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Diversity of *Potamogeton* species during 21 years of succession in a new water reservoir

Diversita rdestů (*Potamogeton* sp.) během 21 let sukcese v nově napuštěné přehradě Rozkoš

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The composition of the *Potamogeton* flora and its changes during 21 years of vegetation succession in the new water reservoir Rozkoš in East Bohemia are described. Ten species and two hybrids were observed at this locality during this period and in two years preceding the flooding. It seems highly probable that this richness was confined only to a short period during the succession. Diversity was correlated with trophic conditions in the reservoir.

Introduction

The succession of vegetation in the new Rozkoš reservoir was studied by the first author during a period of more than 20 years (Krahulec et Lepš 1993, 1994). During this period, an unusually high number of *Potamogeton* species was observed and data on their occurrence in the reservoir were obtained. The collected specimens were revised by the second author of this contribution. The aim of this paper is to draw attention to the high *Potamogeton* species diversity in this reservoir, to record its decline and suggest an explanation.

Study site

A detailed description of the locality was published in previous studies (Krahulec et al. 1980, Krahulec et Lepš 1993) and only basic data are thus given here. The study was carried out on the Rozkoš reservoir (16°4'N, 50°22'E) situated in eastern Bohemia, at an altitude of about 280 m. The bedrock of the area is a lime-rich chalk of Cretaceous (Turonian) age, weathering into deep lime- and clay-rich soils. An average annual temperature is 7.3°C, average sum of annual precipitation is 641 mm (see Krahulec et al. 1980). The relatively warm climate and calcium carbonate-rich soil are responsible for subhalophytic conditions around this locality.

Table 1. - The presence of *Potamogeton* species before the filling of the Rozkoš reservoir (1971) and after filling in 1973 (1974–1993). Within each year, the first column gives data for the upper reservoir, the second column for the lower one; + indicates presence and the existence of a herbarium specimen; - the presence without available herbarium specimen.

	71		74		75		76		77		78		79		80		81		82	
P. acutifolius Link in Roem. et Schult.									+											
P. berchtoldii Fieber in Berchtold et Opiz	+		-	-		-	-	-	-	-		+	-	-				-	-	+
P. crispus L.	+			-				-	-	-	+	-	-	-	-			-		-
P. friesii Rupr.										+		+				+				
P. gramineus L.	+																			
P. x *lintonii* Fryer																				
P. lucens L.	+	-		+	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
P. obtusifolius Mert. et Koch	+								+				-							-
P. pectinatus L.	+			+					-	-	-	-	-	-	-	-		-	-	-
P. pusillus L. emend. Dandy et Taylor	+		+						+	+	+	+	-	-				+		
P. trichoides Cham. et Schlechtend.	-			+						+		+		-						
P. x *angustifolius* J. Presl									+	+		+		+						+
Total number of *Potamogeton* spp.																				
Upper part	8		2		1		2		8		4		6		3		1		3	
Lower part		1		5		2		3		8		8		7		3		5		6

	83		84		85		86		87		88		89		90		91		92		93	
P. acutifolius Link in Roem. et Schult.												+										
P. berchtoldii Fieber in Berchtold et Opiz	-		-	-	-	-			-			+	-	-	-		-					
P. crispus L.						-		-		-		+										
P. friesii Rupr.								+		+												
P. gramineus L.																						
P. x *lintonii* Fryer												+		+		+						
P. lucens L.	-			-		-		-		-		+		+		-		+				-
P. obtusifolius Mert. et Koch																						
P. pectinatus L.	-		-	-	-	-	-	-	-	-		-	-	+		-	-	-				
P. pusillus L. emend. Dandy et Taylor								+														
P. trichoides Cham. et Schlechtend.																						
P. x *angustifolius* J. Presl																						
Total number of *Potamogeton* spp.																						
Upper part	3		2		2		1		2				2		1		2					
Lower part				3		4		5		4		6		4		3		2				1

Remarks:
In some years (1976, 1983, beginning of the 1990s) extremely low water level occurred early in the growing period and detection of *Potamogeton* species was based only on fragments found on emerged shores. In addition to these species, *P. nodosus* was found in 1971 in the Rozkoš stream 1 km downstream of the main dam.

The Rozkoš reservoir was filled in 1973. It is situated on a small brook, but most of the water flows into the reservoir through an artificial canal from the Úpa river. The reservoir has a volume of 76×10^{-6} m^3, maximum flooded area of 1001 ha and approximate average throughflow (Q_{355}) of 2 m^3s^{-1}. For this reason, there is no constant flow through the reservoir; the transport of diaspores and other material is more influenced by wind and wave action.

In the flooded area, there were only small water bodies, the largest covering 15 ha. The reservoir is divided into two parts by a dam with a spillway at an altitude of 280.9 m. When the water is above this level, there is only one reservoir, but when the water level is lower there are two partially separated reservoirs. The upper part of the reservoir has a relatively stable water level. There are only occasional increases (max. 0.6 m) above the normal, and the water has higher nutrient content. The water level in the lower reservoir fluctuated from +0.6 to -2-3(-5) m. When dammed, the areas of the upper and lower reservoirs were about 200 and 800 ha, respectively. The timing of fluctuation is rather uniform: the drop in water level usually starts in July, the re-filling of the reservoir starts in spring with melt-water. High water level in spring-early summer was a rare event.

Results

Table 1 summarizes data on the occurrence of individual species in the period immediately before and after flooding. During the period of 23 years, ten *Potamogeton* species and two

Table 2. - Regression lines of decline (following maximum in 1977) in *Potamogeton* species and analysis of covariance (difference between intercepts) of their number (dependent variables) in the upper and lower reservoirs (covariate).

Upper reservoir: $Y = 5.28 - 0.31X$
Lower reservoir: $Y = 7.24 - 0.30X$

	Mean square	d.f.	F statistic	Significance
Main effect reservoir type	28.19	1	15.51	0.0005
Covariate year	56.36	1	31.02	0.0000

hybrids were found. One of these (*P. gramineus*) was only observed before the flooding. Several other species invaded the area during the filling period (*P. obtusifolius*) or after then (*P. acutifolius, P. friesii*). *P.* × *lintonii* originated almost certainly as a result of an *in situ* realized hybridization (Nevečeřal et Krahulec 1994). The origin of *P.* × *angustifolius* (= *P.* × *zizii*) is not so clear; both putative parents (*P. gramineus* and *P. lucens*) were observed in the area before flooding, but this fertile hybrid could also have immigrated from any other locality although it is rather rare (Nováková 1982). Only a few species were present in the area during the whole period after flooding: *P. lucens, P. crispus, P. berchtoldii, P. pectinatus*; most were present only for a short period. The lower reservoir, poorer in nutrients, had a longer period with higher number of *Potamogeton* species. The decline in species number was linear and similar in both reservoirs (indicated by practically the same slope), but the intercept was significantly different (Table 2). This means that in both reservoirs the conditions for survival of *Potamogeton* species were gradually changing in a similar way, but the lower reservoir had more favourable conditions than the upper one.

In the time of maximum richness of *Potamogeton* species at the end of the 1970s, most species were found in lagoons formed behind *Typha latifolia* belts after the rise of water level.

Discussion

With respect to its *Potamogeton* flora, for a decade the Rozkoš reservoir was probably one of the richest localities in the Czech Republic. Except of *P. compressus*, all narrow leaved species (sect. *Graminifolii* and subgen. *Coleogeton*) known from this country occurred here. The Rozkoš reservoir was probably the only one in the Czech Republic with a recent occurrence of *P. friesii*; it is the first locality of *P.* × *lintonii* in the whole Central Europe (Nevečeřal et Krahulec 1994). According to the data published by Černohous (1978), it was the second known locality for *P.* × *zizii* in E Bohemia in the 1970s. Occurrence of *P. nodosus* in the Rozkoš stream ca 1 km downstream of the dam completed the number of species found during the 1970s.

The following questions appear in this context: Which ecological factors were so unique as to enable this high concentration of species? Will this locality be so rich in *Potamogeton* species in the future or was this richness only a short term event during succession?

In fact, the *Potamogeton* flora was rather rich in the area before flooding: eight species were found there (Krahulec 1981). These species occurred mainly in the existing fishpond, in small pools and in a brook. *P. gramineus* occurred in a clay pit filled by water. All of these localities (except the brook) are now submerged in the area of the present upper reservoir.

The first years after the filling of the reservoir were characterized by hypertrophic conditions and good water transparency caused by the low density of fishstock: both these factors caused an extremely high production of both submerged and floating macrophytes (and water snails - Krahulec et al. 1980). The peaks of hypertrophic conditions were in 1973 and 1974, i.e. in the two years after flooding. During this period, the reservoir was an important place for wintering of various water bird species which are the vectors most probably responsible for dispersal of new species of plants (see Krahulec et al. 1980, Krahulec et Lepš 1993 for details).

In the following years, the trophic conditions and water transparency continuously decreased; after this decrease, slow eutrophication started together with differentiation of both reservoirs in the composition of water plants and in water chemistry. Maixner et Sládeček (1983) found differences already existing in 1979, with the upper part showing higher nutrient content and also higher organic pollution. This sequence corresponds to the known course of trophic conditions in reservoirs (Godshalk et Barko 1985). The years with the highest number of *Potamogeton* species (1977, 1978) correspond to the lowest nutrient level of the reservoir and, probably also to the still rather good water transparency. In 1977, the number of *Potamogeton* species was the same in both parts of the reservoir. However, the lower reservoir had significantly higher diversity during the 1980s; the better quality of water in the lower reservoir was a result of self-purification processes (e.g. precipitation of phosphorus - see Maixner et Sládeček 1983). It is highly probable that the better water quality here was also enhanced by its filtration by *Dreissenia polymorpha*, a mollusc species which invaded the area at the end of the 1970s and had a massive explosion during the 1980s (V. Koza, pers. comm.). We consider the diversity of *Potamogeton* species to be positively correlated with successional stages, because similar trends in succession were observed also in other reservoirs in Central and Eastern Europe (Kuflikowski 1986, Zerov 1976). The high *Potamogeton* diversity seems to us as a relatively short term stage during succession in a newly formed reservoir. Similar development as in *Potamogeton* was observed in other submerged macrophytes (e.g. *Myriophyllum spicatum* or *Ceratophyllum demersum*); only *Callitriche hermaphroditica* had a mass development during the 1980s, which, however, followed the invasion by this species (Černohous 1980, Krahulec et Lepš 1993).

On the other hand, the existence of two connected reservoirs with great differences in water chemistry and with stable and fluctuating water would increase the diversity of conditions in the future which seems a necessary condition for some diversification of submerged macrophyte flora.

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Souhrn

V průběhu sledování sukcese na přehradě Rozkoš u České Skalice došlo k velkému nahromadění rdestů (*Potamogeton*), zejména v prvním období po napuštění. Celkem zde bylo pozorováno 12 druhů či mezidruhových hybridů (tab. 1). K nejvzácnějším nálezům tohoto období patří *P. friesii* a *P.* × *zizii*, později zde byl objeven na první lokalitě ve střední Evropě *P.* × *lintonii* (*P. crispus* × *P. friesii*). Tento počet byl zvýšen ještě ojedinělým nálezem *P. nodosus* v potoce Rozkoš pod hlavní hrází. Maximální nahromadění odpovídá období s nízkou trofií nádrže a nízkou rybí obsádkou, tedy období s velmi čistou vodou. Od doby maximálního rozvoje došlo k lineárnímu poklesu počtu pozorovaných druhů. Tento pokles byl statisticky významně nižší v dolní nádrži, která má nižší trofii vody (tab. 2).

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