data recording, explained only 2.5 % of the variability in species composition. Similar results are seen for example, in weed vegetation (Lososová et al. 2004). For data analysis, the data from all ponds were combined together or divided into two large groups. Any generalization is very problematic, because no two ponds with the same features exist. For one thing, the management treatments and their intensities are based on the characteristics of the ponds and for another thing, the characteristics of ponds are further influenced by the management practices. The impact of the treatments is not the same in all ponds or even in the same pond in different periods. For example, the impact of herbicides depends on the weather. It was apparent that in the wet year, 2002, the direct effect of herbicide was not as high as in the dry year, 2003. Additionally, the vegetation quickly regenerated in 2002. In 2003, the regeneration was restricted.

The question is whether or not it is meaningful to study vegetation dynamics of a habitat influenced by interconnected factors. Our first experiences show that storage ponds especially are suitable for studying the dynamics of individual species and vegetation cover. However, the results of numerical methods must not be overestimated. Frequent observations on the locality are essential for understanding the dynamical processes in the vegetation.

3. The management and occurrence of rare species

Many management practices widely used on fishponds and storage ponds are generally considered damaging to vegetation, especially to rare occurring species. In fact, the long-term, country-wide changes in landscape use and management, which have also occurred in fishpond management, have led to the extinction or endangerment of a number of species (Chán 1999, Čeřovský et al. 1999, etc.). This phenomen was decribed also in other European countries, especially for Isoëto-Nanojuncetea species and communities (e.g. Täuber 2000, Popiela 2005). On the other hand, the knowledge about the distribution of selected endangered species is still fragmentary (Šumberová 2003). It is often overlooked that many fishponds and storage pond systems have been managed in the same way for decades, and rare species are repeatedly confirmed there. On the storage pond system Hluboká, the following species, listed as critically endangered (Holub & Procházka 2000), were found: *Cyperus flavescens*, *C. michelianus*, *Lindernia procumbens*, *Najas minor* and *Tillaea aquatica*. Additionally, there or on the fishponds, many taxa listed as highly endangered (*Elatine triandra*, *Coleanthus subtilis*) or endangered (*Butomus umbellatus*, *Cyperus fuscus*, *Elatine hydropiper*, *Leersia oryzoides*, etc.) occur. All these species were observed repeatedly in strong populations, when ponds were dried in 2001–2003.

Utilization of the storage ponds and management practices, especially herbicide spraying and mowing, always destroy part of population of each plant species. The species typical for exposed pond bottoms and other types of wetlands posses many adaptations which allow them to survive in the habitats with frequent disturbance and restricted period of duration. The most important are a high ecomorphological plasticity and an ability to create long-term seed bank (cf. Hejný 1960, Lampe 1996, Poschlod et al. 1999, Bissels et al. 2005, Urban 2005). Necessary for the maintenance of hygrophilous annuals in the landscape are (a) permanent establishment of new suitable habitats – e.g. muddy river deposits or cut backwaters with natural dynamics of flood and exposure, open sites in perennial vegetation due to summer drought (Rudner 2005), etc., or (b) regular use and management of the habitat. Storage ponds prove that sensitive plant species can exist even in an intensively utilized habitat, without any intervention of nature conservancy organizations and the attendant financial expenses (cf. Filípková 2001, Šumberová 2003). The possible decline in fishpond management in the Czech Republic, connected with socio-economical changes or restrictions due to nature conservancy projects, would probably endanger the rare species of exposed pond bottoms more than the intensification in the 1960s–1980s of the 20th century. In other European countries, the process of extreme fishponds reduction has occurred in the past (Andreska 1997). Similar landscape changes have led to the endangerment of vegetation of exposed pond bottoms and other wetland communities outside of Europe, for example in Japan (Shimoda 1985, 1986, 2005).

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