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METHODOLOGICAL OVERVIEW AND A CASE STUDY OF THE HUNGARIAN BRYOPHYTE MONITORING PROGRAM

Beáta Papp[1], Péter Ódor[2] & Erzsébet Szurdoki[1]

1. Department of Botany, Hungarian Natural History Museum, H-1476 Budapest, Pf. 222., Hungary
2. Department of Plant Taxonomy and Ecology, Loránd Eötvös University, H-1117 Budapest, Pázmány P. sétány. 1/C, Hungary

Abstract: Long term investigation of the local population sizes of selected, threatened bryophyte species and long term surveys on the composition and diversity of bryophyte vegetation of different plant communities rich in bryophytes (wetlands, dry grasslands, saline-alkali areas and forests) are going on in the framework of the Hungarian National Biodiversity Monitoring System. In the present paper the methodology of species and community monitoring of bryophytes is described in detail, and with the aim of demonstrating the possibilities of the long term community monitoring on the basis of a case study focusing on the observation of the dynamics of an alkaline grassland stand for three years.

INTRODUCTION

Started in the year 2000, the Hungarian National Biodiversity Monitoring System set two aims: (1) long term investigation of the local population sizes of selected species (species monitoring, Török 1997) and (2) long term investigation of the composition and diversity of different organism groups in representative stands of different communities (plant and animal community monitoring, Kovácsné Láng & Török 1997). In the case of bryophytes both kinds of monitoring is going on in the framework of the National Biodiversity Monitoring System.

The selected species for monitoring are threatened in Europe (ECCB 1995), listed in the appendices of EU Habitat Directive (1992) and Bern Convention (1979) occurring in Hungary. Earlier recorded and potential new localities of these species were checked and the sizes of populations were estimated. These populations are regularly visited. These long-term investigations supply data about the Hungarian distribution of selected species and changes in condition, threat status of local populations. This information makes it possible (1) the estimation of national and international threat status of selected species, (2) providing

biological background in the preparation of government decisions, (3) establishing any further scientific investigation concerning the population dynamics of these species.

In the framework of the bryophyte community monitoring, selected stands of communities rich in bryophytes (wetlands, dry grasslands, saline-alkali areas and forests) have been surveyed. Changes in species composition (species pool, frequency, distribution), distribution of functional groups (distribution of ecological indicator values, life strategies), characteristic variables of assemblages (e.g. diversity) are examined. The main questions of the bryophyte vegetation monitoring is, how the above mentioned characteristic features change during a long-term period in the selected stands. This study will provide information in the future about the dynamics of bryophyte vegetation of different habitats, from which there is only a limited amount of scientific information available (During & ter Horst 1985, Söderström & Jonsson 1989, van Tooren et al. 1990, During & Lloret 1996, Jonsson & Esseen 1998, Fenton *et al.* 2003, Aude & Ejrnaes 2005). The selected stands represent plant communities and habitats of special merit from nature conservation point of view (Borhidi & Sánta 1999).

Several papers discussed the results of species monitoring, including Papp *et al.* (2000) which described the methodology and preliminary results of species monitoring. The possibility and problems of monitoring of species living in different substrates (shaded rocks, wetlands, decaying wood) were summarized in Papp *et al.* (2002). The estimation of threat status and categorization according to IUCN criteria of some species in Hungary were published in Papp *et al.* (2003).

In the present paper the methodology of species and community monitoring of bryophytes is described in detail, and with the aim of demonstrating the possibilities of the long term community monitoring on the basis of a case study focusing on the observation of the dynamics of an alkaline grassland stand for three years.

METHODOLOGY OF THE SPECIES MONITORING

The 6 species included in the bryophyte species monitoring in Hungary are as follows: *Buxbaumia viridis* (Moug. ex Lam. et DC) Brid. ex Moug. et Nestl., *Dicranum viride* (Sull. et Lesq.) Lindb., *Hamatocaulis vernicosus* (Mitt.) Hedenäs, *Mannia triandra* (Scop.) Grolle, *Orthotrichum rogeri* Brid., and *Pyramidula tetragona* (Brid.) Brid.

Firstly, the earlier known localities of these species were checked based on location data of the investigated species in procession of the Bryophyte Herbarium of the Hungarian Natural History Museum, Budapest (BP) and that of the Eger Teacher's College (EGR). The retrieval of localities was mainly based on locality description of herbarium specimens and the diaries of Ádám Boros and László Vajda from their field trips (Boros 1915-1971, Vajda 1933-1978). These localities were visited (in the case of unsuccessful confirmations two or three times). In

the case of unsuccessful confirmation the habitat conditions of the site were investigated in order to see if we may expect finding the species again, or if the site has changed so dramatically (or even had been destroyed) that we can not regard the site as the potential locality of the species any more. If the bryophyte was found on the cited locality, the exact site was measured by GPS equipment, the size of its population was estimated and its potential habitats in nearby, other localities were also investigated.

The measurement of population size of the species was carried out by the estimation of number of individuals according to Hallingbäck *et al.* (1998). In the case of each species investigated we followed the suggestion of ECCB (European Committee for Conservation of Bryophytes) to estimate the number of individuals and population size.

In the case of species living on the bark of living trees and decaying wood (*Buxbaumia viridis, Dicranum viride, Orthotrichum rogeri*) the population size corresponds to the number of trees colonised, while in the case of species living in patches and mats the populations is equivalent to the number of colonies. *Pyramidula tetragona* grows in patches of about 2 x 2 cm. In the case of this species the number of patches can be regarded as the number of individuals. The rare and endangered *Drepanocladus* species occur in the wetlands of Hungary in patches of about 200 cm^2, the number of these patches is the population size. In the case of *Mannia triandra,* the thalloid liverwort, the number of colonies is equal to the population size.

The frequency of monitoring should correspond to the life strategies of the species (During 1979, 1992). It is 3-4 years in the case of perennial species (P) and long-lived shuttle species, and 1 year for the annual shuttle (AS), colonist (C) and short lived shuttle (SL) species. The sampling should be carried out in the most adequate period of the year determined on the basis of earlier herbarium data. On the same locality for the same species the sampling should be done in the same month in each year investigated.

METHODOLOGY OF THE COMMUNITY MONITORING

Monitoring of bryophyte vegetation was carried out in wetlands (20 stands representing 11 communities), dry grasslands (11 stands representing 8 communities), saline-alkaline grasslands (4 stands representing 2 communities) and forests (16 stands representing 8 communities). The return interval of sampling is 3 years in wetlands, 2 years in dry grasslands, yearly in alkaline grasslands and 4 years in forests. The size of the permanent quadrates is 10 x 10 m in wetlands, dry grasslands and alkaline areas, while in forests quadrates of 16 x 16 m are used. The following methods are used for sampling of bryophyte assemblages: (1) list of species weighted with abundance; (2) systematic sampling on the ground level (including soil, rocks, decaying wood) recording presence/absence data; (3) sampling of epiphytic bryophyte vegetation (only in forests).

Complete species list of the quadrate

Species occurring in the quadrate is recorded and their abundance-frequency value is estimated in different substrates separately. The substrates may be soil, rocks, decaying woods, and living trees. The abundance-frequency value of each species is estimated on an ordinal scale of 4 levels as follows:

1. Very rare: only few individuals are detected.
2. Rare: the frequency of the species is intermediate but its abundance is low.
3. Frequent: the frequency is high but the abundance of the species is low or it appears in a few, large patches.
4. Abundant: both the frequency and the abundance of the species are high, it usually covers more than 10% of the quadrate.

In terms of nomenclature we followed Erzberger & Papp (2004). Based on this way of sampling the following variables are calculated: species richness of the quadrate, frequency of different life strategy type categories (During 1979, 1992, Orbán 1984), proportion of short lived strategies (summed proportion of fugitive, annual shuttle, short lived shuttle and colonist categories), proportion of water requirement categories (Zólyomi and Précsényi 1964, Orbán 1984), in the case of dry grasslands proportion of European distribution categories (Düll 1983, 1984, 1985, 1992).

Systematic sampling on the ground level of the quadrate

In wetlands, dry grasslands and alkaline areas in the quadrates of 10 x 10 m (100 m^2) size the bryophyte vegetation is systematically sampled in 25 sampling units of 0.5 x 0.5 m size that are set out on a grid at 2 m intervals. In forests the quadrate size is larger (16 x 16 m) and the number of sampling units is 64 using the same grid design. In the sampling units the occurrences of species are recorded (presence/absence data) and the substrates (soil, rock, decaying wood) of the species are marked.

Based on this way of sampling the following variables are calculated: species richness of the quadrate, mean species richness of sampling units, Simpson diversity and evenness of quadrates (Tóthmérész 1996), frequency and relative frequency of species, relative frequency of life strategy types and water requirement categories, proportion of short lived strategies, in the case of dry grasslands proportion of European distribution categories.

Systematic sampling of epiphytic bryophyte vegetation in forests

In the sampling of epiphytic bryophyte vegetation every standing tree (living or dead) present in the quadrate are included, which has a circumference at breast height more than 60 cm. The sampling of epiphytic bryophytes is carried out in three levels: 10 cm (1. level), 70 cm

(2. level), 140 cm (3. level) upwards from the base of the tree. In each level in a cylinder jacket of 10 cm wide (from the marked level 5-5 cm upward and downward) the occurrence of the species are recorded (presence/absence data). During this way of sampling a sampling unit is defined as a cylinder on one level on a given tree. Besides the occurrence of bryophytes, the circumference, the species and the living/dead status of the tree is recorded in each sampling unit.

Based on this sampling in each level the same variables are calculated as in the case of ground level sampling.

DYNAMICS OF THE BRYOPHYTE VEGETATION OF AN ALKALINE GRASSLAND: A CASE STUDY

Introduction

Long term investigation of the dynamics and succession of different vegetation types has been a widely practiced research area in botany (e.g. Begon *et al.* 1996, Knapp *et al.* 1998, West *et al.* 1981). Unfortunately, this is quite limited in bryophyte research, and the duration of such studies of dynamics is rarely longer than couple of years (During & ter Horst 1985, Söderström & Jonsson 1989, van Tooren *et al.* 1990, During & Lloret 1996, Jonsson & Esseen 1998, Fenton *et al.* 2003, Aude & Ejrnaes 2005). The major aim of the bryophyte community monitoring in Hungary is to produce long term data from permanent quadrates of different vegetation types. Although this project was started only in 2000, in this case study we are able to show some preliminary results about the dynamics of an alkaline grassland based on the analysis of a 3-year old dataset. We sought answers for the following questions: (1) are there any differences among the three investigated years in community characteristics, frequency of species and life strategy types; (2) whether or not these differences depend on the length of period (one or two years).

Material and Methods

The studied area is located in the Great Hungarian Plain in central Hungary (N 47°05'04.1", E 19°05'47.4"), in the vicinity of Apaj village at an elevation of 100 m a.s.l. This area has a moderately continental climate with characteristically high sunny hours, high daily and yearly temperature fluctuations as well as relatively low air humidity. The mean yearly sum of the sunny hours is ca. 2000-2100. The mean yearly temperature 10-11 °C. The coldest month is January (-1.5 - -2 °C), the warmest month is July (21-22 °C). The mean yearly temperature fluctuation is considerable, 23-24 °C. It is one of the most rainless areas in Hungary (500-600 mm/year). Drought is frequent in summer. The area is an alkaline grassland characterised by high sodium and magnesium concentration in the soil. The vegetation represents the *Achilleo-*

Festucetum pseudovinae community, dominated by *Festuca pseudovina* and *Achillea asplenifolia*. Among the tussocks of vascular plants open soil patches can be found partly covered by bryophytes (*Drepanocladus aduncus, Brachythecium albicans* and different short lived acrocarpic mosses). The short lived bryophytes occur only in relatively wet periods of the year in early spring and autumn. Two short lived bryophytes *(Enthosthodon hungaricus, Phascum floerkeanum*) occurring here are included in the Red Data Book of European Bryophytes (ECCB 1995).

The above-described systematic sampling was carried out in a 10 x 10 m quadrate in early spring of 2002, 2003 and 2004. Based on the data collected the following characteristics are compared among the studied years: species richness (cumulative species list of sampling units), mean species richness of sampling units, number of occurrences (summed frequency of species), proportion of short lived life strategies, frequency of species and the frequency of life strategies. The dynamics of species and life strategies were expressed as the frequency differences and squared frequency differences (turn over) between years.

	2002	2003	2004
species richness of quadrate	17	18	22
species richness of sampling units	4.56 (±1.42)	4.88 (±1.92)	5.16 (±2.32)
number of occurrences	114	122	129
proportion of short lived strategies	0.5088	0.5656	0.5581

Table 1. Community characteristics of the investigated quadrate in different years. The species richness of sampling units did not differ among years (ANOVA, $F(2,72) = 1.57$, $p>0.1$).

Results

The species richness and the number of occurrences is slightly increased during the investigated period in the quadrate but the species richness of sampling units did not change (ANOVA $F(2,72)=1.57$, $p>0.1$, Table 1). The proportion of short lived species was between 0.5 and 0.6 in the studied years. The numbers of colonization and extinction in the sampling units are similar; comparing the summed frequencies of species (between 114 and 129) the sum of difference values were very low (between 7 and 15, Table 2). However, the turn over values (summed squared difference) were high (between 121 and 170), and it was higher between 2002 and 2003, than comparing 2002 and 2004. Between 2002 and 2003 6 species colonized (*Bryum algovicum, Phascum curvicolle, P. floerkeanum, Pottia intermedia, Pterygoneurum ovatum, Rhynchostegium megapolitanum*) while 5 species disappeared (*Bryum caespiticium, Bryum capillare, Funaria hygrometrica, Pottia bryoides, Pottia lanceolata*). Between 2003 and 2004 7 species colonized (*Acaulon muticum, Bryum caespiticium, B. capillare, B. ruderale, Enthosthodon hungaricus, Pleurochaete squarrosa, Pottia bryoides*) while 3 disappeared (*Phascum curvicolle, P. floerkeanum, Rhynchostegium megapolitanum*).

Species	Life strategy	Frequency			Difference of frequencies			Squared difference of frequencies		
		2002	2003	2004	2002-03	2003-04	2002-04	2002-03	2003-04	2002-04
Acaulon muticum	AS	0	0	1	0	1	1	0	1	1
Barbula unguiculata	C	20	19	18	-1	-1	-2	1	1	4
Brachythecium albicans	P	23	22	22	-1	0	-1	1	0	1
Bryum algovicum	SL	0	2	1	2	-1	1	4	1	1
Bryum bicolor	C	6	3	3	-3	0	-3	9	0	9
Bryum caespiticium	C	1	0	1	-1	1	0	1	1	0
Bryum capillare	C	1	0	1	-1	1	0	1	1	0
Bryum radiculosum	C	2	4	1	2	-3	-1	4	9	1
Bryum ruderale	C	0	0	4	0	4	4	0	16	16
Dicranella varia	C	4	2	3	-2	1	-1	4	1	1
Drepanocladus aduncus	P	23	24	24	1	0	1	1	0	1
Enthosthodon hungaricus	SL	0	0	2	0	2	2	0	4	4
Funaria hygrometrica	F	1	0	0	-1	0	-1	1	0	1
Homalothecium lutescens	P	8	4	7	-4	3	-1	16	9	1
Phascum curvicolle	AS	0	1	0	1	-1	0	1	1	0
Phascum cuspidatum	AS	5	13	6	8	-7	1	64	49	1
Phascum floerkeanum	AS	0	2	0	2	-2	0	4	4	0
Pleurochaete squarrosa	C	0	0	1	0	1	1	0	1	1
Pottia bryoides	AS	2	0	2	-2	2	0	4	4	0
Pottia davalliana	AS	1	2	1	1	-1	0	1	1	0
Pottia intermedia	SL	0	7	9	7	2	9	49	4	81
Pottia lanceolata	SL	1	0	0	-1	0	-1	1	0	1
Pseudocrossidium hornschuchianum	C	12	12	14	0	2	2	0	4	4
Pterygoneurum ovatum	SL	0	1	1	1	0	1	1	0	1
Rhynchostegium megapolitanum	P	0	1	0	1	-1	0	1	1	0
Thuidium abietinum	P	2	2	4	0	2	2	0	4	4
Tortula ruralis	C	2	1	3	-1	2	1	1	4	1
Sum		***114***	***122***	***129***	***8***	***7***	***15***	***170***	***121***	***135***

Table 2. Frequency and dynamical characteristics of species. Life strategies are following: P-perennial, SL-short lived shuttle, AS-annual shuttle, C-colonist, F-fugitive

Except for *Rhynchostegium megapolitanum* all of these species are short lived acrocarpic mosses belonging to the fugitive, annual shuttle, short lived shuttle and colonist life strategy types. In all years the most frequent species were *Barbula unguiculata* (colonist), *Brachythecium albicans* (perennial), *Drepanocladus aduncus* (perennial) and *Pseudocrossidium hornschuchianum* (colonist). This frequent species had very low turn over values (0 to 4). Species with high turn over values (*Bryum bicolor, B. radiculosum, B. ruderale, Homalothecium lutescens, Phascum cuspidatum, Pottia intermedia*) had low or intermediate frequency values and belong to short lived life strategy types (colonist, annual shuttle and short lived shuttle), except *Homalothecium lutescens*, which is a perennial species. In 2002-2003 period *Phascum cuspidatum, Pottia intermedia, Homalothecium lutescens* and *Bryum bicolor* had the highest turn over values, while between 2003-2004 *Phascum cuspidatum, Bryum ruderale*, *B. radiculosum* and *Homalothecium lutescens*. While the proportion of perennial species frequencies was close to 0.5 in all years their turn over values were low, comparing to short lived strategy types (annual shuttle, colonist and short lived shuttle, Table 3). Similarly, the species level comparison, the turn over values of strategy types were higher in one year periods (2002-2003 and 2003-2004) than in the two-year interval of 2002-2004, except for the short lived shuttle type. Looking at different periods varying strategy

types had the highest turn over values: for 2002-2003 annual shuttle, short lived shuttle and colonist, for 2003-2004 colonist and annual shuttle, for 2002-2004 short lived shuttle.

Life strategy	Frequency			Difference of frequencies			Squared difference of frequencies		
	2002	2003	2004	2002-03	2003-04	2002-04	2002-03	2003-04	2002-04
Perennial	56	53	57	-3	4	1	9	16	1
Short lived shuttle	1	10	13	9	3	12	81	9	144
Annual shuttle	8	18	10	10	-8	2	100	64	4
Colonist	48	41	49	-7	8	1	49	64	1
Fugitive	1			-1	0	-1	1	0	1
Sum	***114***	***122***	***129***	***8***	***7***	***15***	***240***	***153***	***151***

Table 3. Frequency and dynamical characteristics of life strategies.

Discussion

Analyzing the species composition of bryophytes of the alkaline grassland based on observations in one sampling quadrate, it is easy to separate three characteristic groups of species: (1) perennial, mainly pleurocarpic mosses with high frequency, (2) short lived mosses with intermediate frequency and (3) very rare species. Although the duration of this study period was too short for describing the dynamics of this community type, it is possible to formulate some preliminary conclusions. Investigating only some characteristic descriptors of the community they seemed to be stable: both the species richness and the proportion of short lived and perennial species are more or less constant in the three years. Behind these community characteristics an intensive dynamics can be found on species level, with high number of local colonization and extinction events. The summarized turn over value of a two-year interval was similar than the values of the consecutive years, and it is supposed it would not increase comparing longer periods. The most common perennial species (e.g. *Brachythecium albicans, Drepanocladus aduncus*) had low turn over values during the investigated period. The occurrence of rare, short lived species (e.g. *Acaulon muticum, Phascum curvicolle, P. floerkeanum, Pterygoneurum ovatum*) is accidental they can not reach high frequency in species composition in any year. The most characteristic members of this community are the short lived (colonist, annual shuttle and short lived shuttle) species with intermediate frequency, which in some years are more or less missing and while in others quite frequent (e.g. *Pottia intermedia, Phascum cuspidatum* and *Bryum* species). The yearly fluctuations of these mosses make the species composition of this community very unpredictable and stochastic for a selected year. It is possible that even long-term studies can not explain and predict the stochastic behavior of these species. It is supposed that they are very common in propagulum bank by their long living, maybe dormant tubers and large spores (Hock *et al.* 2004). These short lived species with intermediate frequency are responsible for

the high turn over of the bryophyte vegetation of dry grasslands (During & ter Horst 1985, During & Lloret 1996) and of temporary substrates as dead wood (Kimmerer 1993, Söderström & Jonsson 1989). These species are much more rare in closed ground vegetation (closed grasslands, forest floor), however they occur in the propagulum bank, and able to colonize the mineral soil of disturbed patches (Jonsson & Esseen 1998). It is hoped that the dynamic processes of the bryophyte layers of different community types can be clarified after future investigations based on the analysis of long term data set of permanent quadrates.

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