An overview of options and limitations in the monitoring of endangered bryophytes in Hungary

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Abstract

To clearly establish the threat status of potentially endangered bryophytes, it is important to explore and check their earlier occurrences. The earlier known localities of several rare species in Hungary (*Brachydontium trichodes, Buxbaumia viridis, Campylostelium saxicola, Dicranum viride, Hamatocaulis vernicosus, Fissidens arnoldii, Orthotrichum rogeri, Pyramidula tetragona, Rhynchostegium rotundifolium, Taxiphyllum densifolium*) were investigated by the authors in the last three years. The reliability of these investigations concerning the population changes and rarity depend on the biological features of species and the thoroughness of earlier investigations. The requirements of successful confirmation of old occurrences and monitoring are: (1) narrow habitat specificity, (2) temporarily stable habitat, (3) perennial or long-lived life strategy, (4) the plant should be easily and undoubtedly recognisable in the field (biological features of the species); (5) strictly defined (exactly described) earlier known localities, (6) thoroughly revealed distribution in the past (technical features of the monitoring). The aim of this paper is to assess the options, challenges and levels of reliability of species monitoring in the case of rare species, which differ in the above characters.

The practical value of information concerning the distribution and population changes of species depends considerably on how the species' biological and the investigation's technical features and possibilities can be reconciliated. Unfortunately, in most cases some of these requirements are not realised. We have to conclude that the earlier and recent distribution of certain species, which do not correspond well to the biological bases of successful monitoring, can not be established with good accuracy. Estimation of their threat status and monitoring of their population changes will have to be continued but the above described challenges need to be taken into account.

Keywords: endangered bryophytes, Hungary, monitoring, threat status

Introduction

In the last decade considerable international effort of bryologists and nature conservationists is observed in the framework of ECCB (European Committee for Conservation of Bryophytes) to conserve bryophytes in Europe. In many European countries red lists or red data books for bryophytes have been compiled (ECCB 1995: 32), and in some countries bryophytes are included in the lists of the legally protected species (ECCB 1995: 24). Most of these lists, however, are written in a national perspective, often use different categories of rarity and do not take into account the rarity or abundance of species on a larger geographical scale (Söderström 1995). The Red Data Book of European Bryophytes (ECCB 1995) tries to list the rare species in the scope of the whole continent, using the IUCN categories for rarity modified for bryophytes (Hallingbäck et al. 1998). The results of these activities are that bryologists are more encouraged to set the biological priorities of the bryophyte conservation (Söderström et al. 1998, Bisang and Hedenäs 2000, Longton and Hedderson 2000, Laaka-Lindberg et al. 2000). Internationally organised field works and data collections are going on in several countries (e.g. Hodgetts 2000, Urmi and Schnyder 2000, Pavić et al. 1998, Piippo and Urbanski 1998) and bryologist are able to establish the scientific basis of bryophyte conservation for decision makers and nature conservationists (Hallingbäck and Hodgetts 2000)

In Hungary, the genus *Sphagnum* and 58 bryophyte species are legally protected (Appendix). Most of these species are included in the Red Data Book of European Bryophytes (ECCB 1995), and the others are locally rare species (e.g. *Calliergon* spp., *Campylium elodes*, *Drepanocladus* spp., *Meesia triquetra*, *Scorpidium scorpioides*) living in endangered mires and wet meadows. Intensive bryological investigations are going on concerning the distribution and population changes of species rare in Europe (Papp et al. 2000) (species monitoring), and to survey the compositional changes of bryophytes in different habitats (Papp and Rajczy 1995, 1998) (habitat monitoring). These studies are part of the Hungarian National Biodiversity Monitoring System (Kovácsné Láng and Török 1997, Török and Kun 1997) supported by the Environmental Ministry of Hungary. This monitoring provides information about the vegetation and compositional changes of the bryoflora in Hungary and

it gives biological reference for nature conservation authorities in the selection and management of protected areas.

Species monitoring forms the basis of the investigation of distribution and population changes of the species and estimate their threat status according to new IUCN categories (Papp et al. 2000). This monitoring includes the revision of herbarium specimens, confirmation of species in earlier localities, and includes the attempt of finding new localities in its potential habitat, estimating the size of local populations, visiting regularly the known localities. The reliability of these investigations concerning the population changes and rarity depends on the biological features of species and the thoroughness of earlier investigations.

In this paper the authors wish to share their experience on the possibilities and reliability of species monitoring in the case of some model species.

Material and methods

The species we discuss in this paper represent different biological features: habitat requirements, habitat specificities, life strategies (During 1979, 1992); they are included in the list of Bern Convention (The convention on conservation of European wildlife and natural habitats 1979), or/and in the Red Data Book of European Bryophytes (ECCB 1995) and in the legally protected species list of Hungary (Appendix). These are the following: *Orthotrichum rogeri*, *Dicranum viride*, *Pyramidula tertragona*, *Buxbaumia viridis*, *Hamatocaulis vernicosus*, *Fissidens arnoldii*, *Taxiphyllum densifolium*, *Rhynchostegium rotundifolium*, *Campylostelium saxicola*, *Brachydontium trichodes.* The specimens of these species were revised in bryophyte herbaria of Hungary (Budapest, Eger), and the published data were thoroughly examined. The earlier found localities were visited (in the case of unsuccessful confirmations two or three times). If the bryophyte was found on the cited locality, the size of its population was estimated and its potential habitats in other localities were also investigated. In the case of unsuccessful confirmation habitat conditions of the site were investigated in order to see if we may expect finding it 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.

Nomenclature of the species follows Corley et. al. (1981), Corley et Crundwell (1991) and Schumacker et Váňa (2000).

Results and discussion

Our work hypothesis is that for successful monitoring of species the following characteristics are important:

- biological features: narrow habitat specificity, stable habitat, perennial or long lived life strategy, easy identification in the field;
- features of earlier investigations: strictly defined earlier localities, thoroughly revealed earlier distribution.

Table 1. shows how the model species correspond to the requirements of a reliable monitoring.

The narrow habitat specificity helps to find easily the species in the locality. The confirmation of an earlier occurrence is usually successful, if the species in the site is connected to a substrate, which is rare on the locality, and it could be exactly localised (e.g. a big rockwall in the forest, walls of the ditch of a water mill) or if the habitat is well confined and its territory is not extended (as wet meadows in Hungary, where *Hamatocaulis vernicosus* once occured).

If the habitat of a species is stable, the probability of extinction is less serious, and the success of finding does not depend on the period of investigation (e. g. long lasting substrates: rock walls, mires).

Perennial/long-lived life strategy also helps to find the species during the whole year in the same place. The fluctuation of population is low in time, the reliability of population size estimation is high.

If the species is taxonomically stable and its identification is easy in the field (so called "good species") the probability of finding it is higher and the estimation of population size is more accurate.

The strictly defined earlier localities evidently help greatly in searching for the species exactly on the same locality, where it was found earlier.

The thoroughly revealed earlier distribution and population size is an important precondition for the estimation of distribution and population changes, which is the base of ascertainment of the threat status.

Our knowledge on the earlier distribution of several species is very incomplete despite the Hungarian bryophyte flora is well known thanks to the activity of earlier Hungarian bryologists, mainly Ádám Boros and László Vajda. The bryophyte collection of Ádám Boros

contains 84000 specimens and this is a unique, representative material for the whole Carpathian basin and the mountain systems of the Carpathians. He made field trips throughout the country, he returned again and again to the bryologically interesting sites. He intentionally looked for the rare species, which were interesting and valuable for his collection. After the enormous life work of Ádám Boros and László Vajda it is quite difficult to find species new to Hungary, or even new localities of rare species (Boros 1968, Orbán and Vajda 1983). But these data are 40-50 years old and as the decline of populations of most species has happened in the last 10-20 years due to human activity, these early data are not sufficient for the assessment of the recent distribution or to ascertain the threat status of the species. The authors have built a database of rare bryophyte species in Hungary, which contains 7879 entries. Almost half of the records originate from Boros and one-third from Vajda. Their detailed diaries (Boros 1915-1971, Vajda 1933-1978) on their field trips contain exact descriptions of their routes, register lots of field observations, which help greatly to find the same place. List of the other species found at the sites and sometimes notes, observations about the rare species looked for are included. Moreover, most of the mentioned specimens can be checked as they are deposited in our herbarium. The diaries and the Bryophyte Herbarium of the Hungarian Natural History Museum (BP) provide a valuable help in the monitoring.

The quantity and quality of old data are remarkably good and adequate for the present-day monitoring in Hungary. However, to find a species and describe its locality and habitat accurately, earlier was also dependent on the biological features of the plant also for the early collectors. Despite the thorough and enormous work of these two bryologists the species distribution is not well explored in case of those which do not correspond to the first four biological features (Table 1.: *Ortotrichum rogeri, Dicranum viride*, *Pyramidula tetragona*, *Buxbaumia viridis*). We do not expect the threat status of those taxa can be clarified anytime in the future.

The two species in the first column of the Table 1. have wide habitat requirements and their identification on the field is also difficult. *Orthotrichum rogeri* lives in open oak-ash-elm forests, mainly on *Fraxinus* trees in Hungary. It has three records altogether. It could have been very rare in its habitat, because the herbarium specimens are very poor, contain only small patches of the plant. It can occur in any tree of the forest and it lives together with other *Orthotrichum* species, which are very similar to each other. The localities were visited and in two sites the habitat conditions seemed to be suitable for the species, but it was not found.

The records of the species are 40-50 years old, and since then there are no new data. It is supposed that new data may come up only by chance during regional floristic surveys or other monitoring activities, which would thoroughly investigate a small area. *Dicranum viride* has similar features. According to the Red Data Book of European Bryophytes (ECCB 1995), it lives mainly on the bark of deciduous trees in permanently humid forests. Its habitat is similar in Hungary as well. It could occur on any tree in an extended, large forest. Its close relative, *D. tauricum*, lives in the same habitat and, moreover, occasionally they are found on the same tree and it is difficult to distinguish them in the field. The second species is more common in Hungary, and considerable part of its herbarium specimens were misidentified (Erzberger 1999). *Dicranum viride* is not as rare in its habitat as *Orthotrichum rogeri*, hence it was found in some old and new localities. However, in this case the estimation of its population size was almost impossible. For example, in one of the recently known largest populations, among the 30 sampled patches on 10 different trees, 27 were *D. viride* and 3 were *D. tauricum*. It means that the occurrence of *D. viride* is proved and it seems to be more frequent on this site than its relative, but the estimation of population size on the field is too uncertain.

The temporary, very short presence poses great challenge for the successful monitoring as in the case of *Pyramidula tetragona* (Table 1.). In Hungary it lives in open calcareous or non-calcareous grasslands. Usually the territory of these areas is not large, and the habitat can be exactly located. As the life strategy of this species is annual shuttle, it appears in spring, produces spores very quickly, then it dies in the dry season, and in autumn it may appear again. The size of the population could be very variable in different years, because the appearance of the species is strongly connected with the weather conditions as e.g. the duration and quantity of rains. It has two old confirmed and one new locality from some basalt hills close to each other in the same region of Hungary. In other old localities our recent search was unsuccessful (Papp et al. 2000). Usually it grows in patches of 1-2 cm diameter. Several patches can be found often near to each other in a group within a 1 m^2 area. In extended grasslands several groups may occur 5-10 m away from each other (Table 2.). The number of groups and patches are very variable in different years. There are only a few groups and patches, which appear in each year and the sporophyte production fluctuates as well. Year 2001 was unfavourable for this species, because the spring was very dry. The population of Tátika did not appeared, at Gulács we found only one patch with a few sporophytes. However, the species has shown more stability spatially as we have supposed before. Several patches were found on the same place or very close, to where we saw them

the year before. It is very interesting if we consider the steep slopes with rubbles and crumbly soil rolling down which provide a very unstable habitat. Despite the species always has capsules it seems it does not colonise the potential new microhabitats, but the stability of groups spatially is a characteristic feature. The colonisation ability of the species seems quite limited. Hence the disappearance of a population in a year is a real danger. The estimation of local population sizes is almost impossible, because of the fluctuation in the appearance of the species and it is difficult to locate it at old sites.

Buxbaumia viridis is also a very problematic species (Table 1.). In Hungary, it has only one record from decaying wood, (which is its main substrate in Western and North Europe, (ECCB 1995)) and in the other localities it was found on acidic soils in humid forests. The occurrence of the species on soil is a unique rarity but it was also mentioned from Finland (Oitinen 1967). The identification of the species is proved to be not easy. The old specimens of two localities have very young capsule. These specimens are very doubtfully identifiable, because the angular edge or the indusium of the capsule is not recognisable and the peristome teeth can not be examined. The indusium is a very characteristic feature as it is preserved in its synonym name *Buxbaumia indusiata*. It has indusium if the cuticle splits longitudinally and peels off on the back of the capsule and remains on it as large, ragged pieces (Smith 1978). It can be seen well on mature capsules. Two old specimens with mature capsules have no indusium but the capsule is not angled and the peristome teeth are in a single row. It seems that the latter specimens belong to the less rare relative, *Buxbaumia aphylla*. The species was refound in one locality (Papp et al. 2000), where it lives on decaying wood, despite that it has no stable habitat as we consider that the occurrence of the logs of suitable size and in suitable decaying stadium are limited in time. The locality was very exactly defined, because this is a small area in a narrow valley, where each piece of decaying wood were investigated thanks to another project dealing with epixyl bryophytes. When *B. viridis* was found the first time there in 1999, the population has lived on three decaying logs with 16 sporophytes. Next year only one sporophyte appeared on one log in the same season of the year. In 2001 we have not found any individual. This is a sign referring to that the population size could fluctuate very much. It is supposed that for the survival of local population continuous presence of well-decayed logs is needed in time (Söderström 1988). The confirmation of earlier occurrences of the species in other localities, where it appeared on acidic soil, was unsuccessful. In these cases the largest problem was the dimensions of habitat where it could appear, as it could live anywhere in an extended forest. The only help is that according to the literature, notes in the

diaries and the study of old specimens, it is frequently accompanied by *Leucobryum glaucum*, which is also rare in the mentioned areas, but can be recognised easily.

There are species which correspond to almost all requirements (Table 1.), but the search was unsuccessful. *Hamatocaulis vernicosus* lived in wet meadows with good water supply. Bryologists visited these kinds of habitats several times in the 50s-60s of the last century. On the basis of literature, it was abundant in clear patches in these meadows. It was well identifiable on the basis of the collected materials. The localities of the species have changed dramatically due to eutrophization, drainage and desiccation. All known localities were checked in the past years without success. At present at least, the species may be treated as disappeared from Hungary. Fortunately, its populations are not isolated. Most of the localities are on the western border of Hungary, in the proximity of the Alps, where the species occurs and it is hoped that it can recolonize the Hungarian habitats again. Only one earlier local population was isolated in the central part of Hungary surrounded by drier areas of low altitude, which can be regarded as extinct (Fig. 1).

In the case of several species the confirmation of old data was successful and the recent distribution can be safely established (Table 1.). These species mainly meet the expected requirements of reliable monitoring.

In Hungary the main habitats of *Fissidens arnoldii* are vertical, calcareous rockwalls of ditches at watermills (Papp et al. 2000). Its distribution in the past was well known as Boros was interested in the bryophyte flora of watermills and visited them all over the country. The watermills can be located easily, they are marked on the maps. The species can be distinguished from the relatives due to its obtuse leaf apex by handlens. It can be found during the whole year, like most aquatic bryophytes, which are adapted to good, continuous water supply. However, the old watermills are mostly abandoned or destroyed, although sometimes reconstructed in Hungary. At many places there is no water in the ditch of the mill. At most localities the habitat of the species is so much altered that the conditions are simply not adequate any more. Thus the species has become seriously threatened. It has only four confirmed localities recently (Fig. 2.). One locality is a ruinous watermill, where there is no water in the ditch but the species is still alive. The species is endangered at this locality. Consequently, mainly on the basis of criterion B of IUCN (restricted area of occupancy, few localities) now it should be placed into the EN category (Hallingbäck et al. 1998, Papp et al. 2000).

The other species group, which can be monitored successfully, is the one living on large rockwalls in shaded, humid forests (e.g. *Taxiphyllum densifolium, Rhynchostegium rotundifolium, Campylostelium saxicola, Brachydontium trichodes*). The earlier bryologists were interested in these habitats very much. Boros and Vajda visited the bryologically most interesting boulders, rock outcrops, and ridges several times. Since these rock outcrops are landmark objects, they can be easily located and visited practically at any time by using maps and/or earlier field notes. To look for a species on such places, however, is not easy – to climb up and thoroughly investigate the walls searching for tiny plants like *Campylostelium saxicola* or *Brachydontium trichodes*. In spite of the difficulties many old data were successfully checked on these habitats, even the non-perennial ones, but usually we returned repeatedly to the place in search of them. Unfortunately, in Hungary the microclimate of many such rocky habitats has become drier in the past decades due to the relatively dry weather and improper forestry activity (e.g. clear cutting). Hence species of shaded rocks are also considerably threatened in the country.

Conclusions

Many bryophyte species are not suitable for the clear establishment of the threat status, because the population size fluctuates (as it can be seen in the case of ephemeral, short-lived species) or the species has wide habitat requirements and is rare in its habitat. In the latter case we do not know where to look for it, as the territory where it could occur is too large. New data of these species may come up only by chance during intense investigations of small areas, such as regional floristic surveys. We have to conclude that the earlier and recent distribution of certain species, which do not correspond well to the biological bases of successful monitoring, can not be established with good accuracy. Estimation of their threat status and monitoring of their population changes will have to be continued but the above described challenges need to be taken into account.

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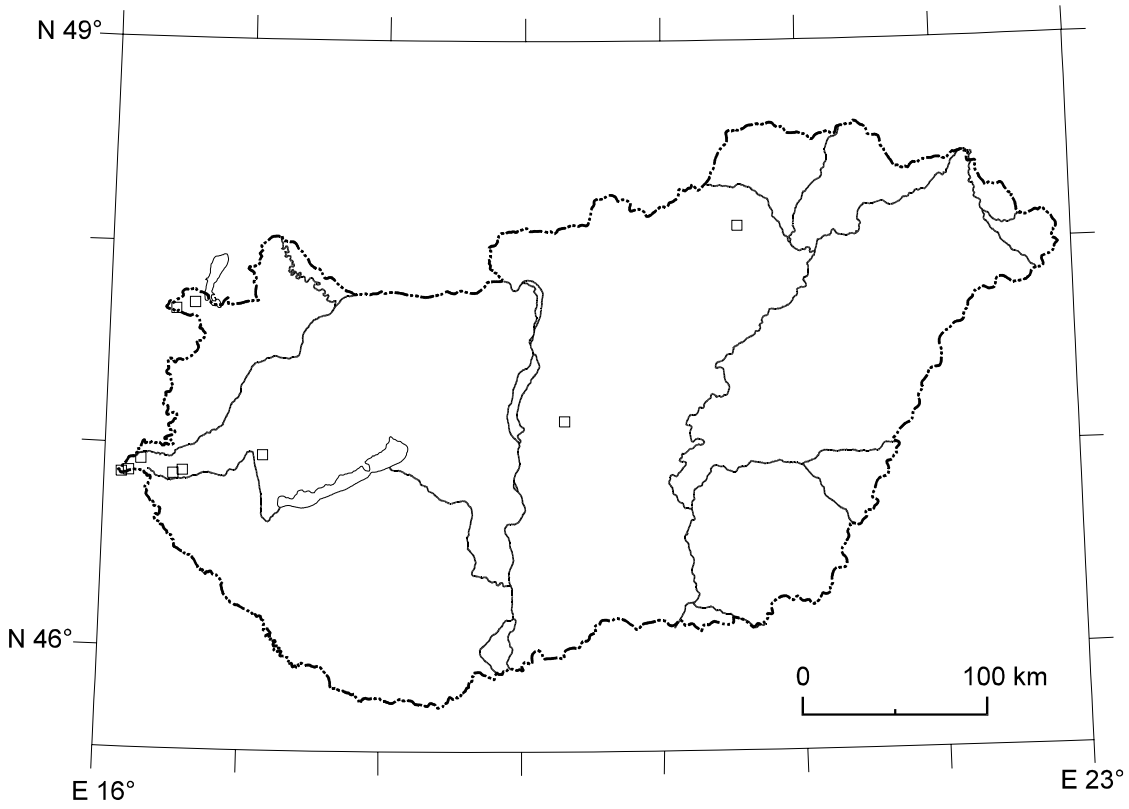

Fig. 1. Distribution of Hamatocaulis vernicosus in Hungary. Square – record before 1970, checked without success.

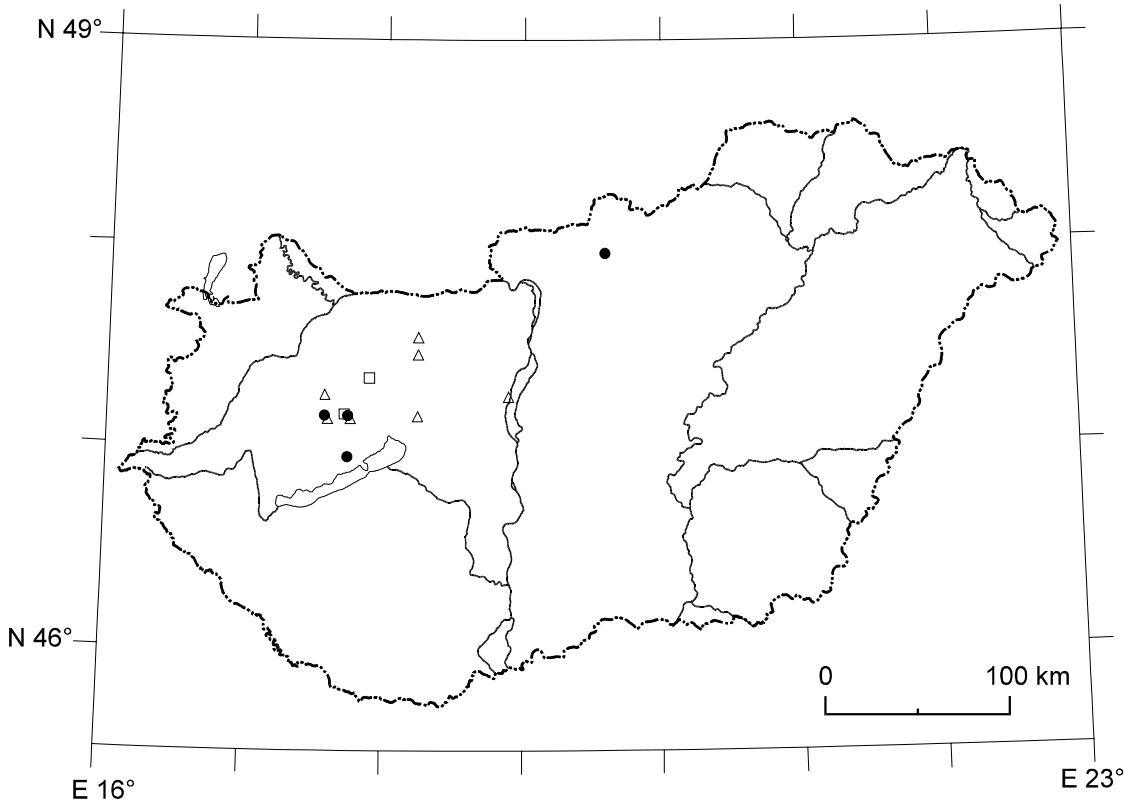

Fig. 2. Distribution of Fissidens arnoldii in Hungary. Square – record before 1970, checked without success (triangle – destroyed habitat, black circle – record after 1970).

Table 1. Correspondence of species with requirements of successful confirmation of earlier occurrences and monitoring.+: species corresponds to the requirement; -: species does not correspond to the requirement; Ortrog - *Orthotrichum rogeri*, Dicvir - *Dicranum viride*, Pyrtet - *Pyramidula tertragona*, Buxvir - *Buxbaumia viridis*, Hamver - *Hamatocaulis vernicosus*, Fisarn - *Fissidens arnoldii*, Taxden - *Taxiphyllum densifolium*, Rhyrot - *Rhynchostegium rotundifolium*, Camsax - *Campylostelium saxicola*, Bratri - *Brachydontium trichodes*

Requirements	**Ortrog Dicvir**	**Pyrtet**	**Buxvir**	**Hamver**	**Fisarn**	**Taxden Rhyrot**	**Camsax Bratri**
Narrow habitat specificity	-	+	-	+	+	+	+
Stable habitat	+	-	-	+	+	+	+
Perennial, long-lived species	+	-	-	+	+	+	-
Easy identification in the field	-	+	-	+	+	+	+
Strictly defined earlier known localities	-	+	-	+	+	+	+
Thoroughly revealed earlier distribution	-	-	-	+	+	+	+

Table 2. Population size of *Pyramidula tetragona* in the investigated localities. Patch: ca. 1 cm^2 dense turf of shoots probably coming from the same prothallium. Group: Assemblage of closely occurring patches within ca. 1 m^2.

locality	**Tátika hill**			**Szent György hill**		**Gulács hill**	
year	1999	2000	2001	2000	2001	2000	2001
patches	7	4	0	29	35	10	1
groups	1	1	0	9	7	6	1
sporophyte	66	19	0	246	104	84	4

Appendix. List of bryophytes legally protected in Hungary.
Part of the Decree of Environmental Ministry (13/2001. V. 9.). Ministerial decree on the publishing of the protected and strictly protected plant and animal species, strictly protected caves, and the important plant and animal species in nature conservation point of view of the European Community. [13/2001. (V. 9.) KöM rendelet: A környezetvédelmi miniszter rendelete a védett és a fokozottan védett növény- és állatfajokról, a fokozottan védett barlangok köréről, valamint az Európai Közösségben természetvédelmi szempontból jelentős növény- és állatfajok közzétételéről.]
E – endangered, V- vulnerable, R – rare, K - insufficiently known according to Red Data Book of European Bryophytes; Bern - included in the Bern Convention.

Name of species	Threat status in Europe
Asterella saccata (Wahlenb.) A. Evans	V
Aloina bifrons (De Not.) Delg.	R
Amblystegium saxatile Schimp.	R
Anacamptodon splachnoides (Brid.) Brid.	E
Anomodon rostratus (Hedw.) Schimp.	R
Brachydontium trichodes (Web.) Milde	R
Brachythecium geheebii Milde	R
Brachythecium oxycladum (Brid.) Jaeg.	R
Bryum neodamense Itzigs. ex C. Müll.	V
Bryum stirtonii Schimp.	K
Bryum versicolor A. Br. ex B. & S.	R
Bryum warneum (Roehl.) Bland. ex Brid.	R
Buxbaumia viridis (Moug. ex Lam. & DC.) Brid. ex Moug. & Nestl.	V, Bern
Calliergon giganteum (Schimp.) Kindb.	
Calliergon stramineum (Brid.) Kindb.	
Campylium elodes (Lindb.) Kindb.	
Campylostelium saxicola (Web. & Mohr) B., S. & G.	R
Cephalozia lacinulata . J. B. Jack ex Spruce	V
Desmatodon cernuus (Hüb.) B. & S.	V
Dicranella humilis Ruthe	R
Dicranum viride (Sull. & Lesq.) Lindb.	V, Bern
Didymodon glaucus Ryan	V
Drepanocladus lycopodioides (Brid.) Warnst.	
Drepanocladus revolvens (Sw.) Warnst.	
Drepanocladus sendtneri (Schimp. ex H. Müll.) Warnst.	
Entosthodon hungaricus (Boros) Loeske	R
Ephemerum cohaerens (Hedw.) Hampe	E
Ephemerum recurvifolium (Dicks.) Boul.	R
Fissidens algarvicus Solms	K
Fissidens arnoldii Ruthe	R
Fissidens exiguus Sull.	R
Frullania inflata Gottsche	V
Grimmia plagiopodia Hedw.	R
Grimmia sessitana De Not.	R
Grimmia teretinervis Limpr.	V

Hamatocaulis vernicosus (Mitt.) Hedenäs	K, Bern
Hilpertia velenovskyi (Schiffn.) Zander	R
Jungermannia subulata A. Evans	R
Lophozia ascendens (Warnst.) R. M. Schust.	R
Mannia triandra (Scop.) Grolle	R, Bern
Meesia triquetra (Richter) Aongstr.	
Neckera pennata Hedw.	V
Orthotrichum rogeri Brid.	V, Bern
Orthotrichum scanicum Grönv.	E
Orthotrichum stellatum Brid.	R
Phascum floerkeanum Web. & Mohr	K
Physcomitrium sphaericum (Ludw.) Brid.	R
Pterygoneurum lamellatum (Lindb.) Jur.	V
Pyramidula tetragona (Brid.) Brid.	V, Bern
Rhynchostegiella jacquinii (Garov.) Limpr.	R
Rhynchostegium rotundifolium (Brid.) B., S. & G.	R
Riccia frostii Austin	R
Riccia huebeneriana Lindenb.	R
Scorpidium scorpioides (Hedw.) Limpr.	
Sphagna (20 species)	
Taxiphyllum densifolium (Lindb.ex Broth.) Reim.	R
Tortula brevissima Schiffn.	R
Warnstorfia exannulata (B., S. & G.) Loeske	
Weissia rostellata (Brid.) Lindb.	R