Zbornik gozdarstva in lesarstva 85 (2008), s. 11 - 26

GDK: 173.2+180+19(045)=111
Prispelo / *Recived*: 3. 3. 2008
Sprejeto / Accepted: 5. 5. 2008

Izvirni znanstveni članek
Original scientific paper

BRYOPHYTE SPECIES DIVERSITY OF FOREST ECOSYSTEMS IN SLOVENIA (INTENSIVE MONITORING PROGRAMME)

Lado KUTNAR[1], Andrej MARTINČIČ[2]

Abstract

As part of the Intensive Monitoring Programme (IM) of Forest Ecosystems in Slovenia, the bryophyte flora and vegetation have been studied on 11 IM plots and 64 vegetation sub-plots (10×10 m). On the IM plots, high species diversity of bryophytes has been assessed. The total number of bryophytes was 109; among them 82 species belonging to the mosses (*Bryophyta*) and 27 species to the liverworts (*Marchantiophyta*). The mean number per plot was 27 species, ranging from 13 species on the Brdo plot to 36 species on the Borovec and Draga plots. The most common moss species are *Hypnum cupressiforme, Ctenidium molluscum, Tortella tortuosa, Brachythecium velutinum, Isothecium alopecuroides, Dicranum scoparium, Polytrichum formosum, Fissidens taxifolius, F. dubius* (*Bryophyta*); and liverworts are *Radula complanata, Chiloscyphus profundus, Plagiochila porelloides* and *Metzgeria furcata* (*Marchantiophyta*). Regarding the substrate preference, the opportunistic species that inhabit very different substrates are prevalent; and the second main group are bryophytes inhabiting wood material (epiphyte, epixylic species). Using multivariate techniques (cluster analysis, DCA), the bryophytes have proved to be valuable indicator of site conditions (bedrock, surface rockiness, soil type, micro- and regional climate, vegetation) and forest stand conditions (dominant tree species, dead wood).

Key words: bryophytes, *Bryophyta*, *Marchantiophyta*, species diversity, substrate preference, ground vegetation, intensive monitoring of forest ecosystems, Forest Focus, cluster analysis, DCA, Slovenia

PESTROST MAHOVNIH VRST V GOZDNIH EKOSISTEMIH SLOVENIJE (PROGRAM INTENZIVNEGA SPREMLJANJE STANJA GOZDNIH EKOSISTEMOV)

Izvleček

V okviru Programa za intenzivno spremljanje gozdnih ekosistemov oz. Intenzivni monitoring (IM) v Sloveniji smo na 11 IM ploskvah in 64 pod-ploskvah (10×10 m) preučevali tudi mahovno floro in vegetacijo. Na IM ploskvah smo ugotovili veliko pestrost mahovnih vrst. Skupaj smo popisali 109 vrst, od katerih je bilo 82 listnatih mahov (Bryophyta) in 27 vrst jetrenjakov (Marchantiophyta). V povprečju smo našli 27 vrst na ploskev, v razponu med 13 vrstami na ploskvi Brdo in 36 vrstami na ploskvah Borovec in Draga. Med najpogosteje popisanimi listnatimi mahovi so Hypnum cupressiforme, Ctenidium molluscum, Tortella tortuosa, Brachythecium velutinum, Isothecium alopecuroides, Dicranum scoparium, Polytrichum formosum, Fissidens taxifolius, F. dubius, med jetrenjaki pa Radula complanata, Chiloscyphus profundus, Plagiochila porelloides in Metzgeria furcata. V pogledu vezanosti na določeno rastno podlago prevladujejo oportunistične vrste, ki rastejo na zelo različnih podlagah. Drugo večjo skupino sestavljajo mahovi, ki naseljujejo lesnate podlage (epifitne in epiksilne vrste). S pomočjo uporabe multivariatnih tehnik (klastrska analiza, DCA) smo dokazali, da so tudi mahovi dober indikator rastiščnih razmer (geološka matična podlaga, površinska skalnatost, talni tip, mikro- in regionalna klima, vegetacija) in sestojnih razmer (prevladujoča drevesna vrsta, odmrli les).

Ključne besede: mahovi, Bryophyta, Marchantiophyta, vrstna pestrost, vezanost na substrat, pritalna vegetacija, intenzivno spremljanje gozdnih ekosistemov, Forest Focus, klastrska analiza, DCA, Slovenija

UVOD
INTRODUCTION

In order to monitor effects of air pollution as well as other anthropogenic and natural stress factors on the condition and development of forests and to contribute to a better understanding of cause-effect relationships in forest ecosystem functioning, a Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems was implemented in 1994 (de VRIES *et al*. 2003b). For the Intensive Monitoring Programme (IM), more than 860 Level II plots were selected, representing the major forest ecosystems of the actively participating countries.

In Slovenia, IM started in 2004. Based on information of present state situation of forest ecosystems and potential treats, the IM plots were selected systematically (ČATER *et al.* 2003). A larger number of observations and measurements were made on these plots in order to investigate factors and processes at the ecosystem scale, such as surveys of crown condition, soil characteristics and soil solution chemistry, tree growth, atmospheric depositions, phenology, foliar chemistry, meteorology, air quality and ozone.

Since the vegetation is a good bioindicator of environmental changes, the ground vegetation survey was carried out, too (KUTNAR 2006). Knowledge of the ecological niche of numerous plant species allows changes in underlying en-

[1] dr. L. K., Gozdarski inštitut Slovenije, Večna pot 2, SI-1000 Ljubljana, Slovenija, lado.kutnar@gozdis.si

[2] prof. dr. A. M., Zaloška 78a, SI-1000 Ljubljana, Slovenija

vironmental factors to be deduced from vegetation changes. Thus, the long-term study of vegetation dynamics can provide information on changes in the forest ecosystem. The main objective of the assessment of diversity in ground vegetation is to get information on changes due to natural dynamics and disturbances (air pollution, climate changes, etc.).

As part the ground vegetation survey, the biodiversity of bryophyte flora was of special interest. With regard to ecological monitoring, bryophyte species assemblage may give insight in microsite habitat conditions. Bryophytes are often regarded as having a subordinate function in vegetation (DIERSSEN 2001). This may be reasonable for productive sites with overwhelming competition of vascular plants for space and other resources. However, in sites with extreme conditions, such as arctic and alpine tundras, bogs, exposed cliffs, rocks, and wet tropical mountain woodlands, bryophytes are among the best adapted plants (DIERSSEN 2001).

Slovenia has very rich bryophyte flora (MARTINČIČ 2002, 2003). This is not only due to climatic and geological-petrographic diversity, but also owing to considerably variety and the state of preservation of the habitat types in which the bryophyte thrive: bogs and fens, alpine rocky regions, alpine regions with grasslands and snow valleys, numerous springs and secondary biotopes with cultivated land, old fruit trees, stony enclosures and road cuts. Among the important bryophyte habitats are also the well preserved near-natural forests and virgin forest with decaying tree trunks. The near-natural forests in the Dinaric region of Slovenia are considered biodiversity of the dead wood inhabiting bryophytes (ÓDOR / van DORT 2002).

The aim of this study as part of the IM Programme in Slovenia was to describe the bryophyte flora diversity of IM plots, and to characterise the frequencies of the species on different sites and substrata (e.g. soil, wood, rock).

RESEARCH PLOTS AND METHODS
RAZISKOVALNE PLOSKVE IN METODE

The study was carried out on 11 IM plots all over Slovenia (Fig.1), which were selected in systematic way to represent the mayor forest ecosystems (ČATER *et al*. 2003, KUTNAR 2006). Five of 11 IM plots are more intensive plots with larger set of monitoring surveys and measuring equipment, while six of them are less intensive (Tab. 1). The more intensive plots are fenced.

At each of the 11 IM plots, set of four 10×10 metres vegetation sub-plots were placed systematically in the central part of all 11 plots, whereas on the more intensive IM plots an additional set of four vegetation sub-plots were placed out of fenced area (Fig. 2). On fenced, more intensive plots, the number of vegetation sub-plots was 8 with the total sampling area of 800 m^2. On less intensive plots, the sampling area of 4 sub-plots was 400 m^2.

On the total of 64 vegetation sub-plots, the bryophyte species were recorded. Species richness, frequency and taxonomic type of bryophytes were estimated. The bryophytes on

Fig. 1: Distribution of plots for intensive monitoring of forest ecosystems in Slovenia (14 regional units of the Slovenian Forest Service are represented)

Slika 1: Razporeditev ploskev za intenzivno spremljanje gozdnih ekosistemov v Sloveniji (predstavljenih je 14 območnih enot Zavoda za gozdove Slovenije)

three different strata were recorded separately; on mineral soils (terricolous bryophytes on forest ground), on woody material (including dead wood of logs, fallen branches, snags, bark of living trees), and on rock material (stones of different dimensions, rocks).

The substrate preference of species, based on previous studies in Slovenia (e.g. MARTINČIČ 2002, 2003), was characterised as follows (see also DIERSSEN 2001, ÓDOR / van DORT 2002): opportunistic (O; no clear substrate preference, occurring on very different materials), epiphyte (WE; occurring mainly on bark of living wood), epixylic (WX; occurring mainly on soft decomposing woody material), lignicolous (W, occurring on living and dead wood), epilithic (R; occurring mainly on rocks, stones), terricollous (S; occurring mainly on mineral soil). The characterisation of species substrate preference is shown in Appendix.

We took into account three bryophyte divisions: *Bryophyta* (mosses), *Anthocerotophyta* (hornworts) and *Marchantiophyta* (liverworts). The source for nomenclature was MARTINČIČ (2003) for mosses (acrocarps and pleurocarps), and SCHUMACKER / VÁŇA (2005) for hornworts and liverworts (hepatics).

The basic statistics of the species richness were made by Microsoft Office Excel 2003, and the Cluster analysis and

Table1: General characterisation of the intensive monitoring plots of forest ecosystems in Slovenia

Preglednica 1: Splošna oznaka ploskev za intenzivno spremljanje gozdnih ekosistemov v Sloveniji

N. Št. pl.	**Name of IM plot** Ime ploskve	**Region/ Geo-position** Območje/ Bližina kraja	**Elevation** Nadmor. višina	**Dominant tree species** Prevladujoča drevesna vrsta	**Soil unit** Talni tip	**Parent material** Matična podlaga	**Latin (scientific) name of plant association** Latinsko ime združbe	**Status/ Fence** Status/ Ograjenost	**Vegetation sampling area** Popisna površina za vegetacijo
1	KRUCMANOVE KONTE	Pokljuka	1397 m	*Picea abies*	Eutric Cambisols, Rendzic Leptosols	Moraine	*Aposerido-Piceetum* ZUP. (1978) 1999 var. geogr. *Helleborus niger* subsp. *niger* ZUP. (1995) 1999	less intensive / unfenced	400 m^2
2	FONDEK	Trnovski gozd	827 m	*Fagus sylvatica*	Rendzic Leptosols, Eutric Cambisols	Limestone	*Seslerio autumnalis-Fagetum* M.WRAB. ex BORHIDI 1963 var. geogr. *Anemone trifolia* DAKS.91	more intensive / fenced	800 m^2
3	GROPAJSKI BORI	Sežana	420 m	*Pinus nigra*	Chromic Cambisols	Limestone	*Seslerio-Pinetum nigrae* ZUP. 1999 nom. prov	less intensive / unfenced	400 m^2
4	BRDO	Kranj	471 m	*Pinus sylvestris*	Dystric Cambisols	Fluvioglacial gravels and sands	*Vaccinio myrtilli-Pinetum* KOB. 1930 var. geogr. *Castanea sativa* TOM. 1940	more intensive / fenced	800 m^2
5	BOROVEC	Kočevska Reka	705 m	*Fagus sylvatica*	Rendzic Leptosols, Eutric Cambisols	Limestone, Dolomite	*Lamio orvalae-Fagetum* (HT. 1938) BORH. 1963 var. geogr. *Dentaria polyphyllos* KOŠ. 1962	more intensive / fenced	800 m^2
6	KLADJE	Osankarica, Pohorje	1304 m	*Picea abies*	Dystric Cambisols	Dioritoid (Tonalite)	*Avenello flexuosae-Piceetum* M.WRAB. ex HADAČ in HADAČ et al. 1969 corr. ZUP. 1999 var. geogr. *Aposeris foetida* ZUP. 1999	less intensive / unfenced	400 m^2
7	TEMENJAK	Vinska gora, Dobrna	729 m	*Fagus sylvatica*	Rendzic Leptosols Eutric Cambisols	Dolomite	*Lamio orvalae-Fagetum* (HT. 1938) BORH. 1963 var. geogr. *Dentaria pentaphyllos* (MAR. 1981) MAR. 1995	less intensive / unfenced	400 m^2
8	LONTOVŽ	Kum	958 m	*Fagus sylvatica*	Rendzic Leptosols, Eutric Cambisols	Dolomite	*Lamio orvalae-Fagetum* (HT. 1938) BORH. 1963 var. geogr. *Dentaria pentaphyllos* (MAR. 1981) MAR. 1995	more intensive / fenced	800 m^2
9	GORICA	Draga, Loški potok	955 m	*Fagus sylvatica Abies alba*	Rendzic Leptosols, Eutric Cambisols	Dolomite	*Omphalodo-Fagetum* (TREG.57) MAR. et al. 1993 var. geogr. *Calamintha grandiflora* SUR. (2001) 2002	less intensive / unfenced	400 m^2
10	KRAKOVSKI GOZD	Kostanjevica na Krki	160 m	*Quercus robur Carpinus betulus*	Gleysols	Pleistocene sediments	*Pseudostellario europaea-Quercetum roboris* ACC.1973	less intensive / unfenced	400 m^2
11	MURSKA ŠUMA	Lendava	170 m	*Quercus robur Carpinus betulus*	Gleysols, Fluvisol	Alluvium	*Querco roboris-Carpinetum* SOÓ 1940	more intensive / fenced	800 m^2

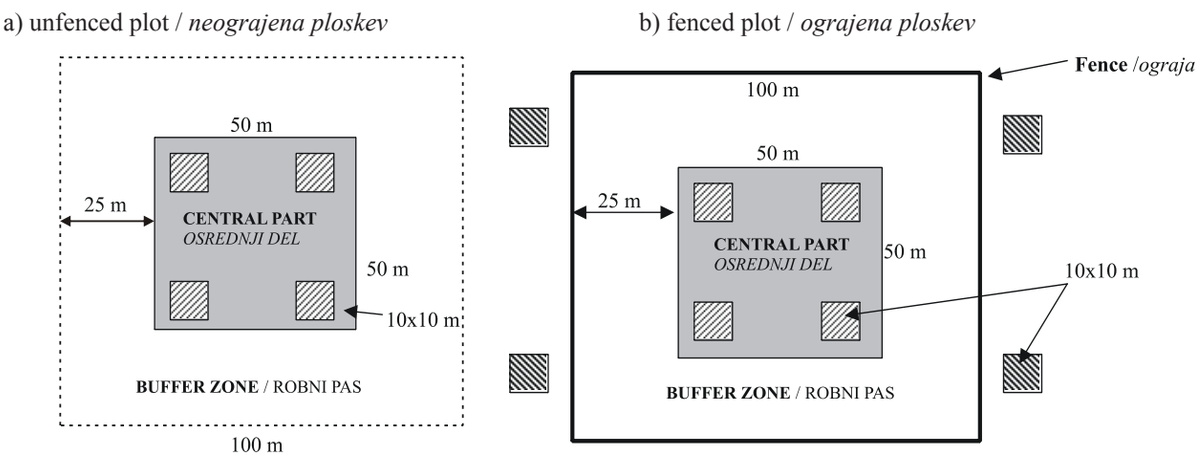


Fig. 2: Scheme of vegetation sub-plots distribution on IM plots in Slovenia: a) unfenced plot; b) fenced plot

Slika 2: Shema razporeditev vegetacijskih (pod)ploskev na IM ploskvah v Sloveniji: a) neograjena ploskev; b) ograjena ploskev

Detrended correspondence analysis (DCA, HILL /GAUCH 1980) by the PC-ORD program (McCUNE / MEFFORD 1999, 2006).

RESULTS AND DISCUSSION
REZULTATI IN RAZPRAVA

SPECIES DIVERSITY
VRSTNA PESTROST

On 64 vegetation subplots of 11 IM plots, the high bryophyte species diversity was recorded. Altogether, 109 bryophytes species were found (Table 2, Appendix). The number of mosses (*Bryophyta*) was 82. A total of 27 species of hepatics were found; there were no hornworts (*Anthocerotophyta*) among them. The majority of bryophytes recorded grow on one substrate only (44 %), one third of species on two substrata, and 23 % of them on three different substrata.

In the sampling area of 400 m^2 in the central part of 11 IM plots, the mean number of 25 species was recorded (Table 3). The mean species richness per all 11 IM plots (unfenced and fenced) was 27, ranging from 13 to 36 species.

The most common habitat of bryophytes is woody material. On average, we found 19 wood inhabiting bryophytes per IM plot. On soil of the Gropajski bori plot, no bryophyte species were recorded. On the Brdo, Krakovski gozd and Murska šuma plots, there is no rocky material on the plot surface and therefore there are no bryophyte inhabiting rocks.

No species were found to occur on all IM plots (see Appendix). The number of species present on more than half of plots (6 and more) is 17, and 23 species occurring on two plots and 47 species on one IM plot only.

Hypnum cupressiforme is a species with the highest number of occurrences (see Appendix). It is present on 10 IM plots. Considering IM plots, other very common species are *Brachythecium velutinum* (on 9 plots) and *Radula complanata*

Table 2: Number of bryophytes on intensive monitoring plots in respect to different taxonomic groups and their occurrence on different substrata (soil, rock, wood)

Preglednica 2: Število mahovnih vrst na ploskvah za intenzivni monitoring glede na taksonomske skupine in njihovo pojavljanje na različnih podlagah (tla, kamen, les)

	B (*Bryophyta*)	**M (*Marchantiophyta*)**	**Total**
On 3 substrata *na 3 podlagah*	19 (76 %)	6 (24 %)	25 (23 %)
On 2 substrata *na 2 podlagah*	30 (83 %)	6 (17 %)	36 (33 %)
On 1 substrate *na 1 podlagi*	33 (69 %)	15 (31 %)	48 (44 %) (S: 9 %, R: 17 %, W: 18 %)
sum	82 (75 %)	27 (25 %)	109 (100 %)

(9), *Polytrichum formosum* (8) and *Chiloscyphus profundus* (8), *Ctenidium molluscum*, *Tortella tortuosa*, *Isothecium alopecuroides, Dicranum scoparium* and *Plagiochila porelloides* (all 7).

Considering the three different substrata and all 64 subplots, *Hypnum cupressiforme* was recorded in 71 cases (maximal potential number is 192). Other species with higher frequency of occurrence are: *Ctenidium molluscum* and *Radula complanata* (both in 50 cases), *Tortella tortuosa* (45), *Isothecium alopecuroides* (38), *Dicranum scoparium* (33), *Fissidens taxifolius* (33), *Brachythecium velutinum* (32) and *Plagiochila porelloides* (32).

Regarding substrate preference, the opportunistic species prevail (51 species or 47 % of all species), representing about half of the species number of each IM plot. Only 17 opportunistic species were recorded on all three substrata, with 9 species among them occurring on 6 to 10 IM plots. The most frequent opportunistic species of moss group are *Hypnum cupressiforme*, *Brachythecium velutinum*, *Ctenidium molluscum*, *Tortella tortuosa, Isothecium alopecuroides*, *Dicranum scoparium*; and *Plagiochila porelloides* and *Metzgeria conjugata* from the liverwort group. These species are very common species in Slovenia, distributed in very different habitats, and at a wide altitudinal range. Generally, the species inhabiting two different substrata grow epiphytically, on bottom of the tree-stems and roots, and often spreading from wood to soils and rocks. Almost two thirds of all opportunistic species are present on two or one IM plots only.

The second main group consists of bryophytes specialized on woody substrate, colonising the living/growing trees (epiphyte) or dead wood (epixylic) or both (lignicolous). The number of epiphytes is 14 (13 % of all species) and they grow mostly on bark of the broadleaved trees. The epiphytes growing on spruce and pine are very rare. Among the most frequently recorded epiphytes are *Plagiothecium laetum*, *Pterigynandrum filiforme* and *Dicranum montanum* from the moss group, and *Radula complanata*, *Metzgeria furcata*, *Frullania dilatata* from the liverwort group.

Table 3: The total bryophyte species richness of intensive monitoring plots, and separately on different substrata (soil, rock, wood)

Preglednica 3: Pestrost mahovnih vrst na celotnih ploskvah za intenzivni monitoring in ločeno po različnih podlagah (tla, kamen, les)

Location (IM plot) *Lokacija (IM ploskev)*	**CENTRAL PART (sampling area of 400 m²)** *OSREDNJI DEL (popisna površina 400 m²)*	**CENTRAL PART + OUTSIDE THE FENCE (sampling area of 2 × 400 m²)** *OSREDNJI DEL + ZUNAJ OGRAJE (popisna površina 2 × 400 m²)*	**SOIL** *TLA*	**ROCK** *KAMEN*	**WOOD** *LES*
1-KRUCMANOVE KONTE (Pokljuka)	33	/	19	19	19
3-GROPAJSKI BORI (Sežana)	23	/	0	14	15
6-KLADJE (Pohorje)	18	/	6	2	16
7-TEMENJAK (Vinska gora, Dobrna)	31	/	18	18	21
9-GORICA (Draga, Loški potok)	36	/	18	15	24
10-KRAKOVSKI GOZD (Kostanjevica)	26	/	11	0	22
2-FONDEK (Trnovski gozd)	23	26	4	15	17
4-BRDO (Kranj)	11	13	8	0	8
5-BOROVEC (Kočevska Reka)	28	36	16	20	22
8-LONTOVŽ (Kum)	27	33	20	23	19
11-MURSKA ŠUMA (Lendava)	18	24	2	0	23
Min	11	13	0	0	8
Max	36	36	20	23	24
Mean / Povprečje	24,9	26,4	11,1	11,5	18,7

The number of epixylic species is small (12 species or 11 % of all species) owing to the managing activities in all studied forests. Among the dead wood inhabiting bryophyte species, the liverworts are more common than mosses, but most of them occur on one or two IM plots only. More frequently found epixylic species are *Chiloscyphus profundus*, *Lepidozia reptans*, *Blepharostoma trichophyllum* from the liverwort group, and *Plagiothecium nemorale* and *Herzogiella seligeri* from the moss group. On all IM plots, we recorded 15 terricolous species (14 % of all species), the commonest among them being *Polytrichum formosum*, *Fissidens taxifolius* in *Eurhynchium angustirete*. All other terricolous species occur on one or two IM plots.

Only 11 species are characterised as epilithic (10 % of all species), the commonest among them being *Schistidium apocarpum*, *Rhynchostegium murale*, *Anomodon attenuatus* and *Neckera crispa*.

SIMILARITY/DISSIMILARITY OF SPECIES COMPOSITION OF PLOTS

PODOBNOST/RAZLIČNOST V VRSTNI SESTAVI PLOSKEV

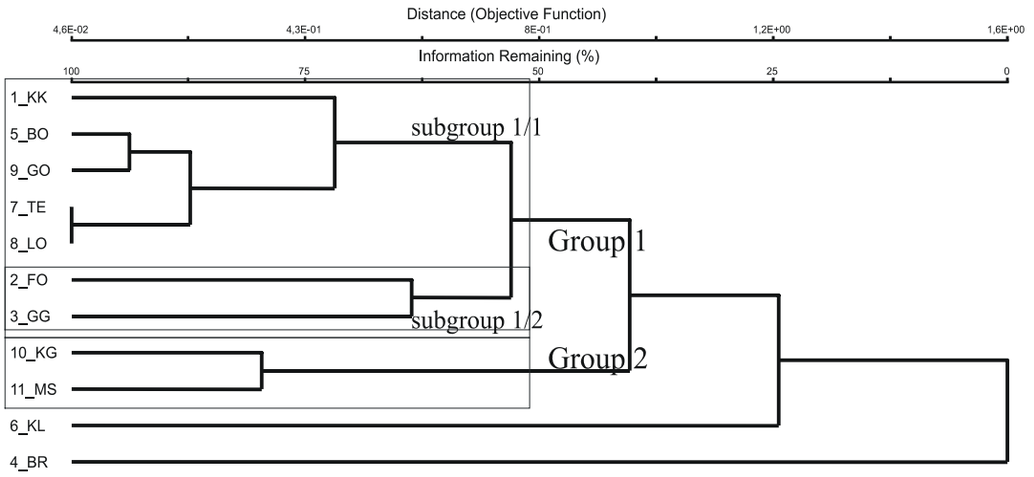
The cluster analysis and DCA ordination (Graphs 1 in 2) perform groups of similar IM plots in respect to bryophytes species composition. Like vascular plant species of IM plots (KUTNAR 2006), the similar bryophytes species composition indicates specific site conditions of certain groups (Graphs 1 in 2). Regarding bryophyte species composition, the similarity/ dissimilarity of IM plots is a result of different influencing factors. One of the most significant factors that control the bryophyte species composition is dominant tree species of forest stands, which (a) influence site condition and (b) represent important substrate for wood inhabiting species (epiphytic, epixylic). Although forest stands modify the different regional climate toward more mesic, somehow unified micro-climate condition of forest ecosystems, the differences among IM plots are significant (see cluster and DCA). The significant impact of regional climate (phytogeographic region) could be observed in the case of beech dominant plots. Bedrock and soil conditions appear to be an important environmental factor for terricolous species directly and for bryophytes inhabiting bottom of the tree-stems and roots indirectly.

Based only on bryophytes species composition, the *Pinus sylvestris* forest (Brdo plot, *Vaccinio myrtilli-Pinetum* var. geogr. *Castanea sativa*) and *Picea abies* forest (Kladje plot, *Avenello flexuosae-Piceetum* var. geogr. *Aposeris foetida*), both on rather acid soil (Dystric Cambisol), are clearly separated from other plots in clustering and ordination analyses (Graphs 1 and 2), which is not only due to specific bryophyte composition of these two plots, but also to low species number per plots. On the Brdo plot, only 13 bryophyte species were recorded. The open pine stands have relatively dry soil and micro-climate conditions, while the bark and wood of pine do not create most favourable conditions for bryophytes. In contrast to other plots, the acidophilic terricolous species are the most important bryophytes of these plots; among these are e.g. *Dicranum spurium, Leucobrym glaucum, Sphagnum subnitens.* The number of epiphyte and epixylic species is small. The separate position of the Brdo plot in cluster and DCA graph (Graphs 1 and 2) is mainly a result of six specific bryophytes occurring on this plot only, e.g. *Dicranum polysetum*, *Pleurozium schreberi*, *Scleropodium purum*, *Hylocomium splendens.*

On the Kladje plot, altogether 18 species were found; 9 of them were liverworts. Almost half of them are epixylic. High share of hygrophytic liverworts species indicate humid air conditions of this site. The following species were found only on the Kladje plot: *Tritomaria execta*, *Cephalozia bicuspidata* and *Calypogeia integristipula*; *Blepharostoma trichophyllum*, *Chiloscyphus profundus*, *Lepidozia reptans*, *Tetraphis pellucida* are more common species on IM plots.

In cluster analysis (Graph 1), all other research sites form two groups (clusters). The first group is larger, and the majority of its plots are located on calcareous bedrock such as limestone and dolomite rocks.

The first group is divided into two different subgroups, the first one (1/1) is mostly characterised by the presence of beech forest. The exception in this subgroup is the Krucmanove konte plot on Pokljuka; the secondary spruce forest (*Aposerido-Piceetum* var. geogr. *Helleborus niger*) grows on potential, natural beech forest sites. On this plot, the influence of carbonate substances of mixed moraine is also very pronounced. More than half of bryophytes found on the Krucmanove konte plot are also common to beech plots from this cluster, with the majority of them being opportunistic species. Surprisingly, a rather small number of liverworts was found on this plot, e.g. epiphyte species *Radula complanata* and *Ptilidium ciliare*; epixylic *Blepharostoma trichophyllum*; opportunistic *Plagiochila porelloides* and *Jungermannia leiantha*. Only on this plot, 9 specific species (mostly

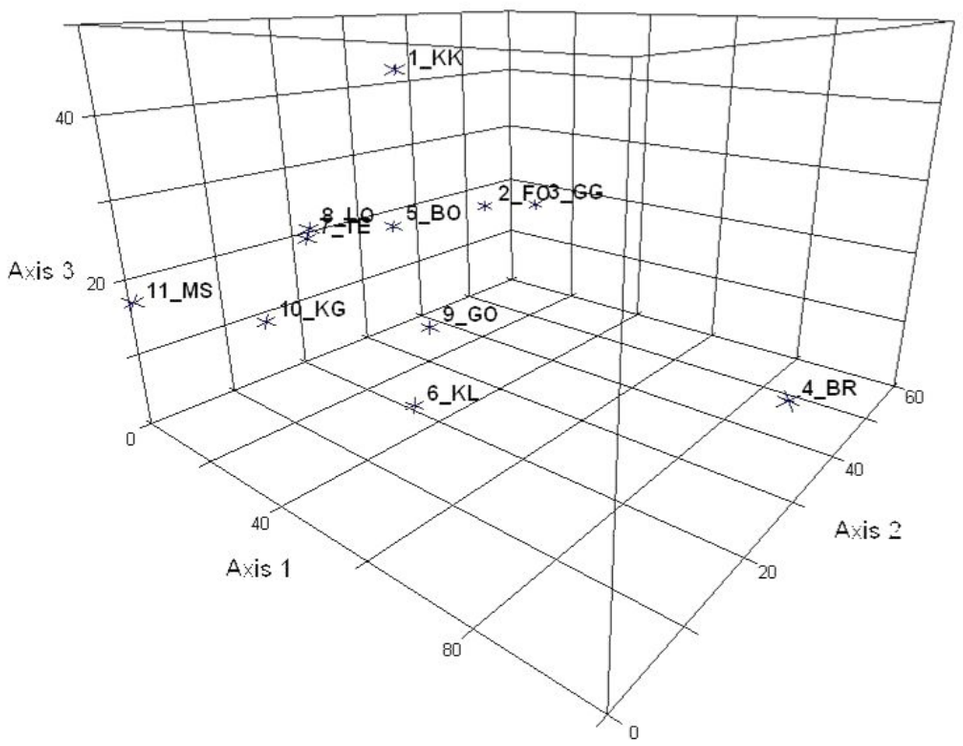


Legende/Legenda:

1_KK: KRUCMANOVE KONTE (Pokljuka); 2_FO: FONDEK (Trnovski gozd); 3_GG: GROPAJSKI BORI (Sežana); 4_BR: BRDO (Kranj); 5_BO: BOROVEC (Kočevska Reka); 6_KL: KLADJE (Osankarica, Pohorje); 7_TE: TEMENJAK (Vinska gora, Dobrna); 8_LO: LONTOVŽ (Kum); 9_GO: GORICA (Draga, Loški potok); 10_KG: KRAKOVSKI GOZD (Kostanjevica na Krki); 11_MS: MURSKA ŠUMA (Lendava)

Graph 1: Clusters of similar IM plots based on bryophytes species composition

Graf. 1: Skupine podobnih ploskev na osnovi sestave mahovne flore



Graph 2: DCA analysis of IM plots based on bryophytes species composition

Graf. 2: DCA analiza na osnovi sestave mahovne flore

opportunistic) were assessed, and among these high elevation and cold climate indicate *Brachythecium starkei*, *Sanionia uncinata*, *Heterocladium dimorphum*, *Rhytidiadelphus loreus*, *Mnium ambiguum*, *Mnium thomsonii*.

The beech sites of this subgroup (1/1) form the two different pairs of IM plots. On these four beech plots, more than 60 species were found, with about one third of liverwort species among these. About 60 % of the species are common to all four plots, with about half of the species of each plot being opportunistic. The shares of other groups, like terricolous, epilithic, epixylic and epiphytic, are more or less even.

It seems that the regional climate has some influence on the species composition and consequently on the cluster grouping (Graph 1). Namely, the Borovec plot and the Gorica plot, both located in the Dinaric phytogeographic region and characterised by similar soil condition of Rendzic Leptosols and Eutric Cambisols on dolomite and limestone, are overgrown with different forest types. The first plot is overgrown with montane beech (*Lamio orvalae-Fagetum* var. geogr. *Dentaria polyphyllos*), the second with fir-beech forest (*Omphalodo-Fagetum* var. geogr. *Calamintha grandiflora*), but they share 58 % of the common species. Between the Temenjak and Lontovž plots, even higher similarity of species composition was observed: around 75 % of the total species composition are common to both plots. These two sites on dolomite bedrock are located in the same region and overgrown by the Prealpine montane beech forests (*Lamio orvalae-Fagetum* var. geogr. *Dentaria pentaphyllos*).

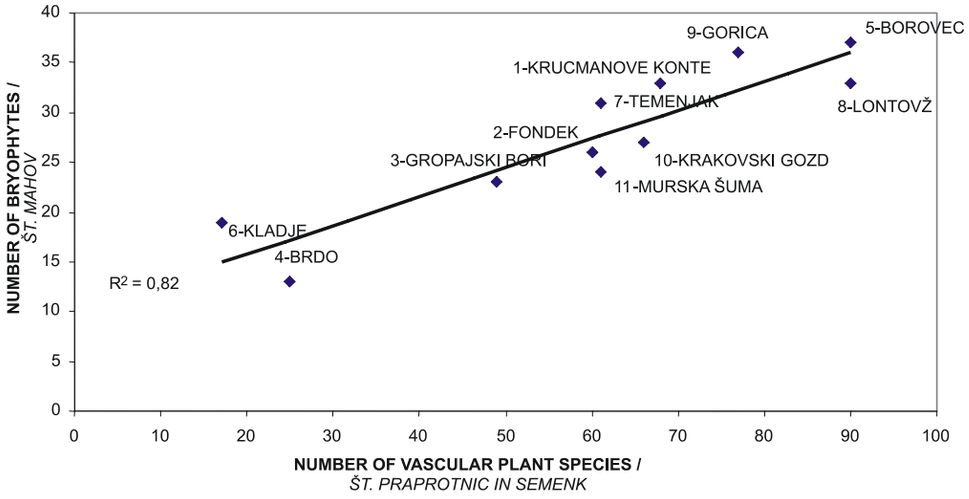
In the second subgroup (1/2), two very different plots are clustered. Both plots are significantly influenced by the (Sub-)Mediterranean climate. The first plot, Fondek, is covered by the Submediterranean beech forest (*Seslerio autumnalis-Fagetum* var. geogr. *Anemone trifolia*), whereas the Gropajski bori plot is covered by the secondary forest of *Pinus nigra* admixed with thermophilous broadleaved trees (*Seslerio autumnalis-Pinetum nigrae*). The common trait of these two sites is predominance of *Sesleria autumnalis* in herb layer. Beside this, high share of plot-surface is covered by limestone rocks. Similar to vascular plants, the bryophytes indicate very warm site conditions by the presence of submediterranean-temperate species *Eurhynchium striatulum* and *Rhynchostegiella tenella*; subatlantic-submediterranean species *Porella arboris-vitae* and *Pterogonium gracile*. The characteristic ecological group of these two plots are epilithic species, for example *Campyliadelphus chrysophyllus*, *Homalia besseri*, *Neckera crispa*, *Pterogonium gracile*; and several opportunistic species, such as *Rhynchostegiella tenella*, *Ctenidium molluscum* and *Homalothecium sericeum* that commonly grow on rock material. Differences in bryophyte composition of these two plots, especially in the number of epiphytes, is due to different dominant trees. Only two epiphytes were found on the Gropajski bori, where *Pinus nigra* dominates, quite an unfavourable substrate for bryophytes. On the Fondek plot with the dominant beech trees, the number of epiphytes is much higher. More than half of bryophytes of both plots are opportunistic species.

In the second group (2), the Murska šuma plot (*Querco roboris-Carpinetum*) and the Krakovski gozd plot (*Pseudostellario europaea-Quercetum roboris*) are overgrown with lowland forests of *Quercus robur* and *Carpinus betulus*. The most numerous bryophyte group is composed of opportunistic species, which represent more than half of the total species composition and indicate more wet soil conditions with significant influence of a high groundwater-table. Among the species inhabiting wood and bark, epiphytes prevail. In the favourable conditions of high air-humidity, as an effect of damp soils, they occur mostly on the bark of oaks and other trees. Among six epiphytes of the Krakovski gozd plot, and nine of the Murska šuma plot, there are *Frullania dilatata*, *Pterigynandrum filiforme*, *Radula complanata* and *Plagiothecium laetum*. It seems that dead wood of pedunculate oak is not very favourable substrate for bryophyte, therefore only a small number of epixylic species, such as *Chiloscyphus coadunatus*, *C. profundus* and *Plagiothecium nemorale*, was recorded. On these two plots, the terricolous species are rare, and due to the lack of rocks on the plot-surface there are no epilithic species. Bryophytes occurring only on the Krakovski gozd plot are *Atrichum tenellum, Plagiomnium elatum* and *Plagiomnium undulatum*, while those occurring only on the Murska šuma plot are *Amblystegium subtile, Leskea polycarpa, Pseudoleskeella nervosa* and *Pylaisia polyantha*.

BRYOPHYTE VS. VASCULAR PLANT SPECIES DIVERSITY

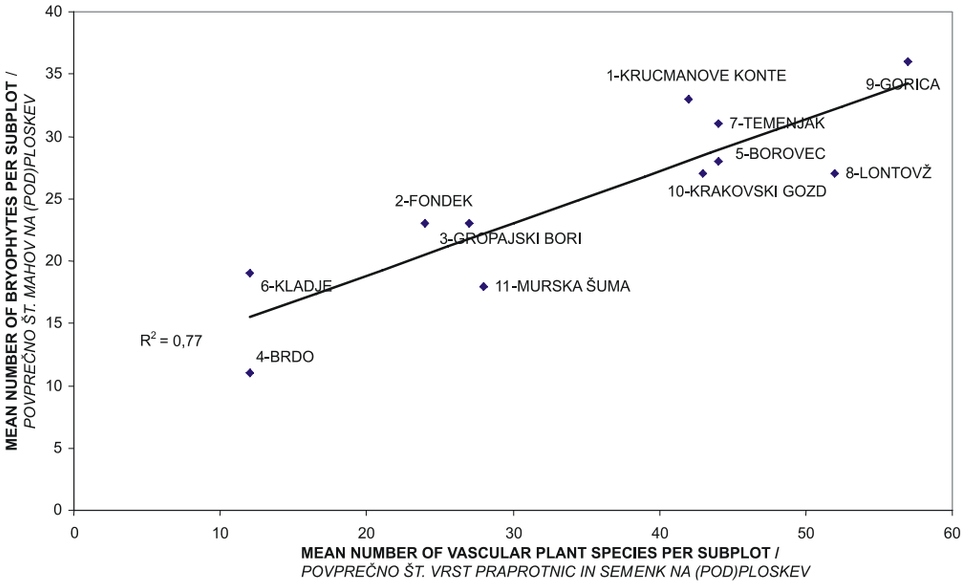
MAHOVNA PESTROST V PRIMERJAVI S PESTROSTJO VASKULARNIH RASTLIN

A positive relationship between the total number of bryophytes and vascular plants (KUTNAR 2006) on IM plots was found (Graph 3). The Borovec plot has the highest number of bryophytes (36) as well as vascular plant species (90). Relatively low numbers of bryophytes and vascular plants



Graph 3: Total number of bryophytes in relation to number of vascular plant species of IM plots

Graf. 3: Celotno število mahovnih vrst v primerjavi s številom višjih rastlin (praprotnic in semenk) IM ploskev



Graph 4: Average number of bryophytes in relation to average number of vascular plant species per sub-plots

Graf. 4: Povprečno število mahovnih vrst v primerjavi s povprečnim številom višjih rastlin (praprotnic in semenk) na (pod)ploskvi

were recorded on the two plots situated on Dystric Cambisols, the Kladje plot (18, 16) and Brdo plot (13, 25). The mean number of bryophytes per sub-plots (10×10m) also increases with the mean number of vascular plants (Graph 4).

CONCLUSIONS
ZAKLJUČKI

The number of mosses (*Bryophyta*) recorded in our study represents 13 % of all species known in Slovenia (632 species, MARTINČIČ 2002), while the number of liverworts (*Marchantiophyta*) is over 17 % of all species known in our country (156 species, MARTINČIČ 2002). Compared to about 9 % of Slovenian vascular plant species assessed on all IM plots (KUTNAR 2006, MARTINČIČ et. al. 2007), a high diversity of bryophytes species was established.

A comparison with the result of other countries involved in the Intensive Monitoring Programme (DOBREMEZ *et al*. 1997, de VRIES *et al.* 2003a, SEIDLING 2005) shows a rather high species diversity of forest ecosystems in Slovenia (KUTNAR 2006). For example, on the 101 IM plots in France, the total number of terricolous species is 71 (DOBREMEZ *et*

al. 1997) in comparison to 62 species growing on soil on 11 IM plots in Slovenia.

The bryophytes species diversity also proved to be a valuable indicator of common ecological conditions. Based only on the bryophytes species composition, it seems that the IM plots were clustered in respects to phytogeographical and ecological/site conditions of the research sites.

SUMMARY
POVZETEK

Z vstopom v EU se je Slovenija vključila tudi v vseevropski Program intenzivnega spremljanja stanja gozdnih ekosistemov oz. Intenzivni monitoring (IM). V Sloveniji izvajamo IM na 11 ploskvah (ČATER *et al*. 2003), ki so bile izbrane na podlagi informacij o gozdnih ekosistemih (klima, geološka podlaga, tla, vegetacija, sestojne razmere) in o potencialnih škodljivih vplivih na gozd (npr. ozon, dušik, težke kovine, suša, poplave). V okviru programa IM spremljamo stanje drevesnih krošenj, stanje tal in talne raztopine, rast dreves, količino in kakovost zračnih usedlin, fenološke spremembe, vsebnost hranil v iglicah in listih drevja. Dodatno se merijo tudi meteorološki parametri, ugotavlja kakovost zraka in popisujejo poškodbe zaradi ozona. Po enotni metodologiji spremljamo tudi stanje in spremembe (pritalne) vegetacije (KUTNAR 2006). Glavni cilj spremljanja vegetacije v okviru IM programa je pridobivanje informacij o spremembah rastlinske vrstne pestrosti (sestave) zaradi naravne dinamike (npr. naravna sukcesija gozda) in motenj (npr. onesnaženje zraka, klimatske spremembe).

V prvi fazi IM smo analizirali tudi mahovno floro, saj je Slovenija ena izmed držav z relativno bogato mahovno floro (MARTINČIČ 2002, 2003). Namen raziskave je bilo vrednotenje vrstne pestrosti mahovne flore na IM ploskvah v Sloveniji ter analiza pojavljanja vrst na različnih rastiščih in substratih. Raziskava pestrosti mahovne flore je potekala na 11 IM ploskvah (slika 1), od katerih je pet bolj intenzivnih (ograjenih). Mahove smo determinirali na 4 vegetacijskih (pod)ploskvah (velikost ploskev 10×10 m, popisna površina 400 m^2) v osrednjem delu vseh 11 IM ploskev (slika 2). Na bolj intenzivnih ploskvah smo dodali 4 primerjalne (pod)ploskve zunaj ograde, tako da je bila celotna popisna površina 800 m^2. Na vseh 64 (pod)ploskvah smo mahove popisali ločeno po 3 različnih substratih: a) na tleh (mahovi rastoči na razvitih tleh), b) na lesnati substanci (mahovi na odmrlih deblih, vejah, panjih in na skorji živih dreves), c) na kamnu (mahovi na kamnih in skalah različnih dimenzij). Na osnovi predhodnih raziskav (npr. MARTINČIČ 2002, 2003) in literature (DIERSSEN 2001, ÓDOR / van DORT 2002) smo opredelili vezanost vrst na rastni substrat na naslednji način: O – oportunistična vrsta (ni razvidna vezanost na določeno podlago in se pojavlja na različnih); WE – epifitna vrsta (pojavlja se predvsem na skorji dreves); WX – epiksilna vrsta (pojavlja se na različno razgrajenem, odmrlem lesu); lignikolna vrsta (W, pojavlja se na živem in odmrlem lesu), R – epilitna vrsta (pojavlja se predvsem na skalah, kamnih); S – terikolna, talna vrsta (pojavlja se predvsem na mineralnih tleh). Obravnavali smo različne skupine mahov, *Bryophyta* (listnati mahovi), *Anthocerotophyta* (rogačarji) in *Marchantiophyta* (jetrenjaki). Kot nomenklaturni vir smo uporabili MARTINČIČ (2003) za listnate mahove (akrokarpi in pleurokarpi) in SCHUMACKER / VÁŇA (2005) za rogačarje in jetrenjake (hepatike).

S programskim paketom Microsoft Office Excel 2003 smo opravili osnovne statistične analize vrstne pestrosti, s paketom PC-ORD program (McCUNE / MEFFORD 1999, 2006) pa klastrsko analizo in DCA-ordinacijo ploskev.

Na vseh 64 vegetacijskih (pod)ploskvah na 11 IM ploskvah smo skupaj popisali 109 vrst mahov (preglednica 2, priloga), od tega je bilo je bilo 82 listnatih mahov in 27 jetrenjakov (med hepatikami nismo našli nobene vrste rogačarja). Od vseh mahov se jih le 23 % pojavlja na vseh treh različnih substratih, 33 % na dveh različnih in kar 44 % samo na enem substratu.

Na popisni površini 400 m^2 v osrednjem delu IM ploskev smo v povprečju našli 25 različnih vrst mahov. Na vseh 11 ploskvah (ograjene in neograjene z različno popisno površino) smo popisali od 13 do 36 različnih vrst in povprečno 27 vrst na ploskev (preglednica 3). Najpogosteje evidentirana vrsta je bila *Hypnum cupressiforme* (glej prilogo), ki se pojavlja na 10 IM ploskvah. Druge zelo razširjene vrste so *Brachythecium velutinum* (na 9 IM ploskvah) in *Radula complanata* (9), *Polytrichum formosum* (8) in *Chiloscyphus profundus* (8), *Ctenidium molluscum, Tortella tortuosa, Isothecium alopecuroides, Dicranum scoparium* in *Plagiochila porelloides* (vsi na 7 ploskvah).

Tudi če upoštevamo vse tri različne podlage in vseh 64 (pod)ploskev, je vrsta *Hypnum cupressiforme* najpogostejša. Ta vrsta je bila najdena v 71 primerih (potencialno maksimalno število je 192). Druge vrste z večjo frekvenco pojavljanja so: *Ctenidium molluscum* in *Radula complanata* (oba popisana 50-krat), *Tortella tortuosa* (45), *Isothecium alopecuroides*

(38), *Dicranum scoparium* (33), *Fissidens taxifolius* (33), *Brachythecium velutinum* (32) in *Plagiochila porelloides* (32).

Med vrstami mahov prevladujejo oportunistične vrste (47 % vseh vrst), ki predstavljajo približno polovico vseh vrst na posamezni IM ploskvi. Drugo največjo skupino sestavljajo vrste, ki rastejo na lesnih substratih. Poleg nekaj lignikolnih vrst, ki uspevajo tako na živem kot odmrlem lesu, smo popisali tudi 14 epifitnih vrst (13 % vseh vrst) in 12 epiksilnih vrst (11 %). Vrst, ki rastejo pretežno na mineralnih tleh z različno vsebnostjo organskih snovi (terikolne), je bilo 15 (14 %). Najmanjšo skupino sestavljajo epilitne vrste (10 %).

Klastrska analiza in DCA-ordinacija IM ploskev je združila ploskve z največjo vrstno podobnostjo mahov. Tako kot višje rastline (KUTNAR 2006) tudi podobna sestava mahovne flore kaže na podobnost v rastiščnih in sestojnih razmerah. Vrstna sestava mahov je rezultat različnih dejavnikov, med njimi je zelo pomemben vpliv prevladujoče drevesne vrste v sestoju, ki vpliva tako na rastiščne razmere in hkrati predstavlja tudi rastni substrat za mahove (epifitne in epiksilne vrste). Predvsem na primeru bukovih gozdov se kažejo tudi določeni vplivi regionalnega podnebja na vrstno sestavo. Poleg tega pa so razlike oz. podobnosti med sestavo vrst odvisne tudi od geološke matične podlage in talnih razmer.

Samo na osnovi vrstne sestave mahov sta se jasno oddvojili ploskvi Brdo in Kladje, za kateri so značilna distrična tla (grafikona 1 in 2). Skupna značilnost ploskev, od katerih je prva poraščena pretežno z gozdom rdečega bora, druga pa s smrekovim gozdom, je specifična vrstna sestava in majhno število mahovnih vrst. V razmeroma odprtem sestoju rdečega bora na ploskvi Brdo, kjer so tla in mikroklima razmeroma sušna, smo popisali le 13 mahovnih vrst. Na število mahov negativno vplivajo tudi drevesa oz. les rdečega bora, ki ni ugodna rastna podlaga za uspevanje mahov. Vrste, ki smo jih zabeležili samo na tej ploskvi, so *Dicranum polysetum*, *Pleurozium schreberi*, *Scleropodium purum*, *Hylocomium splendens* in acidofilni terikolni vrsti *Sphagnum subnitens* in *Dicranum spurium*. Med 18 vrstami, popisanimi na ploskvi Kladje na Pohorju, je kar 8 jetrenjakov, kar kaže na visoko zračno vlago na tej ploskvi. Vrste, ki smo jih popisali samo na tej ploskvi, so *Tritomaria execta*, *Cephalozia bicuspidata* in *Calypogeia integristipula*.

Vse druge IM ploskve so uvrščene v dve skupini (grafikon 1). Večina ploskev prve, večje skupine leži na karbonatni podlagi (apnenec, dolomit). Naprej se skupina deli na dve podskupini. Prva podskupina (1/1) vključuje različne tipe bukovih gozdov, izjema med njimi je le ploskev Krucmanove konte na Pokljuki. Na potencialno rastišče bukovega gozda nakazujejo različni fagetalni elementi, ki se na tej ploskvi pojavljajo skupaj z vrstami sekundarnega smrekovega gozda. Več kot polovica vseh mahov, ki smo jih popisali na ploskvi Krucmanove konte, se pojavljajo tudi na drugih ploskvah iz te podskupine, ki pa so poraščene z bukovim gozdom. Na ploskvi smo popisali razmeroma majhno število jetrenjakov, kot so epifita *Radula complanata* in *Ptilidium ciliare*, epiksilna vrsta *Blepharostoma trichophyllum* ter oportunistični vrsti *Plagiochila porelloides* in *Jungermannia leiantha*. Med vrstami, ki nakazujejo višje nadmorske višine in hladnejše razmere, so *Brachythecium starkei*, *Sanionia uncinata*, *Heterocladium dimorphum*, *Rhytidiadelphus loreus*, *Mnium ambiguum*, *Mnium thomsonii*.

Druge ploskve pa tvorijo po dva para, v prvem sta ploskvi Borovec in Gorica, v drugem pa ploskvi Temenjak in Lontovž. Na teh štirih IM ploskvah smo determinirali več kot 60 različnih vrst mahov, med temi je bila približno tretjina jetrenjakov. Okoli 60 % vrst je skupnih vsem štirim ploskvam bukve in približno polovico vrst na vsaki ploskvi je oportunističnih. Kot kaže, se regionalni klimatski vpliv odraža tudi na vrstni sestavi in posledično tudi na združevanju skupin v klastrski analizi. Ploskvi Borovec s preddinarskim gorskim bukovim gozdom in Gorica z dinarskim jelovo-bukovim gozdom, ki ležita v dinarskem območju v podobnih talnih razmerah, imata velik delež (58 %) skupnih mahovnih vrst. Še bolj pa sta si po vrstni sestavi mahov podobni ploskvi Temenjak in Lontovž, ki ju porašča predalpski gorski bukov gozd na dolomitni matični podlagi, saj smo na teh dveh ploskvah ugotovili kar okoli tri četrtine skupnih vrst.

V drugi podskupini (1/2) sta precej različni ploskvi: Fondek, ki je poraščen s primorskim bukovim gozdom, in ploskev Gropajski bori z gozdom črnega bora s primešanimi termofilnimi listavci. Poleg večje skalnatosti ploskev je njuna skupna značilnost tudi izrazitejši vpliv toplejše (mediteranske) klime, ki se deloma kaže tudi v prevladovanju jesenske vilovine v zeliščni plasti obeh ploskev. Tako kot ostala flora tudi mahovi kažejo na toplejšo klimo, med njimi sta predvsem submediteransko-temperatni vrsti *Eurhynchium striatulum* in *Rhynchostegiella tenella* ter subatlantsko-submediteranski vrsti *Porella arboris-vitae* in *Pterogonium gracile*. Značilno ekološko skupino predstavljajo epilitske vrste *Campyliadelphus chrysophyllus*, *Homalia besseri*, *Neckera crispa*, *Pterogonium gracile* ter oportunistične vrste *Rhynchostegiella tenella*, *Ctenidium molluscum* in

Homalothecium sericeum, ki navadno rastejo na skalnati podlagi. Število epifitskih vrst je zaradi prevladujoče bukve na ploskvi Fondek večje kot na rastno bolj neugodnih črnih borih na ploskvi Gropajski bori.

V drugi glavni skupini (2) sta ploskvi Murska šuma in Krakovski gozd. Zanju je značilno pojavljanje nižinskega gozda doba in belega gabra na tleh, ki so pod izrazitim vplivom visoke podtalnice, kar se kaže tudi v sestavi mahovne flore. Več kot polovica vrst sicer predstavljajo oportunistične vrste, močno pa je zastopana tudi skupina epifitov. V razmerah visoke zračne in talne vlažnosti naseljujejo predvsem razpokano skorjo na deblih doba in drugih drevesnih vrst. Med epifitskimi vrstami teh ploskev so na primer *Frullania dilatata*, *Pterigynandrum filiforme*, *Radula complanata*, *Plagiothecium laetum*. Vrste, ki se pojavljajo samo na ploskvi Krakovski gozd, so *Atrichum tenellum, Plagiomnium elatum* in *Plagiomnium undulatum*, samo na ploskvi Murska šuma pa smo popisali vrste *Amblystegium subtile, Leskea polycarpa, Pseudoleskeella nervosa* in *Pylaisia polyantha*.

Klastrska analiza in DCA ordinacija sta potrdili, da so tudi mahovi dober indikator splošnih okoljskih razmer, saj skupine ploskev na osnovi podobnosti vrstne sestave mahov odsevajo tudi določene rastiščne posebnosti in fitogeografski položaj ploskev.

Na IM ploskvah smo ugotovili pozitivno korelacijo med številom višjih rastlin (KUTNAR 2006) in številom mahov (grafikona 3 in 4). Na ploskvi Borovec smo našli največje število mahov (36) in prav tako višjih rastlin (90).

Na IM ploskvah smo evidentirali 13 % vseh listnatih mahov in 17 % vseh jetrenjakov v Sloveniji (MARTINČIČ 2002), kar je razmeroma veliko v primerjavi z 9 % višjih rastlin (KUTNAR 2006, MARTINČIČ et. al. 2007). Tudi primerjava z drugimi državami, vključenimi v Program intenzivnega spremljanja stanja gozdnih ekosistemov (DOBREMEZ *et al*. 1997, de VRIES *et al*. 2003a, SEIDLING 2005), dokazuje veliko pestrost naših gozdov (KUTNAR 2006). Na 101 IM ploskvah v Franciji (DOBREMEZ *et al*. 1997) so popisali 71 terikolnih vrst mahov (na tleh rastočih), medtem ko smo na 11 IM ploskvah v Sloveniji zabeležili 62 takih vrst.

ACKNOWLEDGEMENT
ZAHVALA

The study was performed as part of the Intensive Monitoring Programme in Slovenia (Forest Focus) and was financially supported by the Ministry of Agriculture, Forestry and Food and, partly, by the Slovenian Research Agency (Forest Biology, Ecology and Technology Research Programme P4-0107). We wish to thank all collaborators from the Slovenian Forestry Institute for their field and technical assistance. Thanks are also due to reviewers whose criticism has considerably improved an earlier version of the manuscript.

REFERENCES
VIRI

ČATER, M. / HOČEVAR, M. / KALAN, P. / KOVAČ, M. / KUTNAR, L. / MAVSAR, R. / SIMONČIČ, P. / SMOLEJ, I. / URBANČIČ, M. / VEL, E., 2003. Intensive monitoring programme in Slovenia (IMP-SI): basic structural document: project document.- Ljubljana: Slovenian Forestry Institute; Wageningen: Alterra, 68 pp.

DE VRIES, W. / REINDS, G. J. / POSCH, M. / SANZ, M. J. / KRAUSE, G. H. M. / CALATAYUD, V. / RENAUD, J. P. / DUPOUEY J. L. / STERBA, H. / VEL, E. M. / DOBBERTIN, M. / GUNDERSEN, P. / VOOGD J. C. H., 2003a. Intensive Monitoring of Forest Ecosystems in Europe. Technical Report 2003.- UN/ECE EC, Brussels, Geneva, 161 pp.

DE VRIES, W. / VEL, E. / REINDS, G. J. / DEELSTRA, H. / KLAP, J. M. / LEETERS, E. E. J. M. / HENDRIKS, C. M. A. / KERKVOORDEN, M. / LANDMANN, G./ HERKENDELL, J. / HAUSSMANN, T. / ERISMAN, J. W., 2003b. Intensive monitoring of forest ecosystems in Europe - 1. Objectives, set-up and evaluation strategy.- Forest Ecology and Management 174, 1-3: 77-95.

DOBREMEZ, J. F. / CAMARET, S. / BOURJOT, L. / ULRICH, E. / BRÊTHES, A. / COQUILLARD, P. / DUMÉ, G. / DUPOUEY, J. L. / FORGEARD, F. / GAUBERVILLE, C. / GUEUGNOT, J. / PICARD, J. F. / SAVOIE, J. M. / SCHMITT, A. / TIMBAL, J. / TOUFFET, J. / TRÉMOLIÈRES. M., 1997. RENECOFOR - Inventaire et interprétation de la composition floristique de 101 peuplements du réseau (Campagne 1994/95). Département des Recherches Techniques, Office National Forêts, Fontainebleau, Université de Savoie, 513 pp.

DIERSSEN, K., 2001. Distribution, ecological amplitude and phytosociological characterization of European bryophtes.- Bryophytorum Bibliotheca, Berlin, Stuttgart, Band 56, 289 pp.

HILL, M. O. / GAUCH, H. G., 1980. Detrended correspondence analysis: an improved ordination technique.- Vegetatio 42: 47-58.

ICP Ground Vegetation, 2002. MANUAL on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests - Part VIII: Assesment of ground vegetation. International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, 19 pp. http://www.icp-forests.org/pdf/manual8.pdf

KUTNAR, L, 2006. Intenzivni monitoring vegetacije gozdnih ekosistemov v Sloveniji = Intensive monitoring of vegetation of forest ecosystems in Slovenia.- In: HLADNIK, D. (ed.). Monitoring gospodarjenja z gozdom in gozdnato krajino, Studia forestalia Slovenica,). Ljubljana: Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, 127: 277-290

MARTINČIČ A., 2002: Mahovi.- V: HLAD, B. / SKOBERNE, P. (eds.): Pregled stanja biotske raznovrstnosti in krajinske pestrosti v Sloveniji. MOP, Agencija RS za okolje, Ljubljana, pp. 67-68.

MARTINČIČ, A., 2003. Seznam listnatih mahov (*Bryopsida*) Slovenije.- Hacquetia 2, 1: 91-166.

MARTINČIČ, A. / WRABER, T. / JOGAN, N. / PODOBNIK, A. / TURK, B. / VREŠ, B. / RAVNIK, V. / FRAJMAN, B. / STRGULC KRAJŠEK, S. / TRČAK, B. / BAČIČ, T. / FISCHER, M. A. / ELER, K. / SURUINA, B., 2007. Mala flora Slovenije.- Tehniška založba Slovenije, Ljubljana, 967 pp.

McCUNE, B. / MEFFORD, M. J., 1999. PC-ORD: Multivariate Analysis of Ecological Data, Version 3.0.- MjM Software Design, Gleneden Beach, Oregon, USA, 237 pp.

McCUNE, B. / MEFFORD. M. J., 2006. PC-ORD: Multivariate Analysis of Ecological Data. Version 5.10.- MjM Software, Gleneden Beach, Oregon, USA.

ÓDOR, P. / van DORT, K., 2002. Beech dead wood inhabiting bryophyte vegetation in two Slowenian forest reserves. Zb. gozd. lesar., 69: 155-169.

PETRICCIONE, B., 2002. Survey and assessment of vegetation in the CONECOFOR permanent plots.- V: MOSELLO, R. / PETRICCIONE, B. / MARCHETTO A. (eds.). Long-term ecological research in Italian forests ecosystems. Journal of Limnology 61, Suppl.1: 19-24.

ROBIČ, D. / ACCETTO, M., 2001. Pregled sintaksonomskega sistema gozdnega in obgozdnega rastlinja Slovenije.- Ljubljana, Oddelek za gozdarstvo in obnovljive gozdne vire Biotehniške fakultete, tipkopis, 18 pp.

SCHUMACKER, R. / VÁŇA, J., 2005. Identification keys to the liverworts and hornworts of Europe and Macaronesia (Distribution and status).- Sec. Ed. Sorus. Poznań, 209 pp.

SEIDLING, W., 2005. Ground floor vegetation assessment within the intensive (Level II) monitoring of forest ecosystems in Germany: chances and challenges.- European Journal of Forest Research 124: 301-312.

APPENDIX. Occurrences of bryophyte species (B - *Bryophyta* division; M - *Marchantiophyta* division - liverworts) on intensive monitoring plots in Slovenia, and on different substrata (s - soil, r - rock, w - wood). The characterisation of species by the substrate preferences (Sub) are following: O - opportunistic; WE - epiphyte; WX - epixylic; W- lignicolous; R - epilithic; S - terricollous.

PRILOGA. Pojavljanje mahovnih vrst (B – deblo *Bryophyta*, M - deblo *Marchantiophyta* – jetrenjaki) na ploskvah za intenzivni monitoring in po različnih podlagah (s - tla, r - kamen, w - les). Oznaka vrst glede vezanosti na rastni substrat je sledeča: O - oportunistična vrsta; WE - epifitna vrsta; WX - epiksilna vrsta; W- lignikolna vrsta; R - epilitna vrsta; S - terikolna, talna vrsta.

				3_GG	**2_FO**	**5_BO**	**7_TE**	**8_LO**	**9_GO**	**1_KK**	**6_KL**	**4_BR**	**10_KG**	**11_MŠ**		
				3-GROPAJSKI BORI	**2-FONDEK**	**5-BOROVEC**	**7-TEMENJAK**	**8-LONTOVŽ**	**9-GORICA**	**1-KRUCMANOVE KONTE**	**6-KLADJE**	**4-BRDO**	**10-KRAKOVSKI GOZD**	**11-MURSKA ŠUMA**		
				Pinus nigra	***Fagus sylvatica***	***Fagus sylvatica***	***Fagus sylvatica***	***Fagus sylvatica***	***Fagus sylvatica, Abies alba***	***Picea abies***	***Picea abies***	***Pinus sylvestris***	***Quercus robur, Carpinus betulus***	***Quercus robur, Carpinus betulus***	**N OF PLOTS** ***N ploskev***	**OCCURRENCES OF FREKVENCA POJAVLJANJA po podploskvaM in substratih**
1	Hypnum cupressiforme Hedw.	B	O	w	s, w	s, r, w	s, r, w	r, w	s, r, w	r, w		s, w	s, w	w	10	71
2	Radula complanata (L.) Dum.	M	WE	r, w	r, w	w	s, r, w	s, r, w	w	r			w	w	9	50
3	Brachythecium velutinum (Hedw.) B., S. & G.	B	O	r	w	s, w	s, r, w	s, r, w	s, r, w	s, r, w	w			w	9	32
4	Chiloscyphus profundus (Nees) J.J. Engel & R.M. Schuster	M	WX			s, w	w	s, w	r, w		w	w	w	w	8	24
5	Polytrichum formosum Hedw.	B	S		s, w	s, w	s	s	s	s, w	s, w	s			8	23
6	Ctenidium molluscum (Hedw.) Mitt.	B	O	r, w	r, w	s, r, w	s, r	s, r, w	r	s, r, w					7	50
7	Tortella tortuosa (Hedw.) Limpr.	B	O	r	s, r	r, w	s, r	s, r, w	s, r	s, r					7	45
8	Isothecium alopecuroides (Dubois) Isov.	B	O			r, w	s, r, w	s, r	s, r, w	r			w	w	7	38
9	Dicranum scoparium Hedw.	B	O	w		s, r, w	s, w	s, w	s, w	s, r, w	s, w				7	33
10	Plagiochila porelloides (Nees) Lindenb.	M	O			s, r	s, r, w	s, r, w	w	s, r, w	w		w		7	32
11	Fissidens taxifolius Hedw.	B	S				s, r, w	s, r, w	s, r	s, r			s	s	6	33
12	Fissidens dubius P. Beauv.	B	O	r, w		s, r, w	r	s, r, w	r, w	s, r					6	28
13	Plagiothecium laetum B., S. & G.	B	WE			s	s, w	s, w		w	s, w			w	6	28
14	Metzgeria furcata (L.) Dumort.	M	WE		w	s, r, w	w	w	w					w	6	25
15	Schistidium apocarpum (Hedw.) B. & S.	B	R	r	r	r	r	r		r					6	18
16	Brachythecium campestre (C. Muell.) B., S. & G.	B	O	w	w	s, w			s, r				s, w	s, w	6	14
17	Eurhynchium angustirete (Broth.) T. Kop.	B	S			r, w	s, w	s, r	r, w	w	w				6	14
18	Metzgeria conjugata Lindb.	M	O			w	s, r, w	s, r, w	s, w					w	5	27
19	Neckera complanata (Hedw.) Hueb.	B	O	r, w	r, w	r			w				w		5	17
20	Plagiothecium nemorale (Mitt.) Jaeg.	B	WX		w	s, w		s, w					w	w	5	16
21	Pterigynandrum filiforme Hedw.	B	WE			w	r, w	r, w	w				w		5	16
22	Rhynchostegium murale (Hedw.) B., S. & G.	B	R			r	r	r	s, r	r					5	15
23	Bryum Hedw. sp.	B	-	w			r	s, r, w	s, r	s					5	12
24	Frullania dilatata (L.) Dumort.	M	WE	w	w	w	s, w						w		5	12
25	Brachythecium populeum (Hedw.) B., S. & G.	B	O			s, r		r					s, w	w	4	14
26	Neckera crispa Hedw.	B	R	r	r	r			s						4	12
27	Herzogiella seligeri (Brid.) Iwats.	B	WX		s, w				w	s, w	w				4	11
28	Anomodon attenuatus (Hedw.) Hueben.	B	R		r	r							s, w	w	4	8
29	Homalothecium sericeum (Hedw.) B., S. & G.	B	O	r	r	r, w							w		4	7

30	Brachythecium rutabulum (Hedw.) B., S. & G.	B	O		w								s, w	w	3	10
31	Plagiothecium denticulatum (Hedw.) B., S. & G.	B	W				w	s, w						w	3	10
32	Anomodon viticulosus (Hedw.) Hook. & Tayl.	B	O		r, w								w	w	3	8
33	Blepharostoma trichophyllum (L.) Dumort.	M	WX						w	w	w				3	8
34	Dicranum montanum Hedw.	B	WE						s			w	w		3	8
35	Amblystegium confervoides Brid.	B	R	r			r	r							3	5
36	Jungermannia leiantha Grolle	M	O			w	w			s, w					3	3
37	Thuidium delicatulum (Hedw.) Mitt.	B	O				s, w						s	w	3	4
38	Brachythecium salebrosum (Web. & Mohr) B., S. & G.	B	O							s	w			w	3	3
39	Chiloscyphus coadunatus (Sw.) J.J. Engel & R.M. Schust.	M	WX	w			w						w		3	3
40	Homalothecium philippeanum (Spruce) B., S. & G.	B	O	r, w	r, w										2	13
41	Eurhynchium striatulum (Spruce) B., S. & G.	B	O		r, w	s									2	11
42	Homalia trichomanoides (Hedw.) B., S. & G.	B	WE										w	w	2	11
43	Lepidozia reptans (L.) Dumort.	M	WX						w		s, w				2	9
44	Bazzania trilobata (L.) S. F. Gray	M	O						s, w		s, w				2	8
45	Plagiomnium cuspidatum (Hedw.) T. Kop.	B	O										s, w	w	2	8
46	Porella platyphylla (L.) Pfeiff.	M	O	r	r										2	8
47	Campylophyllum halleri (Hedw.) Fleisch.	B	R					r		s, r					2	7
48	Dicranella heteromalla (Hedw.) Schimp.	B	O				s	s, w							2	6
49	Tetraphis pellucida Hedw.	B	WX						w		w				2	6
50	Plagiothecium undulatum (Hedw.) B., S. & G.	B	O							s, w	s, w				2	5
51	Ptilidium ciliare (L.)Hampe	M	WE							w		w			2	4
52	Ulota crispa (Hedw.) Brid.	B	WE						w				w		2	4
53	Calypogeia azurea Stotler & Crotz	M	O			s					r				2	3
54	Eurhynchium hians (Hedw.) Sande Lac.	B	S				s, r	r							2	3
55	Leucobryum glaucum (Hedw.) Aongstr.	B	S	w								w			2	3
56	Rhynchostegiella tenella (Dicks.) Limpr.	B	O	r, w				w							2	3
57	Thuidium recognitum (Hedw.) Lindb.	B	O			r							w		2	3
58	Atrichum undulatum (Hedw.) P. Beauv.	B	S			s			s						2	2
59	Eurhynchium schleicheri (Hedw. F.) Jur.	B	O				w		s						2	2
60	Mnium marginatum (Dicks.) P. Beauv.	B	O						r	r					2	2
61	Mnium stellare Hedw.	B	O		r			r							2	2
62	Nowellia curvifolia (Dicks.) Mitt.	M	WX						w			w			2	2
63	Dicranum polysetum Sw.	B	S									s, w			1	8
64	Heterocladium dimorphum (Brid.) B., S. & G.	B	O							s, r, w					1	8
65	Pleurozium schreberi (Brid.) Mitt.	B	O									s, w			1	8
66	Lejeunea cavifolia (Ehrh.) Lindb.	M	O				s, r, w								1	6
67	Rhytidiadelphus loreus (Hedw.) Warnst.	B	O							s, w					1	6
68	Thuidium tamariscinum (Hedw.) B., S. & G.	B	O						s, r, w						1	4
69	Brachythecium starkei (Brid.) B., S. & G.	B	O							s, w					1	3
70	Campylium stellatum var. protensum (Brid.) Bryhn ex Grout	B	O							s, r, w					1	3
71	Rhizomnium punctatum (Hedw.) T. Kop.	B	O						s, r, w						1	3
72	Scapania aspera M. & H. Bern.	M	R			r									1	3
73	Amblystegium subtile (Hedw.) B., S. & G.	B	W											w	1	2
74	Apometzgeria pubescens (Schrank) Kuwah.	M	O					r							1	2
75	Atrichum tenellum (Roehl.) B. & S.	B	S										s		1	2
76	Cirriphyllum tommasinii (Sendtn. ex Boul.) Grout	B	O				r, w								1	2
77	Dicranum spurium Hedw.	B	S									s			1	2
78	Homalia besseri Lob.	B	R	r											1	2
79	Pedinophyllum interruptum (Nees) Kaal.	M	O					s, r							1	2
80	Plagiothecium cavifolium (Brid.) Iwats.	B	S					s							1	2
81	Sanionia uncinata (Hedw.) Loeske	B	O							r, w					1	2
82	Scleropodium purum (Hedw.) Limpr.	B	S									s			1	2
83	Tritomaria exsecta (Schmidel) Loeske	M	WX								w				1	2

84	Brachythecium B., S. & G. sp.	B	-	w											1	1
85	Calypogeia integristipula Steph. Steph. Steph. Steph.	M	WX								w				1	1
86	Campyliadelphus chrysophyllus (Brid.) Kanda	B	R	r											1	1
87	Cephalozia bicuspidata Dumort.	M	R								r				1	1
88	Chiloscyphus polyanthos (L.) Corda incl. var. pallescens (Ehrh. ex Hoffm.) C.Hartm.	M	WX			w									1	1
89	Encalypta streptocarpa Hedw.	B	O			r									1	1
90	Hylocomium splendens (Hedw.) B., S. & G.	B	O									s			1	1
91	Hypnum pratense (Rabenh.) W. Koch ex Hartm.	B	S							r					1	1
92	Leskea polycarpa Hedw.	B	WE											w	1	1
93	Mnium ambiguum H. Muell.	B	O							w					1	1
94	Mnium thomsonii Schimp.	B	O							s					1	1
95	Odontoschisma denundatum (Mart.) Dum.	M	WX						w						1	1
96	Orthotrichum lyellii Hook. & Tayl.	B	WE		w										1	1
97	Plagiomnium elatum (B. & S.) T. Kop.	B	S										s		1	1
98	Plagiomnium rostratum (Schrad.) T. Kop.	B	O			r									1	1
99	Plagiomnium undulatum (Hedw.) T. Kop.	B	O										s		1	1
100	Porella arboris-vitae (With.) Grolle	M	O		r										1	1
101	Porella cordaeana (Huebener) Moore	M	WE		w										1	1
102	Pseudoleskeella nervosa (Brid.) Nyh. var. laxifolia	B	WE											w	1	1
103	Pterogonium gracile (Hedw.) Sm.	B	R		r										1	1
104	Pylaisia polyantha (Hedw.) Schimp.	B	WE											w	1	1
105	Rhodobryum roseum (Hedw.) Limpr.	B	S							r					1	1
106	Rhynchostegium confertum (Dicks.) B., S. & G.	B	O			w									1	1
107	Riccardia chamaedryfolia (With.) Grolle	M	W						w						1	1
108	Schistidium Brid.sp.	B	-					r							1	1
109	Sphagnum subnitens Russ. ex Warnst.	B	S									s			1	1