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CHANGES IN BIODIVERSITY IN THE NATIONAL NATURE RESERVE OF THE BOHDANEČSKÝ POND FROM THE EXPLORATIONS BY THE HADAČ BROTHERS IN THE 1950'S TO THE PRESENT TIMES

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ABSTRACT

This paper deals with the botanically interesting locality of the Bohdanečský pond and its surroundings in the Pardubice region. Thanks to botanists´ interest in this locality, there is a lot of floristic data that can be used for evaluation of the area development in terms of species and habitat diversity. Although there is a demonstrable decline of rare plant species, this locality still belongs to the most valuable reserves in the Czech Republic. The current state of the locality is influenced by many factors, e.g. spontaneous succession, management methods of the NNR, the influence of landscape management around the NNR, or global factors (eutrophication, climate change, etc.). Present surveys carried out since 2000 show that the condition of the NNR can be positively influenced by appropriate controlled interventions which include regular meadow mowing and removal of harvested biomass, occasional mowing of reeds and tall sedge vegetation, as well as revitalisation measures for surface water (ponds, pools, water flows).

INTRODUCTION

The ponds of Bohdanečský and Matka represent only a fragment of former grandiose system of 300 ponds in the region of Pardubice. They were founded in the 15th and 16th centuries on the area enclosed by the watercourse of Elbe in the river basin of the Chrudimka and Loučná rivers. Fish farming in the ponds mostly developed under Vilém from Pernštejn, who built the 34 km long Opatovický Channel (finished in 1513) to supply the ponds (Šebek, 1990). However, under Ferdinand III., fish farming declined; the ponds were destroyed, drained, and new settlements were founded in their place. While in 1560, there were 230 ponds in the Pardubice region, only 157 remained in 1743. Another considerable decline of fish farming came during the 19th century with further draining of ponds, cutting oaks on dams and dismantling the stone dams. At the turn of the 19th and 20th centuries, the number of ponds slightly increased from 21 (in 1881) to 32 (in 1948) (Šebek, 1990).

The Bohdanečský pond and its surroundings in the cadastral area of Lázně Bohdaneč were declared a state nature reserve (SNR) "*Bohdanečský rybník and rybník Matka*" in 1951. The category of SNR was replaced by the category of national nature reserve (NNR) in 1992 according to the law No. 114/1992 Col. The protected area was enlarged by the Zábranské and Zástava ponds and re-declared as NNR "*Bohdanečský rybník*" with the area of 247,7674 ha in 2005.

The oldest documents, manuscripts and herbarium items from this locality belong to the taxa of *Potamogeto*n x *angustifolius* and *Potamogeton gramineus* (Vodák, 1899). Exploration of this area was pushed forward especially by Emil and Jan Hadač (Hadač & Hadač 1943, 1948), later by Černohous (1968), Procházka (1972), Faltys (1993), Prausová (2005; 2010) and Prausová & Bálková (2015).

Because the spontaneous development of the vegetation within the ponds of Bohdanečský and Matka headed towards a monocenosis of reeds overgrowing not only the water surface, but also the coastal moist meadows, revitalisation measures were undertaken in this area in 2000–2005 (revitalisation of the Matka pond, restoration of pools in the filled North-West bay of the Bohdanečský pond and renewal of regular mowing of the moist meadows). This helped to regenerate several biotopes and to increase the biodiversity of the area (Prausová, 2010).

The aim of this work is to record changes in the character and size of forest and non-forest sites in the current area of the NNR during 1937–2014 and the changes in species diversity in this territory since the 1950s.

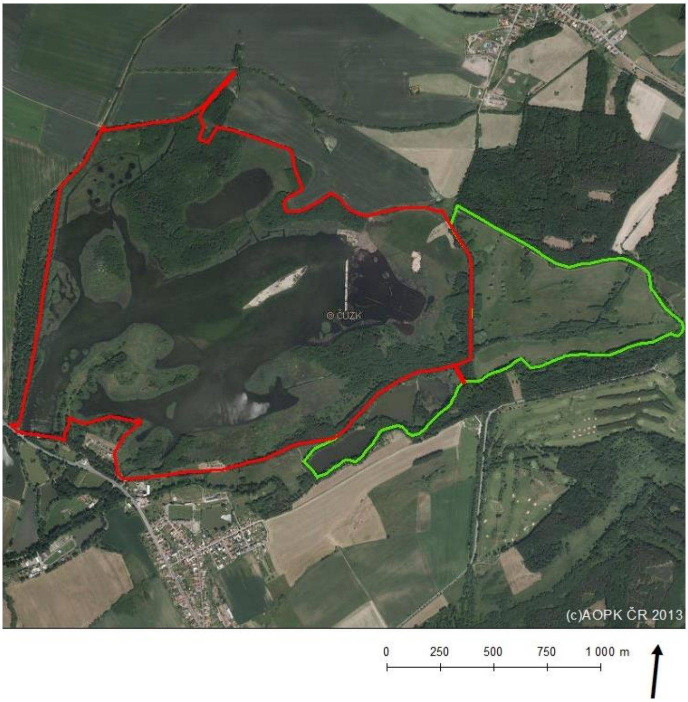
MATERIAL AND METHODS

Nature characteristics of the area of interest

The NNR of *Bohdanečský rybník* is situated at the North-West edge of the town of Lázně Bohdaneč near Pardubice in the region of Eastern Bohemia, at the altitude of 220 MAMSL (Fig. 1). In geomorphological terms it ranks into the district of *Bohdanečská brána* valley in *Pardubická kotlina* basin, which is a part of the Hercynian system (Demek & Mackovčin, 2006). There are glacial, fluvioglacial and terrace sediments there (Tomášek, 2007). In hydrological terms, this area belongs to the basin of the Elbe. The ponds are supplied by the Opatovický channel, which branches off from the Elbe near Opatovice at the altitude of 225 MAMSL and flows back into the Elbe near Semín at the altitude of 202 MAMSL (Vlček *et al.*, 1984). The area falls into the climatic region W2 with 50–60 summer days and 160–170 days with the average temperature of 10°C at minimum. The total amount of precipitation during the growing season is 350–400 mm, in winter 200–300 mm (Tolasz *et al.*, 2007).

According to the map of reconstructed natural vegetation (Mikyška, 1969), there are flood plains, alder carrs and their succession stages (*Alno-Padion*, *Salicetea purpureae*, *Alnetea glutinosae*, *Phragmitetea*), and fens (*Tofieldietalia*). The map of potential natural vegetation of the CR (Neuhäuslová *et al.*, 1998) states in this area *Pruno-Fraxinetum*, partly in complex with *Alnion glutinosae*, and *Melampyro nemorosi-Carpinetum*. According to the phytogeographical classification, this area is situated in the sub-district of Pardubické Polabí in the district of Východní Polabí in the Czech thermophyticum (Skalický, 1988).

Fig. 1: Current area of the Bohdanečský pond NNR (red – NNR, green – buffer zone), source map WMS - aerial photo on geoportal.cuzk.cz 2015, boundary line of the NNR and its buffer zone by AOPK ČR 2013



Description of controlled reconstruction of the *Matka* pond and meadows in its surroundings

From January to September 1999, the embedded pond of *Matka* (overgrown with reed monocenosis) was reconstructed, enlarging its area from 0.78 ha to 7 ha, which is its cadastral size. The mud was removed, the embedded edges were extracted and shallow lagoons were created. The banks of litoral zones were sloped to the gradient of 1:5 up to 1:15.

Management of unmown meadows by the Matka pond began in 1999. Trees from natural seeding were cut, and stumps were pulled up. In the following years, regular mowing was carried out. Its schedule and technology was designed to suppress the reed spread, to support the populations of orchidaceous plants and to gradually change the species composition, promoting herbaceous plants, low grass and bent-grass species.

Assessment of changes of site diversity using historical aerial photographs, current and historical vegetation surveys

A vegetation map of the Bohdanečský pond NNR and its buffer zone was produced in 2014, by update and methodological adjustment of the map source of Natura 2000 (Nature Conservancy Register of Occurences, AOPK ČR 2013b). Both the natural habitats and those with anthropogenic burden were classified according to the Catalogue of biotopes of Natura 2000 network (Chytrý *et al.*, 2009). The proportion of particular sites´ species diversity and the total number of species found in the NNR (index <1) was assessed on the basis of a detailed inventory of vascular plant taxons made in particular sites in the NNR (Prausová & Bálková, 2015).

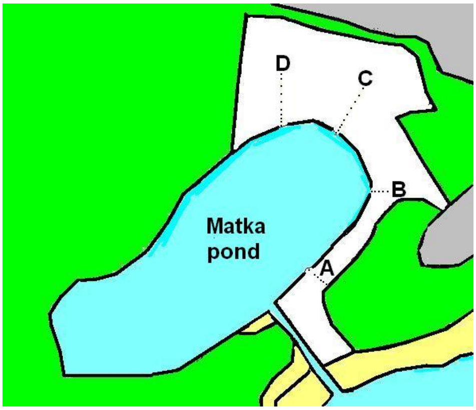
To record long-term changes of forest and non-forest sites in the area of interest, 8 site types were defined (water pools, wetlands, shrubbery, deciduous forests, mixed forests, meadows, fields, built-up areas). These types were identifiable in all available aerial photographs from 1937, 1954, 1984 and 2014, which served for assessment changes in abundance of these sites. The aerial photographs from the years 1937–1984 were bought from the Military Topographic Institute with seat in Dobruška. Those from 2014 were downloaded from www.portal.nature.cz.

In ArcGIS 10 program, all aerial photographs were georeferenced and the changes of site abundance of these 8 site types were assessed. Available results of floristic research (Hadač & Hadač 1943, 1948; Procházka, 1972; Faltys, 1993; Prausová, 2005; Prausová & Bálková, 2015) were compared, focusing on the changes in abundance of especially protected species and endangered species according to the Regulation No. 395/1992 Col., resp. to Red List of Vascular Plants (Grulich, 2012) and on invasive taxons of vascular plants (Pyšek *et al.*, 2012).

Assessment of changes of species- and site diversity in the revitalised area of the Matka pond using permanent line transects

Changes of species composition in areas influenced by revitalisation of the Matka pond were monitored in years 2000, 2002, 2003 and 2010 by means of four line transects, which followed the moisture gradient from the water surface further into the adjacent stands (Fig. 2). The line transects were composed of permanent squares of 1 m^2 surface. The cover-abundance of particular species was assessed by means of 9-grade Braun-Blanquet cover-abundance scale (Moravec *et al.*, 1994).

Fig. 2: Drawing of line transects A – D, blue- Matka pond, Bohdanečský pond, white – meadows at Matka pond, beige – reed beds, green – forests, grey – fields



Line A was placed in the South-East part of the Matka pond and is composed of 6 permanent spots. The distance between them is 2, 10 and 15 m, the total line length was 45 m. Line B is situated in the Eastern part of the Matka pond and involves 5 permanent spots with distances of 7–9 m between them. Line C is situated in the North-East part of the pond and is 100 m long. It contains 10 permanent spots 2, 10, or 15 m far from each other. Line D was placed in the Northern part of the pond, is 100 m long and contains 10 permanent spots at a distance of 5, 10, or 15 m from each other. Each line started in open water of Matka pond, i. e. the first relevé was located in water.

Statistical analyses

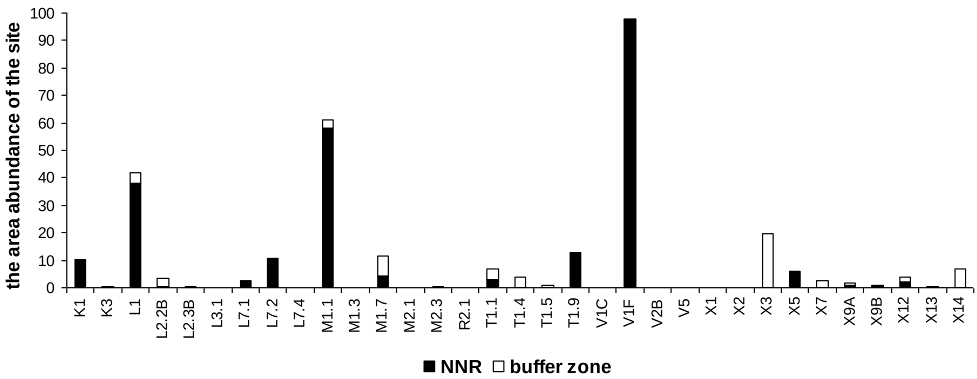
The development in all transects within 10 years was assessed by the multivariate method. Detrended correspondence analysis (DCA) in Canoco program (Ter Braak & Šmilauer, 2000) was used. Unwanted spatial variability was removed using covariates, and positions of the squares on the transect were encoded as covariates. CanoDraw software (Ter Braak & Šmilauer, 2000) was used to generate Canoco figures and only best fitting species were visualised (marked by an abbreviation composed of 3 first letters of both parts of the species name).

RESULTS

Current state of species and habitat abundance in the Bohdanečský pond NNR

In 2014, 23 natural habitats and 10 habitats with anthropogenic burden were found in the Bohdanečský pond NNR and its buffer zone. As for the area, the largest site types in the NNR are eutrophic pool (V1F=97,92348 ha) and reeds (M1.1=58,22256 ha), in the buffer zone extensively farmed fields (X3=19,83878 ha) and high sedge stands (M1.7=7,473139 ha). The area abundance of the 33 habitats is shown in Fig. 3.

Fig. 3: Abundance of natural habitats and habitats with anthropogenic burden in the Bohdanečský pond NNR and its buffer zone

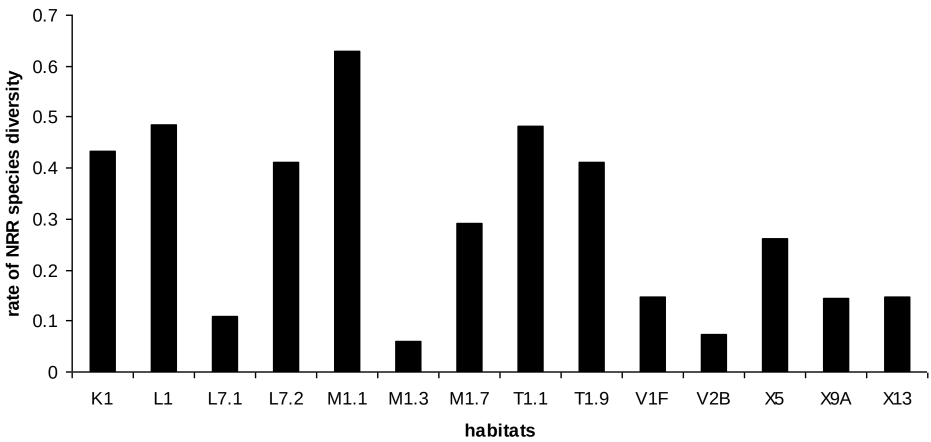


According to the floristic research of the area (Prausová & Bálková, 2015), there are approximately 490 taxons of vascular plants in the sites inside the NNR. The proportion of the most important natural sites, and sites with anthropogenic burden in total species diversity of the territory, is shown in Fig. 4. Habitats with a ratio smaller than 1% in total species diversity in the NNR are not represented in the figure.

Fig. 4: Proportion of particular natural habitats and habitats with anthropogenic burden in total species diversity (habitats K3, L2.2B, L2.3B, L3.1, L7.4, M2.1, M2.3, R2.1, T1.4, T1.5, V1C, V5, X1, X2, X3, X7, X9B, X12, X14 have index < 0,01)

Abbreviations of habitats:

K1 – Willow carrs, K3 – Tall mesic and xeric scrub, L1 – Alder carrs, L2.2B – Ash-alder alluvial forests, L2.3B – Hardwood forests of lowland rivers,L3.1 – Hercynian oak-hornbeam forests, L7.1 – Dry acidophilous oak forests, L7.2 – Wet acidophilous oak forests, L7.4 – Acidophilous oak forests on sand, M1.1 – Reed beds of eutrophic still waters, M1.3 – Eutrophic vegetation of muddy substrata, M1.7 – Tall-sedge beds, M2.1 – Vegetation of exposed fishpond bottoms, M2.3 – Vegetation of exposed bottoms in warm areas, R2.1 – Calcareous fens, T1.1 – Mesic Arrhenatherum meadows, T1.4 – Alluvial Alopecurus meadows, T1.5 – Wet Cirsium meadows, T1.9 Intermittently wet Molinia meadows, V1C – Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with Utricularia australis and U. vulgaris, V1F - Macrophyte vegetation of naturally eutrophic and mesotrophic still waters with common aquatic species, V2B – Macrophyte vegetation of shallow still waters with Hottonia palustris, V5 – Charophycae vegetation, X1 – Urbanized areas, X2 – Intensively managed fields, X3 – Extensively managed fields, X5 – Intensively managed meadows, X7 – Herbaceous ruderal vegetation outside human settlements, X9A – Forest plantations of allochtonous coniferous trees, X9B - Forest plantations of allochtonous broadleaf trees, X12 – Stands of early successional woody species, X13 – Woody vegetation outside forest and human settlements, X14 – Streams and water-bodies without vegetation of conservational importance



As for water pools, there was no substantial change in area during the whole period (1937–2014) except for the period after 2000, when revitalising measures were undertaken renewing several filled pools. Abundance of wetlands increased until 1954. Some of them arose from filled pools, some from abandoned waterlogged meadows. Fields were once concentrated in Polák peninsula at the Bohdanečský pond. Their area decreased four times until 1954 and they completely disappeared from the NNR after 2000. The abundance of built-up areas is unimportant. Slight increase in abundance of forests under management with higher proportion of coniferous species (especially *Pinus sylvestris*) occurred in the 1950s–1970s. Since the 1990s, the abundance of coniferous forests has not changed. Great and substantial changes can be seen in abundance of meadows, broadleaf forests and shrubs.

Fig. 5: Abundance of broad vegetation units in the Bohdanečský pond NNR (without the buffer zone) in aerial maps from 1937–2014 (Zlámalová, 2015)

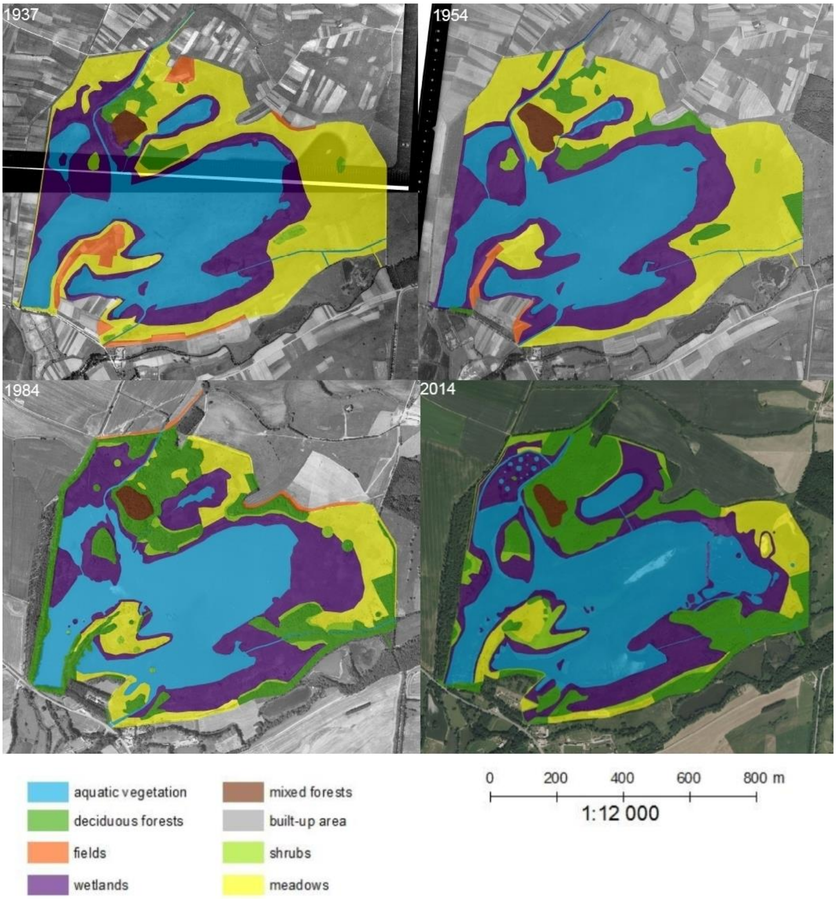
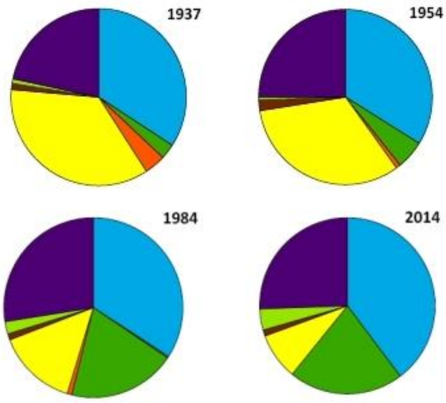


Fig. 6: Changes in abundance of broad vegetation units in the Bohdanečský pond NNR (without the buffer zone) in aerial maps from 1937–2014



Thanks to the absence of mowing and grazing of meadows and to spontaneous spreading of woody plants, the abundance of broadleaf forests has substantially increased. Notably, the occurrence of wetland alders overgrowing unmowed meadows and wetlands has increased; their abundance increased two-fold during 1937–1954, and nearly four times during 1954–1984. At present, broadleaf cover represents approximately 52% of the whole NNR area. Among shrubs, willow carrs predominate. Their cover increased more than four times during 1937–1914, the most rapid rise of their abundance in water pools´ littorals and unmown moist meadows occurring since the 1990s until the present. In 1937, meadows represented almost 89% of the current NNR area while nowadays they only account for 22% of the area. The most noticeable decrease in meadow area was in motion between the 1960s and 1990s. Changes in abundance of the 8 delineated habitats are shown in Fig. 5 and 6.

According to the research of the Hadač brothers from the 1940s (Hadač & Hadač, 1943; 1948), 352 taxons of vascular plants were found in the area of current NNR, thereof were 5,4% of especially protected species (according to regulation No. 395/1992 Coll.) and 13,6% endangered species (according to Grulich, 2012).

In the floristic inventory of Procházka (1972), 380 taxons were registered, thereof 4,5% of especially protected species and 12,6% of endangered species. Faltys (1993) included in his floristic inventory also large surroundings of the NNR and he registered 600 taxons with 2% of especially protected species and 11,6% of endangered species.

In research conducted in 2005 (Prausová, 2005), 490 taxons of vascular plants were found, thereof 2,2% of especially protected species and 11,4% of endangered species. In the latest research from 2015, several newly discovered species were added (*Eleocharis uniglumis*, *Nymphaea candida*, *Sparganium natans*, *Utricularia vulgaris*), 11 especially protected species were registered (according to regulation No. 395/1992 Coll., subsequently amended), and 60 taxons endangered according to the Red List of the CR (Grulich, 2012) were found.

Presence of especially protected and endangered taxons in the NNR in particular periods is shown in Table 1.

Table 1: Survey of current especially protected taxons found in the NNR in particular inventories (Hadač & Hadač, 1943, 1948; Procházka, 1972; Faltys, 1993; Prausová, 2005; Prausová & Bálková, 2015)

Degree of protection by Decree No. 395/1992 Coll. (§1 – critically endangered, §2 - strongly endangered, §3 – endangered)

Taxon	Degree of protection	Hadač. 1943, 1948	Proch. 1972	Falt. 1993	Praus. 2005	Praus. Bál. 2015
Groenlandia densa	§1	+	+	-	-	-
Liparis loeselii	§1	+	+	+	-	-
Utricularia vulgaris	§1	+	+	-	-	+
Allium angulosum	§2	+	+	+	-	-
Dactylorhiza incarnata	§2	+	+	+	+	+
Dactylorhiza sambucina	§2	+	-	-	-	-
Nymphaea candida	§2	+	+	-	-	+
Orchis ustulata	§2	+	+	-	-	-
Pedicularis palustris	§2	+	+	-	-	-
Potamogeton alpinus	§2	-	-	-	+	-
Ranunculus lingua	§2	+	+	+	+	+
Sagina nodosa	§2	+	+	-	-	-
Sparganium natans	§2	-	+	+	-	+
Carex davalliana	§3	+	+	+	+	+
Carex pulicaris	§3	+	+	+	+	+
Dactylorhiza majalis	§3	-	+	+	+	+
Hottonia palustris	§3	+	-	+	+	+
Hydrocotyle vulgaris	§3	+	+	+	+	+
Menyanthes trifoliata	§3	+	+	+	+	-
Ophioglossum vulgatum	§3	+	+	+	+	-
Parnassia palustris	§3	+	+	-	-	-
Platanthera bifolia	§3	+	-	-	-	-
Thelypteris palustris	§3	-	-	+	+	+

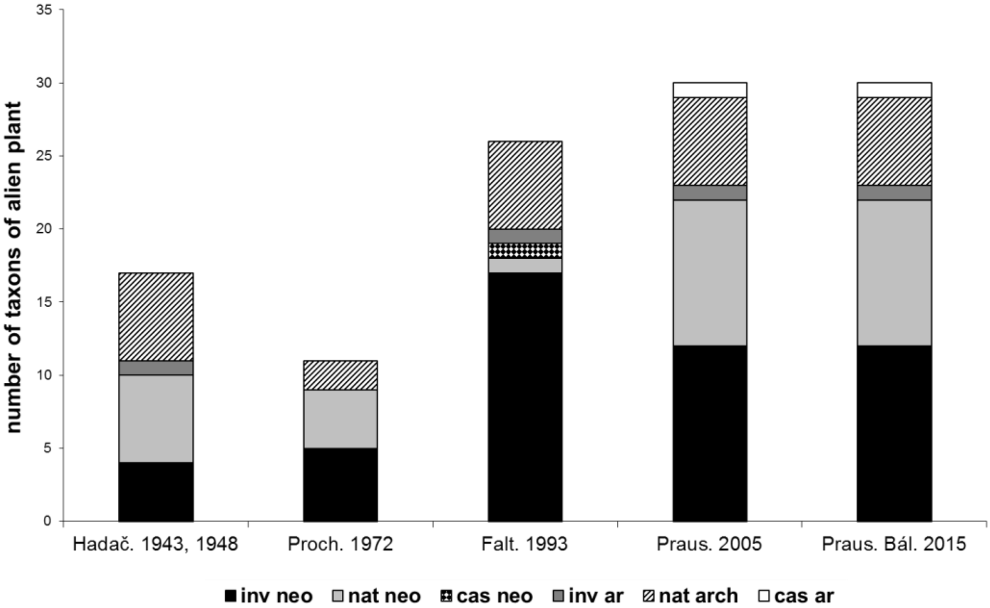
During the whole period of 1943–2015, *Carex davalliana, C. pulicaris, Dactylorhiza incarnata, Hydrocotyle vulgaris,* and *Ranunculus lingua* were repeatedly found in botanical inventories. The first four species survive in meadows where regular or occasional mowing did not cease, i.e. where the interval of consecutive mowing does not exceed two years. The population size of these species is currently small and it responds to the character of the territory management. In the period of most intensive management measures (2000–2005), the population size of *Dactylorhiza incarnata* increased to almost 1000 individuals. Nowadays, there are tens of them. *Ranunculus lingua* survives in loosened young reeds in gradually filled pools. Increase in the number of its flowering individuals was recorded after revitalisation measures on the Matka pond and in the north-west bay of the Bohdanečský pond. A short-time presence was noticed with *Dactylorhiza sambucina* and *Platanthera bifolia*. While *P. bifolia* was probably repeatedly overlooked, the finding of *D. sambucina* by the Hadačs (Hadač & Hadač 1943; 1948) was its last record in this locality.

A matter of interest is the presence of *Potamogeton alpinus* in newly created pools in the north-west bay of the Bohdanečský pond (Prausová, 2005). Before, this species was last recorded by Husák and Černohous (1986) in the NNR. Currently, the pools in the north-west bay are eutrophic and considerably shaded. The presence of *P. alpinus* was not checked.

The species of *Groenlandia densa, Orchis ustulata, Pedicularis palustris, Sagina nodosa* and *Parnassia palustris* were being found in the NNR only until the beginning of the 1970s and 1980s. At that time, both calcareous and non-calcareous fens were overgrown by wetland alders and biotopes of these taxons disappeared from the NNR. Only *Liparis loeselii* remained until the end of the 20th century in wetland alders and reeds near the Dolanská bay (Faltys, 1993). Similarly, the species of *Allium angulosum* was being found until the end of 1990s. Since the 1980s, water pools have been colonised by eutrophic species, which replaced rare mesotrophic species like *Groenlandia densa*. The latest revitalisation measure in the NNR was renewal of the Bohdanečský pond and of its littoral in the Dolanská bay. Species of *Nymphaea candida* (Horník, in litt.), *Utricularia vulgaris* (Faltysová, in litt.) and *Sparganium natans* (Lysák, in litt.) reappeared after a long time on the new water bodies with mesic site parameters.

In the NNR, 33 alien taxons (Fig. 7) according to the catalogue of alien species of vascular plants in the CR (Pyšek *et al*., 2012) were recorded. These species are bound to anthropogenic sites (path edges, pond dams etc.). From current explorations of the territory (Prausová, 2005; Prausová & Bálková, 2015) arises that most spread are neophytes, whose increase in the habitat began at the end of the last century. Among neophytes recorded as early as by the Hadač brothers (1943, 1948), there are *Acorus calamus, Aesculus hippocastanum, Galinsoga parviflora, Impatiens parviflora, Symphoricarpos albus, Syringa vulgaris* and *Veronica persica*. In the 1950s, archaeophytes were more common, e.g. *Armoratia rusticana, Bryonia alba, Lepidium draba, Echinochloa crus-galli, Lathyrus tuberosus, Solanum nigrum* and *Tripleurospermum inodorum*.

Fig. 7: Survey of categories of alien species of vascular plants in the current NNR. The Bohdanečský pond recorded in particular botanical inventories (Hadač & Hadač, 1943, 1948; Procházka, 1972; Faltys, 1993; Prausová, 2005; Prausová & Bálková, 2015);
neo – neophyte, ar – archaeophyte, inv – invasive, cas – casual, nat – naturalised, cult – cultivated species



Changes of species- and site diversity in the revitalised area of the Matka pond

The development in all transects within 10 years was assessed by the multivariate method - Detrended correspondence analysis (DCA) in Canoco program (Ter Braak & Šmilauer, 2000). The first four ordination axes of the DCA analysis in transect A, B, C, D represent 50%, 39%, 35%, 40% of the variability, respectively. Graphs of the analysis transects A and B are shown (Fig. 8). Graphs of the transects C and D are given the large amount of information difficult to read and are not displayed.

Within the monitored period, the highest number of taxons in transect A was found in 2003, in transects C and D in 2002. In 2010, the highest number of taxons in transect B was found and the most substantial increase in number of taxons in comparison with the year 2003 appeared. Different development in transect B was caused by a significant slowdown of the succession process in the habitat resulting from a very intensive disturbance (removal of turf and strong compression with heavy machinery transporting the extracted sediment). Regular mowing of expansive *Calamagrostis epigejos* has been going on since 2003. In transect A, the highest cover in permanent plots appeared in 2002–2003. In this period, the water surface of the Matka pond was maintained at the highest level because of the rails (Rallidae). Subsequent decrease of herb cover in permanent plots was due to repeated disturbances – ruts and shallow depressed areas made by tractors or digging by wild boar. In transect B, the cover in particular permanent plots significantly differed from each other. The heaviest cover was present in the plots most distant from the Matka pond, which were mowed.

The second, third and fourth plot of the line transect A had similar development heading from open stands of *Sparganium erectum*, *Schoenoplectus lacustris* and aquatic macrophytes towards high reeds of *Phragmites australis* and *Typha latifolia* or towards species accompanying reeds (*Mentha aquatica*, *Alisma plantago-aquatica*). Low species predominated in disturbed areas (ruts by tractors, digging by wild boar). In 2003, more macrophytes growing in open reeds appeared in this line in the 1st relevé. In other transects, aquatic macrophytes were missing due to the negative influence of fish stocks.

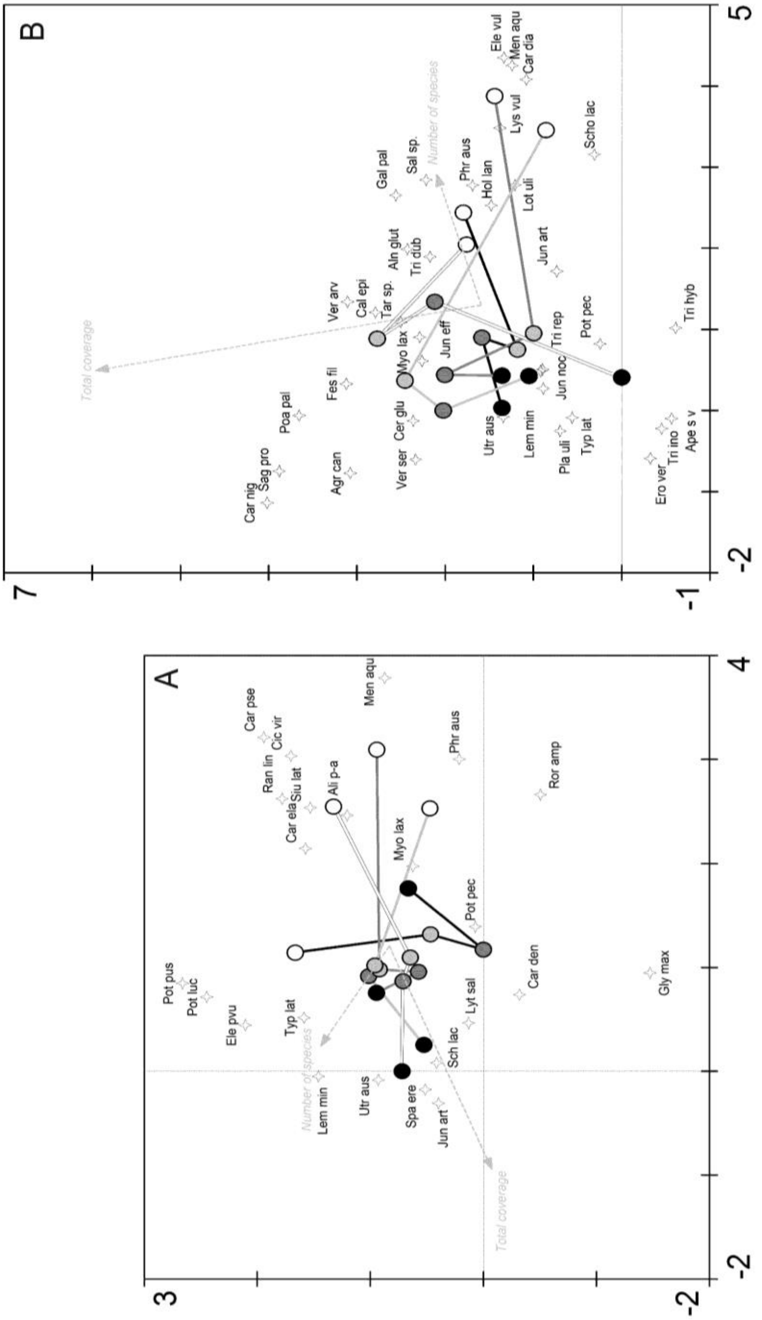
In transect B, the development in the first permanent plot was going on from aquatic macrophytes through open reeds towards closed stands of *Phragmites australis*. In 2003, aquatic macrophytes were recorded in the 2nd permanent plot in transect B, where they were protected from predation by fish. In 2002 in the other plots of transect B, the number of species increased thanks to the presence of species with low competitiveness (*Cerastium glutinosum*, *Potentilla supina*, *Trifolium dubium*, *T. fragiferum*), which appeared in denuded and disturbed areas.

In 2010, species indicating more stable communities predominated (especially high sedge and reed species). The development in transects A and B was similar, beginning with species bound to water (aquatic macrophytes, littoral wetland species) and ending with reed species. The development in transects C and D was analogous: the first permanent plots in both transects contained communities of aquatic macrophytes and were hardly changing at the beginning of monitoring (2000–2003). Subsequently they developed towards closed stands of *Phragmites australis* and *Typha latifolia*. In 2010, a consistent cover of these species was growing there due to their clonal propagation. After 2003, the number of taxons was falling in all plots of both transects. The cover increased in some plots, and decreased in others. High sedge and reed species propagated, also species tolerating unsteady water regime were abundant (*Phalaris arundinacea*, *Calamagrostis canescens*). Thanks to re-establishment of occasional mowing, heliophilous species and non-competitive species locally survive, which would not be possible in closed reeds.

In transects A and B, the development in particular plots was more vacillating than in transects C and D due to more frequent disturbances in transects A and B. A very strong disturbance during revitalisation influenced the development especially in transect B plots, slowing down the overgrowing of denuded areas. In the following period, a mild disturbance was caused by mowing of *Calamagrostis epigejos*. In transect A, the disturbance during revitalisation was more moderate, but in following years a repeated disruption appeared (occasional travel of tractor, intensive digging by wild boar). Thus some small temporary water pools with aquatic and wetland plants emerged. During 2002–2005, annual mowing was temporarily done to suppress the reeds expanding from the pond towards the alder. In transects C and D, a disturbance similar to that in transect A took place during the revitalisation. Subsequent development was not substantially influenced, except for temporary mowing in 2002–2005 which reduced the high reeds expansion.

Fig. 8: Changes in the permanent line transect A and B in years 2000–2010. DCA analysis, the first two ordination axes affect 43% (transect A) and 33% (transect B) of the total variability. Squares position in the transect were used as covariates.

Colours represent different years: black circle - 2000, dark grey circle – 2002, light grey circle – 2003, white circle – 2010, line connecting permanent squares in a transect: black line – square 1, dark grey line – square 2, light grey line – square 3, white line – square 4.



DISSCUSSION

Changes of habitats since 1943 can be seen in vegetation and species composition in the whole NNR. The original 27:1 proportion of forest-free area to forests changed to 3:1. However the number of species bound to broadleaf forests and shrubs and species especially protected or endangered, did not rise together with the increase of broadleaf forest and shrub cover. Diminishing area of open water surface, eutrophication caused by filling, pond management, and intensive agricultural exploitation of the NNR surroundings caused a decrease of aquatic macrophytes´ abundance in the ponds. Rare species of aquatic plants (*Groenlandia densa*, *Potamogeton gramineus*, *P.* x *angustifolius*, *Utricularia minor*, *U. vulgaris* etc.) were replaced by common species which conform to the new conditions, e.g. the abundance of *Ceratophyllum demersum*, *Potamogeton natans*, *Potamogeton pectinatus*, and *Lemna minor* increased. Decrease in the number of especially protected and endangered species was mainly caused by diminishing area of meadows; self-seeding of woody plants and reeds brought about decline of precious fen meadows of *Caricion davallianae* alliance and of originally abundant bear grass meadows of *Molinion caeruleae* alliance. Aging monocenoses of *Phragmites australis* that replaced loosened reeds worsened conditions for heliophilous species like *Ranunculus lingua*, *Sium latifolium* etc. Waterlogged unforested enclaves among alders and moist reeds by the ponds disappeared; they were habitats of *Pedicularis palustris* and once abundant *Liparis loeselii*. After 2000, many species recorded in inventories from the turn of the 1970s and 1980s were found again on revitalised water bodies in the NNR – e.g. *Hottonia palustris*, *Potamogeton acutifolius*, *P. alpinus* (Prausová, 2005). In 2014, *Utricularia vulgaris* (leg. et det. H. Faltysová, rev. L. Adamec) and *Nymphaea candida* (leg. et det. J. Horník) were rediscovered in the newly revitalised part of the Bohdanečský pond near the Dolanská bay and also *Sparganium natans* (leg. et det. F. Lysák) was found again in the depression filled with water in the Dolanská bay. Thanks to the long seed dormancy, plants weak in competition remain in the habitat (*Eleocharis ovata*, *E. acicularis*, *Isolepis setacea*, *Limosella aquatica*, *Myosurus minimus*) and they quickly respond to disturbance and denudation of moist banks of ponds, pools and water streams renewing their populations (Prausová, 2015). During 1999–2003, disrupting measures were realised in the frame of revitalisation of the Matka pond, the north-west bay and Dolanská bay of the Bohdanečský pond, which resulted in a significant restoration of the species diversity. Thus the number of taxons found in the NNR in 2000–2005 approached the state recorded by Procházka (1972). In the past, there probably existed some sites with dry soils and moderate supply of nutrients, where *Dactylorhiza sambucina* and *Orchis ustulata* could grow, as stated by the Hadačs (Hadač & Hadač, 1943; 1948) and Procházka (1972). Such sites are not present in the NNR nowadays. They were overgrown by shrubs and unmown vegetation with a high number of nitrophilous species. Non-indigenous species, among which neophytes have predominated since the 1990s, also contribute to the increase of the NNR species diversity. There is a justifiable fear of species exchange, a situation when invasive species force out the indigenous ones from their natural habitats. The species exchange is considered one of the most important causes of species diversity decline at present (Sala *et al.*, 2000). But the main factor which supports spreading of invasive species is disruption, having thus both positive and negative influence on the species diversity in the whole territory. Among the alien plants, there are not only annual plants (e.g. *Impatiens glandulifera*, *I. parviflora*), but also perennial species including woody plants. According to so-called Black and Grey List of species demanding a special approach (Pergl *et al.*, 2013), the greatest danger can be seen in species classified in categories BL1–4, which are represented in the Bohdanečský pond NNR by *Reynoutria japonica* (BL1), *Acer negundo*

(BL2), *Populus* x *canadensis* (BL2), *Robinia pseudoacacia* (BL2), *Helianthus tuberosus* (BL3), *Solidago canadensis* (BL3) and *Quercus rubra* (BL4).

A detailed exploration of vegetation changes in four line transects A–D at the Matka pond confirmed the importance of revitalisation measures for renewal of species diversity of the territory. It also emerged from the research that in three years after revitalisation, pioneer communities are replaced by more stable communities of predominating sedge, broadleaf herbs, and later reeds. In places with most unsteady water regime, *Calamagrostis canescens* and *Phalaris arundinacea* predominate in the long term.

As explorations show, the current condition of the NNR is a result of interaction of many factors which influence the diversity of the territory. Apart from the spontaneous succession, which is not inhibited by regular management in the whole territory, pond management (manipulation with water level, fish stock, effect of tributary streams) acts as an essential factor. This factor influences not only the trophy of the environment, but also the condition of littoral and submerged vegetation, which is affected e.g. by herbivorous fish browsing, fish digging in the mud and turbidity increase. The intensity of agricultural measures significantly modifies the natural development process of aquatic vegetation (Podbielkowski & Tomaszewicz, 1979; Hejný *et al.*, 2000). Zákravský and Hroudová (2010) state that extensification of pond management immediately influences many factors, such as water quality, vegetation expansion etc.

Overpopulated semi-barbarous ducks and swans cause considerable eutrophication and browse aquatic macrophytes. The influence of overpopulated wild boar is also considerable. Regular mowing and removing of the biomass enhances restoration of meadow and wetland vegetation, and leads to increase of populations of especially protected species, e.g. *Dactylorhiza incarnata, Carex davalliana, Carex pulicaris, Ranunculus lingua* etc. Well-timed mowing during earing of *Phragmites australis* considerably diminishes its expansion into meadows.

The whole NNR demands a complex care which should promote populations of rare species (plants, animals, fungi etc.) and their communities. The correct solution will probably be a mosaic and well-timed mowing with local prioritising of particular species. It is desirable to increase the proportion of forest-free areas in the NNR, and to create a mosaic of sites with a different successional stage.

CONCLUSION

The Bohdanečský pond NNR has been an important locality for biologists since the botanical explorations of the Hadač brothers (Hadač & Hadač 1943; 1948). Although it is situated near the agglomeration of Pardubice and in a tight contact with the town of Lázně Bohdaneč, precious habitats with especially protected and endangered species of vascular plants have remained there until the present. Thanks to the interest of botanists in this locality, there is a wide range of floristic data that can serve for assessment of the NNR development from the point of view of species and site diversity. Current condition of the locality is influenced by many factors, such as spontaneous succession, NNR management, exploitation of the landscape in the NNR surroundings and global factors (eutrophication of the environment, climatic changes etc.). Recent research conducted since 2000 has shown that the NNR condition can be enhanced by appropriate controlled measures, which include regular mowing of the meadows and removal of the biomass, occasional mowing of reeds and high sedge and revitalisation measures focused on water bodies (ponds, pools, streams).

At present, a renewed management according to the current management plan is applied in the NNR. The meadows surrounding the Bohdanečský and Matka ponds are mowed. The water level in the Bohdanečský pond is adjusted with regard to the presence of amphibians, demands of birds and non-forest vegetation. The condition of aquatic macrophytes and influence of fish stock are regularly checked and evaluated.

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