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DYNAMICS OF *SPHAGNUM* CUSHIONS IN THE WILLOW CARR OF BENCE-TÓ MIRE (NE HUNGARY) AND ITS NATURE CONSERVATION ASPECTS

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Abstract: We studied the dynamics of peat moss cushions in 1994–1997 at the strictly protected willow carr of Bence-tó mire (NE Hungary), where the amount of *Sphagnum fimbriatum* Wilson subsp. *fimbriatum* and *S. squarrosum* Crome has been decreasing from year to year. We recorded the size of 25 selected *Sphagnum* cushions, the proportion of *Sphagnum* species making up the cushions, and the vascular plant species found in the cushions. The *Sphagnum* carpets broke up into smaller cushions, and below a critical size (~660 cm^2) the risk of their disappearance was high. The two *Sphagnum* species disappeared at approximately similar rates, but cushions consisting of both species were more likely to survive than single-species cushions. As their environment became wetter in 1997, the cushions increased in size, but the two *Sphagnum* species were not able to survive the sudden rise of the water level in 1998. For protection of Hungarian *Sphagnum*-dominated mires the aim is to minimize fluctuation of the water level, which can be achieved by reconstructing the buffer zone.

Key words: *Sphagnum fimbriatum* subsp. *fimbriatum, Sphagnum squarrosum,* fen, carr, mire, floating mire, NE Hungary, decline, conservation

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INTRODUCTION

The most conspicuous degradation process in Hungarian *Sphagnum*-dominated mires is the rapid reduction of *Sphagnum* species. One objective of our research in the mires of the northern part of the Great Hungarian Plain has been to determine how the size and species composition of *Sphagnum* cushions found on the Bence-tó mire change through the years.

The *Sphagnum* mires (Nyíres-tó, Báb-tava, peaty bed of the Navad-patak River, Zsid-tó and Bence-tó) found in the Berg Plain, in the northern part of the Great Hungarian Plain, have been drying out more often since the beginning of the 1960s (Nagy 2002). The gallery forests (*Fraxino pannonicae-Ulmetum, Querco robori-Carpinetum*) and meadows (*Alopecuretum pratensis*) of four of these mires (the exception is Nyíres-tó) have been cut off and are now under cultivation. All the mires except Nyíres-tó have been damaged by fire. To stop this degradation, the Directorate of Hortobágy National Park has been supplying water to Nyíres-tó and Báb-tava since 1985 (Simon 1992b), and to Zsid-tó and Navad-patak since 1994. Within the framework of nature conservation measures, regeneration of the gallery forests is also in progress. Unfortunately, no detailed botanical examinations before and during the floods were made in any of the four mires.

As Bence-tó was the only one of the five *Sphagnum*-dominated mires found on the Bereg Plain not supplied with water artificially until the beginning of our research (August 1994), a detailed study of the vegetation dynamics done in parallel with the study of the other four mires enabled us to examine the consequences of artificial water supply (Nagy, Figeczky & Penksza 1998; Nagy, Figeczky, Penksza *et al*. 1998; Nagy, Molnar *et al*. 1998; Nagy *et al.* 1999, Nagy 2002).

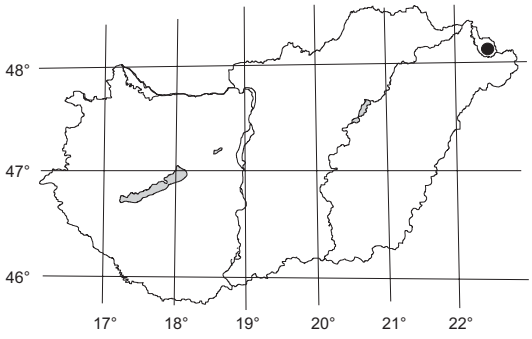

Fig. 1. The location of the study area (●).

MATERIAL AND METHODS

The Hungarian *Sphagnum*-dominated mires lie in the southern marginal zone of these ecosystems in Europe, at least in the lowlands. They are extremely sensitive to changes in their environment.

The Bence-tó mire (48°08'43" N, 22°27'12" E) is situated in the northeastern corner of the Great Hungarian Plain in the eastern part of Central Europe, near the Hungarian/Ukrainian border, between Tákos and Csaroda villages (Fig. 1). We have been conducting fieldwork in the area since 1994.

Bence-tó is a C-shaped, silted oxbow lake. It is approximately 1.5 km long and 70 m wide, surrounded by arable land on all sides without any buffering forest or meadows.

During the study the distribution and amount of precipitation and the groundwater level varied greatly, as confirmed by data from the nearest weather station, Csaroda, only 2 km SW of the study area (Fig. 2). We assume that the amount and pattern of the precipitation and groundwater level at the Csaroda weather station and at the investigated mire are similar. Until 1997, open water was observed at the site only sporadically. The draining of the lake accelerated from 1994 and continued until 1996. During the whole summer in 1997, only shallow water (20–30 cm deep) was found at the deepest part of the lake. In that year, caterpillars of *Lymantria dispar* devastated the vascular vegetation of Bence-tó. Directly and indirectly owing to the nearly 900 mm of precipitation in 1998, the lake was suddenly filled up with water; since that time its water level has been more or less continuously high.

In the Holocene, alluvial clay and silt layers were deposited onto the gravel sediment of the Pleistocene river basin of the Bereg Plain. The bed of the Tisza River gradually shifted from the eastern part of the plain towards the southwest, leaving a labyrinth of oxbow lakes and channels behind. The chain of them runs roughly along the border between the warm and cold temperate zones. The number of sunny hours is *ca* 1950, and annual mean temperature is 9.4–9.5°C. Annual precipitation is 630–660 mm, of which 370–380 mm falls during the vegetation period (Marosi-Somogyi 1990).

At the strictly protected Bence-tó site, 25 *Sphagnum* cushions were selected for study. Examining more cushions might have caused damage to the mire. We recorded two typical, mutually perpendicular lengths the selected *Sphagnum* cushions. the proportion of *Sphagnum* species making up the cushions, and the vascular plant species found in the cushions. We considered the last measured size of the live cushion as well as the size of the dead cushion. The sampling points were marked with small flags. The approximate area of the Sphag-

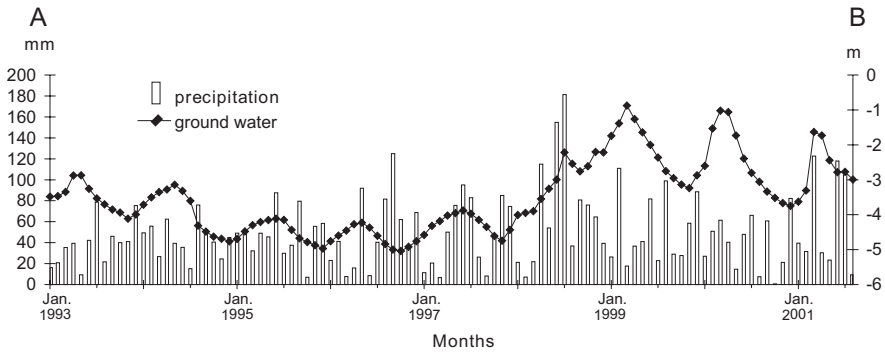

Fig. 2. Distribution and amount of precipitation (A) and groundwater level (B) in subsequent years at the weather-station of Csaroda from 1 January 1993 to 31 August 2001.

Fig. 3. This cushion consisted mainly of *Sphagnum fimbriatum* subsp. *fimbriatum* and covered the lower part of individuals of *Typha angustifolia*. A large number of *Cicuta virosa*, *Lycopus europaeus, Carex pseudocyperus* and *Lysimachia vulgaris* covered the study area due to the sudden increase of moisture and light. In the foreground of the picture, *Rumex hydrolapathum* can be seen. Bence-tó mire, 11 October 1997.

num cushions was calculated by multiplying the two lengths.

The nomenclature for vascular plants and their associations follows Simon (1992a), and for peat mosses follows Flatberg (1994).

RESULTS AND DISCUSSION

GENERAL DESCRIPTION

Most of the *Sphagnum* cushions were found on peat covering the stem base of *Salix cinerea* near the surface and on peat among the willows; fewer were found on peat among individuals of *Typha angustifolia* (Fig. 3).

Thirty-one vascular plant species were observed on the examined *Sphagnum* cushions (Table 1).

In 1997, *Cicuta virosa* and *Carex pseudocyperus* were the most common species during the entire vegetation period on cushions located among willows wasted by caterpillars of *Lymantria dispar*.

CHANGES IN THE *SPHAGNUM* SPECIES COMPOSITION OF THE CUSHIONS

The proportion of *Sphagnum fimbriatum* Wilson subsp. *fimbriatum* in the cushions decreased during the years of the study, while that of *S. squarrosum* Crome increased. At the start, the proportion was 60% *S. fimbriatum* subsp. *fimbriatum* to 40% *S. squarrosum*. The proportion of *S. fimbriatum* subsp. *fimbriatum* increased between 5 September 1994 and 11 June 1995, and considerably decreased from 11 October 1995 to 12 June 1996, when its average proportion was nearly equal with that of *S. squarrosum* in the *Sphagnum* cushions.

Table 1. Vascular plants found in *Sphagnum* cushions at Bence-tó mire in 1994–1997.

Date of the record	08.09. 1994	01.05. 1995	11.06. 1995	24.04. 1996	24.06. 1996	12.06. 1996	01.09. 1996	11.10. 1997
Number of living cushions	25	25	24	22	18	17	16	15
Species	% of the living *Sphagnum* cushions under examination where the vascular species recorded were present							
Salix cinerea	96	88	88	82	72	76	81	53
Lycopus europaeus	68	44	71	32	39	35	38	53
Lysimachia vulgaris	64	–	–	18	28	29	31	20
Typha angustifolia	56	40	46	9	11	6	–	33
Galium palustre	48	–	25	5	28	29	31	20
Solanum dulcamara	40	4	8	14	11	12	13	13
Lythrum salicaria	32	8	29	18	44	41	38	–
Polygonum lapathifolium	24	4	13	–	6	6	6	–
Carex pseudocyperus	20	4	4	5	6	6	6	67
Agrostis stolonifera	12	8	8	5	6	6	–	7
Agrostis canina	12	–	–	–	6	6	–	–
Dryopteris carthusiana	8	8	8	9	11	12	13	13
Glyceria maxima	8	8	8	9	–	–	–	7
Cicuta virosa	8	4	4	–	–	–	–	80
Rumex hydrolapatum	8	4	8	9	6	6	–	7
Lactuca serriola	8	–	–	–	–	–	–	–
Chrysanthemum serotinum	4	4	4	–	–	–	–	–
Juncus effusus	4	4	4	5	6	6	6	–
Chamaenerion angustifolium	4	–	–	–	–	–	–	–
Oenanthe aquatica	4	–	4	14	6	6	6	–
Poa palustris	4	–	17	18	11	12	13	–
Cirsium arvense	–	–	–	5	6	6	6	–
Echinochloa crus-galli	–	–	–	–	–	6	–	–
Gratiola officinalis	–	–	–	–	–	–	–	7
Phalaris arundinacea	–	–	–	–	–	–	–	7
Ranunculus repens	–	–	17	–	–	–	–	–
Scutellaria galericulata	–	–	–	–	–	6	–	–
Setaria pumila	–	–	–	–	–	6	–	–
Sonchus palustris	–	–	–	–	6	6	6	7
Stellaria media	–	–	–	5	6	6	6	–
Urtica dioica	–	–	–	–	–	–	–	7
Number of species	21	14	18	17	19	22	15	16

The records after that time indicate that the average proportion of *S. fimbriatum* subsp. *fimbriatum* started to increase again.

SPHAGNUM SPECIES COMPOSITION OF THE CUSHIONS

During the whole study period there were seven cushions consisting only of *Sphagnum fimbriatum* subsp. *fimbriatum*. Four cushions contained only *Sphagnum squarrosum*. Five *Sphagnum* cushions were mixed, of which four were dominated by *Sphagnum fimbriatum* subsp. *fimbriatum*.

In nine peat moss cushions only individuals of one of the *Sphagnum* species were observed temporarily; at other times, other *Sphagnum* species were also present in them. Among these mixed cu-

shions, six were dominated by *S. fimbriatum* subsp. *fimbriatum.*

SIZE CHANGE AND DECAY OF *SPHAGNUM* CUSHIONS

It is hard to tell whether a *Sphagnum* cushion is alive or dead, or when it died if dead. Between 8 September 1994 and 11 October 1997, 11 of the 25 studied *Sphagnum* cushions died (Fig. 4).

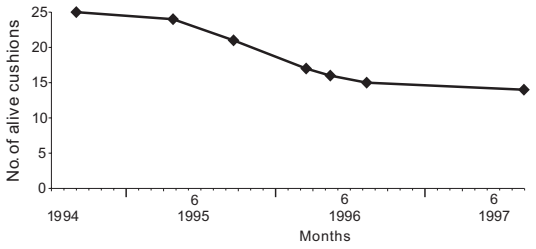

Fig. 4. Changes in the number of living cushions at Bence-tó mire in 1994–1997.

During the examination period, five of the seven *S. fimbriatum* subsp. *fimbriatum* cushions, three of the four *S. squarrosum* ones and three of the fourteen mixed ones died (Fig. 5). The smaller cushions may have died in any period of the year; the larger ones died after winter, in spring or early summer.

The average size of the dead cushions (three-year averages) was 660 cm^2, and of the living ones 7700 cm^2. This means that larger *Sphagnum* cushions had a better chance of survival than smaller ones.

In the decay process, smaller *Sphagnum* cushions dried out, while larger ones divided into smaller pieces. The newly formed smaller cushions were less likely to survive. At first the smaller, apparently live patches were separated by dead (dry) strips of peat moss. These living patches later became completely separated. *Sphagnum* species were not always able to overgrow *Salix cinerea* leaves fallen on the cushions, and this seemed to be one of the reasons for division. Intensive treading by wild boars *Sus scrofa* also disrupted the *Sphagnum* carpet.

The reason for the decay can be well understood if we observe the size development of *Sphagnum* cushions between September 1994 and October 1997. The living *Sphagnum* cushions were largest on 24 April 1996, as by that time most of the smaller cushions had died but the larger ones just had started to divide. After that period the average size of the living *Sphagnum* cushions decreased drastically (Fig. 6). Since the high water level of 1998, *Sphagnum* species have not occurred on the territory. The rate of growth of *Sphagnum* species could not match the fast rise of the water level. Both of the *Sphagnum* species have disappeared from the area.

Water supply conditions in the study area and their consequences for *Sphagnum* species.

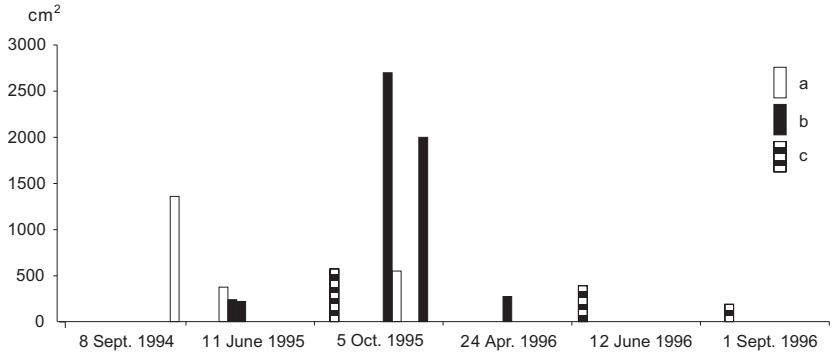

Fig. 5. Species composition and approximate size of dead *Sphagnum* cushions at Bence-tó mire in 1994–1996 at the time of their death. a – *Sphagnum squarrosum*, b – *S. fimbriatum* subsp. *fimbriatum*, c – mixed cushion.

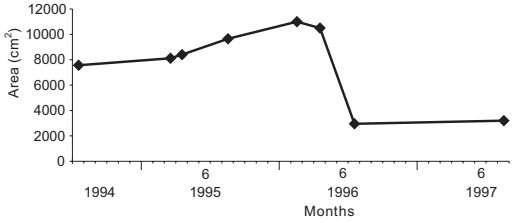

Fig. 6. Mean area of *Sphagnum* cushions alive at Bence-tó mire in 1994–1997.

Drought periods are frequent in northeastern Hungary, and they are usually followed by extremely wet years, so *Sphagnum* has to cope with droughts and sudden floods. In 1994 and 1995, Nyíres-tó bog (Bereg Plain, 7 km NE of Bence-tó mire) dried completely due to temporary failure of a well. Then, in 1996, after new flooding the mosses were covered with several decimeters of water. The individuals of *Sphagnum fallax* found here overgrew this water column in a few weeks and the vegetation of the mire started to regenerate. The situation was similar in the case of Nyírjes-tó (Sirok, Mátra Mountains, N Hungary). During the summers of 1996 and 1997 the mire was completely dried, while in the summers of 1998 and 1999 the moss layer was covered with 20 cm of water on average, and in some parts 70 cm, due to the large amount of rain. In both years this water level was overgrown successfully by individuals of *S. fallax*. In these territories the depth of the peat layer below the *Sphagnum* species exceeded one meter.

Unfortunately there are examples of failure as well: in the *Sphagnum*-dominated mire in Egerbakta (Mátra Mountains, N Hungary) the *Sphagnum* species disappeared by 1997 after several decades of droughts. After a 1.5–2.0-meter rise of the water level the *Sphagnum* species disappeared from Navad-patak, Zsidó-tó and Bence-tó, as they did after long dry periods. At the latter three places, floating mires started to form immediately. With the thickening of the peat layer of floating mires, relatively nutrient-poor conditions can develop on their surfaces, which is favorable for colonization by *Sphagnum* species (Balogh 2000). At the same time, the high cation exchange capacity of the *Sphagnum* species increases acidification of the medium (Clymo 1963; McQueen 1987; Tallis 1983), enhancing their spread. This suggests that the disappearance of *Sphagnum* species from these territories might be temporary. The peat layer of all three mires was very thin, and the rise of the water level was very fast and large.

There are several ways by *Sphagnum* species can reappear during the processes of oligotrophication and acidification. They can be introduced from nearby wetlands rich in peat moss species by floods, wind, animals and deliberate planting (Nagy, Figeczky & Penksza 1998; Nagy, Figeczky, Penksza *et al*. 1998; Nagy *et al*. 1999; Nagy 2002), or they can develop from their remains, even from peat 60 years old (Clymo & Duckett 1986). It is also known that *Sphagnum* can disperse considerable distances and establish if conditions are favorable (Soro *et al*. 1999).

CONCLUSIONS

Sphagnum squarrosum and *S. fimbriatum* subsp. *fimbriatum* in the willow carr of Bence-tó had similar survival. The two *Sphagnum* species survived dry periods more successfully if they formed cushions together. During droughts the survival of large *Sphagnum* cushions was greater. These two *Sphagnum* species tolerate decades-long drought periods better than sudden rises of the water level. *Sphagnum* cushions also function as reservoirs of phanerogamic reproduction material. Seeds of vascular plants like *Cicuta virosa, Carex pseudocyperus, Lycopus europaeus, Lysimachia vulgaris* and *Juncus effusus,* and free-floating tangles like *Stratiotes aloides, Utricularia vulgaris, Lemna minor, Spirodela polyrhiza, Hydrocharis morsus-ranae* and *Salvinia natans* in cushions can develop if the environmental conditions are suitable.

The tolerance of *Sphagnum* species to long drought and sudden flood is largely dependent on the species composition of the area and the thickness of the peat layer below the mosses. Due to its water retention capacity, the latter considerably mitigates the effects of sudden fluctuations of

water levels. It can be stated that in Hungary the arrhythmically fluctuating water level is the strongest factor limiting the presence and spread of *Sphagnum* species. The changing water level might be one reason why zonation of *Sphagnum* cushions as described in several studies of Atlantic and Pacific areas (e.g., Wagner & Titus 1984; Rydin 1985, 1986, 1993, 1997; Rydin & McDonald 1985 and references therein) is barely observable in the mires of the Bereg Plain. Reducing water level fluctuations might increase the survival of *Sphagnum* species living in the mire. The best way to accomplish this would be to reconstruct the buffer zones (oak forest) around the mires, and to supply water artificially if necessary. This is being done in the mires of the Bereg Plain.

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