BOTANICAL SURVEY AND SUCCESSIONAL CHANGES OF VEGETATION IN POOLS AFTER RESTORATION PROJECT IN WETLAND NEAR THE CISARSKA CAVE, MORAVIAN KARST

NOVAKOVA ELISKA[1,2], JIROUSEK MARTIN[2,3], MUSIL ZDENEK[4], STEPANKOVA PETRA[3]

[1]Department of Crop Science, Breeding and Plant Medicine
[2]Department of Plant Biology
Mendel University in Brno
Zemedelska 1, 613 00 Brno
[3]Department of Botany and Zoology
Masaryk University, Brno
Kotlarska 2, 611 37 Brno
[4]Moravian Karst Protected Landscape Area Administration
Agency for Nature Conservation and Landscape Protection of the Czech Republic
Svitavska 29, 678 01 Blansko
CZECH REPUBLIC

ela1993@seznam.cz

Abstract: Three shallow pools were done during the restoration project in 2012, with a goal to create a suitable habitat for competitively weak wetland species surviving on the long-term drained locality only in a seed bank. After that, the floristic and phytosociological research was done for whole area of the wetland with special attention to pools, where succession of vegetation was continuously monitored on permanent plots. In total, 101 taxa of vascular plants and bryophytes were recorded on the study site (57 of them in the permanent plots in pools), nine recorded plant species are endangered in the Czech Republic. Vegetation of the study site consists predominantly of tall sedges in most wet places, surrounded by abandoned drained wet meadows. Vegetation of oligotrophic water bodies quickly enveloped in dug pools. During our 2-year monitoring, continual successional change of vegetation was found, with the gradual infiltration of species from surrounding vegetation. Strong effect on the vegetation has also the fluctuating water level. We assume that in the long-term perspective, both the hydrological conditions and other restoration activities will be crucial for surviving of competitively weak endangered wetland species on the locality.

Key Words: bryophytes, Czech Republic, eutrophication, nature conservation, vegetation change

INTRODUCTION

Nature protection and conservation is carried out all over the world to maintain the rest of the still existing and most valuable habitats and their specific organisms (Bakker 2005). Recently, there are many scientific studies which present useful practices that can be used, if there are no financial, legal or social obstacles, by nature conservation agencies for conservation of valuable and mostly endangered habitats or organisms and protecting them against possible deteriorations. In industrial and agriculture landscape of many European countries, including Czech Republic, the restoration of degraded habitats is a common technique for nature conservation (Pfadenhauer, Grootjans 1999, Klötzli, Grootjans 2001, Hájková et al. 2009). For wetlands, re-hydrating of drained habitats and oligotrophication should be the crucial approach to boost biodiversity (Pfadenhauer, Grootjans 1999). Also upper soil removal can be used where annual vegetation survives in seed bank under competitively strong vegetation (Bossuyt, Honnay 2008). Re-introduction of species is necessary for seed-depleted habitats in heavily fragmented landscape (Pfadenhauer, Grootjans 1999).

In the Moravian Karst, wetlands are rare habitats for two reasons. Naturally, because of the permeable limestone bedrock and further, because of drainage created here in the past for better agriculture land use. Therefore a wetland situated close to the Cisarska cave is a valuable area in terms of the nature conservation and protection. It is peculiar that no botanical research took place here before. Only few records of plants were recorded by Lustyk: *Batrachium aquatile*, *Carex acuta*, *Cephalanthea longifolia* and *Phalaris arundinacea* (Z. Musil in verb.) or were found in an electronic popular science material about Moravian Karst: *Batrachium aquatile*, *Lemna minor* (Balák et al. 2006). Boukal et al. (2007) during the inventarization of water beetles recorded here 46 species including few endangered beetles.

In October 2012, the restoration intervention took place in the study site. The ground was deepened by excavators. In deepest patches were created shallow pools, where new oligotrophic wetland plant species germinated from seed bank in a wet mud, and formation of some rare vegetation types in region might occur.

Questions of the present study are: (i) Are there any target plant species for nature conservation on the study site at all? Which species appear after restoration project in newly dug pools? (ii) Which types of vegetation were recorded on the study site and which of them appeared newly in pools? (iii) How did the vegetation change in pools during two years of initial succession and (iv) Was it sufficient restoration intervention for nature conservation on the study site?

MATERIAL AND METHODS

Study site

Wetland near the Cisarsaka cave is situated to north of the village Ostrov u Macochy, in the Moravian Karst, Czech Republic (49° 23′ 03′′ N, 16° 46′ 01′′E, 460 m a. s. l.). Total area of the wetland is about 2.4 ha. This wetland is one of the biggest and the most preserved in the Moravian Karst. The climate is moderately warm, annual average temperature is about 7–8°C, and annual average rainfalls are about 600–700 mm (Quitt 1971, Musil 1993). Geological bed rock is very interesting because of rearrangement of Devonian lime stone over Culm slate and this situation has major impact to local hydrology. Water in this area comes from creek Lopac and from Cisarska cave, quantity of water from each source is dependent on water level and crossing groundwater. Water is able to flow in both directions. This phenomenon was described as an estavela (Demek et al. 1988).

Digging of pools

In October 2012 were excavated three shallow pools and new water basin. This operation improved water situation in wetland. First pool extent is 90 m^2 with a maximum depth 0.4 m, second pool extent is 25 m^2 and maximum depth is 0.2 m and last pool has 30 m^2 and maximum depth is 0.2 m. Water basin is flowing through second pool and meandering near the another pools (Halaš 2011).

Field sampling

The study area was visited several times during years 2013–2014 and total plant species occurrence in wetland area was recorded. We focused especially on dug pools, where started succession of vegetation on bare wet mud. In each pool, one permanent plot was establish for regular monitoring of vegetation change. During two years, six phytosociological relevés were recorded in Pools 1 and 3, only five relevés in Pool 2. The area of the plots is 25m^2. New Braun-Blanquet scale (Westhoff, van der Maarel 1978) was used for estimation of species cover. Water level position was measured simultaneously with vegetation data sampling in a close hole.

The nomenclature in the paper follows Danihelka et al. (2012) for vascular plants and Kučera et al. (2012) for bryophytes.

Data analyses

The phytosociological relevés were digitalized and exported into JUICE 7.0 software (Tichý 2002), where automatic expert system was used for automatic classification of phytosociological relevés (Kočí et al. 2003, Tichý 2005). Both classified and unclassified relevés were further compared with logical formulas, diagnostic species and other characteristics according Chytrý (2011).

A multivariate analysis of phytosociological data was used to visualize the successional changes of vegetation on permanent plots (Canoco 4.0). We used Principal Component Analysis (PCA; log transformation, centred by species) because of linear response of species to the main gradient of variability (length of the 1st axis in Detrended Correspondence Analysis was 2.457). Environmental data (time, total cover of plants and water level) were displayed in the figure (Figure 1) as dummy variables and have only informative value. Time was used as main explanatory variable for Redundancy analysis (RDA) to display the main successional trend (terBraak, Šmilauer 2002).

RESULTS AND DISCUSSION

Floristic survey

The total amount of plant taxa was 101, where 92 taxa were vascular plants and 9 taxa were bryophytes. Three plant species, *Arrhenatherum elatius*, *Cirsium arvense* and *Conyza canadensis*, are considered as invasive (Pyšek et al. 2012). Nine recorded plant species are considered as endangered: *Batrachium aquatile*, *Berula erecta*, *Cephalanthera longifolia* (long term persistence outside the restored parts of the wetland), *Lemna trisulca*, *Limosella aquatica*, *Stellaria palustris*, *Utricularia australis, Veronica scutellata* (Grulich 2012) and *Physcomitrium eurystomum* (Kučera et al. 2012). The total list of plants found on the study site as well as detailed descriptions and localisations of endangered species are published in Nováková (2015).

Phytosociological description

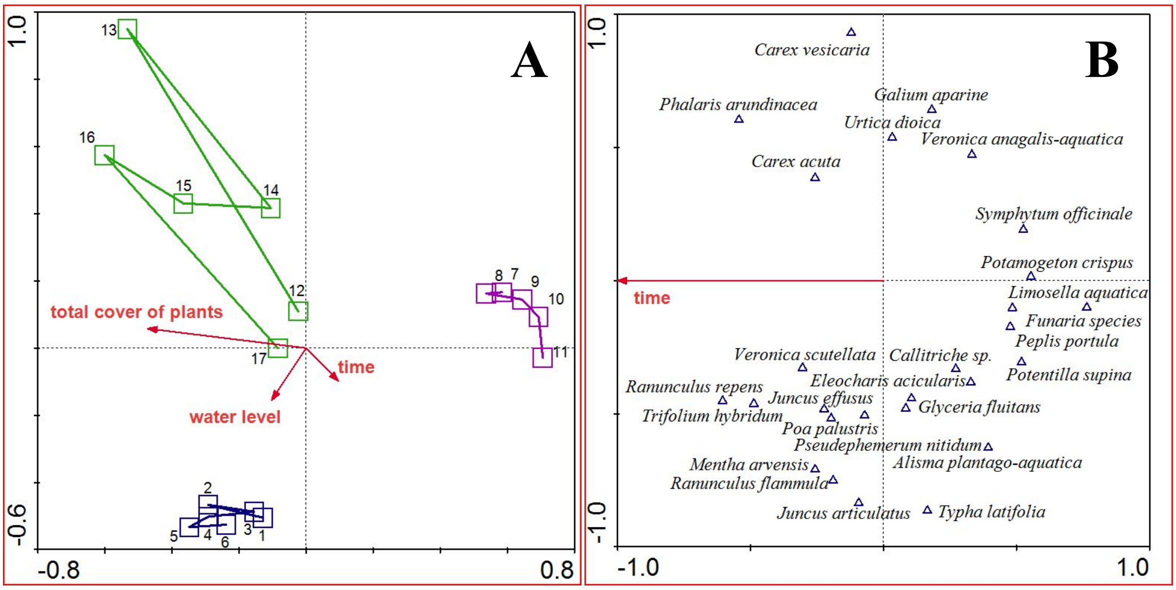
Vegetation in pools changed during time of the monitoring from species-rich vegetation types with a dominance of annual hygrophilous plants (class *Isoëto*-*Nano*-*Juncetea*) with transitions to vegetation from class *Phragmito*-*Magno*-*Caricetea* which was growing in the surrounding of pools. In the surrounding of pools, we found vegetation dominated especially by tall sedges, *Carex acuta* (association *Caricetum gracilis*), *C. vesicaria* and *C. vulpina* (association *Caricetum vesicariae*) or by *Typha latifolia* (association *Typhetum latifoliae*; Chytrý 2011). Vegetation of association *Limosello aquaticae-Eleocharitetum acicularis* (class *Littoreletea uniflorae*) formed only a small patch in Pool 3. Aquatic plants (*Callitriche* sp., *Potamogeton crispus*) were recorded in pools after water level increasing but never formed larger coverage.

Initial succession of vegetation in pools

Succession of vegetation was monitored on three permanent plots and started almost a year after the digging of pools. During two years, five (in Pool 2) or six (in Pools 1 and 3) phytosociological relevés were recorded. On each of the permanent plots the different change in species composition was found (Figure 1). For permanent plots in Pools 1 and 2, the plant species composition did not change much in comparison with permanent plot in Pool 3, where much larger shifts in species composition were observed. The slow change of vegetation with same direction as time indicate slow successional pattern without any other strong influences (Pool 2 in Figure 1A). If we focus on dominants in Pool 2, cover of dominant sedge *Carex vesicaria* was equally high throughout the whole time of monitoring, whereas *Persicaria maculosa* declined and *Phalaris arundinacea* increased (Nováková 2015).

The species composition on permanent plot in Pool 1 haven't changed very well according to the diagram (Figure 1). Never the less, we found continual change in species composition, where competitively weak annual species (*Limosella aquatica*, *Potentilla supina, Rumex maritimus*) were overgrown by *Ranunculus repens* and *Trifolium hybridum* (Nováková 2015). On permanent plot in Pool 3, the species composition change was probably more influenced by water level fluctuations (high *Callitriche* sp. or *Potamogeton crispus* occurrence in July 2013, no individual was found two months later) and perhaps also by phenology of annuals (e.g., *Persicaria maculosa*, *Rumex maritimus*), which appear and create a lot individuals in one time and almost disappear two months later during next monitoring visit. Similarly, to the previous plot, also here we found continual change of species composition from vegetation with competitively weak annuals (e.g., *Chenopodium polyspermum*, *Eleocharis acicularis*, *Gnaphalium uliginosum*, *Limosella aquatica*) to vegetation with competitively stronger perennial plants (*Alopecurus aequalis*, *Phalaris arundinacea*, *Ranunculus repens*, *Trifolium hybridum*; Nováková 2015).

Figure 1 PCA ordination of samples with passively projected environmental data (A), RDA ordination of species, where time was used as environmental variable (B). Only 26 taxa (from total number of 57) are displayed in the Figure 1B in order to improve graph clarity, species selection meets the following criteria: (i) at least two occurrences in the phytosociological data setand (ii) species fit range >18%.



Legend: □[1] *– sample position and number, →– environmental variable, Δ– species position. Numbers of squares correspond to plot numbers, 1–6 for* Pool 1, *7–11 for* Pool 2, *12–17 for* Pool 3. *Colours of samples and lines indicate plot series for particular Pools, dark blue for* Pool 1, *violet for* Pool 2, *green for* Pool 3.

The general pattern of succession is evident from species composition change in Figure 1B (a note: environmental variable *time* was not significant in the analysis, $F = 1.63$, $p = 0.077$, Monte Carlo permutation test with 999 permutations was used), where plant species found during beginning of the monitoring are in the right part of the figure, whereas plant species which occur during later phases of monitoring are displayed in left (see red arrow *time*). In addition to the previously mentioned species we can see also *Peplis portula* or some bryophytes as typical plants of early stage of succession on the one hand and *Carex acuta* or *Juncus effusus* as typical plants of later succession on the second hand.

During the first year of monitoring, mean number of intended species increased from July to September from 20 to 29 species per plot. During the second year, the mean number of intended species was about 20 per plot and relatively constant during a vegetation season (April: 19, June: 19, August: 21, October: 17; Nováková 2015). However, from the restoration point of view, species numbers are a more relevant indicator in older stages than in more initial stages. Moreover, the number of target species for nature conservation is a more important characteristic in ecological restoration than the total number of species (Prach et al. 2014).

CONCLUSION

During our botanical research, the list of plant species included both the vascular plants and bryophytes were done for the first time on the wetland close to the Cisarska cave. A total number of 101 taxa were found, from which 92 were vascular plants and 9 were bryophytes. Nine most interesting records are appointed in the present paper.

Due to the fact that the monitoring of vegetation on permanent plots took only two years, we can only express to the initial phases of the succession. However, we found that initial phases of the succession were very important for dwarf annual amphibious swards that occurred only during first year of monitoring (*Funaria* sp., *Limosella aquatica*, *Peplis portula*). Then the successional trends leading from vegetation with dominance of annuals to vegetation with dominance of perennial plants was recorded. The long-term perspective of overall effectivity of restoration project should be evaluated after future research. Strong influence on vegetation change will have water level fluctuation and only future monitoring will show to us, if some target annual species will be found repeatedly or not. If not, disturbation of vegetation in pools or creating other pools in the surrounding will be important for surviving of the both endangered plants and vegetation of annual amphibious swards.

ACKNOWLEDGEMENT
We thank Eva Gruberová and Miroslav Kovařík from the Administration of the Protected Landscape Area Moravský Kras for their help during the fieldwork. The research was partially covered by the project **GB14-36079G.**

REFERENCES

Bakker J. P. 2005. Vegetation conservation, management and restoration. In: van der Maarel E., Franklin J. *Vegetation ecology*. 2nd rev ed. Great Britan: John Wiley and Sons Ltd.

Balák I., Radači R., Štefka L., Franc D., Jančo J., Kotlánová M., Kotouč L., Kovařík M., Truhlář J. 2006. *Moravský kras interaktivní multimediální počítačová encyklopedie - DVD*. Správa CHKO Moravský kras. Pozemkový spolek Hády.

Bossuyt B., Honnay O. 2008. Can the seed bank be used for ecological restoration? An over view of seed bank characteristics in European communities. *Journal of Vegetation Science* [online]. 19(6): 875–884. [2015-10-18]. Available from: http://www.researchgate.net/publication/227799152 _Can_the_seed_bank_be_used_for_ecological_restoration_An_overview_of_seed_bank_characteristic s_in_European_communities._J_Veg_Sci

Boukal M., Trávníček D., Hamet A., Vancl Z., Cséfalvay R., Vašíčková K. 2007. *Vodní brouci CHKO Moravský kras*. [ms., depo. in Správa CHKO Moravský kras, Blansko].

Chytrý M. [ed.] 2011. *Vegetace České republiky. 3. Vodní a mokřadní vegetace.* 1st ed. Praha: Academia.

Danihelka J., Chrtek J., Kaplan Z. 2012. Check list of vascular plants of the Czech Republic. *Preslia* [online]. 84: 647–811. [2015-10-18]. Available from: http://www.preslia.cz/P123Danihelka.pdf

Demek J., Přibyl J., Hašek V., Meyer S., Štelcl O., Slezák L., Hypr D., Zoufalý J., Dobeš V., Hebelka J., Heger M., Piškula M., Otava J. 1988. *Výzkum ostrovských a vilémovických vod v Moravském krasu.* Sborník referátů ze semináře: Problematika speleologického výzkumu ostrovských a vilémovických vod. Blansko. Okresní muzeum v Blansku.

Grulich V. 2012. Red List of vascular plants of the Czech Republic: 3rd ed. *Preslia* [online]. 84: 631–645. [2015-10-18]. Available from: http://www.preslia.cz/P123Grulich.pdf

Hájková P., Hájek M., Kintrová K. 2009. How can we effectively restore species richness and natural composition of a *Molinia*-invaded fen? *Journal of Applied Ecology* [online]. 46(2): 417–425. [2015-10-18]. Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2009.01608.x/abstract

Halaš L. 2011. *Ostrov u Macochy revitalizace Lopače a protipovodňová opatření*, Zadávací dokumentace stavby [ms., depo. in Správa CHKO Moravský kras, Blansko].

Kočí M., Chytrý M., Tichý L. 2003. Formalized reproduction of an expert-based phytosociological classification: A case study of subalpine tall-forb vegetation. *Journal of Vegetation Science* [online]. 14: 601–610. [2015-10-18]. Available from: http://www .sci.muni.cz/botany/juice/JVS2003b.pdf

Klötzli F., Grootjans A. P. 2001. Restoration of Natural and Semi-Natural Wetland Systems in Central Europe: Progress and Predictability of Developments. *Restoration Ecology* [online]. 9(2): 209–219. [2015-10-18]. Available from: http://onlinelibrary.wiley.com/doi/10.1046/j.1526-100x.2001.00900 2209.x/pdf

Kučera J., Váňa J., Hradílek Z. 2012. Bryophyte flora of the Czech Republic: updated check list and Red List and a briefanalysis. *Preslia* [online]. 84: 813–850. [2015-10-18]. Available from: http://www.preslia.cz/P123Kucera.pdf

Musil R. 1993. *Moravský kras: Labyrint poznání*. Adamov: J. Bližňák.

Nováková E. 2015. *Studium flóry a vegetace mokřadu u Císařské jeskyně v Moravském krasu*. [ms., depo. in Mendel University in Brno, Brno].

Pfadenhauer J., Grootjans A. 1999. Wetland Restoration in Central Europe: Aims and Methods. *Applied Vegetation Science* [online]. 2(1): 95–106. [2015-10-18]. Available from: http://onlinelibrary.wiley.com/doi/10.2307/1478886/abstract

Prach K., Řehounková K., Lencová K., Jírová A., Konvalinková P., Mudrák O., Študent V., Vaněček Z., Tichý L., Petřík P., Šmilauer P., Pyšek P. 2014. Vegetation succession in restoration of disturbed sites in Central Europe: the direction of succession and species richness across 19 seres. *Applied Vegetation Science* [online]. 17(2): 193–200. [2015-10-18]. Available from: http://onlinelibrary .wiley.com/doi/10.1111/avsc.12064/abstract

Pyšek P., Danihelka J., Sádlo J., Chrtek J. Jr., Chytrý M., Jarošík V., Kaplan Z., Krahulec F., Moravcová L., Pergl J., Štajerová K., Tichý L. 2012. Catalogue of alien plants of the Czech Republic (2nd edition): check list update, taxonomic diversity and invasion patterns. *Preslia* [online]. 84: 155–255. [2015-10-18]. Available from: http://www.ms-cbs.cz/_dokumenty/P122Pysek.pdf

Quitte E. 1971. *Klimatické oblasti Československa*. Praha: Academia.

ter Braak C. J. F., Šmilauer P. 2002. *CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5)*. Microcomputer Power, Ithaca, U. S. A.

Tichý L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* [online]. 13: 451–453. [2015-10-18]. Available from: http://www.geobotany.org/teaching/biol475/Tichy2002 _JVS13_451.pdf

Tichý L. 2005. New similarity indices for the assignment of relevés to vegetation units of an existing phytosociological classification. *Plant Ecology* [online]. 179(1): 67–72. [2015-10-18]. Available from: http://link.springer.com/article/10.1007/s11258-004-5798-8

Tuittila E.-S., Vasander H., Laine J. 2000. Impact of rewetting on the vegetation of a cut-away peatland. *Applied Vegetation Science* [online]. 3: 205–212. [2015-10-18]. Available from: http://onlinelibrary.wiley.com/doi/10.2307/1478999/abstract

Westhoff V., van der Maarel E. 1978. The Braun-Blanquet approach. In. Whittaker R. H. [ed.] *Classification of plant communities*. 2nd ed. The Hague, The Netherlands: Junk.