Ecology and palaeoecology of spring fens of the West Carpathians

Edited by
A. Poulíčková, M. Hájek & K. Rybníček

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Preface

Springs and spring fens belong to the most threatened biotopes of all Europe. Their extinction has been accelerated by increasing human influences such as drainages, eutrophication and changes in agricultural practices especially in the last 50 - 60 years. Thus there is a real danger that our natural spring areas may disappear from the landscapes in the near future. They would be lost for mankind generally and in particular for science. This possibility was the very motivation for our project to describe plant and animal life in springs, i.e. the communities of all biota as well as their habitats, and to understand their mutual interactions as far as possible. Last but not least, we tried to study the origins of spring ecosystems and their development in the upper Holocene. Using palaeogeobotanical methods, we hoped to contribute to a better evaluation of all the above mentioned ecological investigations.

Because of comparatively good preservation of numerous spring and fen sites in the northwestern parts of the West Carpathians, we selected this very region for our studies. The region's geology provides, in addition, a very good opportunity for the comparison of two major and contrasting types of spring and fen ecosystems, namely the basiphilous and the acidophilous ones.

Several specialists from four institutions joined their powers to fulfill these aims. Investigation of vegetation, i.e. flora of vascular plants and bryophytes, as well as monitoring of habitat conditions, were the research tasks for the team of the Department of Botany, Masaryk University in Brno (leading researcher Michal Hájek). Experts from the Department of Zoology of the same university studied the most important invertebrates. Algological studies and chemical analyses of spring waters, soils, and plant biomass were provided by the Departments of Botany and Ecology, Palacký University in Olomouc (leading researcher Aloisie Poulíčková). Palaeoecological investigations were carried out by the Palaeoecological Subdepartment of the Institute of Botany, Academy of Sciences in Brno (leading researcher Kamil Rybníček, responsible also for the coordination of the whole project). All the studies were financed mostly by the Grant Agency of the Czech Republic (206/99/1240 and 206/02/0568) and also by the participating institutions (AVOZ 60050516, MSMT 143100010, MSM 0021622416).

This publication summarizes the results of our more than six years' investigations. It brings also together the bibliography of all papers published, or prepared for publishing, in relation to our studies. These documents concern all branches of ecology we were interested in, namely the palaeoecology, description of present vegetation and its dependence on the qualities of its habitats, functions of plant and major animal elements in spring ecosystems, and also recommendations for their protection and management.

It remains to thank all reviewers of the particular parts of the volume for their valuable comments. We also want to acknowledge many specialists for numerous consultations that helped to clarify and solve the problems arising during the research. Our thanks also go to heads and staff of the Protected Landscape Areas of the Bílé - Biele Karpaty Mts, the Moravskoslezské Beskydy Mts, the Strážovské vrchy Mts, the Kysuce and Upper Orava regions, as well as the Tatra National Park, for their interest in and support of our research. Our special thanks are devoted to all friends who helped us in the fieldwork, namely to Petr Wolf for extensive logistical and technical cooperation.

We hope that our results represent a good documentation of the present state of nature in spring and spring fen ecosystems of the NW Carpathians, and that they bring information about their functioning in a landscape. We also believe that they will contribute to the wise management and preservation of these endangered biotopes for, at least, near future.

K. Rybníček, M. Hájek & A. Poulíčková
Brno, Olomouc, December 2004

Chapter 1

The list of Western Carpathian fens under detailed study

M. Hájek & M. Horsák

This chapter presents a list of 164 sites which were studied in detail during the research between 1999-2004. Localities were selected at which not only the conventional phytosociological investigation of vascular plants and bryophytes, but also the investigation of at least one other taxonomical group (cyanobacteria, algae, molluscs, testacea) and/or detailed habitat characteristics (detailed water chemistry, palaeoecological analyses, water level monitoring) have been in progress.

The study sites were classified into fourteen groups according to geographical position. Each group involves one moutain range in one country; in some cases small and little explored mountains were merged into one group. The geographical groups are labelled A-N, which will be used further in the text together with site number to clearly indicate geographical affiliation of the site. Sites are numbered continuously (1-164); they are ranked from south to north in each region. Each site is supplemented by: detailed coordinates; the name of the nearest town, village or large settlement (commune); location of the site; vegetation type(s) prevailing at the fen, and altitude. Other important informations about the structure of the list of studied fens are in the header of Tab. 1.

Abbreviations:

Alt.	Altitude
C.dav	*Caricetum davallianae*
C.ech-Sph	*Carici echinatae-Sphagnetum*
Cf-Cr	*Carici flavae-Cratoneuretum filicini*
Cfusc	*Caricetum fuscae*
Criv	*Cirsietum rivularis*
Cr-Sph.	*Carici rostratae-Sphagnetum*
D-Cl.	*Drepanoclado revolventis-Caricetum lasiocarpae*
E	east
E.v.-Sph	*Eriophoro vaginati-Sphagnetum recurvi*
Gl.-Tr.pum.	*Glauco-Trichophoretum pumili*
Chord.	*Amblystegio-Caricetum chordorrhizae*
J.-Men.	*Junco inflexi-Menthetum longifoliae*
J.sub.	*Juncetum subnodulosi*
Mts	Mountains
N	north
NR	Nature Reserve*
S	south
S.ferr.	*Schoenetum ferruginei*
S.w.-Car.dav.	*Sphagno warnstorfii-Caricetum davallianae*
Sw.-El.	*Sphagno warnstorfii-Eriophoretum latifolii*

V-Cf	*Valeriano-Caricetum flavae*
W	west

* For the sake of clarity, all categories of small protected areas (National Nature Reserve, Nature Reserve, Nature Monument, National Nature Monument) are merged into this abbreviation

Region codes:

A: Bílé Karpaty Mts (Czech Republic: Moravia)
B: Biele Karpaty Mts (Slovakia)
C: Strážovské vrchy Mts & Považský Inovec Mts (Slovakia)
D: Veľká Fatra Mts (Slovakia)
E: Chřiby Mts & Vizovické vrchy Mts (Czech Republic: Moravia)
F: Hostýnské vrchy Mts (Czech Republic: Moravia)
G: Vsetínské vrchy Mts & Javorníky Mts (Czech Republic: Moravia)
H: Moravskoslezské Beskydy Mts & the surroundings of the town of Jablunkov (Czech Republic: Moravia)
I: Kysuce region, the western part (Slovakia)
J: Kysuce region, the eastern part and the northern foothill of the Malá Fatra Mts (Slovakia)
K: Orava region & adjacent parts of the Chočské vrchy Mts (Slovakia)
L: Podhale region (Poland)
M: Liptov basin and southern foothill of the Vysoké Tatry Mts (Slovakia)
N: Spiš basin (Slovakia)

Table 1: The list of all sites under study. Only those sites that were studied in detail, or that are mentioned further in this monograph, are listed. The site codes, each composed of region code and site number, are used further in the text of the monograph. The sites are classified into groups A-N according to the geographical region. If the region covered the territory of two countries, it was divided into two separate groups (e.g. regions A and B). For the geographical distribution of all sites and for the approximate position of regions see Fig. 1, Chapter 2. Regions are ranked approximately from southwest to northeast; the sites are ranked from south to north in each region. Coordinates are presented in WGS84 system. Names of permanent monitoring sites are indicated in bold; the names of sites at which the palaeoecological samples were taken are underlined.

	No.	Site name	Coordinates	Municipality	Locality	Vegetation	Alt.
A	**1**	Machová	N:48°49’43”, E:17°32’19”	Javorník	Machová NR - calcareous spring fen, NE part of the reserve	Cf-Cr	450
A	**2**	Čertoryje - jz.	N:48°50’55”, E:17°25’25”	Tvarožná Lhota	Čertoryje NR - calcareous spring fen, SW part of the reserve	Cf-Cr	390
A	**3**	Čertoryje - sv.	N:48°51’30”, E:17°24’42”	Tvarožná Lhota	Čertoryje NR - calcareous spring fen, SE part of the reserve	Cf-Cr	390
A	**4**	Megovky	N:48°51’01”, E:17°34’56”	Javorník	calcareous spring fen - 100 m N of Megovka lodge	Cf-Cr	465
A	**5**	Jazevčí	N:48°52’15”, E:17°33’21”	Javorník	Jazevčí NR - calcareous spring fen, western part of the reserve	Cf-Cr/J.-Men.	375
A	**6**	U Baladů	N:48°52’56”, E:17°34’09”	Suchov	U Baladů - calcareous spring fen near the Suchovské Mlýny village	Cf-Cr	390
A	**7**	**Hrnčárky**	N:48°54’30”, E:17°40’34”	Strání	Hrnčárky NR - calcareous spring fen 250 m NE of the Klanečnice reservoir	Cf-Cr	440
A	**8**	Studený vrch	N:48°56’12”, E:17°44’15”	Březová	calcareous spring fen 600 m SE of Studený vrch hill (646m)	Cf-Cr	530
A	**9**	Kalábová	N:48°56’22”, E:17°44’39”	Březová	Kalábová NR - calcareous spring fen 950 m N of football pitch	Cf-Cr	520
A	**10**	Chmelinec - niva	N:48°56’26”, E:17°51’11”	Vyškovec	Chmelinec NR - brown moss rich fen in a brook aluvium	Criv	450
A	**11**	Chmelinec - pramen	N:48°56’26”, E:17°51’11”	Vyškovec	Chmelinec NR - calcareous spring fen at a slope above the site 10	Cf-Cr/Criv	455
A	**12**	U Zvonice	N:48°56’27”, E:17°47’16”	Lopeník	U Zvonice NR - calcareous spring fen	Cf-Cr	670
A	**13**	**Hrubý Mechnáč**	N:48°56’33”, E:17°47’54”	Lopeník	Hrubý Mechnáč - calcareous spring fen below the Lopeník saddle	Cf-Cr	642
A	**14**	Hutě, u lesa	N:48°59’25”, E:17°54’20”	Žitková	Hutě NR, shady patch with *Valeriana simplicifolia*	Cf-Cr/Criv	510
A	**15**	Hutě, dolní část	N:48°59’25”, E:17°54’20”	Žitková	Hutě NR - calcareous spring fen, NW part of the reserve	Cf-Cr/Criv	520
A	**16**	Hutě, horní část	N:48°59’25”, E:17°54’20”	Žitková	Hutě NR - calcareous spring fen, middle part of the reserve	Cf-Cr/Criv	540
A	**17**	Kročil, vyvýšená část	N:48°59’35”, E:17°54’22”	Žitková	Pitínské paseky settlement, near the Hutě NR, U Kročila, elevated part	Cf-Cr/Criv	470

A	**18**	Kročil, vpadlina	N:48°59’35”, E:17°54’22”	Žitková	Pitínské paseky settlement, near the Hutě NR, U Kročila, wettest part	Cf-Cr/Criv	470
A	**19**	U Machaly	N:48°59’38”, E:17°53’38”	Žitková	Machala - calcareous spring fen 1 km NW of Hutě NR	Cf-Cr/Criv	515
A	**20**	**Kloboucký potok**	N:49°06’47”, E:18°01’24”	Valašské Klobouky	calcareous spring fen - 200 m W of Bílé potoky NR	Criv	350
A	**21**	Na Nivách (Královec)	N:49°07’48”, E:18°01’25”	Valašské Klobouky	Na Nivách, 1,3 km SWW of the Královec hill	Cf-Cr	550
A	**22**	Javorůvky - prameniště	N:49°08’04”, E:18°02’03”	Valašské Klobouky	Javorůvky NR, large spring wetland at the meadow-forest border	Cf-Cr	555
A	**23**	Javorůvky - louka	N:49°08’04”, E:18°02’03”	Valašské Klobouky	Javorůvky NR - small calcareous spring fen within meadows	Cf-Cr	555
B	**24**	Malejov	N:48°46’08”, E:17°29’32”	Vrbovce	Malejov NR - waterlogged alluvial meadow	Criv	390
B	**25**	Šifflovci	N:48°47’52”, E:17°24’01”	Chvojnica	Šifflovci NR - calcareous spring fen 3 km SW of Žalostiná hill (621 m)	Cf-Cr	434
B	**26**	Žalostiná	N:48°48’52”, E:17°25’50”	Chvojnica	Žalostiná NR - calcareous spring fen	Cf-Cr	539
B	**27**	Borotová	N:48°49’48”, E:17°38’41”	Stará Turá	Borotová NR - calcareous spring fen	Cf-Cr/Criv	437
B	**28**	Záhradská	N:48°50’05”, E:17°41’14”	Lubina	Záhradská NR - calcareous spring fen	Cf-Cr	410
B	**29**	Tlstá hora	N:48°53’24”, E:17°53’41”	Chocholná	calcareous spring fen 1 km E of Tlstá hora hill	Cf-Cr	420
B	**30**	Španie - pramen	N:48°52’29”, E:17°48’59”	Španie	Blažejová NR - calcareous spring fen	Cf-Cr	405
B	**31**	Španie - louka	N:48°52’29”, E:17°48’59”	Nová Bošáca	Španie settlement, calcareous spring fen (NR), lower part	Criv	400
B	**32**	Bošáca, Grúň	N:48°53’40”, E:17°47’55”	Grúň	Grúň NR - calcareous spring fen 400 m SE of the village	Cf-Cr	480
B	**33**	Mituchovci	N:48°56’46”, E:17°58’23”	Horná Súča	Dúbrava, calcareous spring fen near Mituchovci settlement	Cf-Cr	436
B	**34**	Horná Závrská	N:48°58’45”, E:17°56’34”	Horná Súča	Horná Závrská NR - calcareous spring fen	Cf-Cr	382
B	**35**	Vlárský průsmyk	N:49°01’29”, E:18°04’54”	Horné Srnie	calcareous spring fen 200 m E of Zábava settlement	V-Cf	340
C	**36**	Mníchova Lehota	N:48°49’18”, E:18°04’23”	Mníchova Lehota	*Ca*-rich fen on the left bank of Turnianský brook, towards the Jarky settlment	Cf-Cr/J.sub.	310
C	**37**	Opočenská dolina	N:48°53’, E:18°14’	Dolná Poruba	Opočenská Valley - calcareous spring fen at the end of valley	Cf-Cr	450
C	**38**	Omšenská Baba	N:48°54’31”, E:18°14’02”	Omšenie	Omšenská Baba NR - calcareous spring fen, SW slope	Cf-Cr	476
C	**39**	Vápeč	N:48°56’25”, E:18°20’17”	Kopec	Vápeč - calcareous spring fen 900 m E of Vápeč hill (955.5 m)	Cf-Cr	597
C	**40**	Rematina	N:48°56’45”, E:18°27’16”	Zliechov	Zliechov, by the road below the Strážov hill, near the junction to Prievidza	Cf-Cr	712
C	**41**	Hanušová	N:48°56’51”, E:18°29’07”	Zliechov	Hanušová - brown moss rich fen 1.7 km SE of Strážov hill (1213 m)	C.dav.	723
C	**42**	Prečín	N:49°05’39”, E:18°32’58”	Prečín	Podhorie - calcareous spring fen 600 m N of Svarkovica hill (507.5 m)	Cf-Cr	408
C	**43**	Veľká Čierna	N:49°05’29”, E:18°35’38”	Veľká Čierna	fen meadow in the village, below the road junction	V-Cf	501
C	**44**	Čiernanka	N:49°05’42”, E:18°34’24”	Veľká Čierna	Čiernianka - calcareous spring fen 2 km W of the village	Cf-Cr	550

C	**45**	Biela Voda	N:49°06’02”, E:18°33’40”	Bodina	Biela Voda - calcareous spring fen 1100 m SW of Vysoký vrch hill (766 m)	Cf-Cr	406
C	**46**	Kapustové	N:49°06’52”, E:18°33’25”	Bodina	Kapustové - calcareous spring fen 400 m NW Jankov vrch hill (504 m)	Cf-Cr	452
C	**47**	Súľov I	N:49°09’45”, E:18°34’07”	Súľov	Čierny potok I - calcareous spring fen at the end of the valley	Cf-Cr	424
C	**48**	Súľov II	N:49°09’59”, E:18°34’13”	Súľov	Čierny potok II - calcareous sloping spring in the middle of the valley	Cf-Cr	623
D	**49**	Žarnovická dolina I	N:48°51, E:18°58’	Čremošné	Žarnovická Valley, waterlogged meadow 100 m of begining of Rožkovská V.	C.dav.	680
D	**50**	Žarnovická dolina II	N:48°51, E:18°58’	Čremošné	Žarnovická Valley, waterlogged meadow 1 km under Rožkovská Valley	C.dav.	680
D	**51**	Rakša	N:48°52’45”, E:18°53’24”	Rakša	Rakšianske rašelinisko NR - calcareous spring fen	C.dav.	512
D	**52**	Rakytovská dolina I	N:48°53’20”, E:18°58’41”	Blatnica	Rakytovská Valley - calcareous spring fen at the end of the valley	Cf-Cr/C.dav.	736
D	**53**	Rakytovská dolina II	N:48°53’29”, E:18°58’38”	Blatnica	Rakytovská Valley; slope - calcareous sloping spring 350 m of the site 52	Cf-Cr/C.dav.	733
D	**54**	Selenec	N:48°54’33”, E:19°00’14”	Blatnica	Selenec - brown moss spring fen at the end of Selenec valley	C.dav.	747
D	**55**	Blatnická dolina	N:48°55’00”, E:18°56’51”	Blatnica	Blatnická Valley, *Ca*-rich *Sesleria uliginosa* fen 2.5 km of the village	C.dav.	579
D	**56**	Rojkov	N:49°08’55”, E:19°09’20”	Stankovany	Rojkovské rašelinisko NR - calcareous spring fen	C.dav.	433
D	**57**	Stankovany, Močiar	N:49°09’11”, E:19°09’18”	Stankovany	Močiar NR - calcareous spring fen	C.dav./S.ferr.	437
D	**58**	Nad Močiarom	N:49°09’27”, E:19°09’02”	Stankovany	calcareous spring fen 600 m NW of Močiar NR	C.dav./S.ferr.	482
E	**59**	Stříbrnice	N:49°04’27”, E:17°18’16”	Stříbrnice	calcareous spring fen 1.2 km SW of Smraďavka spring (Chřiby hills)	Criv/Cf-Cr	345
E	**60**	Březnice	N:49°11’40”, E:17°38’50”	Březnice	calcareous spring fen 1 km SW of Zlín-Dolní Paseky settlement	Cf-Cr	317
E	**61**	Račné	N:49°12’23”, E:18°01’58”	Lidečko	Račné settlement, 1,5 km W of the Lidečko village	Cf-Cr/Criv	550
E	**62**	Trubiska	N:49°13’40”, E:17°59’14”	Pozděchov	calcareous spring fen along left band of Trubiska brook, near Brhel settlement	Criv	500
F	**63**	Pivovařiska - svah	N:49°19’24”, E:17°53’01”	Hošťálková	Pivovařiska NR - calcareous spring fen in sloping part of the NR	Cf-Cr	470
F	**64**	Pivovařiska - louka	N:49°19’30”, E:17°52’58”	Hošťálková	Pivovařiska NR - waterlogged meadow near a brook	Criv	460
F	**65**	**U Sládků (Semetín)**	N:49°20’18”, E:17°56’51”	Vsetín-Semetín	calcareous spring fen near the U Sládků settlement	Cf-Cr/Criv	400
F	**66**	U Pavlíků	N:49°20’23”, E:17°52’31”	Hošťálková	U Pavlíků - calcareous spring fen near the U Pavlíků settlement	V-Cf/Criv	395
F	**67**	U Matějů	N:49°20’43”, E:17°57’19”	Semetín	U Matějů settlement, 0,5 km SE of Semetín village	Cf-Cr/Criv	480
F	**68**	Kateřinice	N:49°22’36”, E:17°53’43”	Kateřinice	calcareous spring fen in the south edge of the village, above the pub	Cf-Cr	405
F	**69**	Dubcová	N:49°22’59”, E:17°52’33”	Kateřinice	Dubcová NR - brown moss rich fen 500 m SE of hill 575.3 m	V-Cf	500
F	**70**	Košovy – okraj	N:49°23’24”, E:17°49’01”	Rajnochovice	Košovy, the Juhyně Valley, mineral edge of the small poor fen	Cfusc	440
F	**71**	Košovi - centrální	N:49°23’24”, E:17°49’01”	Rajnochovice	*Sphagnum*-fen 1.2 km N of Košovy settlement	Cr-Sph	445

		část					
G	**72**	Stříbrník	N:49°16’34”, E:18°02’57”	Hovězí	Stříbrník NR, at the end of the Verečný Valley	Cf-Cr	580
G	**73**	Skaličí	N:49°18’48”, E:18°17’16”	Karolinka	Skaličí settlement, wet meadow dominated by *Eriophorum angustifolium*	Criv	740
G	**74**	Vesník	N:49°22’01”, E:17°59’13”	Vsetín	calcareous spring fen 270 m SW of U Pavelů settlement	Cf-Cr	455
G	**75**	**Jasénka (Kotrlé)**	N:49°22’41”, E:18°01’24”	Vsetín	calcareous spring fen 350 m N of Kotrlé settlement, above a road	Cf-Cr	565
G	**76**	Jablůnka, obec	N:49°22’45”, E:17°57’20”	Jablůnka	calcareous spring fen at the landslides above the village	Cf-Cr	
G	**77**	**Hrubé Brodské**	N:49°21’59”, E:18°10’30”	Nový Hrozenkov	brown moss rich fen at the end of Hrubé Brodské Valley	Criv/V-Cf	528
G	**78**	Miloňov	N:49°23’15”, E:18°19’34”	Miloňov	calcareous spring fen near NE margin of Miloňov settlement	V-Cf/Criv	675
G	**79**	Soláň	N:49°24’14”, E:18°15’37”	Solanec	Za Hutí - brown moss rich fen 1 km NE of Soláň hill (860 m)	Criv/V-Cf	715
G	**80**	Zákopčí	N:49°25’18”, E:18°11’05”	Hutisko	Zákopčí settlement, large brown moss rich fen	V-Cf	649
G	**81**	Adámky	N:49°25’32”, E:18°15’08”	Prostřední Bečva	Adámky, poor fen meadow near the settlement	C.ech-Sph	539
G	**82**	Poskla	N:49°26’05”, E:18°13’19”	Hutisko	Poskla NR, near the village (the hill Poskla)	C.ech-Sph	510
H	**83**	Bílá	N:49°24’60”, E:18°23’11”	Bílá	between Bílá and Hlavatá, near the road	Cf-Cr	690
H	**84**	Pod Kudlačenou	N:49°25’49”, E:18°19’52”	Horní Bečva	V Ondrových settlement, SE of the Kudlačena NR	Cfusc	630
H	**85**	Černá Ostravice	N:49°28’11”, E:18°31’03”	Staré Hamry	site „Mlýn“, *Eriophorum vaginatum* poor fen in the forested brook valley	E.v.-Sph	593
H	**86**	Podgruň - minerální část	N:49°29’10”, E:18°28’25”	Staré Hamry	Gruň, Podgruň NR in the Podgruň settlement	Cfusc	740
H	**87**	Podgruň - rašelinná část	N:49°29’12”, E:18°28’30”	Staré Hamry	Gruň, Podgruň NR in the Podgruň settlement	C.ech-Sph	794
H	**88**	Vřesová stráň	N:49°30’16”, E:18°44’44”	Mosty u Jablunkova	Vřesová stráň NR - poor fen near Šance settlement	C.ech-Sph	530
H	**89**	Byčinec	N:49°30’54”, E:18°33’30”	Morávka	Byčinec NR, 3 km NWW of the Malý Polom hill	Sw.-El.	700
H	**90**	**Obidová - potok**	N:49°31’03”, E:18°31’23”	Visalaje	Obidová NR - waterlogged poor fen	C.ech-Sph	730
H	**91**	Obidová - kyselá část	N:49°31’03”, E:18°31’24”	Visalaje	Obidová NR - dry poor fen meadow	C.ech-Sph	735
H	**92**	**Obidová - minerál**	N:49°31’03”, E:18°31’25”	Visalaje	Obidová NR - a rich *Sphagnum*-fen	Sw.-El.	735
H	**93**	Kyčmol - jz. část	N:49°31’07”, E:18°37’49”	Horní Lomná	fen meadow 1 km S of the village: mineral-poor part with *Drosera rotundifolia*	C.ech-Sph	615
H	**94**	Kyčmol - střední část	N:49°31’11”, E:18°37’51”	Horní Lomná	fen meadow 1 km S of the village: mineral-rich drier part	Cfusc	615
H	**95**	Kyčmol - sv. část	N:49°31’14”, E:18°37’53”	Horní Lomná	fen meadow 1 km S of the village: mineral-rich spring patch	Sw.-El.	610
H	**96**	Bukovec	N:49°32’57”, E:18°51’29”	Bukovec	Bukovec NR - brown moss rich fen	Sw.-El./Criv	510

I	**97**	Štiavnik	N:49°19’03”, E:18°25’16”	Štiavnik	Štiavnik - calcareous spring fen above Ráztoka settlment (Javorníky Mts, SK)	Cf-Cr	665
I	**98**	**Kelčov - slatina**	N:49°23’03”, E:18°28’47”	Nižný Kelčov	brown moss rich fen near small road to the Skala settlment	V-Cf	650
I	**99**	Kelčov - louka	N:49°24’00”, E:18°28’54”	Nižný Kelčov	wet meadow in the western edge of the village	Criv	650
I	**100**	Kubaľovo	N:49°25’00”, E:18°29’35”	Nižný Kelčov	Zátoka, rich spring *Sphagnum*-fen in the settlement	Sw.-El.	690
I	**101**	Cudrákovci II	N:49°27’45”, E:18°37’51”	Hrubý Buk	Cudrákovci - brown moss rich fen in the settlement	V-Cf	690
I	**102**	Cudrákovci I	N:49°27’47”, E:18°38’30”	Hrubý Buk	Cudrákovci - brown moss rich fen 0.5 km N of hill 736 m	V-Cf	595
I	**103**	**Polková**	N:49°28’24”, E:18°35’53”	Klokočov - Hlavice	Polková NR, above the settlement, poor *Sphagnum* fen	C.ech-Sph	660
I	**104**	**Zajacovci - v osadě**	N:49°28’40”, E:18°37’01”	Zajacovci	rich *Sphagnum*-fen on NW margin of the settlment	Cfusc	690
I	**105**	**Zajacovci - za osadou**	N:49°28’46”, E:18°37’03”	Zajacovci	poor acid fen at a gentle slope along the brook above the settlemet	C.ech-Sph	664
I	**106**	Vrchpredmier	N:49°28’50”, E:18°34’19”	Klokočov	rich *Sphagnum*-fen 1 km NE of Vrchpredmier settlment	Sw.-El.	730
I	**107**	Korcháň	N:49°29’04”, E:18°41’10”	Raková	the Korcháňovci settlement, near the road to Kubriková, poor acid fen	C.ech-Sph	595
I	**108**	Korcháň - u pramene	N:49°29’08”, E:18°41’10”	Raková	Korcháňovci, near the road to Kubriková, moderately rich fen at the spring	Sw.-El.	605
I	**109**	Kubriková	N:49°29’17”, E:18°41’02”	Raková	poor acid fen in the Kubriková settlement, near to bus station	C.ech-Sph	650
I	**110**	Kubriková - Hromadová	N:49°29’31”, E:18°40’23”	Raková	Kubriková settlement, Hromadová, spring fen in abandoned pasture	Cfusc	790
I	**111**	Soglovci	N:49°29’20”, E:18°42’42”	Čadca	Megonky, in the Soglovci settlement	Sw.-El.	532
I	**112**	Jančíkovci - pod chatou	N:49°29’20”, E:18°33’30”	Klokočov	Jančíkovci, small floating poor fen with *Menyanthes trifoliata*	C.ech-Sph	725
I	**113**	Jančíkovci - stružka	N:49°29’26”, E:18°33’22”	Klokočov	Jančíkovci, poor *Shagnum*-fen 300 m NW of the settlment	C.ech-Sph	780
I	**114**	**Jančíkovci - bulty**	N:49°29’26”, E:18°33’22”	Klokočov	Jančíkovci, poor *Shagnum*-fen 400 m NW of the settlment	C.ech-Sph	800
I	**115**	Biely Kríž - dolní část	N:49°29’53”, E:18°32’39”	Biely Kríž	Biely Kríž, poor fen behind the Kysuca hotel, lower part	C.ech-Sph	900
I	**116**	**Biely Kríž - horní část**	N:49°29’54”, E:18°32’47”	Biely Kríž	Biely Kríž, behind the Kysuca hotel, acid poor spring fen	C.ech-Sph	911
I	**117**	U Padyšáka	N:49°29’55”, E:18°42’57”	Čadca	Megonky, near the U Padyšáka settlement	C.ech-Sph	592
I	**118**	Čierne Polesie	N:49°30’39”, E:18°51’50”	Čierne při Čadci	poor fens near to railway, locality of *Eriophorum vaginatum*	C.ech-Sph	479
J	**119**	Terchová	N:49°15’22”, E:19°02’36”	Terchová	Terchová, rich fen W of footbal pitch (the foothill of Malá Fatra Mts)	C.dav.	530
J	**120**	Riečnica	N:49°18’40”, E:19°02’00”	Nová Bystrica	Riečnica, locked area of Nová Bystrica reservoir	V-Cf	660
J	**121**	Lány	N:49°20’59”, E:18°57’22”	Stará Bystrica	Lány NR, large Ca-rich peat-forming fen with *Menyanthes trifoliata*	V-Cf	500
J	**122**	Grigovci	N:49°22’00”, E:19°03’30”	Nová Bystrica	Grigovci, brown moss rich fen southern of the Vychylovské prahy	V-Cf	580

J	**123**	Pišojovci	N:49°22'30", E:19°03'55"	Nová Bystrica	Pišojovci, brown moss rich fen near a road	V-Cf	590
J	**124**	Klubina	N:49°22'35", E:18°55'14"	Klubina	brown moss rich fen - in the Klubinská Valley, 2.5 km NE of the village	V-Cf	550
J	**125**	Skanzen	N:49°23'04", E:19°06'20"	Nová Bystrica	Vychylovka museum, brown moss rich fen 200 m above a millhouse	V-Cf	730
J	**126**	Chmúra	N:49°22'40", E:19°05'30"	Nová Bystrica	Vychylovka museum, Chmúra NR, brown moss rich fen	V-Cf	680
J	**127**	Sviatkovské sedlo	N:49°24'25", E:19°06'20"	Nová Bystrica	Kysuce, Nová Bystrica - rich spring fen in the Sviatkovské saddle	V-Cf	730
J	**128**	Fojtov potok	N:49°23', E:18°55'	Zborov n. Bystricou	fen meadow in the upper part of Fojtov potok valley	V-Cf/Cfusc	590
K	**129**	Švošov	N:49°07'31", E:19°12'59"	Švošov	*Ca*-rich spring fen at the end of the Komjatnianská valley (the Chočské Mts)	C.dav.	475
K	**130**	Studničná	N:49°07'52", E:19°15'48"	Studničná	Studničná, calcareous spring fen 450 m S of the village (the Chočské Mts)	C.dav.	780
K	**131**	Veľké Borové	N:49°11'36", E:19°31'20"	Veľké Borové	*Ca*-rich spring fen near Borinka brook, S of the village (the Chočské Mts)	C.dav.	824
K	**132**	Malé Borové	N:49°13'05", E:19°32'45"	Malé Borové	Malé Borové - brown moss rich fen behind the SE margin of the village	V-Cf	850
K	**133**	Zuberec	N:49°16'18", E:19°39'42"	Zuberec	Blatná dolina - brown moss rich fen 2 km S of Mikulovka hill (1192 m)	V-Cf	800
K	**134**	Peciská III	N:49°17'18", E:19°45'12"	Oravice	Peciská III - rich *Sphagnum*-fen 1.2 km SE of the village	Chord./Sw.-El.	857
K	**135**	Peciská II	N:49°17'28", E:19°44'41"	Oravice	Peciská II - brown moss- and rich *Sphagnum*-fen 1 km S of the village	Sw.-El./D-Cl.	810
K	**136**	Peciská I	N:49°17'36", E:19°44'27"	Oravice	Peciská I - a poor *Sphagnum*-fen 900 m SSW of the village	Sw.-El.	800
K	**137**	Trstená	N:49°21'36", E:19°33'45"	Trstená	Krivý kút - calcareous spring fen 1100 m SW of Uhlisko Hill (860.4 m)	Cf-Cr	759
K	**138**	Beňadovo - u cesty	N:49°24'16", E:19°19'58"	Beňadovo	brown moss rich fen 1.5 km S of Beňadovské rašelinisko NR	V-Cf	685
K	**139**	Beňadovské rašelinisko	N:49°25'17", E:19°19'44"	Beňadovo	Beňadovské rašelinisko NR - rich *Sphagnum*-fen	Chord.	690
K	**140**	Ťaskovka	N:49°27'14", E:19°27'39"	Klin	Ťaskovka NR - calcareous spring fen	Cf-Cr	719
K	**141**	Mútne	N:49°28'13", E:19°17'10"	Mútne	Mútnianska Píla NR - NW margin of a large mire complex	Sw.-El.	770
K	**142**	Slaná Voda - u cesty	N:49°31'17", E:19°28'22"	Oravská Polhora	brown moss rich fen 400 m S of Slaná voda lodge	V-Cf	751
K	**143**	Slaná Voda	N:49°32'02", E:19°28'31"	Oravská Polhora	Slaná voda II - a rich *Sphagnum*-fen 1100 m above Slaná voda lodge	D-Cl.	756
K	**144**	Slaná Voda - za chatou	N:49°32'02", E:19°28'31"	Oravská Polhora	Slaná voda II - a poor *Sphagnum*-fen 1150 m above Slaná voda lodge	Cr-Sph.	756
K	**145**	Sihelné	N:49°31'29", E:19°22'57"	Sihelné	Biela farma - calcareous spring fen 150 m NW of Dušák settlment	Cf-Cr	760
L	**146**	Polana Biały Potok	N:49°17'02", E:19°50'49"	Zakopane	Kościelisko, Polana Biały potok - rich *Sphagnum*-fen	S.w.-Car.dav.	907
L	**147**	Chochołów	N:49°21'18", E:19°49'06"	Chochołów	brown moss rich fen on S margin of the village	V-Cf/Criv	800
M	**148**	Demänová	N:49°02'43", E:19°34'45"	Demänová	Demänovská Valley - brown moss rich fen 700 m SW of Jamy Hill	C.dav.	650

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M	**149**	Pastierske	N:49°03’03”, E:20°01’42”	Štrba	Pastierske II (=Brezové) - rich fen by the confluence of Hľboký Brook´s rivulets	V-Cf	875
M	**150**	Železná voda	N:49°05’15”, E:20°02’43”	Tatranská Štrba	Pri Železnej vode - rich *Sphagnum*-fen, 1 km W of the village	S.w.-Car.dav.	930
M	**151**	Tatranský Lieskovec	N:49°05’27”, E:20°03’20”	Tatranský Lieskovec	Pri prameni - brown moss rich fen 900 m W of the village	C.dav.	920
M	**152**	Zasmrčianský potok	N:49°05’51”, E:20°02’03”	Tatranský Lieskovec	Zasmrčianský potok brook - rich *Sphagnum*-fen on the left band of the brook	S.w.-Car.dav.	920
M	**153**	Mraznica	N:49°06’16”, E:20°09’17”	Štola	Mraznica NR -poor *Sphagnum*-fen in W part of the reserve	Cfusc	920
M	**154**	Červený potok	N:49°06’34”, E:20°12’45”	Gerlachov	Červený Brook - poor *Sphagnum*-fen 1150 m N of village	Cr-Sph.	810
M	**155**	Potôčky, sušší část	N:49°06’37”, E:19°48’38”	Pribylina	Potôčky - rich *Sphagnum*-fen 1 km NE of the village, dry path	S.w.-Car.dav.	780
M	**156**	Potôčky, stružka	N:49°06’37”, E:19°48’38”	Pribylina	Potôčky - rich *Sphagnum*-fen 1 km NE of the wet path	S.w.-Car.dav.	780
M	**157**	Jalovec - Bariny	N:49°07’59”, E:19°37’40”	Jalovec	Bariny - rich *Sphagnum*-fen 200 m S of village	S.w.-Car.dav.	680
N	**158**	Hôrka	N:49°01’10”, E:20°23’43”	Hôrka	petrifying travertine spring on SE margin of the village	Gl.-Tr.pum.	610
N	**159**	Gánovce	N:49°01’26”, E:20°20’05”	Gánovce	petrifying travertine spring 1 km SE of the village	Gl.-Tr.pum.	610
N	**160**	Spišská Teplica	N:49°02’39”, E:20°14’39”	Spišská Teplica	brown moss rich fen on SW margin of the village	C.dav.	700
N	**161**	Popradské rašelinisko	N:49°03’06”, E:20°16’53”	Poprad	Popradské rašelinisko - calcareous fen on SW margin of the town	C.dav.	680
N	**162**	Belianske lúky	N:49°12’52”, E:20°23’25”	Lendak	Belianske lúky NR - brown moss rich fen, northeastern part	C.dav.	677
N	**163**	Vysoká Bazička	N:49°13’14”, E:20°22’28”	Lendak	Vysoká Bazička, *Ca*-rich spring fen 200 m of SW margin of Belianske lúky	C.dav.	699
N	**164**	Podhoranské rašelinisko	N:49°14’45”, E:20°28’04”	Podhorany	rich fen near the confluence of small brooks 1 km NW of the village	C.dav.	623

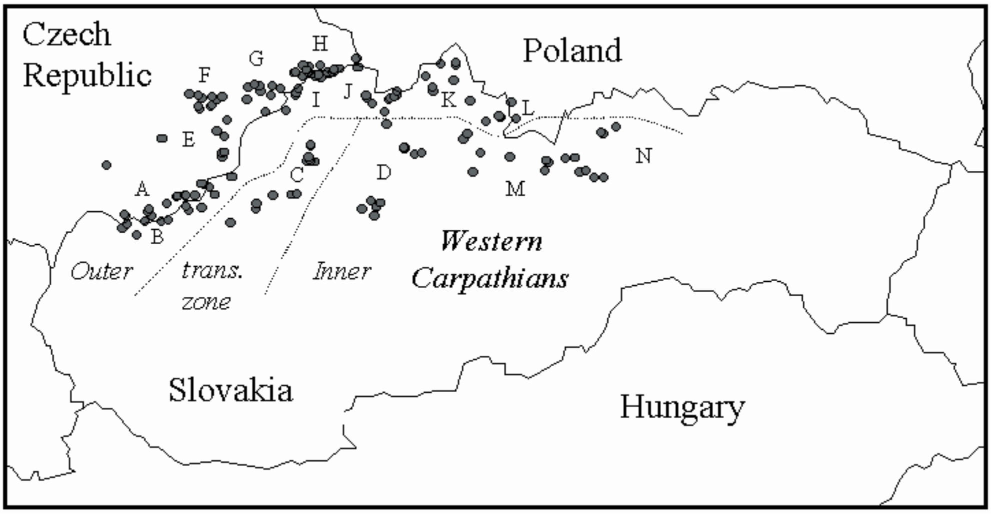
Chapter 2

The study area and its geochemical characteristics

M. Hájek & P. Hekera

The study area consists of three major parts. The first one, the Moravian-Slovakian borderland between the Czech Republic and Slovakia on flysch bedrock, was investigated in greatest detail. The second, the Orava region, is an eastern extension of this West Carpathian flysch zone. The third, the northwestern part of the Inner West Carpathians was investigated extensively with the aim to compare the species composition of spring fens on flysch bedrock with that developed under other biogeographical and geological conditions. For additional information about the geography and nature in all three parts of the area of interest, see Demek & Střída (1971). Geological situation is mapped by Kodym et al. (1967) and by Poprawa & Nemčok (1988). Climatic data can be found in Vesecký et al. (1958) and Quitt (1971).

Figure 1: The distribution of sites that were studied in detail with respect to vegetation and water chemistry and/or composition of molluscan or algal assemblages. The study area did not include the entire West Carpathians, but only their northwestern part. A dotted line within our study area represents the geological boundary between the Inner and Outer West Carpathians. The position of the Strážovské Mts, which form a transitional zone between these two regions in our study area, is also shown. Letters A-N indicate particular regions under study. For their description see Chapter 1.



Moravian-Slovakian flysch borderland

This area was chosen for a detailed study of the relationships between water chemistry and vegetation due to variable chemistry of rocks (Pesl & Žůrková 1967) on the one hand and, on the other, due to similar hydrological characteristics and similar origin of spring fens within this area. The area is located on the western margin of the West Carpathians (regions A-J in Fig. 1) and forms a part of the West Carpathian flysch belt (Paleogene), so called the Outer West Carpathians. Flysch is a kind of bedrock where in each geological stratum (bed) sandstone and claystone alternate. The beds differ from each other both in chemistry and proportion of sandstone and claystone. Each bed mostly occupies a narrow strip stretching from south-west to north-east (Poprawa & Nemčok 1998); the Klippen Belt with abundant limestone forms the nearest strip stretching along the outer edge of the Inner West Carpathians.

The chemical composition of ground water reflects rock chemistry (Rapant et al. 1996). Marls, lime-rich claystone, calcareous sandstone and limestone prevail in the southwestern part of the Moravian-Slovakian flysch borderland (the Bílé Karpaty Unit of Magura Nappe and adjacent southwestern part of the Klippen Belt; regions A-B). Groundwaters are carbonatogenic here and their dominant mineralization process is carbonate dissolution, which conditions the calcium- (magnesium)-bicarbonate chemistry type. This chemistry type supports cold water travertine (tufa) formation. Not only extreme values of calcium concentration (up to 300 $mg.1^{-1}$) have been found in this geological unit, but also springwaters characterised by high magnesium concentration. Towards the northeast, a group of flysch beds belonging to the Rača and Bystrica Units of the Magura Nappe occurs (regions E, F, G, I, J). Water samples from fens on these beds were still characterised by a high concentration of calcium, but a lower content of magnesium and a higher content of sodium, potassium and iron. Iron-rich beds occur mostly in the eastern part of this area (region J). The enhanced content of Na^{+}, K^{+}, Si and Fe in Rača and Bystrica Units is presumably caused by a high share of sandstone facies, which cause the admixture of carbonatogenic groundwaters by the silicatogenic ones. The comparatively high concentrations of iron (a toxic element) and potassium (a limiting nutrient) are of a great ecological importance (Chapter 5).

The northern part of the borderland is formed mostly of decalcified, often iron-cemented sandstone from the Silesian Unit of the Krosno Nappe (Menčík & Tyráček 1985). In aquifers, hydrolythic dissolution of silicates at the interface between water and psammitic-psephitic rocks is a dominant mineralization process. It is supplemented by the ion-exchange reactions on clay minerals (i.e. sulphide oxidation) and/or on iron and aluminium hydroxides (Rapant et al. 1996). These processes resulted in the formation of a specific groundwater type, which is prevalently acidic, rich in iron, silicon and sulphates and poor in all other elements. The calcium concentration is the lowest within the whole study area, but not as extremely low as in waters of some crystalline massifs. The water samples from the area of the Istebna beds (e.g. the Biely Kríž and Polom hills) were the calcium-poorest and the most acidic. This region is an exception among other Slovakian flysch regions with regard to the groundwater acidity, but calcium concentration is not correspondingly low (Rapant et al. 1996).

A rather high chloride, sulphate and sodium content was found throughout all particular regions in the entire borderland. These enhanced concentrations are of geogenic origin. High concentration of sulphates is caused by the oxidation of pyrite, which is contained in the claystones. The groundwater is, therefore, partly sulphidogenic, supports the occurrence of slight halophytes in calcium-rich areas (Hájek 1998), and influences the ion balance in poor acidic waters, too.

The groundwaters of the southwestern part of the borderland are often saturated with CO_2 (Poprawa & Nemčok 1988). However, the majority of water CO_2 occurs in the form of bicarbonates under a high pH of local springs; therefore, the concentration of free CO_2 is low. High bicarbonate content in the groundwaters of the southwestern regions A and B deepens the contrast between this calcium-bicarbonate-type chemistry and the silicatogenic groundwaters of the northeastern regions H and I, which are naturally poor in any form of CO_2. Therefore, the concentration of free aggressive CO_2 is low over the entire flysch belt compared to the West Carpathian crystalline massifs (Rapant et al. 1996).

The data from analyses of fen waters are consistent with those obtained by large-scale water chemistry sampling of open springs without vegetation and sampling of drillholes (Rapant et al. 1996). The only difference is in the concentration of free iron. It is several times higher in fen waters than in free spring and drillhole waters. This is caused by microbial activity, by changes in redox potential, by the presence of dissolved organic matter, and by iron cumulating in patches with more or less stagnant water. Therefore, substantial differences in iron concentrations among particular beds and consistently among the major vegetation types can be observed (Chapter 5).

In the Moravian-Slovakian borderland, altitude, humidity, temperature and geographical position correlate with the main chemical gradients. Calcium-rich rocks are situated in the southwestern part, which is warmer (annual mean temperature at the station Bojkovice is 8.4°C) and drier (annual mean precipitation at the station Bošáca is 713 mm, mean precipitation between April and September is 383 mm). The altitudes of southwestern fens are lower though always exceeding 340 m, and springs often develop on rather steep slopes. On the contrary, northeastern fens are located at higher altitudes (max. 911 m) but at more gentle slopes. In addition, the climate of the northeastern part is cooler and more humid. Mean annual precipitation often exceeds 1400 mm; mean annual temperature can decrease to app. 5°C (Vesecký 1961).

The Moravian-Slovakian borderland is situated in the contact zone of two phytogeographical units, namely the Carpathian, and the Pannonian regions. The potential natural vegetation is represented by deciduous forests of different types, especially by different beech forests often with a high share of silver fir and, at lower altitudes, also the Carpathian oak-hornbeam forests. Only a few small areas in the north-east, which lie at the highest altitudes or at the permanently waterlogged habitats, have been naturally covered with montane or waterlogged spruce forests (Neuhäuslová et al. 1998, 2001). The reconstructed pre-settlement natural vegetation was similar, but probably contained more beech, fir and less hornbeam (Mikyška ed. 1972, Michalko et al. 1987).

The Orava region

The Orava region and its Polish continuation (regions K, L) is a flysch area with a rather complicated geomorphological structure consisting of mountain ranges (the Oravské Beskydy, the Oravská Magura), uplands (i.e. the Podbeskydská vrchovina, the Skorušinské vrchy), undulated furrows (Podbeskydská brázda, Podtatranská brázda) and one flat inter-mountain basin (Oravská kotlina). All three major flysch units of the Magura Nappe meet in this region: the Rača Unit, the Bystrica Unit and the Bílé Karpaty-Orava Unit. This convergence implies that the spatial pattern in groundwater chemistry should be very similar to that of the Moravian-Slovakian borderland. Indeed, the range of concentration values for metallic and semimetallic cations and also the pH range are similar to the westernmost parts of the Flysch Belt (Rapant et al. 1996). An important specific feature, substantial differences in water chemistry occurring here within several small areas, is caused by the above mentioned geological variability. The other differences between the Orava region and the Moravian-Slovakian borderland are in deposition load. The former region is subject to lower nitrogen but higher sulphate deposition than the latter (Rapant et al. 1996: p. 19).

A variation in climatic conditions is also similar to that of the northern part of the Moravian-Slovakian borderland. The majority of studied fens belongs to a cool or moderately cold region with mean annual temperature app. 5°C or less. Annual mean precipitation is rather higher than in the Moravian-Slovakian borderland and varies between 1100 - 1400 mm in central parts of the region. Precipitation is high especially across the main mountain ridge at the northern margin of the region and at the foothill of the Vysoké Tatry Mts on the eastern margin of the region. The altitudes of the studied fens vary between 475 and 907 m (Tab. 1, Chapter 1).

Natural, pre-settlement vegetation differs by the degree of continentality and altitude of particular regions. The upland areas and main mountain chains were covered with mixed deciduous tree stands (beech, silver fir) with spruce. The basin and permanently waterlogged habitats were dominated by spruce and silver fir without any admixture of beech (Rybníček & Rybníčková 2002).

In spite of the great environmental similarity of the Orava region and the Moravian-Slovakian borderland, the flora and vegetation of mires in the Orava region is quite different. Orava mires are rich in boreo-suboceanic, boreo- (sub)continental and boreo-circumpolar plant species (see examples in Rybníček & Rybníčková 2002). This was caused by long postglacial development of mires in the Orava region (Rybníček & Rybníčková 2002) and, therefore, by the relic character of fen vegetation at some sites (Hájek & Háberová 2001).

The Inner West Carpathians

The third studied area represents the northwesten part of the Inner West Carpathians and borders both the above mentioned regions (Fig. 1). It has a rather complicated geological structure. It typically contains cores of Paleozoic and crystalline schists overlaid by Mesozoic shale-sandstone and carbonate lithofacies (limestone, dolomite). These are flatly covered with the Inner-Carpathian Paleogene or Neogene layers. That is why the groundwaters are of various chemistry types depending on the bedrock chemistry. Limestone and Paleogene aquifers have groundwaters of chemical composition similar to that in the flysch belt. Therefore, no difference was found in water chemistry between the limestone area (regions C, D) and calcareous flysch area (regions A, B) during the study. This is due to the abundant insertions of calcite in the flysch bedrock in regions A & B, and because the groundwaters in the Inner-Carpathian limestone mountains are mixed with calcium poorer groundwaters from crystalline, especially granite, core. Both carbonatogenic and silicatogenic groundwaters influence some of the studied fens in relation to the occurrence of noncalcareous sandstone lithofacies in the Inner-Carpathian paleogene.

High diversity of the Inner-Carpathian fens is caused also by the occasional prevalence of sulphatogenic groundwater. The dominant mineralization process here is gypsum and anhydride dissolution resulting in calcium-sulphate type chemistry (Rapant et al. 1996). The sulphates originating during this process condition the biota of the Inner-Carpathian travertine habitats (Chapters 5, 11).

Due to long postglacial history and the large extent of the calcareous fens, a specific group of plants and invertebrate animals is bound to their vegetation types in the

Inner West Carpathians (see Chapter 5, 11). This concerns mainly the regions D, M and N. Fens in the Strážovské vrchy Mts (region C) have a transitional biogeographical position between the Outer and Inner Western Carpathian ones. Such position is partly caused by the transitional character of their geological structure with a very small representation of crystalline rocks and by a high presence of claystones and marls, resembling the Bílé Karpaty Unit of the Magura-Flysch Nappe. The geological structure is also a reason why the northern part of the Strážovské vrchy Mts is sometimes ordered just to the Outer Carpathians. Other factors causing the transitional character of fens in the Strážovské vrchy Mts are small area, low altitude and a rather short postglacial history. These characteristics are also similar to that of the Outer-Carpathian flysch area.

There is a very diverse climate in the Inner-Carpathian part of the study area. The lower altitudes in the southern part of the Strážovské vrchy Mts (Mníchova Lehota, Omšenie, Vápeč) and in the surroundings of the town of Liptovský Mikuláš belong to moderately warm or, respectively, moderately cool regions with mean annual precipitation 650-850 mm. The majority of the study area falls into a cool climatic region with mean annual precipitation 850-1100 mm; only a few fens under study were located in a cold climatic region, which is typical for the highest mountain ridges. The altitude of studied fens varied from 310 to 930 m.

The natural, pre-settlement vegetation consisted mostly of beech forests of various types (calciphilous, submontane, montane, acidophilous) at middle and higher altitudes with silver fir at lower altitudes with patches of hornbeam and oak stands. In the eastern, continental and cooler part of the Liptov and in the adjacent part of the Spiš Basins, coniferous forests dominated, spruce and silver fir prevailed. Few studied fens were located in a zone of montane maple forests. Some studied fens occurred in valleys dominated naturally by montane floodplain alder stands (Michalko et al. 1987).

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Chapter 3

The origin and development of spring fen vegetation and ecosystems - palaeogeobotanical results

E. Rybníčková, P. Hájková & K. Rybníček

Introduction

This paper brings together the most important results of palaeogeobotanical investigations concerning the initiation and further development of present meadow spring fens in the borderland between the Czech and Slovak Republics. The research was carried out between 1998 and 2004, some older data were also included. Five reference sites were chosen for the model studies using pollen and macroscopic analyses as major methods. The investigation was intended as a historical key to understanding the present state and developmental level of the spring fen communities and ecosystems studied simultaneously by a team of specialists in different ecological and taxonomical branches of botany and zoology. We believe that knowing the past of these wetland ecosystems, we will be able to comprehend their present state better and predict their future.

Both pollen and macroscopic analyses were unusually difficult and time-consuming especially due to the high content of mineral particles, frequent changes in ground water level and often also intensive tufa accumulation during the formation of spring sediments. All these factors resulted in a high grade of mineralization of organic matter and poor preservation of botanical objects of our interest, namely the micro- and macroscopic remains. On the other hand, this kind of spring sedimentation was very convenient especially for palaeomalacological analyses. For their results see Horsák & Hájková (Chapter 4).

These difficulties may explain why we have not found any analogous paper from abroad presenting results of pollen and macroscopic analyses from spring sediments similar to ours. Even in the Czech Republic, we are able to refer only to our own study from the foothills of the Šumava Mts (Rybníček & Rybníčková 1974). Earlier pollen analyses of spring mires near the Bílý Kříž in the Beskydy Mts, i.e. in our own region, must be mentioned as well (Jankovská 1995, Rybníček & Rybníčková 1995).

The responsibilities of each author are as follows: Eliška Rybníčková analysed pollen and spores at all five profiles, Petra Hájková determined macroscopic plant remains in four and Kamil Rybníček at one (Královec) of the five profiles. K. Rybníček is responsible for stratigraphic descriptions, final evaluation of the results and compilation of the text. Josef Kyncl identified the wood remains.

The region

The region spreads along both sides of the state border between the Czech and Slovak Republics. It belongs to two major orographic units, namely the Moravskoslezské Beskydy Mts in the north, between Jablunkovský and Lyský průsmyk passes (main altitude between

900-1000 m, max. altitude Lysá hora Mt. 1324 m), and the Bílé Karpaty Mts (the White Carpathians) in the south, with mean altitudes between ca 800 - 900 m (max. elevation at Javorina Mt. 970 m). Both sub-regions belong to the palaeogenic flysch zone of the West Carpathians; however, they differ essentially in the quality of bedrocks and because of that also in the chemistry of spring waters. While in the Moravskoslezské Beskydy Mts the bedrocks consist of different types of mostly decalcified sandstones and acidic claystones, the White Carpathians are composed of calcium-rich marls and limestones. There are great differences in climatic conditions as well. The north is cool and rather humid, the southern part is warm and moderately dry.

The character of natural climax forest vegetation corresponds with these conditions. Mixed beech forests (beech, silver fir, Norwegian spruce) or fir and spruce stands dominated over the 600 m in the Moravskoslezské Beskydy Mts, beech and hornbeam-oak forests, often with several thermophilic elements, covered the White Carpathians especially south of Vlára Pass. For detailed distribution of the natural climax forest types see Mikyška et al. (1968), Michalko et al. (1987) and Neuhäuslová et al. (1998). Spring fens occur only scarcely in both sub-regions at altitudes between ca 500 – 700 m.

For further information about the region see Hájek & Hekera (Chapter 2). Fig.1 presents a schematic plan of the region and the location of the studied sites.

Methods

The methods used were chosen in order to get the best possible data for the reconstruction of local vegetational succession in spring fens and for establishing particular stratigraphic sequences. The results of macroscopic and pollen analyses are the main sources of information.

Field work and sampling

Profile samples were stored as monoliths in metal boxes 10x10x50 cm for later use. They were collected from cleaned exposures of freshly dug pits in the deepest parts of the spring areas. The physical properties of sediments and their component elements were described according to the Troels-Smith (1955) characterization of Quaternary unconsolidated sediments. In our case, it was necessary to add a new category to the standard deposit components, namely the Grana calcarea (GCa), characterising calcareous tufa and/or sinter (unconsolidated or semi-consolidated cold water travertine). It originates during the biogenic precipitation of dissolved calcium in calcitrophic spring waters, forming whole layers of calcareous grains of different size. Grana calcarea occurred generally at three profiles from the White Carpathians. Munsell Soil Color Charts (1954) were used for colour determination.

Macroscopic analyses

Samples of mostly 200 cm^3 volume were collected usually at 5 – 10 cm intervals, respecting all visible stratigraphic borders. Samples were further processed by standard methods, described for example in Berglund ed. (1986). The results are presented in tables. Seeds and similar reproductive organs are given in absolute numbers of findings, tissues (wood, bark, mosses) are presented in volume representation, expressed by + for scarce occurrence (less than ca 5 volume %), ++ for medium occurrence (ca 5 – 25 volume %) and +++ for high volume representation (over ca 25 volume %). Findings of important pollen grains and spores (p) are exceptionally included as (+) or (++) in tables of macroscopic finds.

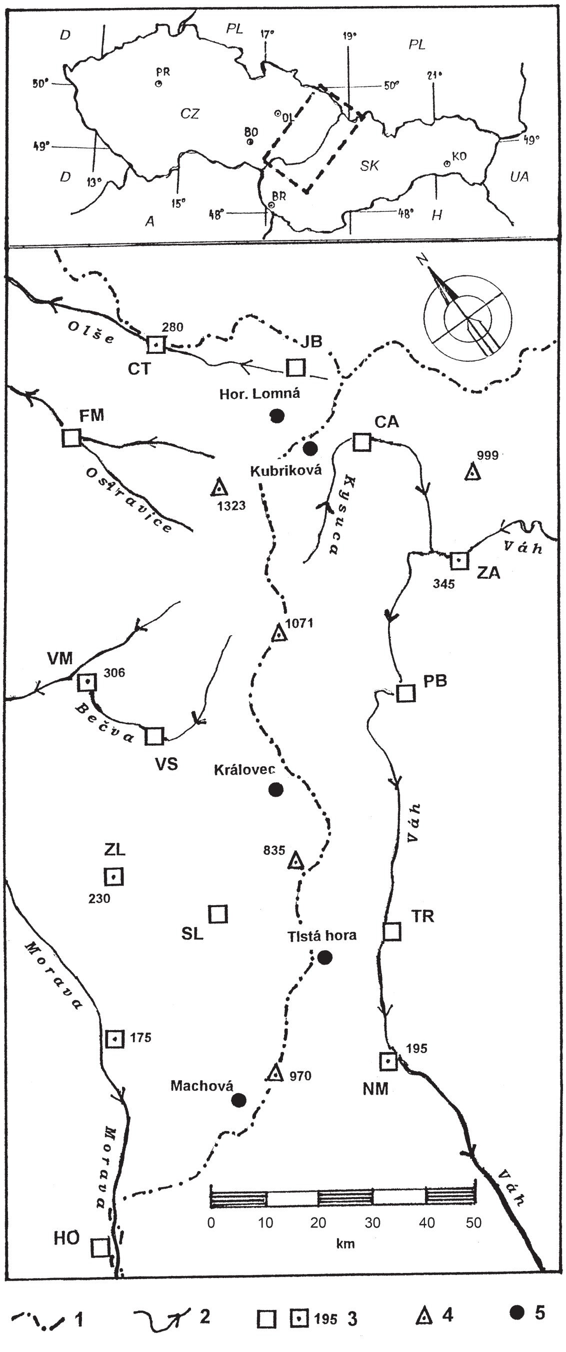

Figure 1. A schematic map of the Moravian - Slovakian borderland and the location of the investigated spring fens. 1. state border, 2. rivers, 3. towns, town altitude (m), 4. important geodesic points (m), 5. location of the investigated spring fen mires. Abbreviations of towns: CA - Čadca, CT - Český Těšín, FM - Frýdek-Místek, HO - Hodonín, JB - Jablunkov, NM - Nové Mesto n./Váh., PB - Považská Bystrica, SL - Slavičín, TR - Trenčín, UH - Uherské Hradiště, VM - Valašské Meziříčí, VS - Vsetín, ZA - Žilina, ZL - Zlín.

Pollen analyses

Intervals for sampling differ between 2.5 and 5 cm at all profiles. The laboratory treatment of sediments also followed standard methods (acetolysis) with pre-treatment of samples with HCl and/or HF. Pollen and spores were counted to at least 1000 pollen grains in one sample. Percentage pollen diagrams are calculated independently for local or predominantly local sporomorphs (AP loc. + NAP loc. = 100%). In the case of *Polypodiophyta* spores, their sum was included in the T sum (AP loc. + NAP loc. + *Polypodiophyta* loc. = 100%) and similar calculation was used for *Bryophyta.* Regional and/or predominantly regional pollen and spores were counted in the same way. The choice of local and regional pollen and spore elements is based first of all on the results of macroscopic analyses and marginally also on prevailing present coenotical affinities of pollen and spores producers.

Nomenclature

The nomenclature of vascular plants follows the Key to Flora of the Czech Republic (Kubát et al. 2002), that of mosses Frey et al. (1995). Names of syntaxa refer to Moravec et al. (1995) or to the names used in the phytosociological part of this volume (Hájek et al., Chapter 5). Nomenclature of sporomorphs is partly based on Beug (2004), but it does not always correspond to the currently used names of their producers and is, therefore, conventional.

Time zonation and ^{14}C dating

Radiocarbon dating of critical layers was carried out in the Radiocarbon Laboratory of the Silesian Technical University, Gliwice, Poland (head Prof. Anna Pazdur). The data are listed in Tab.1 (p. 41) and inserted in particular pollen diagrams and tables. The estimated ages calculated from the curves of accumulation rates of the particular profiles are presented in brackets. All data are in conventional radiocarbon years B. P.

Zonation of local parts of pollen diagrams and tables of macroscopic remains reflects local developmental phases. Chronozones mentioned in the regional part of pollen diagrams follow the proposal by Mangerud et al. (1974).

Spring fens investigated and their stratigraphy

Horní Lomná (MB-5-A), 615 m, 49°31´14´´N, 18°37´51´´E

The site is situated on the foot of a slope on a left bank of the Lomná brook and at the upper margin of Horní Lomná village, south of the town of Jablunkov. It belongs to a complex of small fen mires and waterlogged meadows. The size is estimated to be ca 400 m^2, the maximum depth of spring sediments is ca 110 cm; our profile is ca 100 cm deep. Tab. 2 (p. 42) presents the description of sediments in particular layers. Ground layers below ca 75 cm are minerogenous with a little admixture of herbaceous and wood peat. Middle layers consist of wood and herbaceous peat; in the uppermost 20 cm herbaceous peat prevails. The beginning of spring sediments' accumulation is estimated back to ca 5700 years B. P.

In the present vegetation, *Filipendula ulmaria, Mentha longifolia, Caltha palustris, Cirsium rivulare, Lysimachia vulgaris, Galium uliginosum, Crepis paludosa, Potentilla erecta,* and *Equisetum fluviatile* dominate and/or are common.. *Valeriana simplicifolia, Viola palustris, Carex nigra, C. panicea, Cirsium oleraceum, C. palustre, Lychnis flos-cuculi, Rumex acetosa, Angelica sylvestris, Epilobium palustre, Ranunculus acris, R. repens, Lycopus europaeus* are present. As for mosses, we found scattered *Rhytidiadelphus squarrosus, Calliergonella cuspidata, Brachythecium* sp., *Plagiomnium* *affine* and *P. undulatum.* Similar communities are usually classified in the *Calthion*. Outside the investigated site, several *Sphagnum* species in the *Sphagno-Caricion canescentis* and *Sphagno warnstorfii-Tomenthypnion* communities are rather common.

Neighbouring forests are secondary spruce plantations. Farther on, natural mixed beech-fir- spruce stands can still be found; some of them are protected (e.g. NNR Mionší). In the alluvial stands of the Lomná brook, *Alnus incana, A. glutinosa, Fraxinus excelsior* and *Acer pseudoplatanus* prevail. Small deforested places were extensively used as grazing places or mowed meadows; cereal cultivation was very rare in the mountains. Mikyška et al. (1968) reconstructed herb-rich beech and acidophilous beech forests of the *Eu-Fagion* and *Luzulo-Fagion* respectively in a geobotanical map. Scree forests of the *Tilio-Acerion* can still be found on steep slopes. Communities of the *Alnetea glutinosae* are mapped in the alluvium.

Kubriková, (MB-6-A), 790 m, 49°29´3´´N, 18°40´20´´E

The spring fen is a part of a forest meadow on the eastern slope (15 – 20°) of Velký Polom Mt. It is situated above the Kubriková lonely house near the village of Raková, close to the town of Čadca.

The size does not exceed 500 m^2. The maximum depth of spring sediments is ca 115 cm; our profile was dug out to the depth of 100 cm. Tab. 3 (p. 43) presents the sequence of layers and description of sediments. The ground layers are minerogenous (clay, sand, and gravel) with organic admixture less than 5%. Middle and upper layers are organogenous with variable admixture of mineral particles. Small pieces of charcoal are spread over the whole profile except for the uppermost 15 – 20 cm. The beginning of spring sediments' accumulation is estimated back to ca 2100 – 2200 years B. P. *Carex nigra*, *C. echinata, Eriophorum angustifolium, Cirsium palustre, Crepis paludosa,* and *Potentilla erecta* dominate the present stands. In addition, *Galium uliginosum, Ranunculus acris, Rumex acetosa, Epilobium palustre, Lysimachia vulgaris, Lychnis flos-cuculi, Viola palustris, Listera ovata, Dactylorhiza majalis, Epipactis palustris,* and *Juncus articulatus* are present. In poor moss layer, *Calliergonella cuspidata, Bryum pseudotriquetrum, Rhytidiadelphus squarrosus, Plagiomnium ellipticum, Hypnum pratense, Philonotis fontana, Aulacomnium palustre* and *Climacium dendroides* occur.

Surrounding present vegetation is a secondary spruce plantation with a little admixture of beech, mainly in the shrub layer. Natural pre-cultural vegetation was reconstructed as mixed beech, fir and spruce forests in general, however, silver fir stands with spruce admixture had to be very common in the area. Michalko et al. (1987) mapped mixed beech and montane spruce forests there.

Královec (BK-3-A), 560 m, 49°07´55´´ N, 18°01´40´´ E

A rather small spring fen lies on the southern slope of Královec Mt., ca 1 km SE of the railway station of Valašské Klobouky, inside a meadow and pastureland island used for recreation purposes at present.

The size of the investigated fen is ca 200 – 250 m^2. Its surface is slightly domed and sloping ca 10°– 15°. The depth of spring deposits is ca 135 cm; our samples were collected near the deepest point and covered 125 cm. For the description of layers and sediments see Tab.4 (p. 44). The beginning of organogenous incl. tufa sedimentation dates back to between ca 1300 – 1200 years B. P.

The formation of tufa (GCa) is a conspicuous feature of the deposition and it is observed through the whole profile with maximum intensity between ca 55 and 86 cm.

This very layer dates back between ca 550 - 900 B. P. The ground clayey and stony layer is also very chalky.

In the present fen community (*Carici flavae-Cratoneuretum*), *Eriophorum angustifolium, Carex flava, C. panicea, C. nigra, C. flacca,* and *Potentilla erecta* dominate or are common. *Juncus articulatus, Triglochin palustris, Parnassia palustris, Valeriana simplicifolia, Eriophorum latifolium, Epipactis palustris, Succisa pratensis, Linum catharticum, Cirsium rivulare, Equisetum palustre, E. fluviatile, Dactylorhiza majalis,* and *Mentha longifolia* are present. The moss layer is rather dense and consists of *Cratoneuron commutatum, Campylium stellatum, Calliergonella cuspidata, Fissidens adianthoides, Bryum pseudotriquetrum,* and *Philonotis calcarea.* For the relevé see Hájek (1998, Tab.8, column 1).

The reconstructed natural climax forest vegetation of the vicinity represents a complex of some mixed beech and fir communities with spruce above ca 550 m (see also pollen diagram in Fig. 4). At lower altitudes, oak-hornbeam forests prevailed; however, nearly all of them were deforested and changed into cultivated land during the medieval times. A geobotanical map (Mikyška et al. 1968) reconstructed similarly *Eu-Fagion* and *Carpinion* stands but it did not delimit any very typical fir forest communities here.

Tlstá Hora (BK-4-A), 460 m, 48°53′ 18′′ N, 17°53′16′′ E

The spring fen is situated on a small and almost flat plateau on the eastern slope of Tlstá hora Mt., ca 4 km NW of the village of Chocholná-Velčice near the town of Trenčín. At present, it is surrounded partly by a continuous forest, partly by a deforested area no more used for agricultural purposes, and by several summer cottages.

The size of the fen is about 900 m^2. Its southern part is covered with trees and shrubs along the spring brooklet; the remaining larger part is treeless. The profile was dug in the central place and with its depth 290 cm it is the deepest deposit we studied. For a stratigraphic sequence and sediment description see Tab. 5 (p. 45). The age of the oldest organogenous wood layer is between ca 4300 and 3900 years B. P. This layer may have been connected with an old landslide. The first intensive tufa formation started around 2300 B. P. and lasted for ca 800 years. The next tufa formation was in progress between ca 1200 and 900 B. P. and is still running. Ca-precipitation started ca 600 B. P.

The present calcareous fen mire is covered with stands of the *Carici flavae-Cratoneuretum* with *Triglochin palustris, Blysmus compressus, Potentilla erecta, Eriophorum angustifolium, E. latifolium, Epipactis palustris, Dactylorhiza majalis, Succisa pratensis, Carex panicea, C. nigra, C. flacca,* and *C. flava* as the most common elements. From the margins *Molinia arundinacea* spread. The moss layer is very rich and dense. It consists of *Cratoneuron commutatum, Homalothecium nitens, Campylium stellatum, Philonotis calcarea, Bryum pseudotriquetrum, Fissidens adianthoides, Calliergonella cuspidata* and an alga *Chara* cf. *vulgaris.* Phytosociological relevé was published by Hájek (1998, Tab. 8, column 41).

Reconstructed natural forest vegetation of the closest vicinity (Michalko et al.1987 and own observations) is represented by herb-rich and calcicolous beech forests and with oak- hornbeam as well as thermophilous oak stands. Our pollen analyses indicate a predominant representation of *Fagus*, *Quercus* and *Tilia* while the representation of *Carpinus betulus* is surprisingly low.

Machová (BK-5-A), 460 m, 48°49´ 30´´N, 17°02´25´´E

The sloping spring fen (inclination between ca 10° and 15°) is a part of a larger protected area "Machová" with different types of meadows. It is situated on the northern slope of Velká Machová hill, ca 4 km south of the village of Javorník near the small town of Velká nad Veličkou.

The size of the studied fen site is ca 400 m^2, the maximum depth of spring fen deposits is 110 cm, and the profile is 100 cm deep. Tab. 6 (p. 46) presents the stratigraphy and description of sediments. The spring deposition dates back to ca 1300 years B. P.

Fen communities of the *Carici flavae-Cratoneuretum* subas. *tomenthypnetosum nitentis* dominate the present vegetation. The following vascular plants are common: *Eriophorum latifolium, Carex paniculata, C. panicea, C. flava, C. flacca, Molinia arundinacea, Valeriana dioica, Potentilla erecta, Serratula tinctoria, Succisa pratensis, Parnassia palustris, Crepis paludosa, Epipactis palustris, Gymnadenia densiflora,* and *Salix aurita* (this one in the juvenile stage). In the moss layer, *Homalothecium nitens, Campylium stellatum, Cratoneuron commutatum, Philonotis calcarea, Plagiomnium elatum, Aneura pinguis, Bryum pseudotriquetrum,* and *Climacium dendroides* are present. Two phytosociological relevés were published by Hájek (1998, Tab.8, columns 49 and 50).

In the reconstructed natural forest vegetation (see Mikyška et al. 1968) oak-hornbeam communities prevail being in contact with beech stands above ca. 550 – 600 m. Communities of the *Alnenion glutinoso-incanae* can still be found along streams. Our pollen analyses indicate dominating representation of *Fagus* and *Quercus* in the regional climax vegetation.

Results

For each site, separate pollen diagrams (Figs 2 – 6, p. 58-62) and tables (Tables 7 – 11, p. 48-57) present the evaluation of microscopic (pollen) and macroscopic analyses of the studied profiles. The analyses should result in establishing the local vegetational developmental phases and even inner successional stages in different spring fens we investigated.

Horní Lomná, Table 7, Fig. 2

Besides the dominant *Picea abies* in the tree layer, *Rubus* species and *Sambucus nigra* shrubs were present in local vegetation at the beginning of the development. *Alnus glutinosa* probably occurred just temporarily in a small quantity. Among accompanying herbs, we determined *Ranunculus repens, Ajuga reptans,* and *Stachys sylvatica.* The presence of some *Equisetum* is not sure, the rhizomes found may have grown down from upper layers where spores of horsetails were abundantly documented by pollen analyses. Pollen finds enlarge this list especially with *Filipendula ulmaria, Cirsium* sp., some *Apiaceae* (most probably *Chaerophyllum hirsutum)*, *Veratrum,* and *Petasites.* A remarkable representation of fern spores is an important feature of pollen assemblages belonging to this developmental phase. It indicates that species of ferns must have been very common in the waterlogged spruce forest. Mosses are represented just rarely by *Rhytidiadelphus squarrosus;* finds of *Sphagnum* spores may also indicate the existence of some forest species of this genus. The presence of *Abies alba* in the surrounding regional climax forests is also reflected in macroscopic finds of a few needles transported from close natural forest stands on the slopes above the spring we analysed. No wood remains of silver fir were found.

The next *Abies* stage of the forest phase can be characterised by temporal spread of *Carex remota, Oxalis acetosella* and *Thuidium tamariscinum*, which we found in the corresponding layers. They disappeared soon and the first increasing finds of heliophilic plants, such as e.g. *Carex* cf. *demissa, C. nigra, C. echinata, Potentilla erecta,* and *Ranunculus flammula*, were recorded.

These heliophytes expanded later during the transitional developmental stage of an open spring fen phase. The beginning of this stage started during the 7th century, i.e. long before the settlement of this region. Therefore, it must have been triggered by some natural event, such as e.g. increasing activity of the spring and the subsequent waterlogging of the habitat. However, the origin of the present fen meadow stage, dating back ca 600 years, was certainly conditioned by the total deforestation of the site after the settlement. Progressive human impact including a certain grade of forest grazing (see a growing representation of *Juniperus communis* pollen in pollen diagram, Fig. 2) led to a successive transformation. This resulted in the appearance of several other meadow plants, such as e. g. *Carex canescens, C. panicea, Viola palustris, Prunella vulgaris, Ranunculus acris, Juncus conglomeratus, J. articulatus, Cirsium palustre, Galium* cf. *uliginosum, Lychnis flos-cuculi,* and mosses *Calliergonella cuspidata, Calliergon giganteum,* and some *Sphagnum* species. The presence of these plants was also confirmed by pollen analyses. In addition, several pollen and spore finds enlarge the list with other local elements, e.g. *Filipendula, Caltha, Rumex* cf. *acetosa,* some *Epilobium, Lysimachia vulgaris, Mentha* sp., *Chrysosplenium* sp., *Pedicularis* sp., and some *Equisetum.* The high percentages of *Cyperaceae* pollen are remarkable; they vary between 30 - 50 % of total local pollen in the corresponding assemblages.

Kubriková (Tab.8, Fig. 3)

The investigated fen meadow originated in a forest stony spring with *Abies alba* in the tree layer. *Fagus sylvatica* could grow at the spring margins and certainly in the close neighbouring climax forests. *Sambucus nigra* and some *Rubus* species were present. In the herb layer we found, among others, *Glyceria nemoralis, Carex remota, C. sylvatica,* some sedges of the *Carex flava* group, *Stachys sylvatica, Ajuga reptans, Alisma plantago-aquatica* and *Juncus conglomeratus.* From mosses, *Eurhychium* cf. *angustirete* was found in the forest phase of the fen development. The following pollen enlarge this initial assemblage or confirm its composition: *Salix* sp., *Montia*, *Stachys, Viola* cf. *palustris, Apiaceae* cf. *Chaerophyllum, Chrysosplenium* and *Crepis* t. (most probably *C. paludosa).* Later, *Caltha palustris, Lysimachia nemorum, Ranunculus repens, Cardamine* cf. *amara* appeared. In the tree layer *Picea abies* must have been present. Pollen analyses completed this list with *Lysimachia vulgaris, Lythrum* cf. *salicaria, Pedicularis, Lotus uliginosus* and *Petasites.* This rather long developmental stage lasted from ca 1700 to 650 B. P. At the end of this stage and especially during the next one, scattered charcoals occurred in the corresponding layers. They document artificial deforestation of the forest spring as well as neighbouring tree stands and their transformation into meadows and/or grazing places. In this transitional stage, several elements of forest spring e.g. *Carex remota, C. sylvatica, Crepis, Rubus* sp. persisted and also scattered trees of *Abies* and *Fagus* can be expected. More recently, several meadow species *(Anthoxanthum odoratum, Ranunculus acris,* and *Potentilla erecta)* appeared. The only specific plant for this stage seems to be *Urtica dioica*, probably invading the fen surface after the enrichment of soil due to burning. This may have been also the reason for a very high representation of ferns in and around the site. The finds of *Circaea* and *Listera ovata* pollen, still growing close to the site, are noteworthy. The transitional stage lasted from ca 650 to 300 B. P. and was certainly connected with activities of Walachian colonists, who settled this part of the Beskydy Mts during the 15th and 16th centuries.

The absence of trees and shrubs characterises the last stage of open fen communities. Needles of *Picea abies* certainly come from secondary spruce plantations on the slope in very close proximity. We observed a decreasing presence of forest species and an increasing representation of open fen plants, such as *Carex nigra, C. panicea, C. echinata, C. canescens, Ranunculus acris, R. flammula, Viola palustris, Potentilla erecta, Rumex acetosa, Lychnis flos-cuculi* and mosses *Philonotis fontana, Calliergonella cuspidata, Rhizomnium punctatum, Climacium dendroides,* and *Aulacomnium palustre.* Among local pollen, we also found *Lysimachia vulgaris, Lotus uliginosus, Lathyrus* t. (*L. pratensis ?*), *Rubiaceae (Galium uliginosum* ?), and *Equisetum* spores.

Královec (Tab. 9, Fig. 4)

The beginning of the sedimentation is estimated back to ca 1250 years B. P. The development started in spring outflows inside an alder stand. Remains of *Sambucus nigra, Carex remota, Ranunculus repens, Cardamine amara, Colchicum autumnale,* and mosses *Cratoneuron commutatum, Rhizomnium punctatum, Bryum pseudotriquetrum,* and some *Brachythecium* species were found in the initial community. Alder was naturally succeeded by an *Abies alba* stand with some spruce and, shortly at the beginning, also with some beech admixture, at around 1000 B. P. The changes in tree representation brought also changes in the herb layer, where more or less typical companions of alder stands, e.g. *Carex remota, Colchicum autumnale,* and *Rhizomnium punctatum*, disappeared.

The transitional stage of the development started ca 600 – 700 years B. P. It is marked by a sudden decrease in coniferous trees, expansion of willows and the appearance of heliophilic fen species (*Carex flacca, C. panicea, C. nigra, C. echinata,* several species of *C. flava* group) and some meadow species (*Cirsium rivulare, Rumex obtusifolius, Ajuga reptans).* The beginning of this stage corresponds more or less with the settlement growth in the vicinity and especially in the town of Valašské Klobouky, which followed after catastrophic fires and floods in the 14th century and after Valašské Klobouky received town status in 1356 (Peřinka 1905). These events certainly resulted in extensive deforestation and exploitation of wood for constructing purposes. Finds of charcoals, seeds and pollen of *Rumex obtusifolius, Urtica dioica,* and spores of ferns indicate these activities.

The last stage of open fen vegetation started ca 250 – 300 years ago, probably as a result of the intensification of hay making and grazing. It is characterised by an almost complete absence of any local trees and shrubs and an expansion of the above mentioned heliophilic fen species over the spring area. In addition, *Potentilla erecta, Triglochin palustris, Linum catharticum, Valeriana (dioica?), Eriophorum angustifolium* appeared. The highest representation of *Cyperaceae* pollen and *Equisetum* spores is typical for the pollen assemblages of this stage.

Tlstá hora (Tab. 10, Fig. 5).

The origin of the present calcareous fen is in a spring with *Glyceria nemoralis* inside a beech forest. The age of the first organogenic sediment formation is estimated back to ca 4300 B. P. After some 1500 years, the *Fagus* stage changed into alder stands with a variable and periodical representation of willows. Both stages of the whole forest phase are marked, in addition, by the occurrence of shrubs (e.g. *Sambucus nigra, Rubus* sp., *Cornus sanguinea*) and herbs preferring wet forests and/or forest springs (*Stachys sylvatica, Carex remota, Atropa bella-donna, Solanum dulcamara,* and *Cardamine amara*). *Eupatorium* *cannabinum* and *Ajuga reptans* were found in the upper layers of the alder and willow stage. Mosses occurred very rarely; just a few remains of *Eurhynchium* cf. *hians* and *Cratoneuron commutatum* appeared in the studied material. The developmental phase of the forest spring was very long and ended only ca 600 years B.P.

The transformation of the forest phase into the open calcareous fen communities was rather sudden, short, and lasted ca 100 years. Only the finds of *Caltha palustris* pollen and *Glyceria* cf. *notata* seeds may indicate this transitional stage.

The last developmental stage of the present open calcareous fen communities can be characterised by a total absence of trees and shrubs and a disappearance of their herb companions in the spring area. Pollen of *Cyperaceae* reach very sharply values over 50% of local total pollen sum. Simultaneously, quite a different assemblage of plants appeared: some species of *Carex flava* group*, Triglochin palustris, Linum catharticum,* and somewhat later *Potentilla erecta, Blysmus compressus, Carex flacca,* and *C. panicea* are the main representatives. However, the most characteristic feature is a general occurrence of several calciphilous mosses, such as *Cratoneuron commutatum, Campylium stellatum, Philonotis calcarea, Homalothecium nitens*, *Fissidens adianthoides,* and also *Chara* plants growing directly in the spring outflows. A massive formation of tufa sediments is connected with this type of vegetation.

Machová (Table 11, Fig. 6)

The present spring fen mire originated, similarly to all previous cases, in a forest spring; however, it is much younger. Its basal layers are ca 1300 years old. The tree stand consisted first of all of beech with a varying admixture of willows and, perhaps, also *Fraxinus* and some *Rubus* species. Among accompanying plants were, for example, *Carex pendula, C. remota,* and *C. hirta.* Very frequent must have been also heliophilic *Carex flava* and *Carex nigra* indicating that the tree and shrub stands were not dark and nor too compact. Both sedges have survived at the site up to the present.

The transitional stage between forest and open spring fen phases dates back between ca 800 and 500 B.P. It is marked with the occurrence of, for example, *Ajuga reptans, Caltha palustris, Scirpus sylvaticus* and some *Epilobium*. All these plants disappeared with the end of the stage. Therefore, they can be considered characteristic of it. Another important feature of the transition is the beginning of immigration and the spreading of plants typical for calcareous fen communities, namely *Cratoneuron commutatum, Homalothecium nitens, Linum catharticum,* and *Juncus inflexus*, reaching their maximum in the next treeless developmental stage.

The present calcareous fen vegetation developed during the last stage; its beginning can be dated back to ca 500 B.P. Except for fen plants mentioned above, we ascertained spreading of *Carex paniculata, C. flacca, Potentilla erecta, Valeriana dioica,* and *Succisa pratensis,* and mosses *Calliergonella cuspidata,* and *Campylium stellatum. Homalothecium nitens* has an unusually high representation in the uppermost layers, corresponding well with its present dominance.

Conclusions

Five spring fens and their sediments are representative for the borderland between the Czech and Slovak Republics. They cannot be compared with most other West Carpathian mires, even though their existence is usually bound to spring outflows as well. Their origin, development, peat forming communities, sediments and age are quite different. For example, the mires in the neighbouring Orava region can be even more than 11000 years old (see Rybníček & Rybníčková 2002). The pollen diagrams indicate that all five profiles cover the Subatlanticum period, just the sections Horní Lomná and Tlstá hora are older and inform about the situation also in the Subboreal.

A sequence of two developmental phases with several local stages, namely the initial forest spring phase and the phase of the present open treeless vegetation, seems to be a general feature in the evolution of local spring fen vegetation. Tab. 12 (p. 47) presents schematically a survey of developmental phases and their inner stages as well as major successional trends at individual sites.

From the results presented, the following most important conclusions can be drawn:

1. The beginning of an accumulation of spring sediments differs at the individual sites. The oldest sediments and the slowest rate of their accumulation were observed in Horní Lomná spring fen (nearly 6000 years); the youngest sedimentation and the shortest vegetational succession were found in Machová spring fen (ca 1300 years).
2. The origin and development of the studied spring fen vegetation proceeded in more or less closed stands of forest springs. However, the composition of their tree layers was not the same. In the northern part of the region, the Moravskoslezské Beskydy Mts, the tree stands consisted mostly of coniferous trees (*Picea abies, Abies alba)* with an admixture of *Alnus glutinosa* and/or *Salix* species. In the southern part, the Bílé Karpaty Mts, stands with *Fagus sylvatica* and willows were found. *Alnus glutinosa* was an important component in some stages of the forest phase at Tlstá hora site. The fen of Královec has an intermediate position, starting its development in alder stands but continuing in *Abies alba* spring forest.
3. The succession always continued with transitional developmental stages within the open spring fen phase. Their major feature is a successional instability - forest spring elements were disappearing step by step and heliophilic species of treeless open fens were spreading instead. We believe that the transformation was in most cases initiated and conditioned by human activities connected with the settlement of the region, namely by deforestation, grazing and hay making. Only at Horní Lomná site, the beginning of the transitional stage was probably caused by natural influences, such as strong waterlogging and dying of trees.
4. The last developmental stages are dominated by open treeless fen vegetation. A nearly total absence of trees and shrubs in the spring areas and a growing presence of heliophilic herbs and mosses mark this vegetation. While in the northern part of the region in moderately acidic habitats there are species typical rather for communities of the *Calthion, Caricion fuscae* or *Sphagno recurvi-Caricion canescentis,* in the southern part calciphilous plants typical for the *Caricion davallianae* can be found. The existence of these fen meadow stages is quite short and does not exceed 300 – 600 years. It clearly depends on the intensity of human activities. Due to the recent decrease in farming, the fen communities have been evolving into tall herb stands and, tending regressively into a shrub or even tree cover in the future.
5. Differences in species composition of local vegetation during its succession are conditioned by different calcium contents in spring waters (see Chapter 2) and, in principle, also by the quality of underlying rocks of the northern and southern parts of the region. This is also the reason for an absence of tufa sediments at the sites Horní Lomná and Kubriková and of their very intensive precipitation in the calcitrophic spring fens of the Bílé Karpaty Mts (Královec, Tlstá hora, Machová).

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Table 1: A survey of radiocarbon dates

Sample name (site)	Code	Depth (cm)	Laboratory No	Age in conv. years B.P.
Horní Lomná	MB - 5 - A	54 - 59	Gd 15559	1930±100
		64 - 65	Gd 15557	4140± 90
		85 - 87	Gd 15687	5130± 95
Kubriková	MB - 6 - A	82 - 84	Gd 16297	1730±210
Královec	BK - 3 - A	60	Gd 15174	620±110
		100	Gd 15176	1040±110
Tlstá hora	BK - 4 - A	79 - 81	Gd 15335	600± 70
		89 - 91	Gd 17202	940±105
		217 - 219	Gd 16199	2760±100
		265 - 267	Gd 12389	3920± 70
Machová	BK - 5 - A	71 - 72	Gd 12647	890±100

Table 2: Stratigraphy and description of sediments, Horní Lomná (MB-5-A).
Abbreviations: Limes – boundary; Sicc – dryness; Nig – darkness; Elast – elasticity; Th – herb peat; Tl – ligneous peat; Tb – moss peat; Dh – herbaceous detritus; Dl – ligneous detritus; Dg – fragments of the superterraneous parts of plants; As – fine clay; Ga – fine sand; Gg – coarse sand; Gca – grains of tufa; Test. moll. – mollusc shells; Lapis – stones; A – charcoals.. For details see Troels-Smith (1955).

	from	85	75	55	20	0
cm	to	100	85	75	55	20
Lim		1	1	0	0	-
Nig		1	2	2	3	3
Strf		0	1	2	1	1
Elas		0	0	1	1	1
Sicc		2	2	2	2	1
Colour		5Y 4/1	10YR 3/2	2.5YR 2/4	2.5YR 2/2	5YR 2/2
Th		0.5	1.5	2	1	2
Tl		0.5	0.5	2	2	+
Tb		.	.	+	++	++
Dh		.	.	.	+	1
Dl		++	++	++	1	.
Dg		++	++	++	++	1
As		3	2	++	+	+
Ga		++	+	.	.	.

Table 3: Stratigraphy and description of sediments, Kubriková (MB-6-A). For explanation of abbreviations see Tab. 2.

	from	84	60	25	0
cm	to	100	84	60	25
Lim		1	1	2	-
Nig		1	1	2	3
Strf		0	0	1	0
Elas		0	0	1	1
Sicc		1	2	1	2
Colour		2.5Y 6/0	5YR 5/2	5YR 3/2	10R 3/1
Th		+	3	2	3
Tl		0.5	0.5	1	+
Tb		+	+	0.5	+
Dg		.	+	++	1
As		2.5	++	+	+
Ga		1	0.5	0.5	+
Gg		+	+	.	.
[A]		[+]	[+]	[++]	

Table 4: Stratigraphy and description of sediments, Královec (BK-3-A) For explanation of abbreviations see Tab. 2.

	from	120	114	86	58	38	31	0
cm	to	125	120	114	86	58	38	31
Lim			2	2	1	1	0	-
		2						
Nig		1	3	3	2	2	2	1
Strf		1	3	3	2	2	1	1
Elas		0	1	1	1	2	1	1
Sicc		1	1	2	1	2	2	2
Colour		7.5YR5/2	7.5YR 3/2	5YR 3/3	10YR 2/2	10YR 3/2	5YR 2/2	10YR 4/2
Th		+	+	++	++	+	++	1
Tl		++	1	1	0.5	++	0.5	.
Tb		+	1	1	+	+	0.5	++
Dg		+	+	1	0.5	1	1	1
As		2	1	+	.	1	1	2
Gca		1	1	1	3	2	1	.
Ga		0.5	+	+	+	+	+	+
Gg		0.5	.	.	.	+	.	+
Test. moll.		[1]	[1]	[2]	[2]	[+]	[+]	[+]
Lapis		[4]	[1]	[++]	[+]	[++]	.	[++]
[A]		.	.	.	.	.	[+]	.

Table 5: Stratigraphy and description of sediments, Tlstá hora (BK-4-A) For explanation of abbreviations see Tab. 2.

	from	>285	256	230	189	131	113	90	72	64	36	15	8	0
cm	to		285	256	230	189	131	113	90	72	64	36	15	8
Lim		3	2	2	2	2	2	2	2	2	2	2	1	-
Nig		1	3	3	2	2	3	2	3	1	1	1	2	2
Strf		0	1	2	2	1	2	1	1	1	2	1	1	0
Elas		0	1	2	2	1	2	1	1	1	1	1	1	1
Sicc		0	1	1	1	2	2	2	1	2	2	2	2	2
Colour		2.5YR 6/2	5YR 3/2	5YR 3/4	5YR 3/3	10YR 4/3	5YR 3/2	10YR 4/3	5YR 3/2	10YR 5/4	10YR 4/3	10YR 5/2	10YR 5/3	10YR 4/3
Th		+	.	.	.	0.5	0.5	0.5	1	+	1^2	+	0.5	1
Tl		+	2	1	0.5	0.5	1^2	0.5	0.5	0.5	.	.	.	.
Tb		.	.	0.5	++	0.5	2^3	0.5	2^3	1^2	1^2	1	0.5	1^2
Dg		+	1	2	2.5	+	+	+	+	+	+	+	+	+
As		2	.	.	.	.	.	.	.	.	.	.	.	.
Ga		.	.	.	.	.	.	.	.	.	.	.	.	.
Gca		1	0.5	++	1	2.5	0.5	2.5	0.5	2.5	2	3	3	2
Gg		1	0.5	0.5	.	.	+	.	.	.	.	.	.	.
Test. moll.		[+]	[1]	[1]	[1]	[1]	[2]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
[A]		.	[1]	[1]	[++]	[+]	.	.	.	.	.	.	.	.

Table 6: Stratigraphy and description of sediments, Machova (BK-5-A) For explanation of abbreviations see Tab. 2.

	from	>100	95	77	65	35	10	0
cm	to		100	95	77	65	35	10
Lim		1	1	1	1	1	1	-
Nig		1	2	3	2	1	1	2
Strf		0	0	0	0	0	1	1
Elas		0	0	1	1	1	1	1
Sicc		2	2	1	1	2	2	1
Colour		2.5Y 5/0	5Y 3/2	5YR 3/2	5YR 4/3	7.5YR 5/4	10YR 5/2	5YR 4/2
Th		0.5	0.5	1	1	1.5	1	1
Tl		0.5	1	1	1	++	.	0
Tb		.	.	.	+	0.5	0.5	1
Dg		.	0.5	.	1	.	.	.
As		3	2	2	+	.	.	.
Gca		.	+	+	1	2	2.5	2
Ga		+	.	.	.	.	.	.
Test. moll.		.	.	.	[1]	[+]	[+]	[+]
[A]		.	.	.	.	[+]	.	.

Tab. 12 A temporal comparison of major successional phases/stages in the development of spring fen vegetation

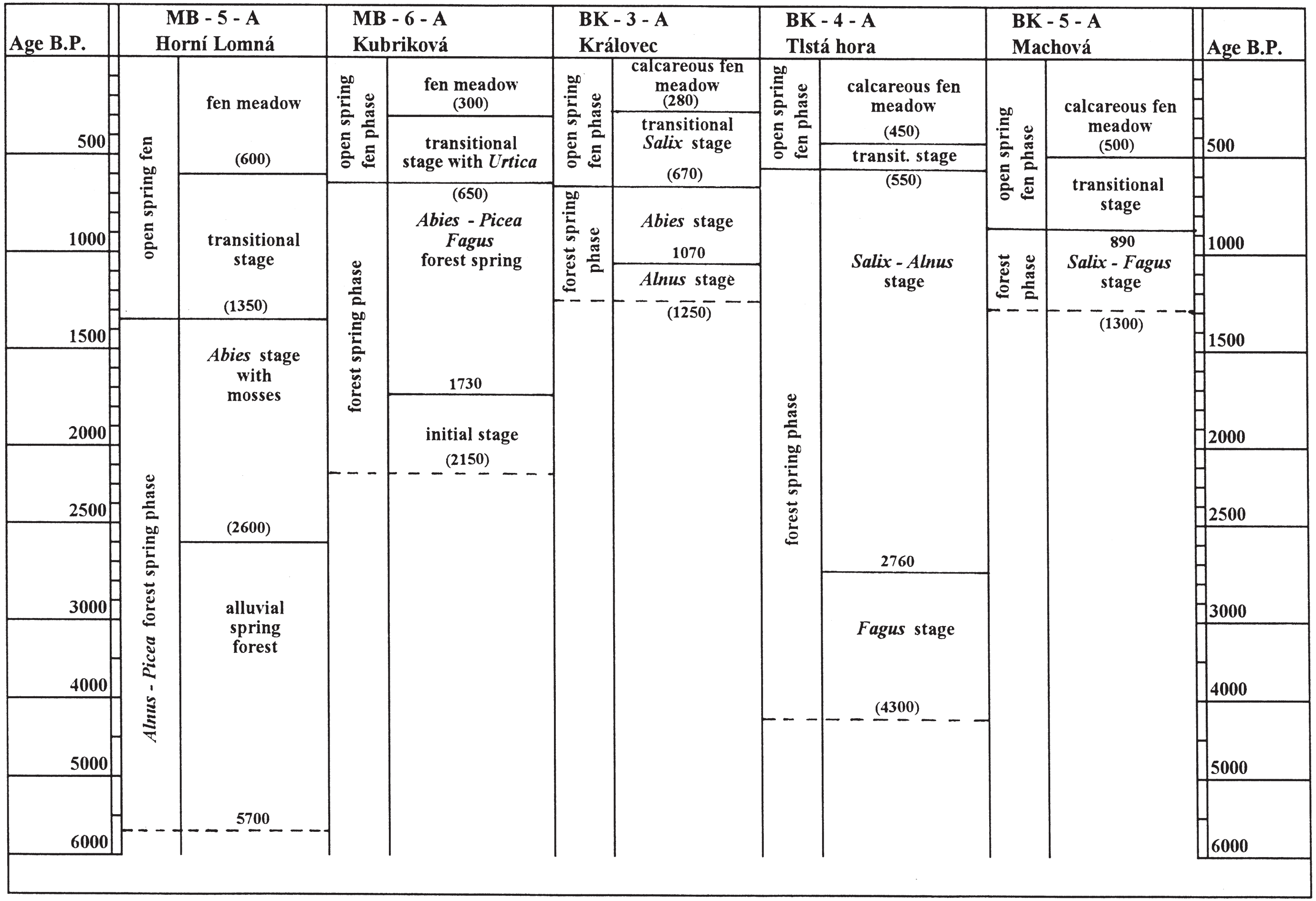


Table 7: Table of macroscopic plant remains from the Horní Lomná (MB-5-A).

Age years B.P.		(5700)		5130				4140	(2600)		1930				(1350)			(600)			
Depth (cm)	**from**	**100**	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**53**	**48.5**	**43**	**38**	**32**	**26**	**20**	**15**	**10**	**5**
	to	**95**	**90**	**85**	**80**	**75**	**70**	**65**	**60**	**55**	**53**	**49**	**43**	**38**	**32**	**26**	**20**	**15**	**10**	**5**	**0**
Volume of analysed sediment		**100**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**100**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Developmental	**phase**	**forest spring phase**													**open spring fen**						
	stage	**alluvial open forest**								***Abies*-stage**					**transition**			**fen meadow**			
Coenococcum geophilum	scl	2	55	42	34	49	64	34	47	15	18	22	30	28	12	39	36	43	34	82	72
Rhytidiadelphus squarrosus	m	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+
***Equisetum* sp.**	st, r	.	.	.	.	++	.	++	.	+	+++	++	.	+	.	+	+	++	++	++	.
Picea abies	s/w	.	.	+++		++	+++	+++	.	.	3	1/+++	2/+++	+++	+++	+++	+++	1	.	.	.
	n	4	.	.	.	.	.	.	3	16	5	5	2	27	.	30	3	.	.	.	.
	c	.	.	.	.	.	.	.	1	3	1	.	1	.	.	.	3	.	.	.	.
Alnus glutinosa	w	.	.	.	++	.	.	.	.	.	.	.	.	.	.	++	.	.	.	.	.
Sambucus nigra	s	.	4	3	4	1	4	.	2	2	.	1	2	.	1	1	.	.	.	.	.
***Rubus* sp.**	s	.	11	4	8	.	5	2	6	3	.	9	16	14	3	6	4	.	.	.	1
Ajuga reptans	s	.	10	3	1	1	3	2	.	3	2	1	2	6	.	.	.	.	3	.	.
Ranunculus* cf. *repens	s	2	2	8	13	4	1	.	2	27	4	4	3	2	.	.	.	.	.	.	.
Stachys sylvatica	s	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Abies alba	n	.	.	.	.	.	.	.	.	7	3	2	.	6	.	5	7	.	.	.	.
Thuidium tamariscinum	m	.	.	.	.	.	.	.	+	+++	++	+++	++	.	.	.	.	.	.	.	.
Carex remota	s	.	.	.	.	.	.	.	.	4	.	2	1	.	.	.	.	.	.	.	.
Brachythecium rivulare	m	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Oxalis acetosella	s	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.

Table 7: Cont.

***Carex flava* agg. (mostly *demissa*)**	s	.	.	.	.	.	.	.	.	.	.	2	1	.	.	13	32	151	103	65	69
Potentilla erecta	s	.	.	.	.	.	.	.	.	.	.	1	.	1	.	5	20	46	128	70	39
Ranunculus flammula	s	.	.	.	.	.	.	.	.	.	.	.	3	1	14	23	41	76	51	52	28
Carex nigra	s	.	.	.	.	.	.	.	.	.	.	.	1	.	1	7	49	80	58	11	12
Carex echinata	s	.	.	.	.	.	.	.	.	.	.	.	3	.	6	41	126	265	96	33	53
Calliergonella cuspidata	m	.	.	.	.	.	.	.	.	.	.	.	+	.	+++	++	+	.	.	.	.
Carex canescens	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	13	2	.	2	.
Philonotis fontana	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	++	.	.	.
Prunella vulgaris	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	11	21	4	.	.
Viola palustris	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	13	11	.	.
Calliergon giganteum	m	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+++	+	.	.
***Eleocharis palustris* agg.**	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.
Glyceria fluitans	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	1	1	.	1
***Sphagnum* sp.**	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+
Juncus conglomeratus	s	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	3	4	4	8	6
Juncus articulatus	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	2	4	1
Ranunculus* cf. *acris	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	.
Carex panicea	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	9	1
Cirsium palustre	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	4
Galium* cf. *uliginosum	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.
Lychnis flos-cuculi	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2
***Myosotis palustris* agg.**	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
Lotus uliginosus	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.

In addition there occur: 55-60: *Lycopodium annotinum* 3 l; 26-32: *Lysimachia nummularia* 1 s; 20-26: *Polygonum lapathifolium* 1 s; 15-20: *Urtica dioica* 1 s, *Bryum pseudotriquetrum* + m; 5-10: *Lotus uliginosus* 1s; 0-5: *Brachythecium* sp. + m.

Explanation of abbreviations for Tabs. 7-11:
(p) – pollen or spores, s – seed, fruit (absolute number), scl – sclerotium (absolute number), c – cone, cone part, n – needles (absolute number), ls – leaf scars, b – bud scales, w – wood, r – rhizome, st – stem, nod – nodus (by *Poaceae*), m - stems and leaves of bryophytes (+ 1-5 stems, ++ 5-25 stems, +++ over 25 stems); (+) and (++) pollen grains and spores; + occurrence less than ca 5 volume % , ++ more important occurrence ca 5–25 volume %, +++ occurrence over 25 volume % for wood and *Equisetum*.

Table 8: Table of macroscopic plant remains and important pollen grains from the Kubriková (MB-6-A). Abbreviations see Tab. 7.

Age years B.P.			**(2150)**				**1730**										**(650)**			**(300)**			
Depth (cm)	**from**		**100**	**97.5**	**92.5**	**88**	**84**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**	**5**
	to		**97.5**	**92.5**	**88**	**84**	**80**	**75**	**70**	**65**	**60**	**55**	**50**	**45**	**40**	**35**	**30**	**25**	**20**	**15**	**10**	**5**	**0**
Volume of analysed sediment			**100**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Developmental	**phase**		**forest spring phase**															**open spring fen**					
	stage		**initial stage**					***Abies-Picea-Fagus* spring stage**										**transition**			**fen meadow**		
***Equisetum* sp.**		st, r	+	+	++	++	++	++	++	+	+	+	+	++	++	+++	+++	++	++	+	++	+	+
***Carex flava* agg. (mostly *C. demissa*)**		s	1	2	1	3	2	4	2	2	.	1	.	2	1	.	.	.	**3**	**74**	**35**	**6**	.
Juncus conglomeratus		s	1	.	1	2	1	1	.	.	.	.	.	1	.	1	.	.	.	.	.	.	1
Glyceria nemoralis		s	7	13	6	10	13	107	45	13	15	17	15	15	14	4	.	.	.	.	.	.	.
Carex remota		s	1	4	8	17	54	52	61	67	42	81	99	128	101	58	16	5	5	7	.	.	.
Carex sylvatica		s	.	2	1	2	4	4	4	8	2	1	5	9	3	13	3	3	7	7	.	.	.
Stachys sylvatica		s	.	1	.	1	2	7	2	2	5	5	3	9	5	2	4	3	.	.	.	.	.
Ajuga reptans		s	.	2	2	1	6	4	.	3	2	3	2	3	6	1	3	3	.	2	.	.	.
Sambucus nigra		s	.	5	10	3	4	2	1	.	1	1	1	4	1	2	1	2	.	.	.	.	.
***Eurhynchium* sp.**		m	.	.	+	+	++	++	+	+	.	+	++	++	+	+	.	.	.	.	.	.	.
***Rubus* sp.**		s	.	.	3	2	4	9	3	6	3	1	3	.	6	2	8	6	**12**	**20**	1	.	.
Myosoton aquaticum		s	.	.	1	.	.	.	.	.	.	.	2	.	.	.	2	.	1	.	.	.	.
Coenococcum geophilum		scl	1	4	4	7	9	15	6	8	3	1	.	12	5	.	2	3	.	16	2	.	.
Abies alba		s/w	+++	.	1	1/++	1	6	2	4/++	1	1	+++	1/++	+++	++	2	.	.	+	.	.	.
		n	.	.	5	9	27	35	28	21	23	38	15	32	24	9	.	.	2	1	.	.	.
Fagus sylvatica		ls/w	.	.	6	15/++	16/+++	22/+++	14/+++	2/++	7/+++	14/+++	13/+++	20/++	14/++	13/+++	18/+++	7/+++	7	.	.	.	.
Caltha palustris		s	.	.	.	.	1	11	15	2	2	5	1	1	.	.	.	.	.	.	.	.	.
Lysimachia nemorum		s	.	.	.	.	2	1	3	1	5	3	.	.	2	3	.	.	.	.	.	.	.
Cardamine amara		s	.	.	.	.	1	1	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.
Ranunculus repens		s	.	.	.	.	.	.	1	1	.	.	.	.	2	.	2	.	.	.	.	.	.
***Plagiomnium affine* agg.**		m	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	+	.	.
Brachythecium rivulare		m	.	.	.	.	.	.	.	+	+	.	.	++	+++	+	.	.	.	.	+	.	.
Calliergonella cuspidata		m	.	.	.	.	.	.	.	.	+	++	+	+	++	.	.	.	.	.	.	.	+++

Table 8: Cont.

Picea abies	n	.	.	.	.	.	1	2	1	.	.	4	1	.	.	.	.	.	.	2	.	.
	s/w	++	.	.	.	.	.	.	2	.	+++	.	2	.	.	.	.	.	++	.	.	1
	b	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	1	.	2
Urtica dioica	s, (p)	.	.	(+)	.	.	(+)	(+)	.	.	.	.	(+)	.	.	.	1/(+)	4/(+)	.	.	(+)	(+)
Carex panicea	s	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	8	2	8	23
Ranunculus acris	s	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	2	3	7	22	9
Anthoxanthum odoratum	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	9	4	12
Potentilla erecta	s,r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	21	17/++	17/++	21
Philonotis fontana	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+++	.	+
Carex echinata	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	26	27	13
Carex canescens	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	7	30	97
Cirsium palustre	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	1	.	2
Glyceria fluitans	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	.	1
Carex nigra	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	12	135
Ranunculus flammula	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	21	4
Poaceae	nod	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	12	4
Viola palustris	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	9	.
Climacium dendroides	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+++	.	+
Rhizomnium punctatum	m	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	++
Rumex acetosa	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+

In addition there occur: 92-97: *Fraxinus excelsior* ++ w; 88-92: *Myosotis palustris* agg. 1 s; 65-70: *Plagiomnium undulatum* + m; 50-55: *Cratoneuron* cf. *filicinum* + m; 15-20: *Juncus articulatus* 2s; 10-15: *Chenopodium album* agg. 1s, *Atrichum undulatum* + m, *Aulacomnium palustre* +++ m; 0-5: *Betula pendula* 3s, *Lychnis flos-cuculi* 5 s.

Table 9: Table of macroscopic plant remains and important pollen grains from the Královec (BK-3-A)

Age years B.P.		(1250)				1040						(670)						(280)				
Depth (cm)	**from**	**120**	**114**	**111**	**104**	**96**	**90**	**86**	**79**	**72**	**66**	**59**	**52**	**45**	**38**	**31**	**27**	**21**	**14**	**7**	**4**	**0**
	to	**126**	**120**	**114**	**111**	**104**	**96**	**90**	**86**	**79**	**72**	**66**	**59**	**52**	**45**	**38**	**31**	**27**	**21**	**14**	**7**	**4**
Volume of analysed sediment (ml)		**200**	**200**	**100**	**200**	**200**	**200**	**100**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**100**	**200**	**200**	**200**	**100**	**100**
Developmental	**phase**	**forest spring phase**										**open spring fen phase**										
	stage	***Alnus* stage**				***Abies* stage**						***Salix* transition stage**						**calcareous fen meadow**				
Alnus glutinosa	w	++	++	++	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	s	8	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex remota	s	4	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus repens	s	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Colchicum autumnale	s	.	3	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
***Brachythecium* sp.**	m	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizomnium punctatum	m	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bryum pseudotriquetrum	m	+	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus sylvatica	w	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	s	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	b	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Abies alba	w	.	.	+	++	++	++	.	.	+	++	++	+	.	.	.	.	.	.	.	.	.
	s	.	.	.	1	8	9	4	3	6	4	1	.	.	.	.	2	.	1	.	.	.
	n	.	.	.	6	32	41	24	22	11	2	.	.	.	.	.	1	.	.	.	.	.
Picea abies	s	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	n	.	.	.	.	6	7	5	4	2.	.	.	.	.	.	.	.	.	.	.	.	1
Fagus sylvatica	ls	.	.	5	9	14	17	7	10	5	19	7	1	.	2	.	2	.	.	.	.	1
***Salix* sp.**	w	.	.	.	.	+	.	.	.	+	+	++	++	++	++	++	+		+			
Sambucus nigra	s	1	3	2	5	7	4	3	1	.	.	1	1	.	.	2	2	.	.	.	.	.
Cardamine* cf. *amara	s	1	.	.	1	.	1	3	.	.	4	7	1	1	1	2	.	.	.	.	.	.
Cratoneuron commutatum	m	.	+	+	+	+	+	.	++	++	++	++	.	++	.	.	.	.	.	.	.	+
Carex flacca	s	.	.	.	.	.	.	.	.	.	4	13	3	3	2	4	1	6	6	5	1	4
Carex panicea	s	.	.	.	.	.	.	.	.	.	1	.	1	1	1	1	3	13	10	20	11	15
Carex nigra	s	1	.	.	.	.	.	.	.	.	.	.	1	1	4	1	1	1	.	.	1	2
***Carex flava* agg.**	s	.	.	.	.	.	.	.	.	.	.	.	.	.	1	8	1	12	11	22	8	7
Cirsium* cf. *rivulare	s (p)	.	.	.	.	.	.	.	.	.	.	2	1	(+)	(+)	(+)	(+)	3	1	1	1	1
Calliergonella cuspidata	m	.	.	.	.	.	.	.	.	.	.	.	.	++	.	.	.	+	.	.	.	+

Table 9: Cont.

Rumex* cf. *obtusifolius	s	.	.	.	.	.	.	.	.	.	6	43	3	1	.	.	.	.	.	.	.	.
Lychnis flos-cuculi	s (p)	.	.	.	.	.	.	(+)	.	.	1	.	1	(+)	.	.	.	.	.	.	.	.
Carex* cf. *echinata	s	.	.	.	.	.	.	.	.	1	.	1	3	5	11	4	1	3	.	.	.	.
Ajuga reptans	s	1	.	.	.	.	.	.	.	.	.	.	.	.	1	3	2	2	.	3	.	.
***Myosotis palustris* agg.**	s	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
Stachys sylvatica	s (p)	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	(+)	2	.	.	.	.
Urtica dioica	s (p)	.	.	.	.	.	.	.	.	.	.	(+)	1	1	1	1	.	.	.	.	.	.
Potentilla erecta	s	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	7	26	25	23	18	10
Linum catharticum	(p)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	(+)	(+)	(+)	.	(+)
Triglochin palustris	(p)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	(+)	(+)	(+)	(+)
***Valeriana* sp.**	(p)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	(+)	(+)
Eriophorum angustifolium	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	1
Accessory plants																						
***Rubus* sp.**	s	.	.	.	5	9	9	7	9	1	.	3	2	.	.	2	.	.	.	.	1	3
Betula pendula	s	2	.	1	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	2	2	3
Carpinus betulus	s	2	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tilia* cf. *cordata	s	.	1	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Coenoccocum geophilum	sd	.	.	2	.	1	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.

In addition there occur: 114-120: *Glyceria* sp. 1s, *Viola* cf. *reichenbachiana* 1s; 111-114: *Lysimachia vulgaris* 1s; 104-111: *Chelidonium majus* 1s; 96-104: *Epilobium palustre* 1s, *Homalothecium nitens* + m; 90-96: *Cornus sanguinea* 1s; 79-86: *Oxalis acetosella* 3s; 66-72: *Agrostis* sp. 1s; 59-60: *Epilobium* sp. (+) p; 52-59: *Juncus* sp. 1s; 45-52: *Corylus avellana* 1s; 38-45: *Galium* cf. *uliginosum* 1s; 31-38: *Viola* cf. *palustris* 1s; 21-27: *Lotus* cf. *uliginosus* 2s; 14-21: *Carex pilulifera* 2s; 0-4: *Mentha arvensis* 1s.

Table 10: Table of macroscopic plant remains and important pollen grains from the Tlstá hora (BK-4-A). Abbreviations see Tab. 7.

Age years B.P.			(4300)		3920			2760											(550)		(450)					
Depth (cm)	from		285	281.5	270	256	243	228.5	214	200	189	173	157	142	131	118	113	106	90	72	64	50	36	25	15	8
	to		281.5	270	256	243	228.5	214	200	189	173	157	142	131	118	113	106	90	72	64	50	36	25	15	8	0
Volume of analysed sediment (ml)			100.0	200	200	200	200	200	200	200	200	200	200	200	200	100	100	200	200	200	200	200	200	200	200	200
Developmental	phase		forest spring phase																	open spring fen						
	stage		*Fagus* stage						*Salix-Alnus* stage											transit	calcareous fen meadow					
Sambucus nigra		s	9	2	7	7	11	15	17	4	2	.	7	.	5	18	16	21	38	.	.	.	.	.	.	.
Eupatorium cannabinum		s	.	1	.	.	.	1	.	11	14	1	.	.	1	4	6	2	2	.	2	.	.	.	.	.
***Rubus* sp.**		s	.	.	.	.	4	6	57	11	1	3	.	1	1	6	8	7	6	.	.	.	.	.	.	.
Stachys sylvatica		s	.	1	.	1	4	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.
Atropa bella-donna		s	.	.	2	1	1	2	.	.	.	.	3	.	1	5	.	.	.	.	.	.	.	.	.	.
Solanum dulcamara		s	.	.	1	8	5	3	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.
Ajuga reptans		s	1	.	.	.	.	1	6	4	.	.	.	.	2	1	.	.	1	.	.	.	.	.	.	.
Cardamine amara		s	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.
Fagus sylvatica		ls	8	30	24	64	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
		s/w	2	10/+++	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		(p)	.	.	.	(++)	(++)	(++)	(+)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Glyceria nemoralis		s	.	3	2	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
***Salix* sp.**		w	.	.	.	.	.	++	.	++	.	.	.	.	++	.	.	.	+	.	+	.	.	.	.	.
		(p)	.	.	.	.	.	.	(+)	(++)	(+)	.	.	.	.	.	.	(+)	.	(+)	.	.	.	(+)	.	.
Alnus glutinosa		w (p)	.	.	.	.	.	.	.	.	(+)	(++)	(+)	(+)	(++)	+++	++	++	.	.	.	.	.	.	.	1
Glyceria notata		s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	30	67	.	.	.	.	.
Ranunculus repens		s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	8	.	.	.	.	.
Carex remota		s	1	.	2	2	.	.	1	.	.	.	.	.	.	2	.	.	.	5	17	.	.	.	.	.
Philonotis calcarea		m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.

Table 10: Cont.

Cratoneuron commutatum	m	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	++	+++	+++	+++	+++	++	+++	+++
Campylium stellatum	m	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	++	++	++	++	+	+	+++
Bryum pseudotriquetrum	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+++	+++	++	+	.	.	+
Carex flava	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	11	7	24	6	4	27	43
Linum catharticum	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	6	1	.	4	3
***Equisetum* sp.**	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	++	++	.	.	.
Homalothecium nitens	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	++
Poaceae	nod	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13	16	1	3	5
Valeriana dioica	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	1	6	.
Potentilla erecta	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	10	3	54	57
Blysmus compressus	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	2	25	77
Fissidens adianthoides	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+++
cf. *Caltha palustris*	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	2	1	.	.
Carex flacca	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	9	.
Carex panicea	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
Accessoric plants																									
Carpinus betulus	w	.	.	.	.	.	.	1/++	.	.	.	.	+++	+++	.	.	.	1/+	++	.	.	.	.	.	2
Fraxinus excelsior	w	.	.	.	.	.	.	.	.	.	.	.	.	.	.	++	.	.	.	.	.	.	++	.	.
Urtica dioica	s	.	.	.	1	1	.	2	2	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.
Coenoccoccum geophilum	scl	.	.	.	.	.	1	9	18	.	.	.	.	.	.	.	.	1	1	1	3	.	.	.	2

In addition there occur: 270-281.5: *Eurhynchium* sp. 18 m; 228.5-243: *Swida sanguinea* + w; 113-118: *Molinia arundinacea* 1s; 90-106: *Molinia arundinacea* 2 s; 72-90: *Corylus avellana* 1s, *Acer* sp. ++ w; 64-72: *Myosotis palustris* agg. 1s; 50-64: *Cirsium* cf. *palustre* 1 s; 36-50: *Chara* sp. 1 o; 8-15: *Carex nigra* 4 s, *Betula pendula* 5 s; 0-8: *Cirsium* cf. *palustre* 2s, *Taraxacum* sp. 1s, *Betula pendula* 1s.

Table 11: Table of macroscopic plant remains and important pollen grains from the Machová (BK-5-A). Abbreviations see Tab. 7.

Age years B.P.		**(1300)**						**890**							**(500)**						
Depth (cm)	**from**	**95**	**90**	**85**	**81**	**77**	**72.5**	**67.5**	**62.5**	**57.5**	**52.5**	**47.5**	**42.5**	**37.5**	**32.5**	**27.5**	**22.5**	**17.5**	**12.5**	**6.5**	**0**
	to	**100**	**95**	**90**	**85**	**81**	**77**	**72.5**	**67.5**	**62.5**	**57.5**	**52.5**	**47.5**	**42.5**	**37.5**	**32.5**	**27.5**	**22.5**	**17.5**	**12.5**	**6.5**
Volume of analysed sediment (ml)		**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Developmental	**phase**	**forest spring phase**							**open spring fen phase**												
	stage	***Salix-Fagus* stage**							***Salix* transition stage**						**calcareous fen meadow**						
Carex flava	s	40	46	78	41	17	16	4	.	3	.	16	31	20	5	.	2	4	.	.	6
Carex nigra	s	.	1	.	.	1	.	.	.	.	.	.	.	.	3	3	.	.	.	.	.
***Equisetum* sp.**	st, r	+++	+++	++	++	+	+	+	++	++	++	+++	+++	++	++	++	++	++	++	++	+
Coenoccocum geophilum	scl	42	46	1	3	6	1	.	2	.	1	1	3	3	2	.	3	2	3	4	4
Carex pendula	s	58	63	44	36	8	9	1	.	.	.	.	.	.	.	.	.	.	.	.	.
***Rubus* sp.**	s	.	2	18	11	11	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex remota	s	.	.	4	4	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex* cf. *hirta	s	.	.	.	4	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Atropa bella-donna	s	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fraxinus excelsior	w	.	.	++	.	.	.	+++	.	.	.	.	.	.	.	.	.	.	.	.	.
Fagus sylvatica	ls	24	32	46	32	14	20	15	1	1		12	14	12	1	.	.	.	.	.	.
	s/w	3	2/++	9	2	.	++	1/+	..	.	.	+	+	.	.	.	.	.	.	.	.
***Salix* sp.**	w	.	++	+++	+++	+++	++	++	++	+	+	+	+	.	.	.	.	.	.	.	.
	(p)			(++)	(++)	(++)	(++)	(+)	(+)	(+)	(+)	(+)	(+)			(+)				(+)	(+)
Ajuga reptans	s	.	.	.	.	.	.	1	16	8	6	6	3	.	.	1	.	.	.	.	.
Viola* sp. *(reich./rivin.)	s	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.
***Epilobium* sp.**	(p)	.	.	.	.	.	.	.	(+)	(+)	.	.	.	.	.	.	.	.	.	.	.
Caltha palustris	s (p)	.	.	.	.	.	(+)	(+)	.	.	(+)	3	.	(+)	.	.	.	.	.	.	.
Scirpus sylvaticus	s	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.

Table 11: Cont.

Cratoneuron commutatum	m	.	.	.	.	.	.	.	.	+++	++	+++	++	+	++	+++	++	++	+++	+++	++
Linum catharticum	s	.	.	.	.	.	.	.	.	.	1	1	1	1	.	.	1	.	1	.	.
Urtica dioica	s (p)	.	.	.	.	.	.	.	.	.	(+)	1	1	(+)	.	2	2	.	.	.	.
Juncus inflexus	s	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	1	.	2	1
Cirsium palustre	s (p)	.	.	.	.	.	.	.	.	.	.	(+)	2	(+)	.	(+)	(+)	(+)	(+)	(+)	.
Poaceae	nod	.	.	.	.	.	.	.	.	1	.	.	1	4	4	1	3	13	1	.	.
Homalothecium nitens	m	.	.	.	.	.	.	+	.	.	.	+	.	.	+	+	.	+	+	+	+++
Campylium stellatum	m	.	.	.	.	.	.	.	.	+	.	.	.	.	.	++	+	.	.	.	+
Carex paniculata	s	.	.	.	.	.	.	.	.	.	.	.	.	1	7	11	8	11	29	69	105
Carex flacca	s	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	2	4	2	22
Valeriana* cf. *dioica	s (p)	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	(+)	(+)	(+)	2	(+)	(+)
Potentilla erecta	s	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	7	15	35	59
Carex panicea	s	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	7
Calliergonella cuspidata	m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	++
Triglochin palustris	(p)	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	.	(+)	.	(+)	.	(+)
Succisa pratensis	(p)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	(+)	.	.	(+)	(+)
Accessory plants:																					
Cornus sanguinea	s/w	+	.	1	.	3	1/+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carpinus betulus	s	.	.	1	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Betula pendula	w	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+

In addition there occur: 85-90: *Sambucus nigra* 5s, *Crataegus* sp. 2s, *Solanum dulcamara* 1s; 62-67: *Alnus glutinosa* ++ w, *Ranunculus* cf. *repens* 1s, *Tilia* sp. + w; 47-52: *Juniperus communis* 1n; 37-42: *Philonotis calcarea* + m; 12-17: *Deschampsia cespitosa* 1s; 0-6: *Molinia arundinacea* 1s, *Plagiomnium elatum* ++ m, *Bryum pseidotriquetrum* ++ m, *Fissidens adianthoides* + m.

Figure 2. Pollen diagram “Horní Lomná” (MB-5-A). Pollen grains and spores occurring scarcely (pollen/spore type, depth cm/ percentage): **Local AP:** *Frangula alnus* 1/0,1, 10/0,1. **Local NAP:** *Bistorta major* 10/0,1, *Campanulaceae* 18/0,1, 22/0,1, 80/0,2. *Epilobium* 0/0,4, 14/0,1. *Geum* 0/0,1. *Lamium* 26/0,1, 76/0,2, 80/,0,2. *Listera ovata* 67/0,2. *Lychnis* t. 10/0,1, 14/0,3, 18/0,2. *Lysimachia vulgaris* 0/0,1. *Mentha* 0/0,1. *Parnassia palustris* O/0,1. *Pedicularis* 0/0,1. *Polygala* 14/0,1. *Senecio* t. 18/0,2. *Silene* t. 14/0,2, 18/0,1. *Solanum dulcamara* 0/0,1, *Trifolium repens* t. 0/0,1. *Vaccinium* 56/0,2, 70/0,2, 80/0,2. *Vicia* t. 30/0,1. **Regional AP:** *Juglans* 0/0,1. *Populus* 45/0,2. **Regional NAP:** *Centaurea cyanus* t. 5/0,1, 10/0,1. *C. jacea* t. 40/0,2, 76/0,2. *Echium* 5/0,1. *Lycopodium clavatum* 0/0,1, *Plantago media* 14/0,2, 22/0,1. *Sparg anium-Typha angustifoila* t. 74/0,2, 89/0,2.

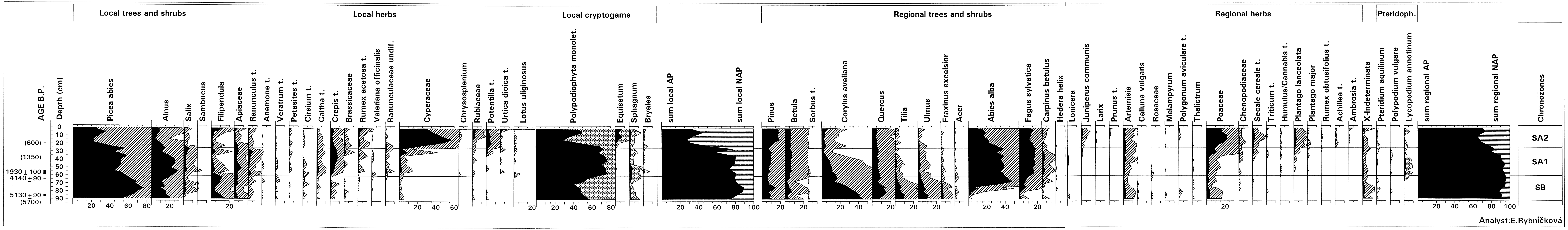


Figure. 3. Pollen diagram “Kubriková” (MB-6-A). Pollen grains and spores occurring scarcely (pollen/spore type, depth cm/percentage): **Local NAP:** *Alisma* 5/0,1, 57,5/0,2, 90/0,2. *Anemone* t. 20/0,3, 25/0,3, 30/0,3. *Campanulaceae* 10/0,2. *Circaea* 22,5/0,2. *Glyceria* t.. 100/0,2. *Lamium* t. 80/0,5. *Lathyrus* t. 15/0,1. *Listera ovata* t. 27,5, *Lotus uliginosus* t. 0/0,6, 60/0,2. *Lysimachia vulgaris* 15/0,1, 60/0,2. *Lythrum* 65/0,2. *Mentha* 100/0,2. *Montia* 86/0,2. *Myriophyllum spicatum* 65/0,2. *Pedicularis* 55/0,2. *Polygala* 5/0,1, 10/0,1. *Ranunculus repens* t. 55/0,6, 60/0,2, 62,5/0,2. *Rubus* t. 65/0,2, 70/0,1. *Stachys* t.60/0,2, 84/0,1, 90/0,2. *Vaccinium* t. 0/0,1, 15/0,1, 57,5/0,2, 84/0,1. *Viola palustris* t. 86/0,2. **Regional AP:** *Cornus sanguinea* 90/0,2, 100/0,2. *Juglans* 10/0,1. *Larix* 75/0,2, 95(0,1, 100/0,2. *Prunus* t. 0/0,1,5/0,2, 60/0,2, 100/0,2. *Sorbus* t. 5/0,1, 15/0,1, 50/0,2, 100/0,3. **Regional NAP:** *Achillea* t. 10/0,1, 15/0,2, 27,5/0,2, *Ambrosia* 0/0,7, 5/0,1, 15/0,1. *Botrychium* 22,5/0,2, 27,5/0,1, 30/0,1. *Caryophyllaceae* 15/0,2, 70/0,4, 75/0,2. *Centaurea cyanus* 10/0,1, 25/0,3, 30/0,2, 40/0,2. *C. jacea* 0/0,1, 15/0,1. *Echium* 15/0,1. *Euphorbia* 15/0,1. *Humulus-Cannabis* t. 19/0,1, 27,5/0,2, 75/0,3. *Plantago media* 5/0,2, 10/0,2, 27,5/0,5. *Polygonum aviculare* 0/0,3. *Polypodium vulgare* 45/0,1, 57,5/0,3. *Rosaceae* 95/0,1. *Rumex obtusifolius* 15/0,1. *Scleranthus annuus* 57,5/0,2. *S. perennis* 15/0,3. *Sparganium-Typha angustifolia* 10/0,1. 82/0,2. *Thalictrum* 80/0,2.

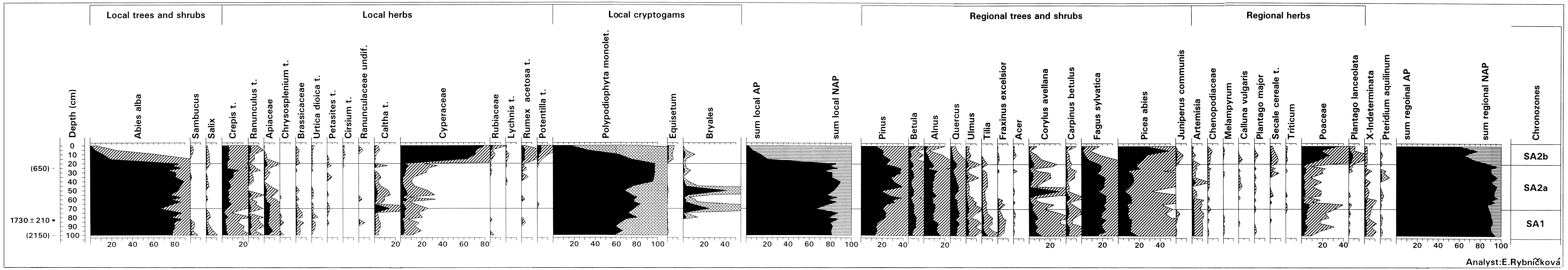


Figure 4. Pollen diagram “Královec” (BK-3-A). Pollen grains and spores occurring scarsely (pollen/spore type, depth cm/percentage): **Local NAP:** *Athyrium filix-femina* 105/0,2. *Bistorta major* 50/0,2. *Campanulaceae* 45/0,2, 50/0,2. *Cystopteris fragilis* 75/0,2. *Epilobium* 60/0,2. *Geranium* 15/0,2. *Impatiens* 60/0,2, 70/0,2, 85/0,2, 90/0,2. *Knautia* 0/0,2, 15/0,2, 25/0,2. *Linum catharticum* 20/0,3, 25/0,2. *Lotus uliginosus* t. 0/0,6, 60/0,2. *Lychnis* 50/0,2, 90/0,2. *Mentha* 65 /0,2. *Sanguisorba officinalis* 0/0,2, 5/0,3, 30/0,4. *Stachys* 30/0,7. *Succisa pratensis* 85/0,2. *Valeriana officinalis* 45/0,2, 55/0,2. *Veronica* 55/0,2. **Regional AP:** *Cornus sanguinea* 75/0,2. *Loranthus* 75/0,2. **Regional NAP:** *Bupleurum* 15/0,2. *Calluna vulgaris* 5/0,2, 65/0,2, 70/0,2. *Caryophyllaceae* undiff. 0/0,2, 10/0,2, 40/0,2. *Centaurea jacea* 20/0,2, 30/0,4. *Cerealia* undiff. 0/0,2, 60/0,2, 105/0,4. *Lycopodium annotinum* 50/0,2. *Polygonum aviculare* 0/0,3, 15/0,2, 20/0,2. *Rumex obtusifolius* t. 55/6,0, 60/0,8. *Sedum* 65/0,2. *Typha latifolia* 15/0,2, 50/0,4.

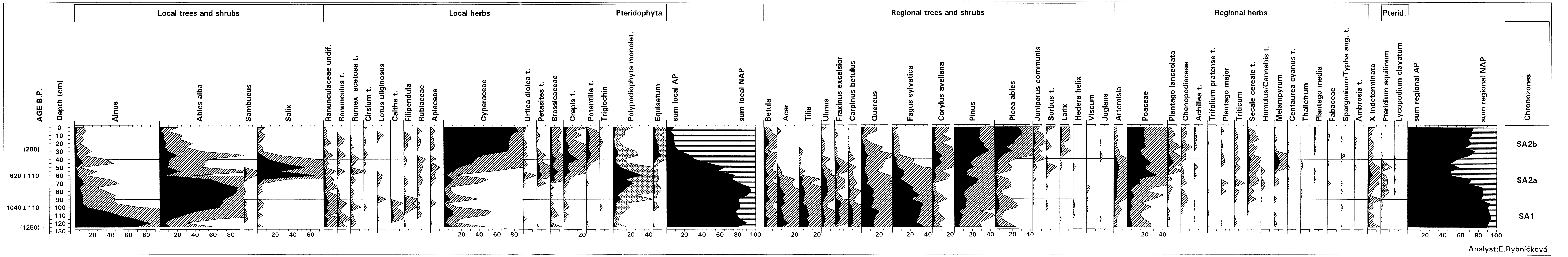


Figure 6. Pollen diagram “Machová” (BK-5-A). Pollen grains and spores occurring scarcely (pollen/spore type, depth cm/percentage): **Local AP:** *Frangula alnus* 25/0,1. **Local NAP:** *Anemone* t.. 65/1,0, 70/0,2. *Epilobium* 60/0,2, 65/0,2. *Lamium* 80/0,2. *Lysimachia vulgaris* 25/0,1, 85,0,5. *Silene* t. 0/0,1, 40/0,3. *Succisa pratensis* 0/1,5, 5/0,3, 10/0,8, 25/0,1. *Urtica dioica* 45/0,3, 60/0,2. **Regional AP:** *Ephedra fragilis* 20/0,1. *Lonicera* 20/0,1. *Prunus* t. 15/0,1, 70/0,2. *Vitis* 20/0,1. **Regional NAP:** *Anthoceros punctatus* 25/0,1, 60/0,2. *Calluna vulgaris* 15/0,1, 55/0,3, 75/0,2, 95/0,2. *Fabaceae* 40/0,2, 60/0,2, *Helianthemum* 15/0,1, 20/0,3, 30/0,3. *Humulus-Cannabis* t. 30/0,3, 45/0,3, 60/0,3. *Lilium martagon* 20/0,1, 25/0,1, 75/0,2. *Sanguisorba minor* 45/0,2. *Selaginella selaginoides* 55/0,5. *Thesium* 10/0,2, 30/0,2. *Trifolium pratense* 25/0,1, *Vaccinium* 10/0,2, 20/0,1.

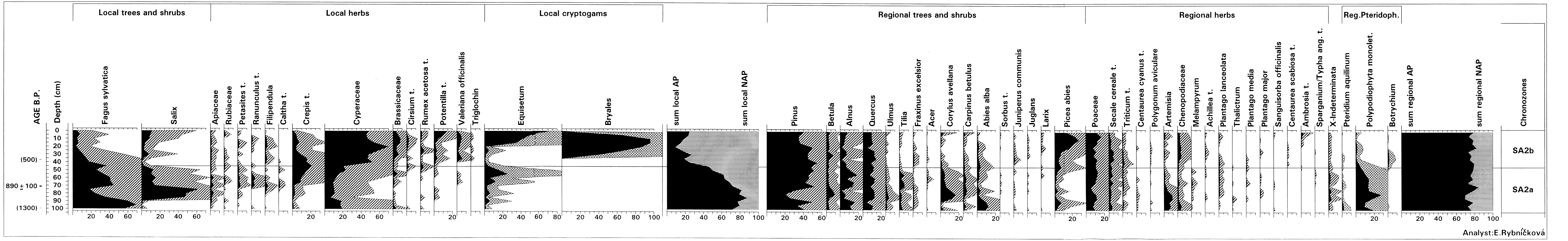
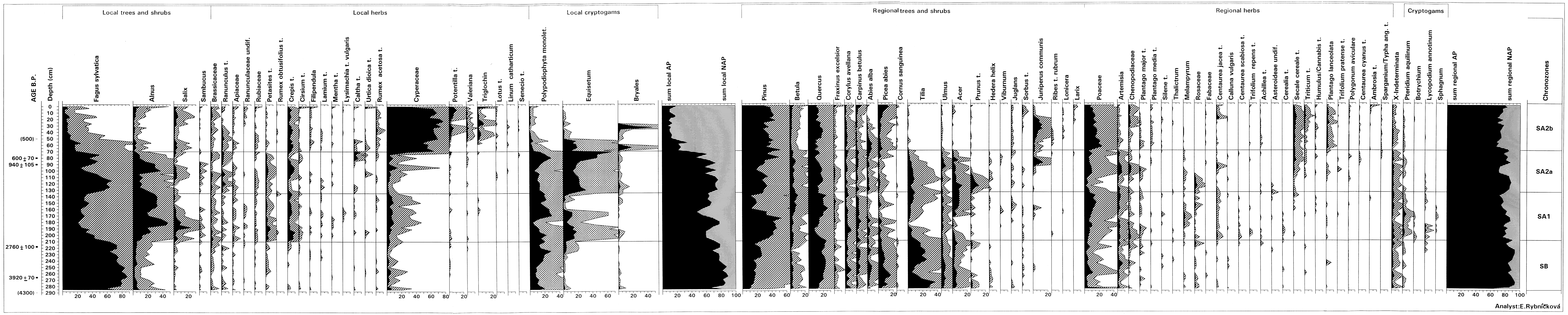


Figure 5. Pollen diagram “Tlstá hora” (BK-4-A). Pollen grains and spores occurring scarcely (pollen/spore type, depth cm/percentage): **Local AP:** *Frangula alnus* 57/0,2, 160/0,2, **Local NAP:** *Alisma* 95/0,3. *Anemone* t.100/0,2. *Serratula* 100/0,2. *Campanulaceae* 0/0,1. *Chrysosplenium* 59/0,1, 170/0,2, 230/0,2, 285/0,3. *Epilobium* 140/0,2. *Geranium* 260/0,2. *Lythrum* 191/0,2. *Monocotyledonae* undiff. 59/0,1, 170/0,2. *Pedicularis* 180/0,2. *Pulmonaria* 180/0,2. *Scrophulariaceae* 36/0,1. *Stellaria holostea* t. 180/0,2. *Succisa pratensis* 19/0,1, 50/0,1, 279/0,2.**Regional AP:** *Ephedra fragilis* 19/0,1, 23/0,1. *Loranthus* 0/0,2, 3/0,1, 33/0,1, 110/0,2. *Pyrus* 33/0,1. *Vitis* 0/0,1, **Regional NAP:** *Anthoceros laevis* 69/0,1. *Echium* 36/0,1. *Fagopyrum esculentum* 45/0,1, 75/0,2. *Lycopodium clavatum* 85/0,2, 100/0,2, 260/0,2. *Lycopodium* sp. 40/0,1, 75/0,1. *Polygala* 270/0,2. *Polypodium vulgare* 200/0,2, *Sanguisorba minor* 19/0,2, 23/0,1, 50/0,2. *S. officinalis* 33/0,1, 71/0,2, 260/0,2. *Scleranthus annuus* 80/0,2. *Symphytum* 27/0,1, 33/0,1, 45/0,2. *Thesium* 0/0,2. *Typha latifolia* 23/0,1, 57/0,1. *Vaccinium* 17/0,1, 45/0,1.



Chapter 4

The historical development of the White Carpathian spring fens based on palaeomalacological data

M. Horsák & P. Hájková

Introduction

The West Carpathian spring fens are unique in terms of frequent tufa precipitation. Above all, the White Carpathian Mts is a region with a nearly exclusive and common occurrence of extremely rich tufa-forming fens (*Carici flavae-Cratoneuretum*). This type of habitat is very suitable for perfect preservation and fossilisation of mollusc shells. The fossil molluscan assemblages of two tufa-forming fens in the White Carpathian Mts were investigated in order to reveal and understand their origin and historical development.

These habitats are really significant from the palaeoecological point of view. It is not usual that the results of pollen and macroscopic plant remains analysis can be compared with the malacological analysis from the same site (Dimbleby & Evans 1974, Preece & Day 1994). Usually, there is no site-overlapping of both palaeobotanical and palaeomalacological approaches because of different fossilisation requirements. Moreover, these methods provide generally more or less different results. Processing of pollen brings information about vegetation composition of a larger area; pollen can be spread at relatively long distances and its correct quantification is sometimes difficult (Sugita et al. 1999). On the contrary, macroscopic plant remains and mollusc assemblages reflect only small-site conditions; molluscs also reflect structural and successional types of habitats.

Methods

The first profile, called Tlstá hora, was sampled at a dug out exposure 290 cm deep. Approximately one-litre sample was taken from each visible layer, determined mainly according to the structure and colour of sediments. In total, 12 layers were distinguished (incl. present) where 10,734 shells were identified. For further stratigraphic description see Chapter 3. From the second profile, called Královec, fossil molluscs were picked out from the samples of plant remains (Chapter 3). In spite of an extremely small volume of these samples, insufficient for standard malacological processing, some informative data were still obtained. Only 515 shells were discovered.

For the descriptions of both sites, studied region, time zonation, and ^{14}C dating see Chapter 3.

Results and discussion

1. Tlstá hora

Table 1 presents the list of species with their ecological classification adapted according to Ložek (1964) and Lisický (1991) and their abundances in individual.

The lower eight layers up to 70 cm represent forest habitats. A relatively species-poor community (17 species) with dominance of common species was found in the base layer (depth 260 cm, 3600 years B.P.). Some calciphilous and thermophilous snails were also found (e.g. *Sphyradium doliolum*, *Orcula dolium*, *Discus perspectivus*). From botanical point of view, the site was a successionally young stony spring in beech forest (Chapter 3). In upper layers, we observed a clear and continuous development towards a climax forest community. Above all, the proportion of strictly forest species and inhabitants of preserved forests increased continuously from 17 to 38. This finding correlates positively with an increasing number of forest vascular plant species and negatively with a decreasing amount of charcoals. The layers 110-90 cm and 90-70 cm represented flysh Carpathian forest climax; both included assemblages consisted of 42 species. More than 30 % of all these species were strictly forest species (sensu Ložek 1964). *Macrogastra latestriata* represented a crucial indicator species of the climax state; three specimens were found in the layer 90-70 cm (650 years B.P., based on ^{14}C dating). This species was very common in the target area during the climatic optimum of the Holocene, as the analyses of forest profiles suggest (Ložek 1999). This snail has survived up to the present only at one site – a virgin beech forest on the northwestern slope of Chmeľová Hill (Slovakia). Our finding documented the presence of more or less untouched forest habitat in this area until the period of the largest Walachian colonisation, which proceeded 700-600 years ago. The whole territory was almost completely deforested during this period and many virgin forest mollusc inhabitants became extinct. The paradox is that immediately after the appearance of *M. latestriata,* the studied site was completely deforested and mollusc community totally changed. Nineteen snail forest species became extinct and species of open habitats appeared. Common open-landscape snails *Vertigo pygmaea* and *Vallonia pulchella* were fairly abundant; also some hygrophilous and simultaneously heliophilous species became more abundant or even new species appeared (e.g. *Vertigo antivertigo*, *Oxyloma elegans*). In the layer 58-32 cm (the second layer after deforestation) *Vertigo moulinsiana* appeared for the first time. This finding confirmed relatively young immigration of the threatened *V. moulinsiana* to the White Carpathian Mts According to the pollen and plant remains in the first period after deforestation (70 cm deep), the site was not regularly grazed and mowed. The occurrence of *Salix* pollen, the survival of some forest plants (e.g. *Carex remota*), and the lack of some typical fen plants (e.g. *Valeriana dioica* and *Blysmus comressus*) suggest this fact. Typical fen communities were found in the next layer; the site was regularly grazed or mowed (not burned). This is consistent with the appearance of *V. moulinsiana.*

2. Královec

Table 2 presents the list of species with their ecological classification (Ložek 1964, Lisický 1991) and numbers of specimens in individual layers. This profile was much younger than the previous one, dating back to only 1250 years B.P., with maximum depth 125 cm. Up to the layer of 41.5 cm (ca 300 years B.P.), the studied site was still covered with forest, but we distinguished three different phases. The first one (up to 100 cm) represents a semi-opened extremely water-soaked alder carr. In this period, some stagnant water molluscs (e.g. *Anisus leucostoma* and *Radix peregra*) were more abundant. The second phase (100-65 cm) was connected with the change of the hydrological regime. The precipitation of tufa apparently increased due to higher run-off. These conditions reflected a significant increase in the abundance of spring snail *Bythinella austriaca* s. lat. Strong human impact characterised the third phase. Heavy exploitation of the site led to partial deforestation and strong eutrophication. Within the plant remains, these changes were indicated by the absence of *Abies alba*, the appearance of *Salix* pollen and ruderal plants *Rumex* cf. *obtusifolius* and *Urtica dioica*. The mollusc community was also affected. We found a fair decrease in species richness and even the abundance of individual species. The layer of 41.5-34.5 cm reflected deforestation as the first appearance of open-landscape species suggests (e.g. *Vertigo pygmaea*, *Vallonia pulchella*). Other consequences of such habitat change were the disappearance of almost all forest species, the decrease in the number of water molluscs, fair increase in the abundance of meadow species, and the appearance of some hygrophilous and simultaneously heliophilous snails.

Conclusions

As documented by both palaeomalacological and palaeobotanical results, the open meadow state of the studied habitats is quite young. It is the result of human activities, mainly extensive deforestation during the largest Walachian colonisation (in progress 700-600 years ago). We are convinced that also the majority of other similar habitats and their unique communities are artificial in the region.

Malacological results correspond well with the palaeobotanical data as far as the initial forest state of habitats and the indication of their deforestation and transformation are concerned. Palaeomalacological analysis brings additional results concerning the structural features and successional development of the studied sites.

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Explanation of abbreviations used in the tables

The species found were subject to ecological classification according to Ložek (1964) and Lisický (1991) with small changes. 1 SI (SILVICOLAE) - strict forest species; 2 - forest species frequently occurring in mesic habitats as well (such as gardens, parks, etc.) - SI(MS), in shrubs - SIth, and in wet habitats - SI(HG); 3 SIh - species of damp forest habitats; 5 PT (PRATICOLAE) - forest-avoiding species; 6 XC (XERICOLAE) - thermophilous and xerotolerant species; 7 MS (MESICOLAE) - mesophilous and mostly euryoecious species, SIp - snails also occurring in forest habitats and rocks; 8 HG (HYGRICOLAE) - species with high moisture demands, but not confined to wetlands; 9 PD (PALUDICOLAE) - extremely hygrophilous terrestrial species living in many types of wetlands. Aquatic species are divided into 4 basic and several transitional ecoelements; RV (RIVICOLAE) - species of running water habitats; STAGNICOLAE (SG) - species of stagnant waters; PD (PALUDICOLAE) - species of overgrown bogs or swamps with ephemeral existence - PDt; (FN) FONTICOLAE - inhabitants of springs.

Species and number of specimens found in the individual layers of Královec calcareous spring fen (Tab- 2). The layers are ranged and numbered from the surface to the bottom.
0: 0-3.5; **1**: 3.5-7; **2**: 7-10.5; **3**: 10.5-14; **4**: 14-17.5; **5**: 17.5-21; **6**: 21-24.5; **7**: 24.5-27.5; **8**: 27.5-31; **9**: 31-34.5; **10**: 34.5-38; **11**: 38-41.5; **12**: 41.5-45; **13**: 45-48; **14**: 48-51.5; **15**: 51.5-55; **16**: 55-58.5; **17**: 58.5-62; **18**: 62-65.5; **19**: 65.5-68; **20**: 68-72; **21**: 72-75.5; **22**: 75.5-79; **23**: 79-82; **24**: 82-86; **25**: 86-89.5; **26**: 89.5-93; **27**: 93-96.5; **28**: 96.5-100; **29**: 100-103.5; **30**: 103.5-107; **31**: 107-111; **32**: 111-114; **33**:114-117; **34**: 117-120; **35**: 120-123; **36**: 123-126, all in centimetres.

Table 1: Species and number of specimens found in the individual layers of Tlstá hora calcareous spring fen. The depth of each layer was measured from the surface and is given in centimetres.

Ecol. groups		Species	0	4-18	18-32	32-58	58-70	70-90	90-110	110-135	135-150	150-180	180-200	200-250	botttom
1	SI	*Platyla polita*	1				1	79	32	54	44	12		4	2
		Vertigo pusilla						34	1	21	4	2			
		Sphyradium doliolum						19	8	4	16		15		1
		Acanthinula aculeata					1	63	43	19	20	14	16	6	1
		Macrogastra latestriata						4							
		Macrogastra plicatula						1							
		Discus perspectivus								9	8	5	8	12	2
		Aegopinella pura						263	107	81	50	7	17	10	4
		Daudebardia brevipes		2			1	16	18	16	2	3	3		
		Daudebardia rufa	2					80	14	22	11		7		
		Vitrea diaphana						15	4	10	9		2	1	
		Helicodonta obvoluta						17	2						
		Petasina unidentata						8	2	1	1	1		1	
		Monachoides incarnatus	1					3	1	2				1	
		Isognomostoma isognomostomos						3							
2	SI(MS)	*Discus rotundatus*						60	7	30	51	18	19	4	
		Alinda biplicata						7	9	18	15	4		3	
		Oxychilus glaber	2					1	6	8					
	SIth	*Aegopinella minor*						1		3	18	1		16	6
		Helix pomatia						3							
	SI(HG)	*Vitrea crystallina*						175							
3	SIh	*Macrogastra ventricosa*						3		1					
		Vestia turgida						133	115	252	51	1	24	6	8
5	PT	*Pupilla muscorum*				4									
		Vertigo pygmaea	66	26	3	95	11								
		Vallonia pulchella	38	47	47	160	24								
	PT(SI)	*Vallonia costata*	16	1	2	9	1								
6	XC	*Cochlicopa lubricella*			2	2									
7	MS	*Cochlicopa lubrica*	42	85	31	40	17	31	39	75	14	11		3	
		Punctum pygmaeum	9	4	1	7		16	5	41	10			4	
		Vitrina pellucida										1			
		Vitrea contracta						24	6	12	29	6	2	12	3
		Oxychilus cellarius						31	16	4	8	2	9		
		Euconulus fulvus	23	5	7	16	7	14	12	32	8	4		12	1
		Plicuteria lubomirskii	1						2			1			
	SIp	*Orcula dolium*							2	15	45	29	47	3	2
		Clausilia dubia						3			1				
8	HG	*Carychium tridentatum*	12	1			3	1112	324	785	274	103	44	175	18
		Columella edentula				1	1	23	13	43	5	1		3	
		Vertigo angustior											5		
		Vertigo substriata	1				2	57	42	74	4		2	23	1
		Succinella oblonga	1				3	38	16						1
		Deroceras cf. *laeve*				2									
9	PD	*Carychium minimum*	51	27	16	111	42	148	121	417	27	38		66	4
		Vertigo moulinsiana	9	3		12									
		Vertigo antivertigo	25	16	10	92	45								
		Oxyloma elegans	28	39	128	140	69	3							
		Zonitoides nitidus					7	67	102	231	48				
10	FN	*Bythinella austriaca* s.lat.	50					120	49	98	51	114	24	202	31
	SG-PD(-t)	*Galba truncatula*	66	31	6	76	30	18	24	49	10	6	1	20	1
	SG-RV	*Radix peregra*	1												
	PDt	*Anisus leucostoma*							11	42	23		1	3	
	RV-PDt	*Pisidium casertanum*				14	1		1	3				4	
		Pisidium personatum	16	1			4	28	8	124	4	1		29	1

Table 2: The profile of Královec. For explanation see the text above.

Ecol. groups		Species / Number of layer	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	SI	*Platyla polita*											1																										
		Sphyradium doliolum																																	1				
		Acanthinula aculeata											1		1		1													1									
		Aegopinella pura										2	1								2									1			1						
		Daudebardia brevipes																														1	1						
		Daudebardia rufa																											3	2									
		Daudebardia sp.											1																										
		Vitrea diaphana										1										1		1								1	1						
		Monachoides incarnatus		4		1		1					1															1		1	1	2	1				1		
		Petasina unidentata										1																											
2	SI(MS)	*Discus rotundatus*															1		1	4									1				1						
		Alinda biplicata											1						1		1	1	1			1	1	8	2	3									
		Fruticicola fruticum																														1		1					
		Arianta arbustorum																										1	1	1			1				1		
	SIth	*Aegopinella minor*	1							1		2		1			1							1															
		Helix pomatia									1																												
	SI(HG)	*Vitrea crystallina*											1							1										2							1		
3	SIh	*Vestia turgida*										1																											
5	PT	*Vertigo pygmaea*			1			5	1	4	4		1																										
		Vallonia pulchella				1			1	8	3	4		1																									
7	MS	*Cochlicopa lubrica*				3	3	1	3	4	1			1																									
		Punctum pygmaeum								1	1																					1	1						
		Perpolita hammonis				2							1																										
		Euconulus fulvus			1	2		1											1																				
		Plicuteria lubomirskii						1																															
	SIp	*Orcula dolium*																											2										
8	HG	*Carychium tridentatum*			1					1		5	2	3	4							1	1					2	8	3		1				2			
		Vertigo angustior				1	2	1	6	3	3			1																									
		Vertigo substriata											1		1																								
9	PD	*Carychium minimum*			3	1		1	1	2		1	1	2	1	2		1	1	1								3	2			2		1					
		Vertigo antivertigo						3	1	8	8	4		1																									
10	FN	*Bythinella austriaca* s.lat.																				2	1	14	20	10	24	6	5	6	3	3	2	4		2			
	SG-PD(-t)	*Galba truncatula*			12	1	7	1		6	3	1		2								1								2	2	4	1	1				1	
	SG-RV	*Radix peregra*																	1										2					1	1		1		
	PDt	*Anisus leucostoma*																																			1		1
	RV-PDt	*Pisidium casertanum*																										2	1	4		1	2	2	4	8	5	1	3
		Pisidium personatum		1														1	1				2	1	3	3	4	2	15	3	2	1		2	3	3	3	1	
~	~	Clausiliidae																													1	2	2	2	3	3		1	1
		Limacidae s.lat.											1																		1								

Chapter 5

Present vegetation of spring fens and its relation to water chemistry

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Introduction

This chapter describes major vegetation types under study with respect to their species composition, leading habitat characteristics and phytosociological classification (Chapter 5.1.). The relationships between vegetation and water chemistry, which were studied between 1999 and 2004 (Hájek et al. 2002), are summarised in separate Chapter 5.2. Special attention is paid to the evaluation of the five-year monitoring of water chemistry at reference sites (Chapter 5.3.).

Methods

The phytosociological research followed the Braun-Blanquet approach (Braun-Blanquet 1964), using some modern methods of formalized vegetation classification (Chytrý 2000), namely using the combinations of species groups (Kočí et al. 2003) and calculating the fidelity as a measure of species concentration in a particular vegetation type (Chytrý et al. 2002). The cover of species was recorded using the nine-grade scale (van den Maarel 1979) for both vascular plants and bryophytes. The plot size was 16 m^2, which is a traditional size for meadow and mire vegetation research (Chytrý & Otýpková 2003). The small-scale vegetation-environment relationships were studied mostly at $1m^2$ plots. As for classification, an attempt was made to respect the local classifications created for particular regions in the scale of the entire flysch Carpathians (Hájek 1998, Hájková 2000, Hájková & Hájek 2000, Hájek & Hájková 2002). For this purpose, the indicator species groups (Tab. 1) were established using the fidelity calculation. It should be noted that these groups are only of limited validity because they were established on regional data sets and cannot be easily transferred into other areas. The combination of particular species groups and, in some cases, also the dominance of some species, were used for defining the vegetation types (for further information about the method see Kočí et al. 2003). Tab. 1 shows the indicator species groups; phytosociological table (Tab. 2, p.97-100) presents the summary of the most important species that differentiate particular major vegetation types. Both, detailed phytosociological classification and author names of the syntaxa, are summarised in Tab. 3. The entire vegetation survey presented here concerns the area of the westernmost and northwestern West Carpathians (Fig. 1, Chapter 2). The study area involves the entire flysch borderland between the Czech and Slovak Republics, the continuation of this flysch zone towards the east (Kysuce, Orava, Podhale and Spiš regions), the Strážovské Mts, the Veľká Fatra Mts and their foothill and the adjacent Inner-Carpathian basins (Chapter 2). The terms Outer and Inner Carpathians are used in the text. Generally, these geological terms concern the West Carpathians. The Inner Carpathians form the southeastern part of our study area while the Outer Carpathians represent mostly a flysch zone at the margin of the West Carpathians (for details see Chapter 2).

Besides summarising the results published earlier, this chapter involves also new, so far unpublished results of some additional analyses. The details of water sampling and analysing are described in Hájek et al. (2002) or in Hájek & Hekera (2004), respectively.

For the details on nomenclature used, see Kubát et al. 2002. The particular ranks of the syntaxa are abbreviated as follows:

cl.	class
ord.	order
all.	alliance
ass.	association
subass.	subassociation

Results

1. Major vegetation types

Both treeless waterlogged meadows and sloping spring fens in the diversified agricultural landscape were investigated. This vegetation can be divided into two major groups: (i) medium or high productive, moderately nutrient-rich **waterlogged meadows** on mineral gley soils belonging to the all. *Calthion* (cl. *Molinio-Arrhenatheretea*) and (ii) low productive nutrient-poor **fens** on organic soils or on calcareous tufa belonging to the cl. *Scheuchzerio-Caricetea fuscae*. The latter group, fens, was the major vegetation type under study. Indirect ordination analysis of more than 1300 studied relevés of fens from over all the West Carpathians revealed that the major gradient in vegetation composition is the poor-rich fen gradient, covering habitats from extremely calcium-poor acidophilous fens to extremely calcium-rich alkaline fens (Hájek 2002). The second main gradient of species-data variation is indicated by an increasing number of nutrient-demanding meadow species (Hájek et al. 2002). Since all the habitats under study have a rather high water level and permanently wet soil, the water level gradient is not so important here. The height of the water table influences species composition of vegetation only on a smaller scale, within vegetation types, and its importance varies between poor and rich fens (Hájková et al. 2004). The classification system of fens, which was used in the vegetation survey of Slovakia (Hájek & Háberová 2001), respects these three major gradients and looks for a diagnostic combination of species that indicate particular parts of the gradients. Gradient analyses conducted in various regions of the Northern Hemisphere have demonstrated that similar gradients have more or less general value and are important over a wide geographic area. Hence, stressing species combinations indicating particular parts of environmental gradients has led to a differentiation of vegetation types that are directly comparable to vegetation types distinguished in other ecological studies from the temperate and boreal zones (cf. Rybníček 1985).

The vegetation of spring wetlands occurring in the study area was classified into 15 associations (Tab. 3, p. 101-103).

Waterlogged meadows of the *Calthion* all. were classified into seven associations (Tab. 3). Among them, the ass. *Angelico-Cirsietum palustris* contains a group of species characterising the *Caricion fuscae* fen (Group *Viola palustris* in Tab. 1) and represents the vegetation type transitional to poor fens. Similarly, the subass. *Cirsietum rivularis eriophoretosum latifolii* is a transitional vegetation type between extremely rich fens and calcium-rich waterlogged meadows. On the other hand, two vegetation types of typical fens (*Valeriano-Caricetum flavae*, communities from the alliance *Sphagno warnstorfii-Tomenthypnion*) are rich in species of the *Calthion* meadows. These four vegetation types described above, where the meadow species coexist with those of the fen, are the richest in species among all the vegetation types observed (Tab. 3).

The following six vegetation types represented the most common fen habitats and were investigated in detail with respect to vegetation, water chemistry and the composition of algae and mollusc assemblages.

Table 1: Locally valid indicator species groups, obtained from the data-set of fen and wet meadow vegetation

Group *Caltha palustris*

Caltha palustris, Crepis paludosa, Scirpus sylvaticus, Chaerophyllum hirsutum

Group *Carex lasiocarpa*

Carex lasiocarpa, Salix pentandra, Drepanocladus vernicosus, Oxycoccus palustris, Carex dioica

Group *Cirsium rivulare*

Cirsium rivulare, Cruciata glabra, Alchemilla vulgaris agg., *Ranunculus acris, Rumex acetosa, Caltha palustris, Lychnis flos-cuculi, Climacium dendroides, Festuca pratensis, Anthoxanthum odoratum*

Group *Cratoneuron commutatum*

Tussilago farfara, Carex flacca, Eupatorium cannabinum, Juncus inflexus, Mentha longifolia, Cratoneuron commutatum

Group *Eriophorum latifolium*

Eriophorum latifolium, Bryum pseudotriquetrum, Campylium stellatum, Carex panicea, Epipactis palustris, Drepanocladus cossonii, Fissidens adianthoides, Tomenthypnum nitens, Juncus articulatus, Parnassia palustris

Group *Juncus inflexus*

Juncus inflexus, Mentha longifolia, Carex hirta, Potentilla reptans, Agrostis stolonifera, Dactylis glomerata

Group *Primula farinosa*

Carex davalliana, Primula farinosa, Pinguicula vulgaris, Carex hostiana, Tofieldia calyculata

Group *Sphagnum fallax*

Sphagnum fallax, Polytrichum commune, Sphagnum magellanicum, S. palustre, S. capillifolium, Nardus stricta, Drosera rotundifolia, Pedicularis sylvatica

Group *Sphagnum warnstorfii*

Sphagnum teres, S. warnstorfii, S. subnitens, S. contortum, Aulacomnium palustre, Drepanocladus exannulatus

Group *Stellaria alsine*

Stellaria alsine, Cardamine amara, Chaerophyllum hirsutum, Stellaria nemorum, Chrysosplenium alternifolium

Group *Triglochin maritima*

Campylium uliginosum subsp. *littorale, Schoenoplectus tabernaemontani, Triglochin maritima, Trichophorum pumilum, Glaux maritima, Plantago maritima*

Group *Viola palustris*

Agrostis canina, Epilobium palustre, Carex echinata, Viola palustris, Carex nigra

1. Extremely *Ca*-rich (tufa-forming) fens
(the ass. *Carici flavae-Cratoneuretum*, Tab. 2, column 8)

This vegetation type is characterized by a combination of rich fen species (*Eriophorum latifolium, Triglochin palustris, Blysmus compressus, Eleocharis quinqueflora, Carex flava, C. davalliana, Campylium stellatum, Bryum pseudotriquetrum, Fissidens adianthoides*), mineral-soil species (*Juncus inflexus, Carex flacca, Tussilago farfara, Eupatorium cannabinum, Linum catharticum, Molinia arundinacea, Succisa pratensis*), and species of highly alkaline springs (*Cratoneuron commutatum, Philonotis calcarea*). The moss *Cratoneuron commutatum* and the sedge *Carex flacca* are the most important indicators because their occurrence in the wetlands of the study area prevails mostly in this vegetation type (Tab. 2, column 8). Cotton grasses (*Eriophorum latifolium, E. angustifolium*), and low sedges (*Carex panicea, C. flava*), dominate the herb layer. Tall sedge *Carex paniculata* can dominate in some places and, in this case, organic matter deposits and carbonates precipitate among its tussocks.

The conspicuous habitat feature is an intense precipitation of calcium carbonate, which in many cases forms a thick, hard layer covering the entire fen surface. Some habitats of this vegetation type, i.e. early successional stages of meadow springs, have a loose tufa layer, though their soil has similar physical-chemical properties due to high content of marl particles that are rich in lime. Organic matter is low in all cases; the amount of soil organic carbon is about 5% (Hájek et al. 2002). The presence of $CaCO_3$ incrustation and/or marl particles is a very typical feature that influences not only the composition of vascular plants and bryophytes, but also the composition of invertebrate animal and algae assemblages.

This vegetation type is typical for calcium- and magnesium-rich bedrocks, especially for flysch claystones, marls and calcified sandstones. In our study area, *Carici flavae-Cratoneuretum* is common in the Bílé Karpaty Mts and in the surroundings of the town of Vsetín (Hájek 1998). The second distribution centre is the marl and limestone area of the Strážovská hornatina Mts (Hájková et al. 2001), which represents the area at the biogeographical boundary between the Outer and Inner West Carpathians. In addition, this vegetation type was locally found in the Orava region (Ťaskovka, Krivý Kút) where bedrock analogous to that of the Bílé Karpaty Mts occurs (Chapter 2).

The vegetation of extremely rich tufa-forming fens often develops as small islands in and around spring outflows in the complexes of mown meadows or seasonal pastures; traditionally it has been scythed at the end of the growing season. It often covers just a few square meters, rarely as much as 0.2 ha. Typical communities have developed in the flysch Carpathians as a result of Walachian colonisation and agricultural practices over the last 600 years (Chapter 3). After the cessation of mowing or due to eutrophication, the vegetation type can easily change into the vegetation of waterlogged meadows (*Cirsietum rivularis*) or wet disturbed soils (*Junco inflexi-Menthetum longifoliae*). Similar situations often result in the development of monospecific *Molinia arundinacea* or *Eriophorum angustifolium* stands.

2. Inner-Carpathian calcareous peat-forming fens
(the ass. *Caricetum davallianae*, Tab. 2, column 9)

This vegetation type develops under similar water chemistry as the previous association. However, this vegetation type is well differentiated due to the presence of the group of rich fen species. These species are confined to relic extensive deposits of rich fens in the Inner

Carpathians and their distribution ranges do not, or only marginally, reach the flysch Carpathians (*Primula farinosa, Carex hostiana, Pinguicula vulgaris, Tofieldia calyculata, Carex lepidocarpa, Juncus alpinoarticulatus, Polygala amara* subsp. *brachyptera*). By analogy, there is also a group of mollusc species with a similar distribution pattern in the Carpathians (e.g. *Vertigo geyeri, Pupilla alpicola*) that are strongly confined to these habitats (Chapter 11). The most common dominants of the Inner-Carpathian rich fens are *Carex davalliana, C. lepidocarpa* and *Drepanocladus cossonii*, while *Eriophorum angustifolium*, *Carex panicea* and *Cratoneuron commutatum* dominate the Outer-Carpathian tufa-forming spring fens.

Major environmental differences between the former and latter vegetation types are in the quality of sediment, stability of pH and mineral richness, hydrology and the Holocene development. The Inner-Carpathian calcareous fens have a long postglacial history, during which they accumulated more calcium-rich fen peat or lacustrine marl than compact calcium carbonate. The deposits are of a larger extent; they are supplied by various water sources, and that is why the extremely alkaline springs influence directly only parts of the fens. The consequence is an accumulation of peat with a high content of organic matter, and in only local or seasonal extremities in water pH and mineral richness contrary to tufa-forming fens. This accumulation is also the most important habitat difference between these fens and the Inner-Carpathian travertine swards (ass. *Glauco-Trichophoretum pumili*). The latter are extremely rich in minerals and salts all year round and are entirely covered with a hard layer of travertine. Another ecologically related but rare association *Schoenetum ferruginei* represents a transitional vegetation type between the two above-mentioned communities (Hájek & Háberová 2001).

The ass. *Caricetum davallianae* occurs both in the Inner West Carpathians and in the Alps. Moravec (1966) described all Carpathian rich fens dominated by *Carex davalliana* as a separate association *Valeriano simplicifoliae-Caricetum davallianae*. However, the dominance of *Carex davalliana* itself does not indicate habitat conditions clearly. The synthesis of large phytosociological material from Slovakia (Hájek & Háberová 2001) confirmed this fact. Thus a part of these *Carex davalliana*-dominated fens belongs rather to the ass. *Valeriano simplicifoliae-Caricetum flavae* described by Pawłowski et al. (1960) – see below. The communities of typical *Caricetum davallianae* lack both the Carpathian elements as well as meadow species and, therefore, they are nearly identical with other analogous stands within the entire distribution range of the Alps and the Carpathians.

The regional distribution centre of the ass. *Caricetum davallianae* are the foothills of the limestone Inner-Carpathian mountains and the adjacent Inner-Carpathian basins. At steep sloping springs without accumulated organic matter, the vegetation transitional to the *Carici flavae-Cratoneuretum* (see above) has developed.

3. Outer-Carpathian extremely *Ca*-rich peat-forming fens
(the ass. *Valeriano simplicifoliae-Caricetum flavae*, Tab. 2, column 11)

The third type of calcium-rich fens with a total absence of *Sphagnum* species is mostly conditioned by mowing. It occurs primarily in flysch zones as a part of the mosaic landscape of forests and secondary grasslands. Only a few stands of this type persist unchanged without mowing, e.g. a rich fen in the Vychylovka open-air museum (site no. J: 125). Generally, this vegetation type produces fen peat, sometime with mineral particles, but only very scarcely with carbonate grains. Due to the surrounding agricultural landscape, the sediment is often relatively rich in nutrients. If water level is permanently high and stabilised, typical fen vegetation develops. If water level decreases and/or nutrient input increases, fen vegetation is gradually replaced by the communities of waterlogged *Calthion* meadows. The degree of base saturation is lower than in the two previous fen types (see Hájek et al. 2002, Tab. 3), but still sufficiently high to prevent the occurrence of *Sphagnum* species. The concentration of iron is high. The dominant moss is *Drepanocladus cossonii*, accompanied by iron-tolerating species of permanently waterlogged habitats (e.g. *Calliergon giganteum*) or, in drier habitats, by species typical for the waterlogged *Calthion* meadows (*Climacium dendroides, Plagiomnium elatum, Calliergonella cuspidata*). Lower pH is probably the major factor supporting the occurrence of specific bryophyte species *Hypnum pratense, Aulacomnium palustre, Philonotis fontana* and *Dicranum bonjeanii,* which otherwise grow only very scarcely in the two previous types of the Carpathian rich fens. Similarly, *Carex echinata* and *Agrostis canina* with similar pH demands may also occur among vascular plants. The coexistence of extremely rich fen species, moderately rich fen species and wet meadow species makes this vegetation rather species-rich but, simultaneously, very sensitive to changes of environmental conditions like water level decrease and eutrophication as well as management changes such as the cessation of mowing.

Like tufa-forming spring fens (vegetation type 1), the *Valeriano-Caricetum flavae* is distributed on flysch bedrock, but at higher altitudes and in habitats with both lower Ca and higher Fe ion concentrations in water. This association is in close contact with typical stands of *Caricetum davallianae* in the regions at the border between limestone and flysch bedrocks, e.g. at the northern foothills of the Chočské vrchy Mts. It implies that primarily ecological and not only geographical features differentiate these two vegetation types. The *Valeriano-Caricetum flavae* is extremely rare in the Czech Republic (e.g. Zákopčí near Hutisko-Solanec). Many communities were found in the Kysuce, Orava, Podhale and Spiš regions, always in flysch sloping and subslope springs.

In the Orava region, communities of the *Caricion lasiocarpae* all. represent several fens with water chemistry like similar to previous vegetation type, but of relic character (Tab. 2, column 13). *Carex lasiocarpa, Drepanocladus vernicosus* and *Menyanthes trifoliata* are of high diagnostic value for this type; relic species are sometimes represented by some rare bryophytes, such as *Meesia triquetra, Calliergon trifarium, Helodium blandowii* and *Scorpidium scorpioides*. This type occurs namely near the Slaná voda spa (site no. K: 143), in the Beňadovo mire (site no. K: 139), in the mire near the Oravice settlement (site no. K: 134-135) and in the Oravská Magura Mts between the village of Hrušín and Kubínska hoľa ridge (near the Puchmajerovej jazierko Nature Reserve).

4. Calcium-rich wet meadows
(the ass. *Cirsietum rivularis*, Tab. 2, column 6-7)

A very clear ecological and successional continuum has been found in calcareous areas: calcium-rich fens dominated by sedges, cotton grasses and brown mosses of *Amblystegiaceae* or *Cratoneuraceae* families continually change into more productive, forb-rich waterlogged *Calthion* meadows characterised by *Cirsium rivulare, Lathyrus pratensis, Poa trivialis, Ranunculus acris, Festuca pratensis, Cruciata glabra, Caltha palustris,* and several species of *Alchemilla vulgaris* group. The ecological interpretation of this continuum is not quite clear (see next chapters), but it seems that the major conditioning factors are nutrient supply, mowing intensity, water regime and a strong edge effect due to the small areas of the habitats. Some communities have a very unique structure: they are very low productive, but rich in meadow species. *Eriophorum latifolium* often dominates such communities, which are classified as the subass. *Cirsietum rivularis eriophoretosum latifolii*. The mean number of bryophyte and vascular plant species is 47, the highest number among all the vegetation types under study (Tab. 3). The coexistence of both rich fen and meadow species is reflected in a low number of diagnostic species. Only *Epipactis palustris* is of high fidelity to this vegetation type.

Cirsietum rivularis is distributed throughout the study area. It is absent in some calcium-poor areas on iron-cemented decalcified sandstone where other vegetation types of waterlogged meadows (*Angelico-Cirsietum palustris, Chaerophyllo hirsuti-Calthetum palustris*) replace it.

5. Moderately calcium-rich Sphagnum-fens

(communities of the alliance *Sphagno warnstorfii-Tomenthypnion*, Tab. 2, column 13)

This vegetation type is characterised by a group of calcitolerant *Sphagnum* species that are able to grow in moderately rich fens (*S. warnstorfii, S. teres, S. subnitens, S. contortum*). This species group is combined with the rich fen species, such as *Eriophorum latifolium, Eleocharis quinqueflora, Carex flava, Drepanocladus cossonii,* and *Campylium stellatum*; in the Inner Carpathians *Carex davalliana, C. lepidocarpa, Pinguicula vulgaris,* and *Primula farinosa* may also occur. The occurrence of species of wet *Calthion* meadows (e.g. *Crepis paludosa, Caltha palustris, Cirsium palustre*) and of poor fen meadows (*Agrostis canina*, *Viola palustris*) is typical for some habitats on the flysch bedrock. Slighly acidophilous bryophytes (*Hypnum pratense, Aulacomnium palustre, Calliergon giganteum, Meesia triquetra, Paludella squarrosa*) and shallow rooting acidophilous vascular plants (*Drosera rotundifolia*) grow in small hummocks or within slightly elevated carpets of calcitolerant peat mosses. The combination of all these species results in high species diversity (Tab. 3). Some moderately calcium-rich fens with calcitolerant *Sphagnum* species of this alliance are generally advanced successional stages of rich fens (Rybníček 1974, Rybníček et al. 1984, Hájek 1999, 2002; Hájková & Hájek 2004a). In a such case, the pH of surface water and the pH of water in moss carpets are major ecological differences between brown-moss dominated and peat-moss dominated fens.

In our region, this vegetation type occurs both at flysch (the Moravskoslezské Beskydy Mts, eastern Kysuce, Orava region) and in the Inner-Carpathian basins. In the latter, it has often developed as an advanced successional stage in rich fens. This vegetation type is absent on extremely *Ca*-rich bedrock, i.e. in the Bílé Karpaty Mts and the Strážovská hornatina Mts.

6. Acidic fens

(communities of the alliance *Sphagno recurvi-Caricion canescentis*; Tab. 2, column 15).

Vegetation strongly dominated by *Sphagnum recurvum* agg. (*S. flexuosum, S. fallax*) or *Sphagnum* sect. *Sphagnum* (*S. palustre, S. papillosum, S. magellanicum*) represents the poorest type of the poor-rich fen gradient. Plants of *Calliergon stramineum* often occur among *Sphagnum* plants, and *Polytrichum* species occupy dry hummocks at sites with a very shallow peat layer. Other moss species are suppressed due to high competition from the dominant *Sphagnum* species. Therefore, the moss layer has a high cover and a high production of biomass, but its species richness is low (Hájková & Hájek 2003). Vascular plants are represented by *Eriophorum angustifolium, Carex nigra, Agrostis canina,* and *Viola palustris* in waterlogged fens or by *Vaccinium myrtillus, V. vitis-idaea*, *Nardus stricta,* and *Pedicularis sylvatica* in drier habitats.

In spite of limited species richness and low fidelity of particular species to this vegetation type, we can distinguish three major subtypes. The first one is dominated by *Sphagnum flexuosum* with the presence of waterlogged *Calthion* meadow species (*Crepis paludosa, Lysimachia vulgaris, Lotus uliginosus, Epilobium palustre*); the second is dominated by *Sphagnum fallax* with an admixture of strongly acidophilic and calcifuge bryophytes (*Sphagnum papillosum, S. magellanicum, S. cuspidatum* var. *viride, S. brevifolium, S. denticulatum*). The third subtype is characterised by the dominance of *Carex rostrata* with the occurrence of other species of calcium-poor sedge stands (*Equisetum fluviatile, Menyanthes trifoliata, Potentilla palustris, Carex diandra, Lysimachia thyrsiflora*, *Galium palustre*). The first two subtypes are classified in the ass. *Carici echinatae-Sphagnetum* (subass. *sphagnetosum flexuosi* and *sphagnetosum fallacis*); the third subtype corresponds to the ass. *Carici rostratae-Sphagnetum*.

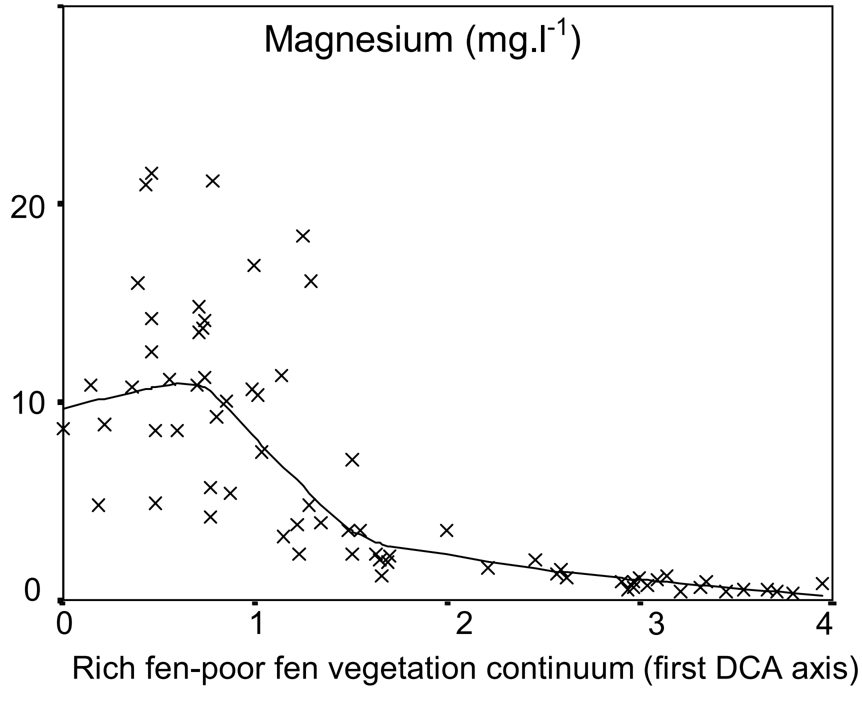
This vegetation type occupies the lime-poorest bedrock. In the borderland between the Czech and Slovak Republics, the occurrence of *Carici echinatae-Sphagnetum* is associated namely with the Istebna beds of the Silesian flysch unit (Hájek et al. 2002). On the Godula beds of the same unit, it mostly occurs at drier, nutrient-enriched or successionally advanced spring fens, which are all strongly dominated by *Sphagnum* (sect. *Sphagnum* or sect. *Cuspidata*) due to superficial acidification. Other occurrences were reported from the Orava region, the Spišská Magura Mts, the foothills of the Vysoké Tatry Mts and from other spring fens on decalcified bedrocks (granite, gneiss, or decalcified sandstone). This vegetation type is totally absent in *Ca*-rich areas.

2. Spatial variation of water chemistry in the flysch part of the Western Carpathians in relation to vegetation composition

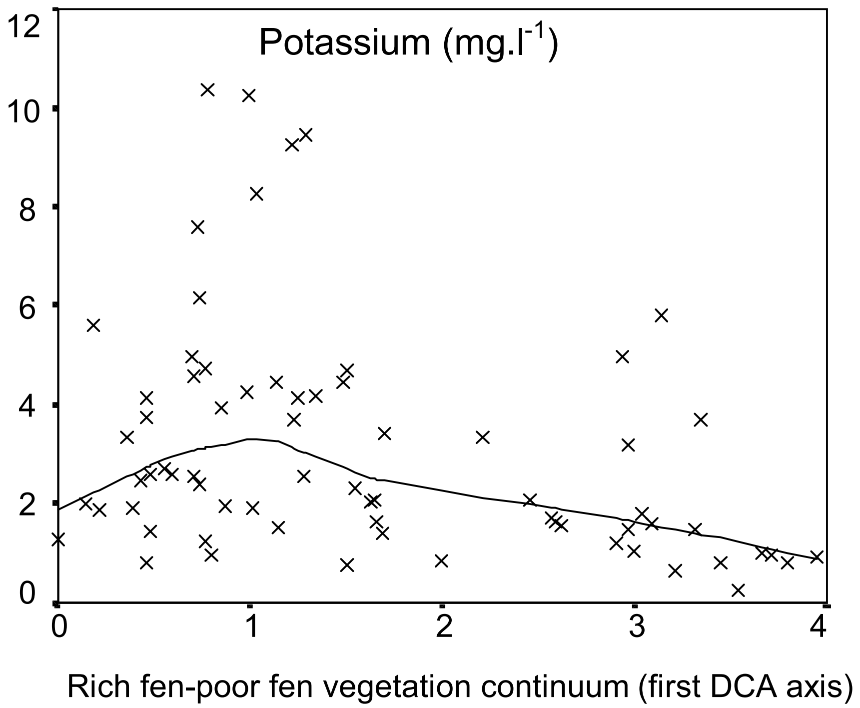
Several springwater chemistry types exist in the study area. The differences in water chemistry among particular geological beds (Chapter 2) are clearly linked to the diversity of fen vegetation at the landscape scale. The poor-rich gradient, from extremely poor and acidic fens to extremely rich fens with tufa formation, conditions also the high diversity of fen vegetation; it is controlled mainly by the springwater pH and by calcium and magnesium concentrations (Hájek et al. 2002). For example, all springwater from beds of the Bílé Karpaty Unit host the vegetation of the ass. *Carici flavae-Cratoneuretum*. On the contrary, the springwater penetrating the mineral-poor Istebna beds of the Silesian Unit conditions the vegetation of acid fens, which represent the poorest extreme of the poor-rich vegetation continuum.

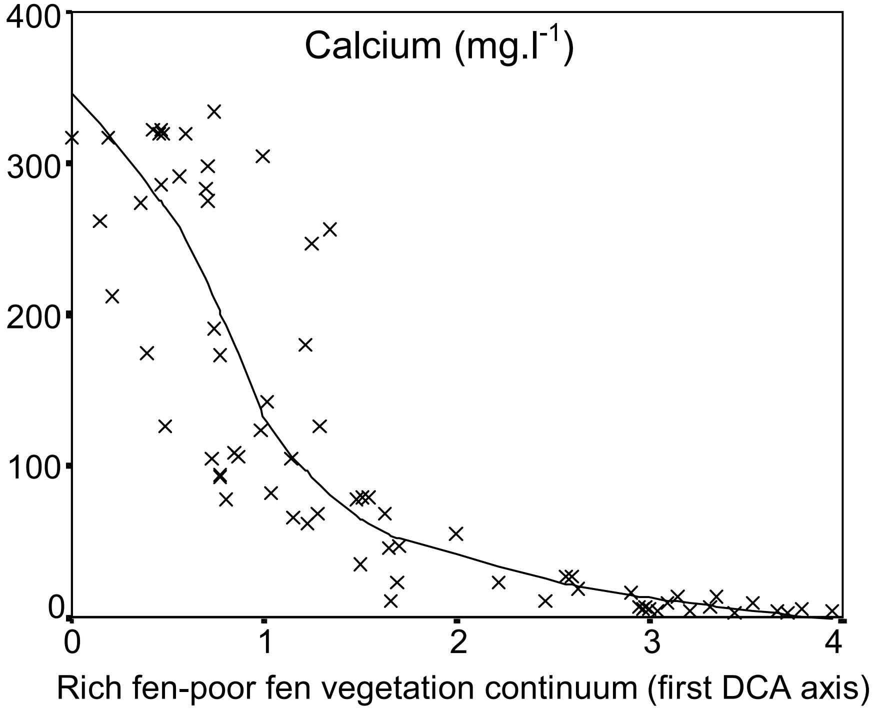
The study conducted by Hájek et al. (2002) showed that the following water chemistry variables increase from the poor to the rich end of the poor-rich gradient in this order: Ca^{2+}, water conductivity, Mg^{2+}, pH, Na^{+}, K^{+}, SO_4^{2-} and Si. On the contrary, ammonium concentrations decrease. The dependence of these variables on the poor-rich gradient is not always linear. Figure 1 based on data from the above cited study shows that pH decreases continually towards poor fens and its relation to the poor-rich gradient is clearly linear. Calcium decreases very steeply from extremely rich tufa-forming fens to peat-forming fens and then it decreases slowly. In fact, it is only an artefact dependent on the scaling of axes. When data of Ca^{2+} concentration are logarithmically transformed, the linear dependence is approximated. A similar dependence for magnesium was found during our study, but variation in its concentration within extremely rich fens is high. Potassium, sodium and iron concentrations change unimodaly along the poor-rich gradient, but, in general, higher values of potassium and sodium were found in rich fens. A lower concentration of potassium in some of the richest tufa-forming fens coincides with low representation of nutrient-demanding wet meadow species (Chapter 5.3). The correlation of other chemical variables (phosphates, nitrates, chlorides, water redox potential) with the poor-rich gradient is not significant. Soil organic carbon, soil organic nitrogen and soil potassium concentrations are significantly higher in poor fens. It is remarkable that soil potassium concentration has an inverse trend compared to water potassium concentration. Both

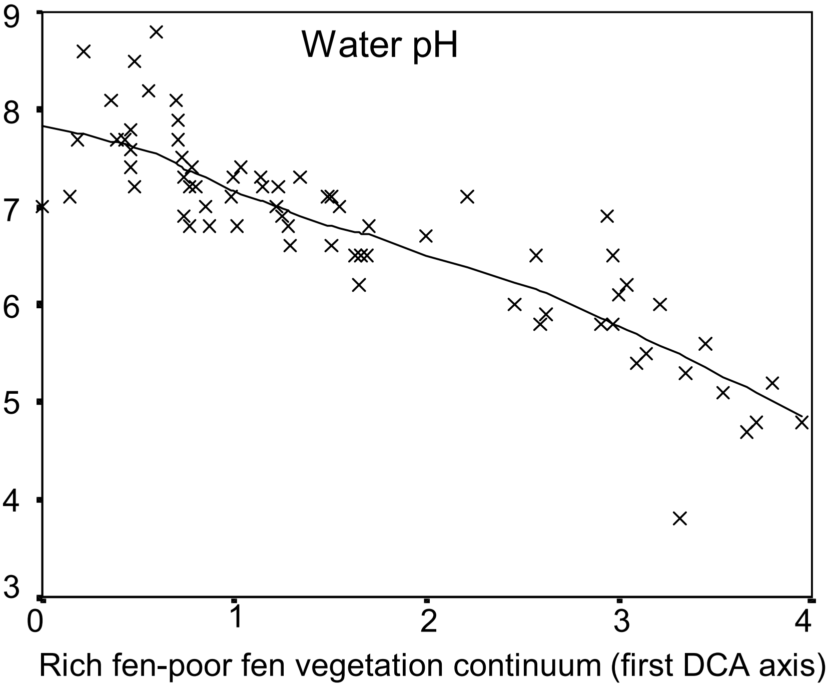
Figure 1**:** The changes of Mg^{2+}, K^+ and Ca^{2+} concentrations and pH along the gradient from extremely rich to extremely poor vegetation. Graphs are based on the data from Hájek et al. 2002. The curves are fitted by locally weighted linear regression.



species richness and aboveground biomass of vascular plants increase significantly towards extremely rich tufa-forming fens. The highest bryophyte richness was found in the middle parts of the poor-rich gradient (Hájková & Hájek 2003).


Potassium (mg.l^{-1})
12
10
8
6
4
2
0
0
1
2
3
4
Rich fen-poor fen vegetation continuum (first DCA axis)

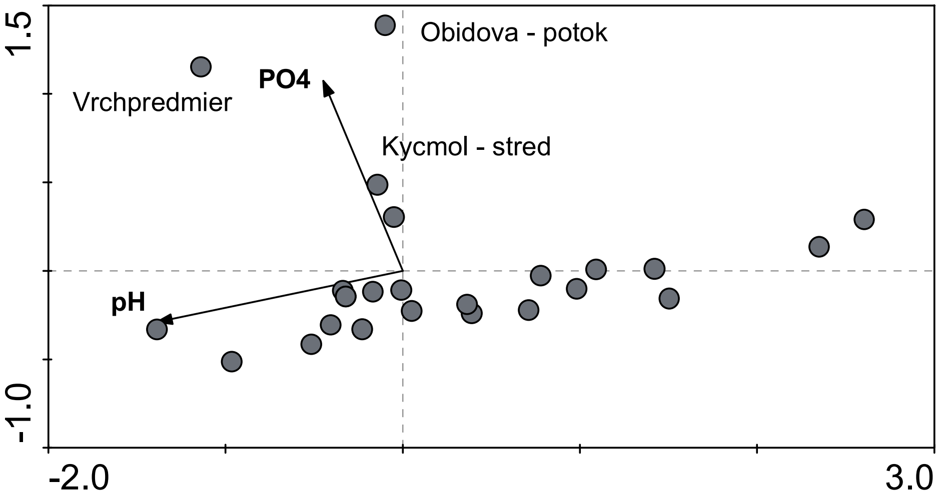

Calcium (mg.l^{-1})
400
300
200
100
0
0
1
2
3
4
Rich fen-poor fen vegetation continuum (first DCA axis)



The differences among major vegetation types are consistent with the above described water chemistry changes along the major vegetation continuum. Conspicuous differences are provided when the ion concentrations in particular vegetation types are compared with those reported usually from the boreal zone and from Western Europe. Various authors (see references in Hájek et al. 2002) have reported lower calcium concentrations (less than 150 $mg.l^{-1}$) in tufa-forming *Cratoneuron commutatum*-springs from Western Europe. Summer calcium concentrations of 150 $mg.l^{-1}$ usually result in tufa formation. Nevertheless, in our study area the compact tufa precipitates first when the calcium concentration reaches values over 250 $mg.l^{-1}$. The explanation of this phenomenon can be found in different ratios among the ion concentrations, in more frequent rainfalls and in the lower temperature regime in our calcium-rich, but still peat-forming fens as compared to tufa-forming fens. There are also regional differences in the length of Holocene development of fen deposits in our study area.

Higher than the usual reported calcium concentrations were found also in poor fens in our study area at flysch bedrock. Several poor acidic fens strongly dominated by *Sphagnum flexuosum* were fed by springwaters with a calcium concentration between 10-15 $mg.l^{-1}$. In boreal fens, this concentration is sufficient for the development of moderately rich fen vegetation dominated by *Tomenthypnum nitens, Sphagnum warnstorfii* and *Drepanocladus cossonii* (e.g. Sjörs 1952, Malmer et al. 1992, Tahvanainen et al. 2002). The reason can be both high iron concentration (about 100 $mg.l^{-1}$) and high phosphate supply in our study area. Iron, in particular the mixture of ferric oxides and calcium carbonate, can immobilise free calcium ions in poor fens. Additionally, free iron ions probably enter the cation exchange mechanism in *Sphagnum* cells (Andrus 1986) and thus prevent efficient calcium absorption into *Sphagnum* plants. The role of phosphorus may be crucial, but it is hardly possible to verify it only by springwater analysis. Several authors have reported that increasing phosphorus supply causes *Sphagnum recurvum* agg. to expand into mires even in calcium-rich habitats (Kooijman & Kanne 1993, Limpens et al. 2003). This finding corresponds well also with our analyses of single water samples from different fen vegetation types (Hájek et al. 2002, Hájková & Hájek 2003), which revealed higher phosphate concentration in monospecific *Sphagnum flexuosum* covers compared to polyspecific stands with calcitolerant *Sphagnum* species. In order to confirm the hypothesis of phosphate oversupply in species-poor acidic fens, we extended the data on poor-fen water chemistry in summer 2003. We sampled water from 24 mutually isolated *Sphagnum* fens. In addition to PO_4^{3-} and total P, we analysed water samples also for Ca^{2+}, Mg^{2+}, Fe, K^+, Na^+, Si, SO_4^{2-}, N-NO_3, N-NH_3, Cl^- and we also measured pH, conductivity, and water redox potential. The data obtained were processed using ordination methods. The stepwise "Forward selection" of the most important variables in CCA (see Lepš & Šmilauer 2003) detected pH as the most important predictor of the species composition of *Sphagnum* fens in the study area. Water pH explained 23.4% of the plant species data. Other variables, including calcium, contributed very little to the model when pH is included as the constraining variable. In short, they did not explain any important part of species data variation (about 9%). In order to verify the hypothesis about the role of phosphorus, we included pH and phosphate concentration into CCA. The analysis orders the majority of *Sphagnum*-fens according to the pH gradient, with the exception of three fen sites with outlying position shifted along the second phosphate-related axis (Fig. 2). The poor fen Obidová-potok (site no. H: 90) is really strongly dominated by *Sphagnum flexuosum* with a high abundance of nutrient-demanding vascular plant species (*Lysimachia vulgaris, Crepis paludosa, Equisetum fluviatile*). *Sphagnum flexuosum* grows very fast at this site, reaching the length of about 30 cm in late autumn. The second site (Vrchpredmier, site no. I: 106) represents the species-rich fen with calcitolerant *Sphagnum* species. However, recently some bryophyte species including *Sphagnum warnstorfii* have disappeared from this spring fen and *Sphagnum flexuosum* cover has increased. The third case is the Kyčmol site (no. H: 94), where high nutrient supply causes a high cover of vascular plants including such nutrient-demanding species as *Lotus uliginosus, Cirsium palustre,* and *Galium uliginosum*. An unusually high cover of *Calliergon stramineum* in the bottom layer is noteworthy. In conclusion, the analysis of spatial variation of water chemistry in relation to *Sphagnum*-rich vegetation confirmed the importance of phosphates for the vegetation composition, but not to such an extent and not entirely in the same sense we expected. The analysis of seasonal variation in phosphate and total phosphorus concentrations did not bring compelling results in the selected fens (see below). It can be explained by the availability of phosphorus, which is absorbed in *Sphagnum* tissues first and, therefore, its concentration in sampled subsurface fen waters is limited.

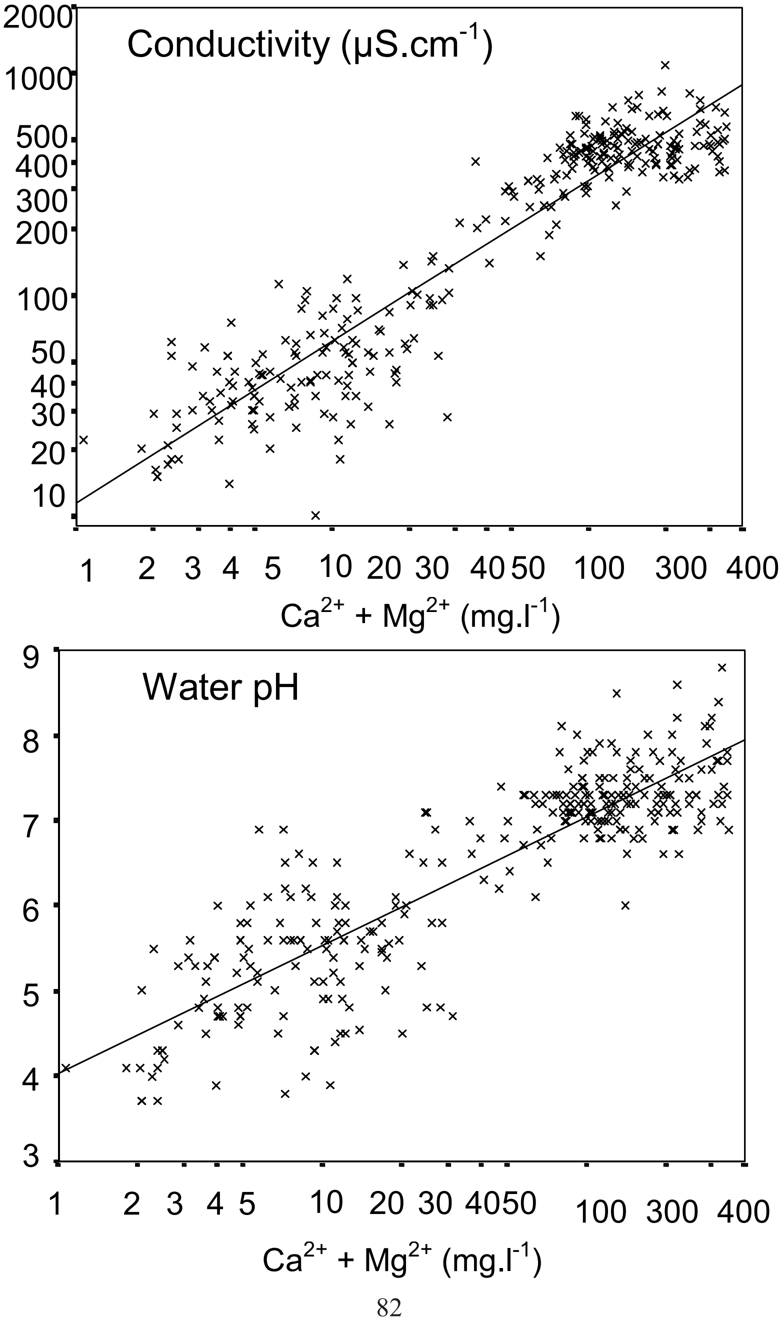
Figure 2: Cannonical Correspondence Analysis of 24 vegetation samples from poor *Sphagnum*-fens with two environmental variables: (i) pH as the most important factor for explaining vegetation variation and (ii) phosphates concentration, whose importance was tested. For further explanation see text.



Iron plays an important role not only in the development of poor fen vegetation on calcium-rich bedrock, but also in the variation in species richness within rich fens. Extremely high iron concentration (to 170 mg.l^{-1}) in some rich fens is probably toxic for some organisms (see Snowden & Wheeler 1993, Vuori et al. 1995). We found that species richness of mollusc communities decreases in some calcium-rich fens due to iron oversupply (Horsák & Hájek 2003, Chapter 11). On the other hand, plant species richness seems unaffected by high iron concentration with one exception - an extremely high number of bryophyte species coexisting on very small plots in iron-rich habitats (Hájková & Hájek 2003). This paradox is presumably caused by reduced competition from potential bryophyte dominants under the direct influence of toxic iron.

Our investigations in the West Carpathians clearly showed that easily measured environmental variables, such as pH and conductivity, are the most appropriate for the characterisation of major vegetation types and, moreover, they are relatively stable over time (Hájek & Hekera 2004, Hájková et al. 2004). The measurement of water conductivity is a tool for exact estimation of the sum of concentrations of bivalent metallic cations (see also Sjörs & Gunnarson 2002). Our data set, combining water chemistry data from permanent monitoring plots (seasonal variation) and single water chemistry data throughout the entire study area, confirmed this fact. Conductivity exhibited logarithmical dependence on the concentration of Ca^{2+} + Mg^{2+}; after the log-transformation of values this dependence became linear (Fig. 3a). The correlation between log-transformed values of Ca^{2+} + Mg^{2+} and conductivity is very strong (r = 0.939). Similar relationship can be found between Ca^{2+} + Mg^{2+} and pH, but not so conspicuously (Fig. 3b). The pH of water depends not only on the concentration of calcium and magnesium, but also on the total concentration of dissolved ions as well as their ratios. Additionally, pH also depends on the content of dissolved organic substances.

Figure 3: The relationship between the concentrations of bivalent cations ($Ca^{2+} + Mg^{2+}$) and physical-chemical properties of water (pH, conductivity). The graphs are based on all available data from the study area. Note that x-axis is in log-scale. The curve is fitted by linear regression.



The results of this large-scale research manifest a high correlation between species composition of bryophyte and vascular plant layers and the poor-rich (pH/calcium) gradient (Hájek at al. 2002). However, some differences in ecological behaviour can be expected between bryophytes and vascular plants. These different responses of vascular plants and bryophytes to environmental gradients have been more often theoretically expected than really tested in ecological case studies. Nevertheless, some recent studies in mires have demonstrated that bryophytes are more sensitive to acidity-alkalinity changes than vascular plants, which are influenced by a complex nutrient supply more or behave more ubiquitously (Chapter 8). To confirm or reject these hypotheses, we investigated the importance of water chemistry and underground water regime for vascular plants and bryophytes in the West Carpathian mires dominated by *Sphagnum* mosses (Hájková & Hájek 2004b). In our study, bryophytes reflected only one clear gradient connected with pH, whereas three equally important environmental gradients, (i) water level amplitude, (ii) pH, and (iii) a complex gradient of nutrient availability, age and thickness of peat layer, determine the occurrence of vascular plants. When the entire data set was subjected to DCA ordination, the first resulting axis was governed by the bryophyte subset, whereas the second one was governed by the vascular plant subset. The species density of vascular plants correlated positively with pH and conductivity, even if small sample plots were used. On the contrary, bryophyte species density showed no relationship to environmental factors.

3. Seasonal variation of water chemistry in major vegetation types

The analyses of vegetation-environment relationships in mires are, among other factors, influenced by the seasonal variation in water chemistry, which reduces the information value of samples analysed just once per site. Surprisingly, just a few detailed works (e.g. Vitt et al. 1995, Tahvanainen et al. 2003) have focused on temporal variations in water chemistry along the entire gradient from extremely rich fens to bogs. Therefore, we established 14 permanent plots from which water samples were taken repeatedly in spring, summer and autumn within five years. The main aims of this monitoring were (i) to compare seasonal patterns in water chemistry among fens of various position on acidity-alkalinity gradient and (ii) to assess the reliability of single water samples compared to repeated samples when characterising fen habitats. Methodical details and the first statistically processed data are presented in the study of Hájek & Hekera (2004). Their study evaluates the results from the first three years of monitoring. It shows that the most stable of the measured variables (pH, conductivity, Na^+, K^+, Ca^{2+} and SO_4^{2-}) are suitable for ecological differentiation of major vegetation types even if single samples are analysed, whereas more fluctuating variables (NO_3^-, Cl^-, Fe, PO_4^{3-} and redox-potential) can be used to a very limited extent. It concerns not only the comparison of environmental conditions among vegetation types, but also the ecological explanation for the major continuum observed in fen vegetation.

This chapter provides detailed data on the fluctuation of those water chemistry variables that have the greatest relevance to vegetation composition in our study area. The changes in ion concentrations during the five-year monitoring are compared within the groups of monitoring sites, which manifest clear differences in relation to species composition of vegetation.

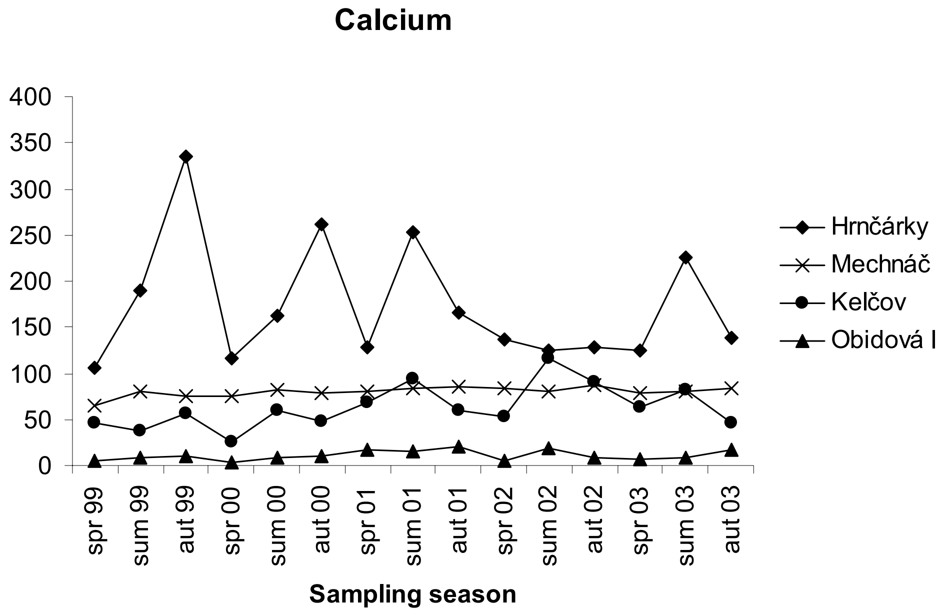
Differences in cation concentrations between *Ca*-poor and *Ca*-rich fens

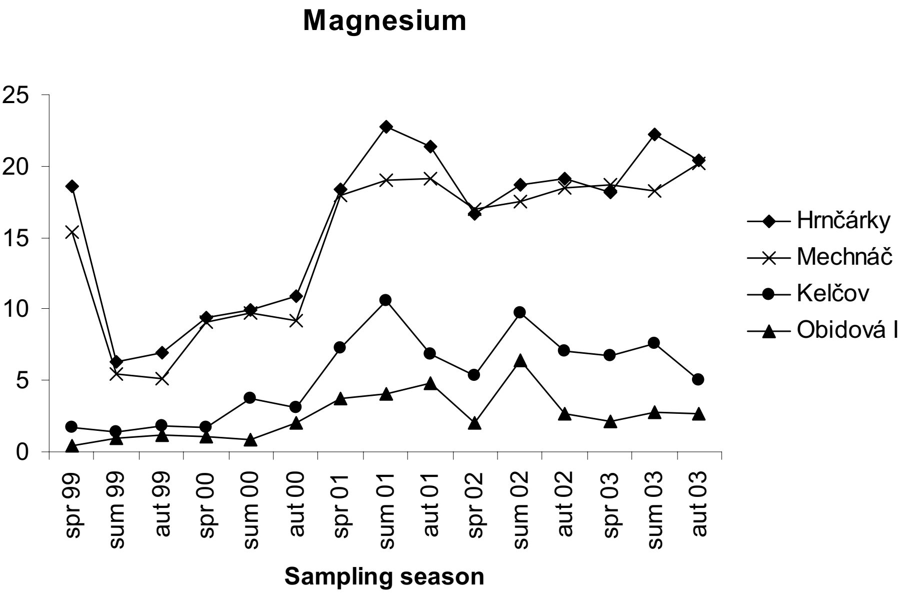
The previous analyses of spring fen vegetation in the West Carpathian flysch zone revealed a strong gradient in the species composition of vegetation, from extremely poor to extremely rich fens. Water calcium concentration represents the major environmental factor controlling this poor-rich gradient (Hájek et al. 2002). In order to confirm this observed fact, we selected four habitat types that are well differentiated with respect to vegetation composition, though possibly overlapping in water mineral richness. The site **Hrnčárky** represents the most typical tufa-forming fens with a well-developed hard layer of tufa ($CaCO_3$). The second site, the **Mechnáč** spring fen, exhibits the lowest water calcium concentration at a single sampling. The calcium carbonate precipitation is less intense, which results in species composition differences contrary to the Hrnčarky site (Hájek 1998, Horsák & Hájek 2003). *Cratoneuron commutatum* is restricted to running water with a higher pH. However, total species composition still corresponds to the extremely rich tufa-forming fens (*Carici flavae-Cratoneuretum*). On the other hand, the third site (**Kelčov** spring fen) is covered with typical stands of another vegetation type of extremely rich fens (*Valeriano-Caricetum flavae*), despite the fact that both pH and calcium concentration are similar to that at the former locality. At the Kelčov site, only very scarce calcium carbonate concretions occur and the moss layer dominant is *Drepanocladus cossonii*. Species typical for the ass. *Carici flavae-Cratoneuretum* (*Cratoneuron commutatum, Carex flacca, Juncus inflexus*) are absent. The fourth analysed fen was a moderately rich *Sphagnum*-fen (**Obidová I.**) with a group of calcitolerant *Sphagnum* species coexisting with the rich-fen species (*Eleocharis quinqueflora*).

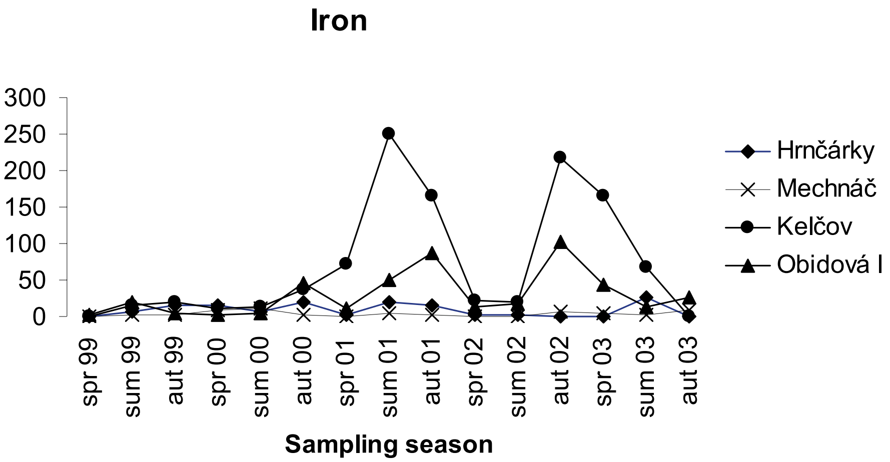
Figure 4 presents seasonal changes in water chemistry at all four sites. It clearly shows that there is very little and only occasional overlapping in calcium concentration, while differences in water pH distinctly change during the chronosequence monitored. Magnesium concentration was very high in both tufa-forming fens and low in peat-forming fen Kelčov and in moderately rich *Sphagnum*-fen Obidová. The iron ion concentration curve did not show any dependence on the concentration of basic ions. It showed two marked peaks during the five-year monitoring, which appeared only at Kelčov (peat-forming extremely rich fen) and, to a lesser degree, at Obidová. It is often reported that iron reaches its maximum concentration in summer (Malmer 1962, Proctor 1994, Vitt et al. 1995). High fluctuation in iron concentration is causally associated with changes in redox-potential and with the concentration of dissolved organic matter (Malmer 1962, Proctor 1994) as well as with microbial activity (Olivie-Lauquet et al. 2001). All responsible factors, such as high organic matter content, high fluctuation of redox-potential and high microbial activity, combine with a high supply of iron from aquifers (iron-cemented sandstones) at both sites, Kelčov and Obidová. It seems that these factors cause the short periods of high iron concentration there.

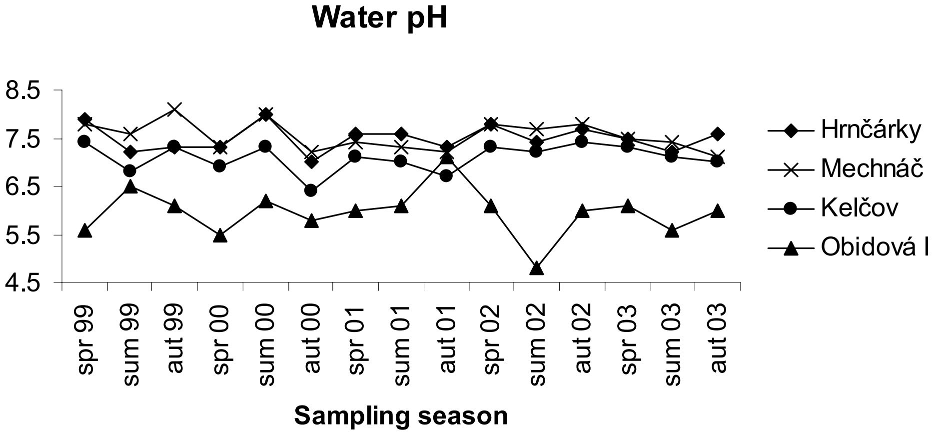
Calcium concentration was found to explain the differences among major vegetation types distinguished along the poor-rich gradient. Thus, our previous results obtained from a large data set of single measurements throughout the entire study area were confirmed (Hájek et al. 2002). These results do not correspond with some other studies that did not cover the whole range of calcium gradient and that, therefore, report that pH is more important for vegetation composition than calcium concentration (see Tahvanainen 2004). In our study, pH differentiated very loosely the habitats with intense tufa precipitation from those with the slight one (Fig. 4). In addition, pH values of calcareous peat-forming fens often overlap with those of tufa-forming fens. Calcium provided a clearer basis for habitat differentiation in all the above described cases.

Figure 4: Seasonal variation of Ca^{2+}, Mg^{2+}, Fe (in mg.l^{-1}) and pH at four reference sites. For details see text.









The marked fluctuation of pH values in moderately rich *Sphagnum*-fens in comparison with the rich calcareous fens (Fig. 4) was confirmed also in a more detailed study by Hájková et al. (2004) who measured pH values in poor and rich fens every 14 days. This fluctuation is probably caused by a low concentration of buffering bicarbonates in poor fens. On the other hand, calcium concentration in poor fens is continuously stable and does not even approximate that in extremely rich fens.

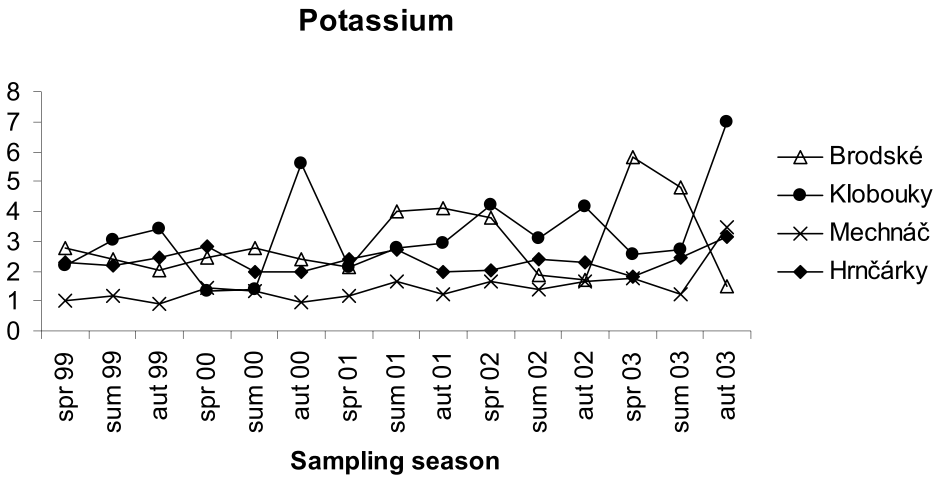
The peak in iron ion concentration may play an important ecological role as well. In two cases, the concentration of iron ions was extremely high and probably toxic (Snowden & Wheeler 1993). This concentration corresponds with the anomalies in the moss layer structure in iron-rich fens (Hájková & Hájek 2003) and with the low species richness of molluscs (Horsák & Hájek 2003). High iron concentration can also influence the availability of calcium because iron forms mixtures of ferric oxides and calcium carbonate and occupies cation exchange sites in bryophyte cell walls. Thus, iron concentrations can increase the habitat differences between tufa-forming and peat-forming spring fens.

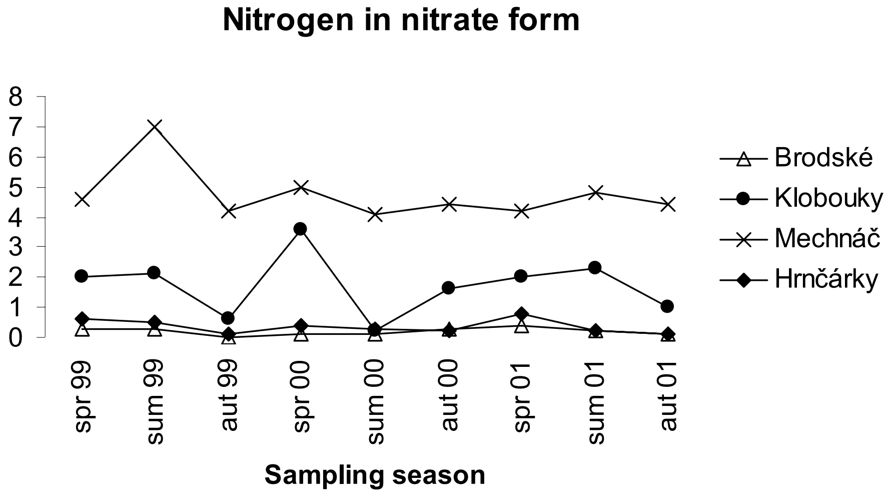
Differences in major nutrients between low and high productive *Ca*-rich fens

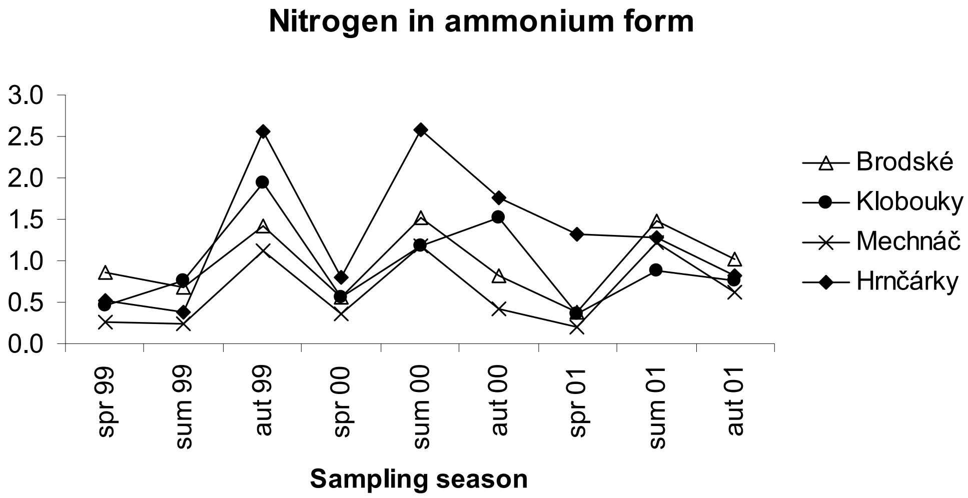
The second most important gradient in species data, independent of the gradient in mineral richness and base saturation, appears within the extremely rich spring fens. This variation, called the fen-meadow gradient, is indicated by an increasing occurrence of nutrient-demanding species of mown moist or waterlogged meadows (e.g. *Poa trivialis, Rumex acetosa, Lysimachia nummularia, Lathyrus pratensis, Scirpus sylvaticus, Cirsium rivulare, Festuca pratensis,* several species of *Alchemilla vulgaris* group, *Ranunculus acris, Lychnis flos-cuculi, Cruciata glabra, Myosotis nemorosa,* and *Angelica sylvestris*). However, the productivity of such fens rich in meadow species is not always high. A very specific site is **Hrubé Brodské**, where the high number of meadow species is associated with an extremely low vegetation biomass (121 g.m^{-2}) and with a species-rich bryophyte layer. On the contrary, the ”meadow site” **Valašské Klobouky** produces seven times higher biomass (874 g.m^{-2}). The seasonal changes of major nutrient concentrations in water taken from these two specific habitats were compared to those of typical rich fens with the absence of meadow species, **Hrnčárky** and **Mechnáč** spring fens. The latter is situated in a complex of intensively grazed pastures and is partly supplied with water from a stream running through nutrient-rich soils. Its biomass is twice as high as the biomass of Hrnčarky fen (286 g.m^{-2}contrary to 120 g.m^{-2}), which is situated in the environment of species-rich seminatural grasslands and woodlands.

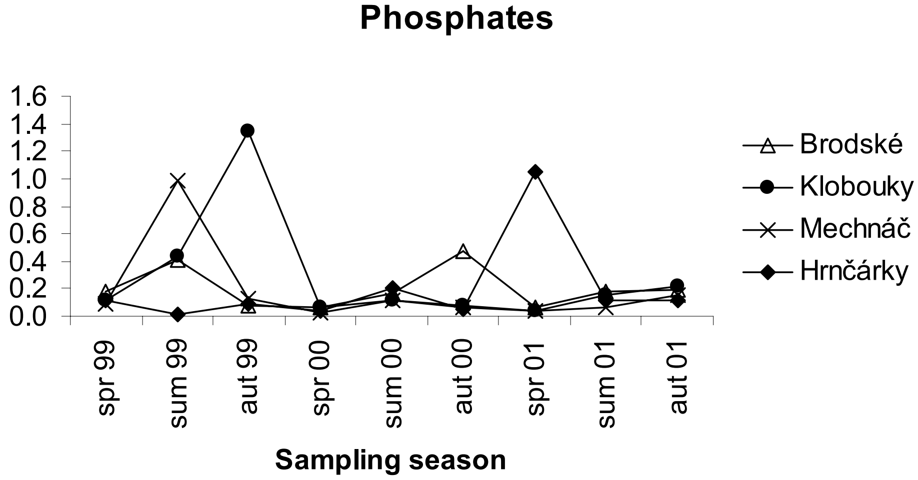
Any previous analysis of water chemistry had not found which nutrients may control the fen-meadow gradient described above (Hájek et al. 2002, Hájek & Hekera 2004). Therefore, Z. Rozbrojová (2005) conducted a diploma thesis to bring data about nutrient concentrations in vascular plant biomass. She studied the importance of particular major elements for the forming of fen-meadow vegetation. An initial evaluation of these data shows that the biomass of fens rich in meadow species contains more potassium and phosphorus. This pattern is also supported by analytical data on the biomass of particular frequent species (e.g. *Cirsium rivulare, C. palustre*). The values of major nutrient concentrations in the water of reference sites coincide with this finding (Fig. 5). Although the differences in potassium and phosphate concentrations between the ”meadow sites” and the ”fen sites” are not statistically significant for the whole time-span of the sampling period (Hájek & Hekera 2004: Tab. 5), long-term monitoring revealed evidence of their increased supply at meadow sites. Both meadow sites had seasonally two to four times higher potassium concentration than the two rich-fen sites, but only during relatively short periods of time (see Fig. 5). Further, short separate peaks of phosphates were observed in both meadow types (Fig. 5). Such an observation raises the question why one meadow site (**Valašské Klobouky**) is so highly productive (874 g.m^{-2} in June) in comparison with other similar sites (up to 300 g.m^{-2}). One explanation can be that there is a in constantly enhanced concentration of nitrates (Fig. 5). However, the spring fen **Mechnáč** surrounded by fertilised pastures had the highest nitrate input among all studied fens, but low concentrations of other major nutrients. Namely, a low concentration of potassium does not support the existence of meadow species. Nitrogen itself contributes to the increasing biomass in **Mechnáč** fen while biomass production in the generally nutrient-poor **Hrnčárky** fen is very low.

Figure 5: Seasonal variation of major nutrients at four reference sites differing in the productivity of vegetation. For details see text.







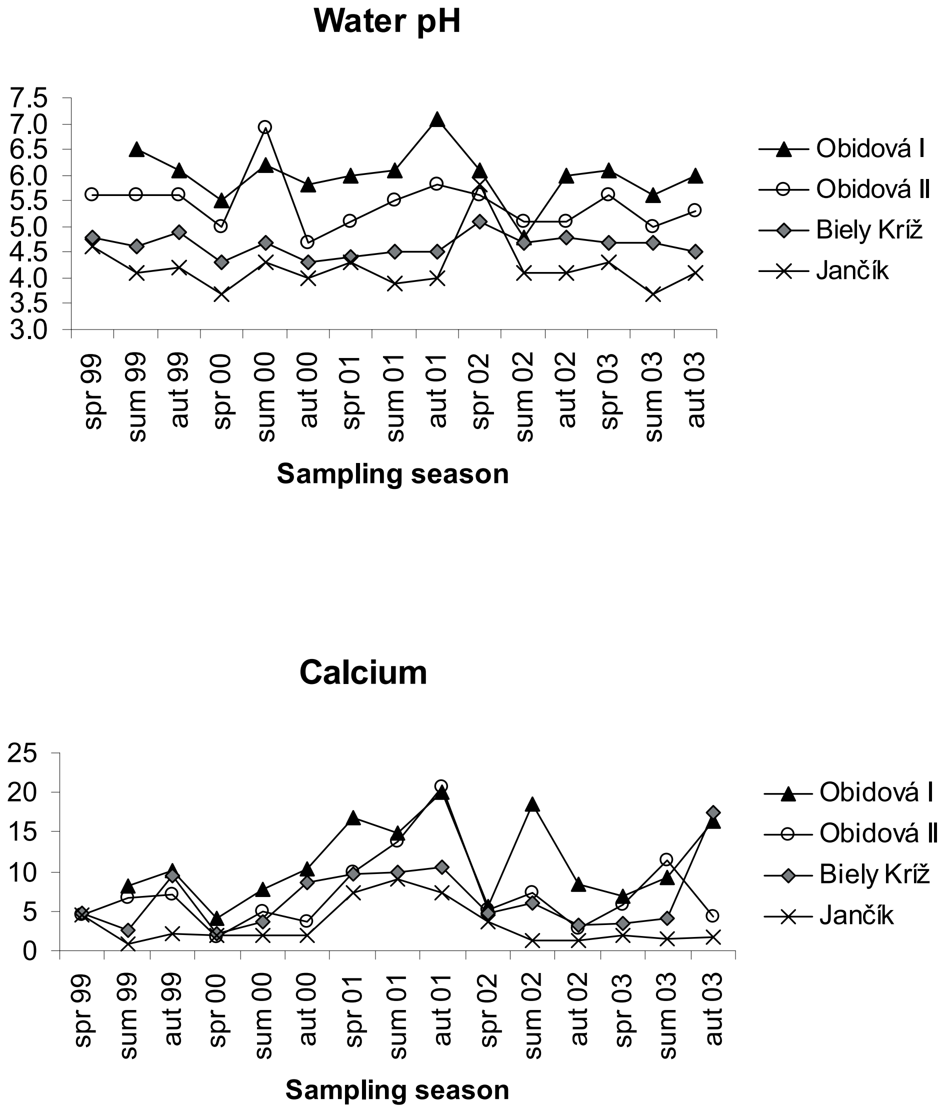


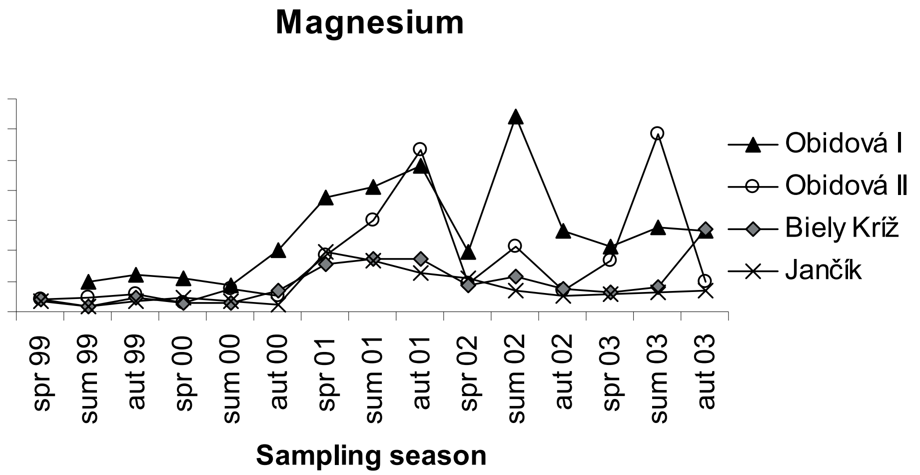
Differences in major nutrients and bases among four representative Sphagnum-fens

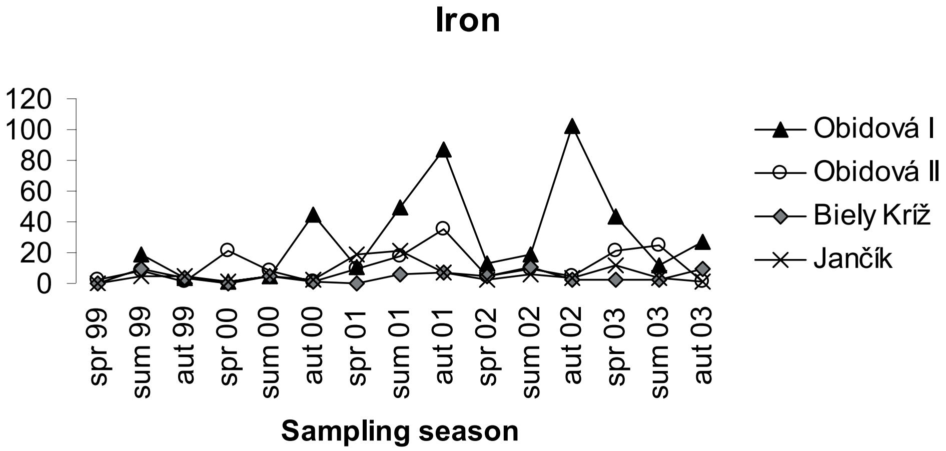
Four monitored moderately rich *Sphagnum*-fens are clearly and constantly differentiated according to pH (Fig. 6). Their differentiation according to calcium and magnesium concentrations is not so clear. Such finding is in full accordance with some recent results obtained in fens of the boreal zone (Tahvanainen et al. 2003).

In our area under study, *Sphagnum*-rich fens had a generally higher iron concentration than the calcareous fens (Hájek et al. 2002). Nevertheless, long-term monitoring shows that this is more true for subneutral, moderate-rich fens than the more acidic, calcium-poor fens. The most acidic fens in our study area, **Biely Kríž** and **Jančík**, never exhibited extremely high concentration of total iron (Fig. 6) and they constantly had the lowest concentrations of magnesium.

Figure 6: Seasonal variation of selected metallic cations and pH at reference *Sphagnum*-rich sites differing in species composition. For details see text.



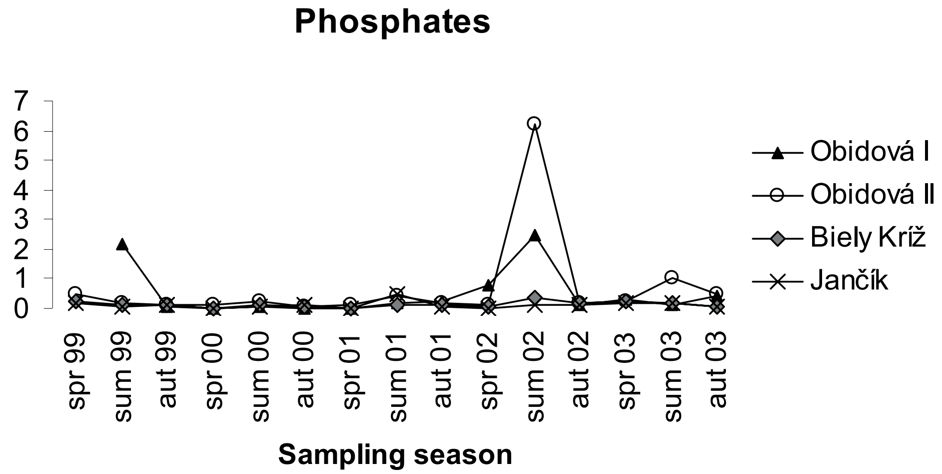


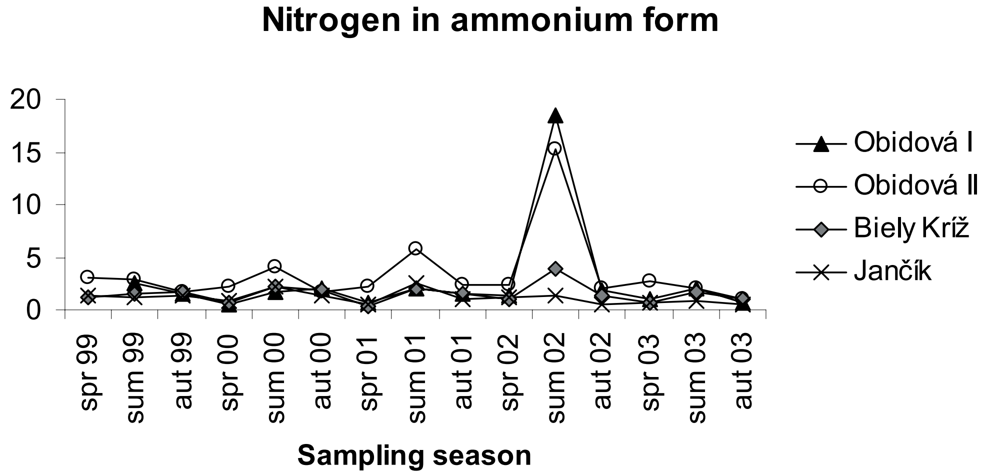


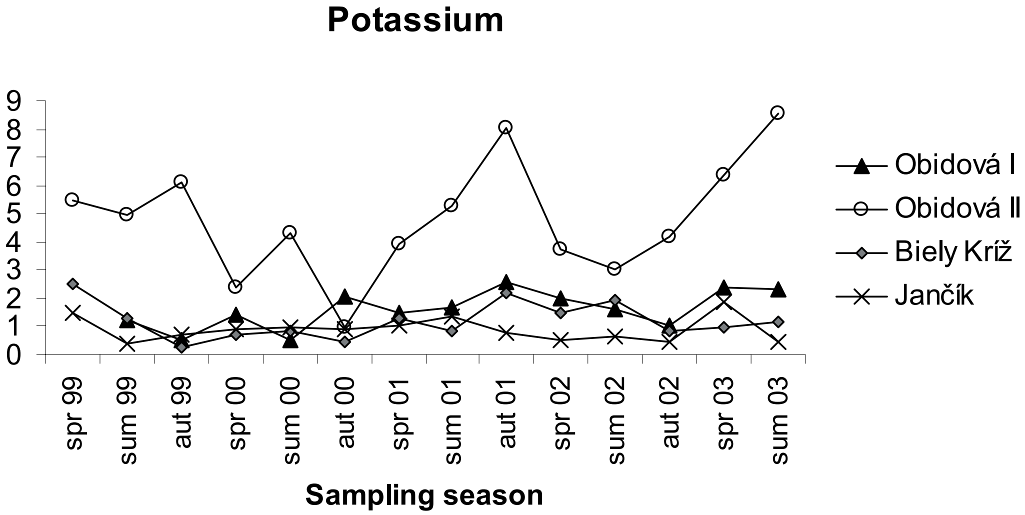
The poor fen **Obidová II** was selected for the study because of the rather unusual structure of its vegetation. The bottom layer of the monitored site is dense and represented only by *Sphagnum flexuosum* with just scattered stems of *Calliergon stramineum*. On the other hand, the herb layer is formed by those plants that demand higher nutrient supply (*Lysimachia vulgaris, Crepis paludosa, Equisetum fluviatile*). Our monitoring revealed that this site is continuously supplied with a high amount of potassium (Fig. 7). In addition, one important increase in phosphates and ammonium was detected in summer 2002 (Fig. 7). The species from the *Sphagnum recurvum* group are able to utilise greater amounts of major nutrients effectively, which enables their vital growth even in moderately rich fens

(Kooijmann & Kanne 1993). *Sphagnum fallax*, the species taxonomically related to *S. flexuosum*, is also known for its positive response to increased nutrients (Limpens et al. 2003).

Figure 7: Seasonal variation of selected major nutrients at reference *Sphagnum*-rich sites differing in species composition. For details see text.







Small-scale differences in seasonal pattern between poor and rich fens

An additional net of permanent plots was established at five most representative fen sites. Permanent sampling points were distributed along several short transects crossing the sites from the central to the marginal parts of each fen. The aim was to determine the role of environmental factors in explaining floristic differences in vegetation on a smaller sampling scale and, in addition, to compare the seasonal variation in environmental factors between calcareous and poor fens. Water pH, conductivity, temperature, redox-potential and water level were measured 20 times at intervals of ca 14 days (2000) or 1 month (2001).

The principal results, presented in the study by Hájková et al. (2004), confirmed high stability of pH values, especially in rich fens. The fluctuation of pH values was significantly higher in poor fens than in rich ones. Greater variation was found for water conductivity, which was very unstable especially at the sites of acidic poor fens. Water temperature showed the smallest fluctuation both in the extremely rich fens and in poor and moderately rich fens.

The reason for unequal variation in pH and conductivity in poor and calcareous fens is probably due to a high concentration of bicarbonates, which buffer water reaction in rich fens on the one hand, and, on the other hand, to a significant seasonal decrease of water level in May and September, which was detected only in poor fens. This causes an increasing concentration of metallic cations and simultaneously an increase in water conductivity. The causal relationship between water level and conductivity values is also demonstrated by a significant partial correlation between these two variables in which pH was eliminated as a covariable.

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Table 2: The most important species for characterizing major vegetation types of fens and waterlogged meadows in the Western Carpathians. The table shows the species with the highest fidelity (> 25) to each vegetation type, the values exceeding this threshold are in bold. Fidelity is a statistical measure of species concentration in the vegetation type (Chytrý et al. 2002). Note that *Agrostis canina, Carex echinata, Drosera rotundifolia, Eriophorum latifolium* and *Sphagnum subnitens* have the fidelity value above 25 in more than one vegetation type. In such case, the species is assigned to that vegetation type in which it reaches the highest absolute fidelity value. Vegetation is classified at an association level, but some regionally rare associations are merged into the ecologically homogeneous vegetation types classified at an (sub)alliance level (*Filipendulenion, Caricion lasiocarpae, Sphagno warnstorfii-Tomenthypnion* and *Sphagno recurvi-Caricion canescentis*). For the basic description, more detailed classification and outline of distribution of particular vegetation types see Table 3 and Chapter 5.1.

Vegetation type no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of relevés	77	38	16	41	74	196	43	129	36	6	42	14	35	29	67
Scirpetum sylvatici															
Scirpus sylvaticus	**37.5**	.	4.1	.	1.0	16.7	4.5	.	.	.	.	.	.	.	.
Filipendulenion															
Filipendula ulmaria	1.7	**41.8**	7.7	.	.	4.4	3.8	.	.	.	2.8	.	5.2	.	.
Cirsium oleraceum	12.4	**30.0**	1.2	.	9.7	7.2	.	.	.	.	.	.	.	.	.
Chaerophyllo hirsuti-Calthetum															
Stellaria alsine	.	.	**72.1**	7.3	.	.	.	.	.	.	.	.	.	.	.
Stellaria nemorum	.	.	**49.6**	.	.	.	.	.	.	.	.	.	.	.	.
Chrysosplenium alternifolium	.	.	**49.6**	.	.	.	.	.	.	.	.	.	.	.	.
Chaerophyllum hirsutum	.	8.6	**43.0**	5.9	.	11.9	3.5	.	.	.	.	.	.	.	.
Cardamine amara	4.1	.	**41.0**	6.8	.	8.1	.	.	.	.	.	.	.	4.3	.
Athyrium filix-femina	.	.	**28.4**	.	.	.	.	.	.	.	.	.	.	.	5.6
Chiloscyphus polyanthos	.	.	**26.4**	.	.	.	3.5	.	.	.	.	.	24.1	1.3	.
Impatiens noli-tangere	21.7	.	**25.4**	.	.	.	.	.	.	.	.	.	.	.	.
Angelico-Cirsietum palustris															
Epilobium palustre	.	.	10.6	**35.1**	.	.	.	.	.	.	.	.	12.1	24.6	5.0
Myosotis nemorosa	6.0	.	13.2	**30.0**	.	13.1	.	.	.	.	3.4	.	.	12.2	.
Carex echinata	.	.	.	**25.8**	.	.	.	.	.	.	15.9	.	23.9	21.8	**25.2**
Junco inflexi-Menthetum															
Juncus inflexus	9.2	.	.	.	**39.2**	3.8	4.2	22.9	.	.	.	.	.	.	.
Mentha longifolia	18.9	.	.	.	**38.1**	6.9	.	6.2	.	.	.	.	.	.	.
Potentilla reptans	12.3	.	.	.	**37.7**	.	.	.	.	.	.	.	.	.	.
Cirsium arvense	1.9	7.2	.	.	**34.1**	.	.	.	.	.	.	.	.	.	.
Carex hirta	18.3	6.2	.	.	**32.0**	15.6	.	.	.	.	.	.	.	.	.
Lysimachia nummularia	15.1	6.8	.	.	**26.4**	18.2	4.8	.	.	.	.	.	.	.	.

Table 2: Cont.

Cirsietum rivularis															
Rumex acetosa	9.0	.	7.3	15.8	.	**32.3**	2.3	.	.	.	.	.	.	.	.
Cirsium rivulare	4.1	.	.	1.7	.	**32.2**	17.8	2.1	.	.	8.7	.	.	.	.
Lathyrus pratensis	7.6	4.9	.	.	7.8	**31.4**	13.5	.	.	.	.	.	.	.	.
Poa trivialis	16.7	.	4.2	5.6	23.2	**27.1**	1.3	.	.	.	.	.	.	.	.
Ranunculus acris	.	.	.	9.3	4.4	**26.6**	13.4	.	.	.	5.4	.	.	.	.
Festuca pratensis	1.4	.	.	8.8	2.1	**26.4**	4.1	.	.	.	.	.	.	.	.
Cruciata glabra	.	.	.	10.0	.	**25.9**	16.3	.	.	.	8.4	.	.	.	.
Caltha palustris	.	2.3	15.4	14.4	.	**25.6**	7.7	.	.	.	4.9	.	.	.	.
Alchemilla vulgaris agg.	.	.	3.1	14.5	.	**25.2**	6.2	.	.	.	6.6	.	.	.	.
Cirsietum rivularis eriophoretosum latifolii															
Eriophorum latifolium	.	.	.	.	.	.	**27.3**	40.4	20.4	.	**25.7**	.	12.3	.	.
Epipactis palustris	.	.	.	.	.	.	**26.0**	22.7	17.5	5.9	18.6	4.5	6.5	.	.
Carici flavae-Cratoneuretum															
Cratoneuron commutatum	.	.	.	.	.	.	3.3	**64.2**	14.3	.	.	.	.	.	.
Carex flacca	.	.	.	.	1.8	.	16.6	**49.2**	7.3	.	.	.	.	.	.
Campylium stellatum s.l.	.	.	.	.	.	.	14.6	**42.3**	23.7	12.5	16.3	11.2	18.0	.	.
Bryum pseudotriquetrum	.	.	.	.	.	.	20.4	**40.0**	18.6	.	23.3	9.5	10.9	.	.
Eupatorium cannabinum	.	.	.	.	21.7	.	4.6	**34.8**	.	.	.	.	.	.	.
Tussilago farfara	.	.	.	.	9.4	.	13.0	**34.1**	.	.	.	.	.	.	.
Fissidens adianthoides	.	.	.	.	.	.	22.0	**33.9**	14.2	.	4.2	2.4	13.0	.	.
Juncus articulatus	.	.	.	.	.	.	19.4	**30.9**	8.7	4.9	22.3	.	9.3	1.2	.
Valeriana dioica	.	.	.	.	.	5.5	9.6	**28.6**	5.7	.	.	.	.	.	.
Chara sp.	.	.	.	.	.	.	.	**28.1**	12.1	6.1	.	2.6	.	.	.
Linum catharticum	.	.	.	.	.	.	1.7	**27.5**	3.7	.	21.4	.	12.1	2.5	.
Molinia arundinacea	.	3.9	.	.	.	.	.	**26.1**	.	.	.	.	.	.	.
Succisa pratensis	.	.	.	5.5	.	.	10.9	**25.4**	10.4	.	.	4.7	9.1	.	.
Carex panicea	.	.	.	7.4	.	1.2	16.0	**25.1**	8.2	.	14.6	5.7	15.4	5.7	.
Caricetum davallianae															
Primula farinosa	.	.	.	.	.	.	.	.	**66.1**	30.9	.	1.4	20.2	.	.
Carex hostiana	.	.	.	.	.	.	.	.	**56.9**	.	.	.	4.3	.	.
Pinguicula vulgaris	.	.	.	.	.	.	.	.	**55.6**	15.4	5.5	23.7	19.4	.	.
Tofieldia calyculata	.	.	.	.	.	.	.	.	**53.7**	8.5	.	.	1.0	.	.
Carex davalliana	.	.	.	.	.	.	3.3	3.1	**52.9**	.	9.8	.	12.4	.	.
Carex lepidocarpa	.	.	.	.	.	.	.	19.6	**50.2**	.	.	3.5	5.5	.	.
Drepanocladus cossonii	.	.	.	.	.	.	.	7.5	**45.9**	.	32.1	12.9	26.6	.	.
Juncus alpinoarticulatus	.	.	.	.	.	.	.	.	**42.0**	.	.	.	.	.	.
Polygala amara	.	.	.	.	.	.	.	.	**40.1**	.	.	.	.	.	.

Table 2: Cont.

Parnassia palustris	.	.	.	1.5	.	.	.	10.9	**34.7**	22.4	19.4	.	13.8	.	.
Triglochin palustris	.	.	.	1.1	.	.	.	12.1	**32.1**	22.0	17.2	6.1	4.4	.	.
Eleocharis quinqueflora	.	.	.	.	.	.	.	4.9	**29.9**	10.0	15.3	16.6	12.6	.	.
Sesleria uliginosa	.	.	.	.	.	.	.	.	**28.3**	.	.	.	.	.	.
Glauco-Trichophoretum pumili															
Schoenoplectus tabernaemontani	.	.	.	.	.	.	.	.	4.5	**92.5**	.	.	.	.	.
Trichophorum pumilum	.	.	.	.	.	.	.	.	4.0	**86.5**	.	.	.	.	.
Plantago maritima	.	.	.	.	.	.	.	.	.	**81.6**	.	.	.	.	.
Triglochin maritima	.	.	.	.	.	.	.	.	23.4	**73.6**	.	.	.	.	.
Glaux maritima	.	.	.	.	.	.	.	.	.	**70.6**	.	.	.	.	.
*Centaurium * compressum*	.	.	.	.	.	.	.	.	.	**70.6**	.	.	.	.	.
Campylium elodes	.	.	.	.	.	.	.	.	.	**40.7**	.	.	.	.	.
Odontites vernus	.	.	.	.	.	.	.	.	.	**40.7**	.	.	.	.	.
Juncus tenuis	.	.	.	.	.	.	.	.	.	**40.7**	.	.	.	.	.
Cladium mariscus	.	.	.	.	.	.	.	.	.	**40.7**	.	.	.	.	.
Schoenus ferrugineus	.	.	.	.	.	.	.	.	21.3	**36.1**	.	.	.	.	.
Valeriano-Caricetum flavae															
Valeriana simplicifolia	.	.	.	9.6	.	1.4	2.6	.	7.9	.	**29.2**	7.3	11.1	2.4	.
Caricion lasiocarpae															
Carex lasiocarpa	.	.	.	.	.	.	1.0	.	.	.	.	**75.5**	.	7.3	.
Drepanocladus vernicosus	.	.	.	.	.	.	.	.	.	.	4.8	**45.8**	5.8	2.1	2.3
Menyanthes trifoliata	.	.	.	.	.	.	.	.	10.6	.	4.3	**42.3**	3.0	10.0	6.7
Oxycoccus palustris	.	.	.	.	.	.	.	.	.	.	.	**39.8**	19.9	.	22.1
Silene pusilla Waldst. et Kit.	.	.	.	.	.	.	.	.	.	.	.	**37.5**	.	.	.
Salix pentandra	.	.	.	.	.	.	.	.	5.0	.	.	**36.6**	9.3	1.7	7.8
Betula pubescens agg.	.	.	.	.	.	.	.	.	11.6	.	.	**36.0**	7.0	2.9	3.4
Pyrola rotundifolia	.	.	.	.	.	.	.	.	.	.	4.5	**32.0**	12.4	.	.
Calliergon trifarium	.	.	.	.	.	.	.	.	8.6	.	.	**30.4**	.	.	.
Meesia triquetra	.	.	.	.	.	.	.	.	8.6	.	.	**30.4**	.	.	.
Scorpidium scorpioides	.	.	.	.	.	.	.	.	.	.	.	**26.5**	.	.	.
Catoscopium nigritum	.	.	.	.	.	.	.	.	.	.	.	**26.5**	.	.	.
Carex chordorrhiza	.	.	.	.	.	.	.	.	.	.	.	**26.1**	15.9	.	.
Carex limosa	.	.	.	.	.	.	.	.	7.1	.	.	**26.1**	.	.	4.4
Riccardia multifida	.	.	.	8.4	.	.	.	.	.	.	.	**25.7**	15.2	.	1.2
Sphagno warnstorfii-Tomenthypnion															
Sphagnum subnitens	.	.	.	.	.	.	.	.	.	.	.	**25.7**	**32.6**	.	.
Sphagnum warnstorfii	.	.	.	.	.	.	.	.	.	.	.	19.9	**73.9**	2.3	.

Table 2: Cont.

Sphagnum teres	.	.	.	.	.	.	.	.	.	.	.	20.6	**55.8**	14.8	7.7
Sphagnum contortum	.	.	.	3.2	.	.	.	.	.	.	.	15.3	**48.8**	.	.
Aulacomnium palustre	.	.	.	9.6	.	.	.	.	.	.	14.2	20.1	**43.9**	16.3	5.9
Carex dioica	.	.	.	.	.	.	.	.	17.3	.	4.0	21.7	**39.4**	.	.
Hypnum pratense	.	.	.	9.7	.	.	.	.	.	.	13.4	3.0	**37.9**	18.5	.
Paludella squarrosa	.	.	.	.	.	.	.	.	.	.	.	.	**33.6**	.	.
Homalothecium nitens	.	.	.	1.1	.	.	8.5	.	8.4	.	14.7	22.8	**32.2**	1.3	.
Drepanocladus exannulatus	.	.	.	.	.	.	.	.	.	.	.	14.9	**29.4**	4.8	11.2
Galium uliginosum	.	.	3.0	14.0	.	.	4.9	.	5.1	.	3.5	9.7	**29.3**	3.2	.
Caricion fuscae															
Ranunculus flammula	.	.	4.2	13.7	.	.	.	.	.	.	3.9	.	7.9	**29.5**	4.3
Sphagno recurvi-Caricion canescentis															
Polytrichum commune	.	.	.	.	.	.	.	.	.	.	.	.	.	4.1	**72.1**
Sphagnum fallax	.	.	.	.	.	.	.	.	.	.	.	13.9	3.3	.	**63.0**
Sphagnum flexuosum	.	.	.	.	.	.	.	.	.	.	.	14.6	15.3	12.7	**55.5**
Nardus stricta	.	.	.	.	.	.	.	.	.	.	.	.	19.3	20.2	**55.5**
Sphagnum palustre s.l.	.	.	.	4.4	.	.	.	.	.	.	.	5.2	10.9	1.3	**53.5**
Calliergon stramineum	.	.	.	.	.	.	.	.	.	.	.	6.5	24.7	13.7	**51.4**
Viola palustris	.	.	4.2	13.0	.	.	.	.	.	.	.	2.0	17.2	18.0	**48.1**
Drosera rotundifolia	.	.	.	.	.	.	.	.	.	.	.	4.1	**35.4**	5.6	**47.3**
Sphagnum magellanicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**40.9**
Agrostis canina	.	.	5.6	**35.7**	.	.	.	.	.	.	5.6	.	**25.8**	**25.4**	**39.8**
Sphagnum capillifolium	.	.	.	.	.	.	.	.	.	.	.	4.1	4.6	5.6	**38.6**
Vaccinium myrtillus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**33.3**
Pedicularis sylvatica	.	.	.	.	.	.	.	.	.	.	.	.	.	9.3	**31.4**
Vaccinium vitis-idaea	.	.	.	3.0	.	.	.	.	.	.	.	.	.	.	**31.1**
Sphagnum papillosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**28.8**
Calamagrostis villosa	.	.	.	3.5	.	.	.	.	.	.	.	.	.	.	**28.8**
Carex nigra	.	.	.	22.3	.	.	1.3	.	.	.	13.8	.	20.5	16.0	**27.2**
Eriophorum angustifolium	.	.	.	3.7	.	.	5.7	17.8	10.4	.	11.8	9.2	17.1	9.6	**24.8**

Table 3: Basic description of vegetation types of waterlogged meadows and fens presented in Table 2: habitats, outline of distribution, author names, higher-rank classification and average species richness of higher plants (bryophytes + vascular plants) per vegetation plot (s.r.).

Waterlogged meadows (*Molinio-Arrhenatheretea* Tüxen 1937); column 1-7 in Tab. 2

	Classification	Habitat	Distribution	s.r.
	***Calthion* Tüxen 1937 em. Lebrun et al. 1949**			
1	*Scirpetum sylvatici* Ralski 1931	Eutrophic wet meadows strongly dominated by *Scirpus sylvaticus*	Entire study area	29
2	*Filipenduletum ulmariae* (Lohmeyer in Oberdorfer et al. 1967) Balátová-Tuláčková 1978	Fallow tall-herb wet meadows strongly dominated by *Filipendula ulmaria*	Entire study area	24
3	*Chaerophyllo hirsuti-Calthetum* (Buttler at al. 1983) Balátová-Tuláčková 1985	Productive wet meadow influenced by running water and occurring in mosaic of meadows and forests	Moravskoslezské Beskydy Mts, eastern Kysuce region, and other mountains on *Ca*-poor bedrock	33
4	*Angelico-Cirsietum palustris* Balátová-Tuláčková 1973	Productive acidic wet meadows with a group of poor fen species	Entire study area with an exception of calcareous areas. Common in the Beskydy Mts, Kysuce and Orava regions	44
5	*Junco inflexi-Menthetum longifoliae* Lohmeyer 1953	Wet disturbed soils, i.e. fallow or grazed wet meadows on extremely mineral-rich soils	Entire calcareous area, especially the Bílé Karpaty Mts, Hostýnské vrchy Mts and Strážovská hornatina Mts	33
6	*Cirsietum rivularis* Nowiński 1927 (but see 7)	Calcium- and nutrient-rich wet meadows with Carpathian species, dominated by *C. rivulare*	Entire study area, with an rare exception of extremely calcium-poor areas	39
7	*Cirsietum rivularis* Nowiński 1927 *eriophoretosum latifolii* Balátová-Tuláčková 1973	Wet meadows dominated by *Cirsium rivulare* and *Eriophorum latifolium*, with rich fen species	Entire study area, with an rare exception of extremely calcium-poor areas	47

Table 3: Cont.

Fens (*Scheuchzerio-Caricetea fuscae* Tüxen 1937); column 7-15 in Tab. 2

	Classification	**Habitat**	**Distribution**	**s.r.**
	***Caricion davallianae* Klika 1934**			
8	*Carici flavae-Cratoneuretum* Kovács et Felföldy 1958	Tufa-forming extremely calcium-rich spring fens dominated by *Cratoneuron commutatum*	The most calcium-rich flysch areas, especially the Bílé Karpaty Mts, Strážovská hornatina Mts and the surrounding of the town of Vsetín	37
9	*Caricetum davallianae* Dutoit 1924	Extremely peat-forming rich fens with occasional precipitation of tufa; often the large valley fens	Inner-Carpathian basins and limestone bedrock of adjacent mountains; absent in flysch	35
10	*Glauco-Trichophoretum pumili* (Šmarda 1961) Vicherek 1973 – variant with rich fen species *	Wet Inner-Carpathian travertine swards without organic matter and with high content of salts	Inner-Carpathian basins (Spiš basin, Liptov basin, foothill of the Veľká Fatra Mts)	20
11	*Valeriano –Caricetum flavae* Pawłowski et al. 1960	Peat forming, Ca-rich, mowed fens with a very scarce tufa, dominated by *Drepanocladus cossonii*	Outer flysch Carpathians, especially the Kysuce, Orava and Podhale regions	44
	***Caricion lasiocarpae* Vanden Berghen 1949**			
12	*Drepanoclado-Caricetum lasiocarpae* Rybníček 1984 *Sphagno-Caricetum lasiocarpae* Steffen 1931 *Amblystegio-Caricetum chordorrhizae* Osvald 1925 *Amblystegio –Caricetum limosae* Osvald 1923	Peat forming, relic rich fens with a stable water regime, mostly dominated by *Amblystegiaceae*, sometimes with a slight occurrence of calcitolerant *Sphagnum* species.	Especially the Orava region: fen near the Puchmajerovej jazierko, Slaná voda, Oravice, Beňadovo, Mútne etc.	31
	***Sphagno warnstorfii-Tomenthypnion* Dahl 1957**			
13	*Sphagno warnst.-Eriophoretum latifolii* Rybníček 1974 *Sphagno warnst.-Caricetum davallianae* Rybníček 1984	Successionally advanced (moderately) rich fens on *Ca*-rich bedrock with acidified surface water and with a high cover of calcitolerant *Sphagna*.	Moravskoslezské Beskydy Mts, Kysuce and Orava regions, Liptov basin, Horehron basin	46

Table 3: Cont.

	***Caricion fuscae* Koch 1926 em. Klika 1934**			
14	*Caricetum goodenowii* J. Braun 1915	Moderately rich fen meadows at mineral, but only slightly calcium-rich soil	Entire study area with an exception of calcareous areas; not occuring in the Bílé Karpaty Mts and Strážovská hornatina Mts	38
	***Sphagno recurvi-Caricion canescentis* Passarge 1964**			
15	*Carici echinatae-Sphagnetum* Soó 1954 *Carici rostratae-Sphagnetum apiculati* Osvald 1923	Acidic, extremely calcium-poor fens dominated by species from the *Sphagnum recurvum* group	Moravskoslezské Beskydy Mts, western Kysuce, Orava, and other non-calcareous mountains.	23

* The association is often classified within the alliance *Scorzonero-Juncion* (Vendelberger 1943) Vicherek 1973; some of studied stands are transitional to *Schoenetum ferruginei* Du Rietz 1925

Chapter 6

Cyanobacteria and algae

A. Poulíčková, P. Hašler & M. Kitner,

Introduction

On the basis of physical factors, springs may be classified into two major series, underwater springs and land springs. The underwater series that arise in ponds (limnocrenes) may be further subdivided into sandy sediment springs and silted sediment springs. The land springs, which arise at ground level, include helocrenes (diffuse marshy spring areas) and rheocrenes, i. e. springs emerging through rocky clefts. Each of spring types has a characteristic flora but in addition, there are a number of important species which are widespread throughout the whole series. There are no species present that can be classified as exclusively "spring" species. The dominant species of the springs as a whole are common freshwater forms found either in running water or in still waters, where they are members of the epipelic and epiphytic flora (Round 1960).

Springs in general are special habitats that are quite different from other surface waters, above all for their physico-chemical stability (Thienemann 1922, Hynes 1976). Even though there are many different spring types, phycological studies have concentrated on few specific springs, such as thermal (Dell´Uomo 1986, Kadiri 2000, Hindák 2001), saline (Kadlubowska 1985), tufa-forming (Pentecost 1991, 1998, 2001, Reichardt 1994, 1995) or acid (Cambra & Hindák 1998, Orendt 1998, Muñoz et al. 2003). Specific ecological features of these environments lead to special cyanobacterial and algal assemblages.

For the more common, cold and moderately mineralized springs, detailed knowledge is limited to a few specific geographic areas - England (Round 1957a), Spain (Aboal et al. 1998) and Denmark (Warncke 1980, Werum 2001). Mountain and high altitude springs are even less investigated and the most relevant studies concern the Pyrenees (Sabater & Roca 1990, 1992) and the Alps (Cantonati 1998).

Moreover, all these papers mentioned above focused on epilithon or epipelon of spring streams or pools. Epiphytic cyanobacteria and algae inhabiting bryophytes have not been studied yet in temperate zones, except of several papers published by Round (1958 a,b, 1960) and partially Cantonati (1998). Moss diatoms were described from Arctic, Subarctic, Antarctic and Subantarctic regions (Ohtani 1986, Ohtani & Kanda 1987, Van de Vijver & Beyens 1996-1999, Van de Vijver et al. 2003). Most papers focused on the floristic approach, without any effort to obtain quantitative data. Ecological data were also limited by technical means applicable in the field conditions of Arctic and Antarctic expeditions. Water content was determined with reference to the F-classification of Jung (1936). This is a humidity scale based on the water content of moss samples determined subjectively as follows: FI = submerged mosses, FII = free-floating mosses, FIII = very wet (water drips from the sample without pressure), FIV = wet (water drips by slight pressure), FV = quasi-wet (water drips after moderate pressure), FVI = moist (little water produced after high pressure), FVII = quasi-dry (only a few drops of water can be squeezed out), FVIII = dry probe. This scale is not very exact, which is why the true water content (in grams of water per 1 g of dry bryophyte matter) was used in our studies (Poulíčková et al. 2001, 2003, 2004).

Epiphytic algae can be obtained from fresh, frozen or fixed mosses by washing or squeezing (Poulíčková et al. 2001). This method is suitable for coccal forms, such as diatoms or desmids. Filamentous algae are better attached to the bryophyte plant; therefore, they can hardly be replaced to the suspension and thus are often overlooked. Cyanobacteria and green algae can be obtained by isolation into cultivation medium. Samples of bryophytes can be also stored as dried material in the herbarium. A dried moss sample can be soaked in water, and algae can be scraped from the surface of moss with a needle under a binocular microscope (Ohtani & Kanda 1987). Most cyanobacteria and diatoms stay undamaged by desiccation unlike green algae which suffer damaged chloroplasts and their identification is impossible (Ohtani & Kanda 1987).

Bryophytes possess several attributes that affect the distribution and abundance of subaeric epiphytic communities. They are among the earliest soil colonisers (Kühnelt 1976) and important components of high-mountain ecosystems (Mani 1962). Bryophytes rapidly absorb large quantities of water, retain them, and thereby also retard the drying out of their underlying substrate. They serve as an insulation against heat, cold and wind (Gressitt 1967, Strong 1967, Corbet 1973), thereby protecting organisms that live within them against climatic changes. Last but not least, due to the perennial life-forms of many bryophytes, they are there when organisms need them. On the other hand, bryophytes are usually inconspicuous, being in a subordinate position in most ecosystems.

Different bryophytes have different life-forms and grow in different colonies. Strong (1967) and Tilbrook (1967) working in Antarctica, wrote that mats of *Polytrichum* and *Dicranum* are less wet and cold than those of *Pohlia,* and consequently harbour more arthropods. *Polytrichum* supports animals to a greater depth probably due to its more developed rhizoid system. Shape, texture and thickness of bryophyte leaves affect the associated organisms. Their influence was previously studied mainly on invertebrates (Edmonson 1944 sec cit. Smith 1982).

Protozoa are small enough to inhabit the film of water in the concavity of the *Sphagnum* leaf, which may be only 300 μm in diameter (Corbet 1973). The protozoa near the top of the plant generally possesses chlorophyll or contains symbiotic algae, while colourless forms are found lower down (Chacharonis 1956). The protozoan fauna of *Sphagnum* is dominated by testate rhizopods. These amoebae feed on bacteria and algal cells growing epiphytically on *Sphagnum* leaves (Richardson 1981). Unlike other protozoa, which tend to move down to moister parts when conditions become unfavourable, the shelled amoebae form little cysts and survive dry periods this way (Heal 1962).

Similar effects described for animals can be expected in the case of other organisms (cyanobacteria, algae) inhabiting bryophytes.

According to Richardson (1981), most algae occur as colonies attached to the surface of leaves and over 90% of algae are found within 2 mm of the leaf base. The number of algae on the youngest leaf is low and increases successively to the seventh or eighth leaf and then decreases probably due to shading. Association between cyanobacteria and mosses can be important in some situations. Cyanobacteria growing on the surface of *Drepanocladus* in pools on the edge of subarctic Swedish mires fix atmospheric nitrogen, which is thought to benefit both the moss and the surrounding plants (Basilier et al. 1978). In *Sphagnum* carpets, unicellular desmids, which float freely rather than being attached, are very abundant. Diatoms are also frequent in this habitat (Richardson 1981).

Sphagna in bogs have their own floras and faunas, whose composition is determined by the special characteristics of these plants. Their acidity, for instance, limits the number of organism groups which may live there. *Sphagnum* carpets can be divided into two layers, the upper one consisting of the heads which, as they grow close together, form a smooth surface. Small animals may run there, and the upper layer effectively insulates the lower one from temperature and humidity fluctuations (Norgaard 1951). The lower or stalk layer, on the contrary, is much thinner and contains small spaces and cavities in which organisms live rather protected from the surface. *Sphagnum* has hollow cells where some rotifers and algae live. In spite of this knowledge of the vertical distribution of animals on *Sphagnum*, no similar data have been published yet concerning algae.

An investigation of epiphytic algae on the leaves of the bryophyte *Cratoneuron commutatum* was performed in a travertine-depositing spring in England (Pentecost 1998). However, if the deposition rate is less than about 2 cm per year, travertines become colonised by a wide range of plants and invertebrates. Among the more prominent colonisers are a group of calcicolous, semi-aquatic bryophytes, and a wide range of algae. These plants become encrusted with travertine and incorporated into the deposits (Irion & Müller 1968). In order to survive, the vertical growth rate of the plants must equal or exceed the growth rate of the travertine. Several kinds of algae, particularly some species of cyanobacteria and diatoms are closely associated with travertine crusts and have been considered to play an important part in the formation of some travertines.

Bryophytes are called the amphibians among plants (Richards 1959) as they straddle, so to speak, the aquatic and the terrestrial worlds. This unique position has rendered them suitable to serve as “stepping stones” or “halfway houses” for organisms as these emerged from archaic water bodies onto land. The ability of bryophytes to live under intermittent wetting and drying was probably of considerable importance in this respect (Smith 1982). If bryophytes really played a role in the colonization of land by organisms, we may expect to find primitive, relict organisms still living in moss, sphagna and hepatics.

Methods

Epiphytic diatoms at permanent sites were taken with the whole substrate (bryophyte). Samples of the same volume were taken from dominant bryophytes with a cutting tool, and carried to a laboratory in polythene bags. Samples for the estimation of vertical distribution were taken by cutting the layers of bryophytes 2 cm thick on the area of 20 cm^2. All these samples were used for quantitative evaluation. Samples for qualitative evaluation (floristic) were taken by squeezing water from bryophytes into sampling bottles.

The fresh bryophyte sample was weighed in the laboratory (fresh bryophyte matter) and then washed out in 100 ml of distilled water and thoroughly squeezed. The content (water with algae and mud) was transferred quantitatively into a tall cylinder of small diameter (up to 20 mm). The sample was left to settle for about 20 minutes, and then decanted. The time of sedimentation can be too short for sedimentation of small species. Some diatomists recommend the sedimentation take place over night, depending on species composition (the representation of small species). The sediment was fixed with formaldehyde and stored in a 50 ml sample container. The squeezed bryophyte material was used for the dry matter assessment. Dry-mass of each bryophyte sample was obtained after oven drying at 85 ˚C for 48 hrs and weighing (dry bryophyte matter). For the quantitative evaluation of diatoms, 400 frustules were counted in a Bürker chamber. The quantity of diatoms was expressed as a number of individuals per 1g of dry bryophyte matter. The effectiveness of the washing procedure was experimentally tested by mineralizing the whole bryophyte sample, using the method for mineralization of epiphytic diatoms (Hindák 1978). The effectiveness reached ˜80%. The water content was estimated as the difference between the dry and fresh bryophyte matter. The height above the water table was measured “in situ” using a 1 meter long ruler. Diatom frustules were mounted in Naphrax and identified according to Krammer

& Lange-Bertalot (1986, 1988, 1991). The relative abundance (%) of individual diatom species in samples was estimated by counting 400 individuals in permanent preparation.

Cyanobacteria were isolated in the laboratory into sterile Zehnder medium (Staub 1961) on agar plates and in a liquid medium with a small piece of cotton wool. Both Erlenmayer flasks and Petri dishes were incubated under the temperature of 22 °C, illumination 50 μmol.m^{-2}.s^{-1} and photoperiod 16/8 L/D cycle. Strains were studied under the LM and identified according to Anagnostidis & Komárek 1988, Komárek & Anagnostidis (1989, 1999), Starmach (1966). Methylene blue staining of native samples was used to distinguish more clearly the mucilaginous sheaths and envelopes.

Desmidiaceae were collected mainly from peaty pools and fresh bryophytes to plastic bottles. Fresh samples were preserved with 4% formaldehyde and investigated under LM. Desmidiaceae were identified according to Coesel (1982, 1991, 1997), Lenzenweger (1996, 1997, 1999), Růžička (1977, 1981).

Statistic software Canoco for Windows using CCA (Canonical Correspondence Analysis, ter Braak & Šmilauer 1998) was used for analysis of the collected data. We established following statistic design. Tested data were downweighted of rare species and not transformed. The analysis was evaluated using Monte-Carlo permutationt test influencing significance of canonical axes together under reduced model of 499 permutations.

Spatial and temporal distribution

Factors influencing epiphytic assemblages at different localities

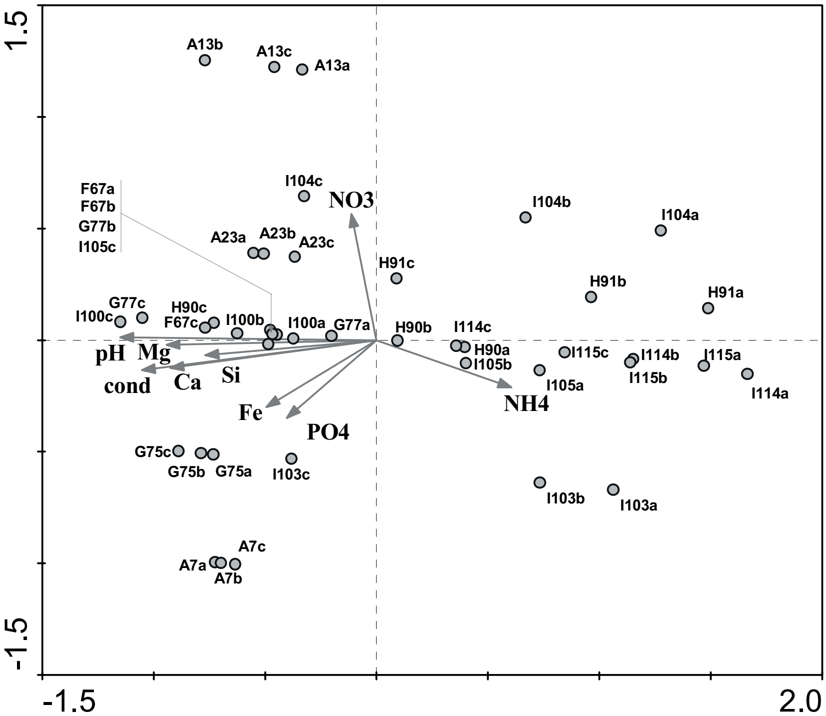
All previously published investigations suggested that the variation in algal abundance and species composition at spring fens is closely related to variation in environmental variables, especially pH and conductivity. A similar pattern of variation was found in algae, bryophytes and vascular plants (Poulíčková et al. 2001, Hájek 1998, Hájková & Hájek 2000, Hašler & Poulíčková 2005.).

The total abundance of algae usually reached millions per 1g of dry bryophyte matter. The least amount of algae was found in mineral-poor spring fens, especially at extremely acidic sites, the highest in springs with the occurrence of tufa formation (Poulíčková et al. 2001, 2003). Algal assemblages were mostly (80-90%) represented by diatoms, and among other algal groups Desmidiales were frequently found, especially at poor acidic fens (Kitner et al. 2004). Cyanobacteria were found in neutral and alkaline springs (Hašler & Poulíčková 2005). Other algae were represented less by several specimens of *Euglena* sp., *Chlamydomonas* sp., and *Trachelomonas* sp. Chrysophyceae were observed in the stage of statocysts.

Altogether, 368 algal taxa were found (selected species see Tabs 1-3). The diatom species richness at individual sites varied from 3 to 32 taxa per site. The lowest species richness was found in extremely acidic springs (pH near 4). Diatoms were represented by *Eunotia glacialis, E. praerupta, E. steineckei, Anomoeoneis brachysira, Stauroneis gracillima* and *Pinnularia pulchra* (Poulíčková et al. 2003). Acidic springs with low conductivity were inhabited mostly by desmids. A total of 40 taxa were found; species *Actinotaenium cucurbitinum, Closterium cynthia* var. *latum, Cosmarium tetraophtalmum, Euastrum ansatum* var. *pyxidatum, Staurastrum senarium* and *Staurodemus cuspidatus* were recorded for the first time from the territory of the Czech Republic; species *Closterium costatum, C. cynthia, C. lunula, Cosmarium cucumis, C. nasutum* f. *granulata, C. pachydermum, C. plicatum, Euastrum dubium* var. *dubium, E. dubium* var *ornatum, E. insulare* var. *insulare, E. insulare* var. *silesiacum, Micrasterias papillifera, M. rotata, Netrium digitus* var. *latum, Pleurotaenium crenulatum* and *Staurastrum punctulatum* were recorded for the first time from Moravia and an additional five taxa new for the Slovak Republic were identified – *Cosmarium plicatum, C. depressum* f. *minutum, C. nasutum* f. *granulata, Mesotaenium degreyi* and *Netrium digitus* var. *latum* (Kitner et al. 2004). Cyanobacteria were missing at extremely acidic sites. They occurred at pH near 6: *Komvophoron minutum, Nostoc commune, Chroococcus turgidus, Phormidium retzii, Leptolyngbya lagerheimii, Chroococcus minor, Oscillatoria granulata, Oscillatoria simplicissima* and *Phormidium tenuissimum* (Hašler & Poulíčková 2005).

In contrast, alkaline sites were dominated by diatoms *Rhopalodia* sp. div., *Diploneis* sp. div., and *Caloneis* sp. div. Records of *Surirella spiralis* and *Campylodiscus hibernicus* are very interesting because of their rare occurrence in the Czech Republic. The species *Caloneis alpestris, C. bacillum, Cymbella helvetica, Diploneis ovalis,* and *Epithemia argus* were observed only at sites with tufa formation. Alkaline sites were rich also in cyanobacteria: *Aphanothece* cf. *castagnei, A. saxicola, Chamaesiphon polonicus, Gloeocapsa alpina, G. atrata, Gloeothece palea, Oscillatoria brevis, Cyanobium diatomica* and *Nostoc calcicola.*

Figure 1: CCA of diatom and environmental data (region codes A-I and locality numbers see Tab. 1 (Chapter 1), arrows – environmental variables, a,b,c – degree of moisture – low, middle, high).



Statistic evaluation of 14 permanent localities showed, that geographical position of the localities (region codes A-I, Fig. 1) is in agreement with differences in geology, ekological variables and species composition (Jarošová 2004). As expected, pH was found as the most powerful environmental variable influencing species composition followed by moisture and conductivity of localities (Fig. 1).

Hustedt (1942) published an account of diatoms from some bryophyte samples in which he recorded a total of 147 species or varieties. However, such large numbers were not recorded in all samples. The species richness ranged from 12 to 85 species. This difference is attributed by Hustedt to the distance from a body of water. Indeed, very many of the 147 forms recorded by Hustedt are also commonly found in free water and therefore not truly characteristic of the land bryophyte flora. In the same paper Hustedt comments on the greater number of species encountered in the last three samples from alkaline soils as opposed to the first two from acid. Thus the epiphytic bryophyte flora appears to be affected by pH of the soil as do the soil diatoms (Lund 1946, Brendemühl 1949).

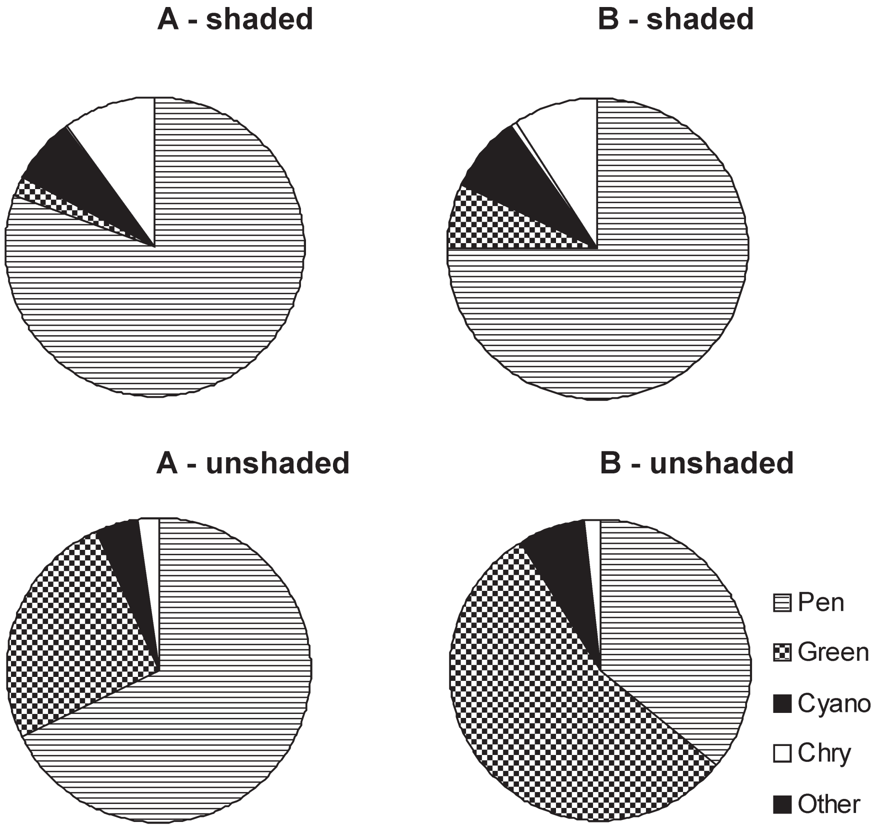
Species composition and abundance of diatoms in springs were compared with other European spring areas (Aboal et al. 1998, Cantonati 1998, Round 1957a). Most of the springs studied by other authors are slowly flowing springs (rheocrenes) or limnocrenes, where epilithon, epipelon and epiphyton can be found. On the other hand, most Carpathian springs represent another type – helocrenes. Dominant diatom assemblages are epiphytic and slightly aerophytic. This is reflected in the presence of aerophilous species and lower numbers of rheophilous species (Foged 1984). Aboal et al. 1998 as well as other authors (Carter & Bailey-Watts 1981, Gasse et al. 1983) state that the dominant ecological factor influencing the distribution of diatoms is ionic strength. Chemically speaking, our sites resemble spring areas of Switzerland, which are situated in rather higher altitudes (Ector & Iserentant 1988). However, the concentration of calcium and some other ions is slightly higher at all Carpathian sites than at comparable sites of northern and western Europe, probably due to the distinctive composition of flysch layers (Hájek et al. 2002).

Factors influencing distribution within one locality

Horizontal distribution

Beside the variation among localities, seasonal variation and intra-site spatial variation have been found in algal assemblages. Our preliminary results led us to the hypothesis that the distribution of epiphytic algae can be influenced by the micro-site moisture gradient. This gradient is markedly developed in mineral poor, *Sphagnum*-dominated fens, where the structure and floristic changes of a bryophyte layer are visible even in the field. The spring streams are dominated by *Sphagnum flexuosum* and rarely by *S. inundatum*. The species *Sphagnum papillosum, S. palustre, S. magellanicum* and *Calliergon stramineum*, were observed at the microsites situated in the central and upper parts of the transects. The tops of the transects often comprised drying-out hummocks of *Polytrichum commune* (Poulíčková et al. 2004). Moisture was found as a factor strongly correlating with the composition of bryophyte and diatom communities. The number of diatoms increases with increasing moisture at microsites. The pattern in diatom community composition reflected the stream-hummock gradient. *Eunotia paludosa* is a typical species of dry hummock tops, accompanied by *Pinnularia rupestris* and *Achnanthes lanceolata*. The species richness and diversity increases towards streams. The diatom species best fitting this gradient were *Eunotia arcus, E. incisa, Pinnularia* sp. and *P. subcapitata*. Moreover there a pH gradient

Figure 2: Representation of algal groups at two places (shading by mesh was 50%) in two localities (A- Jančíkovci, B – Obidová). Pen – pennate diatoms, Green – Chlorophyta, Cyano – Cyanobacteria, Chry – Chrysophyceae.



was identified, where vicariant species *Eunotia paludosa* and *Eunotia arcus* seem to be regulated by pH. However, there is additional variation in habitat conditions which can be explained by moss species composition in the studied fens. We found a significant relationship between the dominance of some moss species and the occurrence of specific diatom species. This correlation is independent of the moisture characteristics and it is impossible to explain it by variation in pH (Poulíčková et al. 2004).

Beside the variables mentioned above, light was found as a factor influencing the representation of different algal groups. The representation of green algae decreases at experimentally shaded places; the opposite tendency occurs in the case of diatoms and cyanobacteria (Fig. 2).

The determination of diatom flora by moisture was previously mentioned by Round (1958 a,b). Beger (1927, 1928) divided the epiphytic diatom community on bryophytes into “xerotisch”, “mesophilish” and “hydrotisch” types. He characterized the “xerotisch” type by *Pinnularia borealis, Hantzschia amphioxys, Melosira roeseana* and *Achnanthes coarctata.* Typical of his “hydrotisch” type are *Melosira dickiei, Tetracyclus braunii, Denticula elegans, D. tenuis, Grunowia sinuata, Navicula perpusilla, N. roteana, N. atomus, Pinnularia brebissonii, Eunotia* spp. and *Cymbella* spp. Only a small number of these species were found by Round (1957 b), possibly due to the fact that Beger´s collections were from calcareous alpine regions, while Round collected bryophyte samples from sandstone cliff.

Beger (1928) mentions three species amongst others, *Pinnularia borealis, Hantzschia amphioxys* and *Navicula mutica*, which he regards as characteristic species of the bryophyte community. These three are, however, very common in soils (John 1942, Lund 1946, Brendemühl 1949). Thus the possibility does arise that the true moss diatoms are very few indeed, and it does point to the great importance of exclusion of soil particles from the samples. The small number of species inhabiting bryophytes at dry places is no doubt a reflexion of the extreme conditions imposed by the aerial habitat. In addition, a size limitation is obvious, for although occasional 60 µm long frustules of *Pinnularia viridis* were found (which is small for this species), the vast majority of species, and all the dominants, have cells less than 20 µm in length (Round 1957b). Some species are so small (up to 5 µm in length) that their identification is difficult (Petersen 1915, Beger 1927, 1928, Lund 1946, Brendemühl 1949). These habitats have one striking feature in common, i.e. the subjection of the communities to periodic or perpetual drought, either actual or physiological. The ability of the bryophyte diatoms to withstand prolonged drought has been shown by Beger (1927). The extreme reduction in diatom species richness combined with frequent occurrence of species *Achnanthes coarctata, Pinnularia borealis* and *Hantzschia amphioxys* were reported from dry sand dune mosses by Round (1958 a,b) and Berger (1927).

Vertical distribution

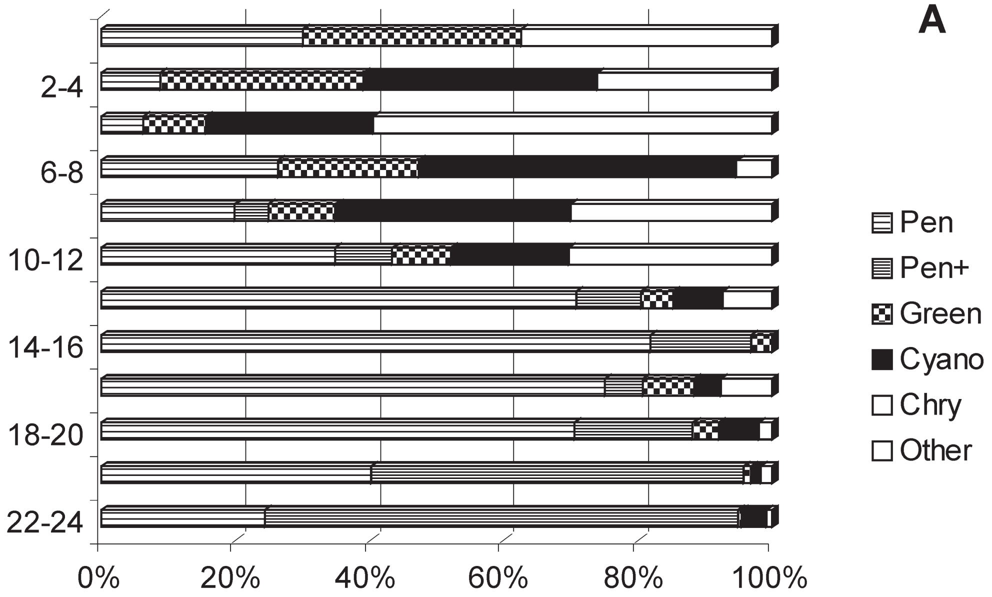
Moisture and light were found as the main factors influencing vertical distribution of epiphytes on *Sphagnum* plants. The abundance of algae significantly increased with the increasing water content (Poulíčková et al. 2003). From this point of view, two different vertical distribution patterns were found. The first type of distribution, with the highest numbers in the deepest part, was observed at springs and near the pools or streams where the substrate can be considered as the source of moisture. The opposite situation with the highest numbers near the bryophyte top was observed on rocks where the air humidity represents the only source of moisture (Nováková & Poulíčková 2004). The representation of empty diatom frustules increases with increasing depth. Living cells can be found to the depth of 34 cm. The representation of green algae is higher at unshaded places and decreases with increasing depth (Fig. 3).

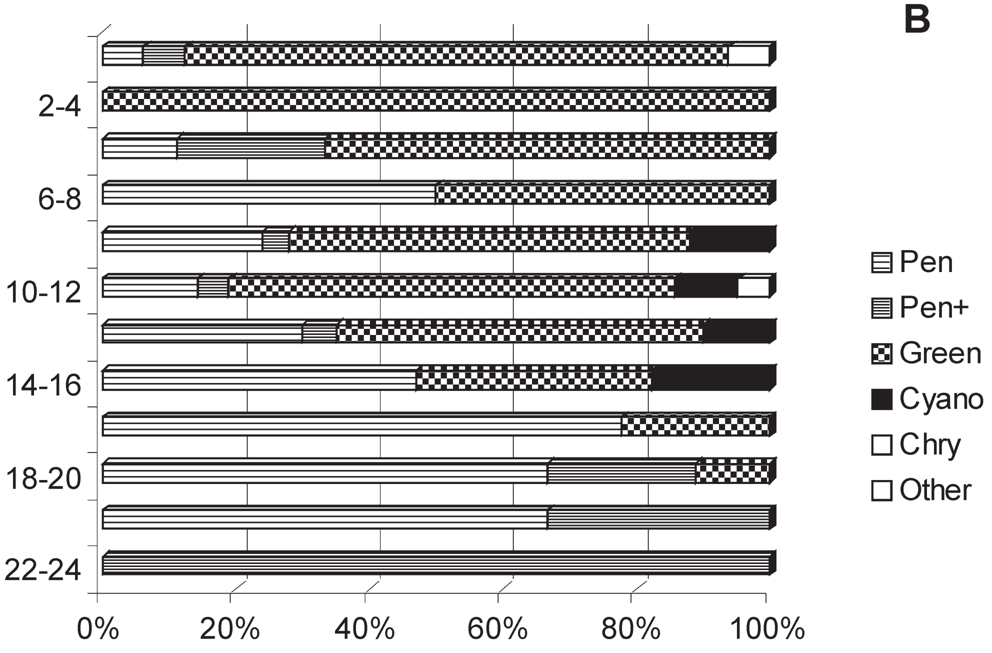
Temporal distribution – seasonal dynamics

Spring water, when it emerges, possesses remarkably constant physical and chemical features. The temperature, responsible on seasonal dynamics in ponds and lakes, is fairly constant throughout the year in springs (Thienemann 1922). Temperature itself does not greatly affect the distribution of diatoms (Hustedt 1937-1939).

Although seasonal dynamics are not usually expected at a spring ecosystem, helocrenes represent an exception. Seasonal dynamics are usually influenced by seasonal changes in light, temperature, moisture or nutrient conditions. Seasonal variability in total abundance has no general tendency. On the other hand, some tendencies were observed in the representation of different groups.

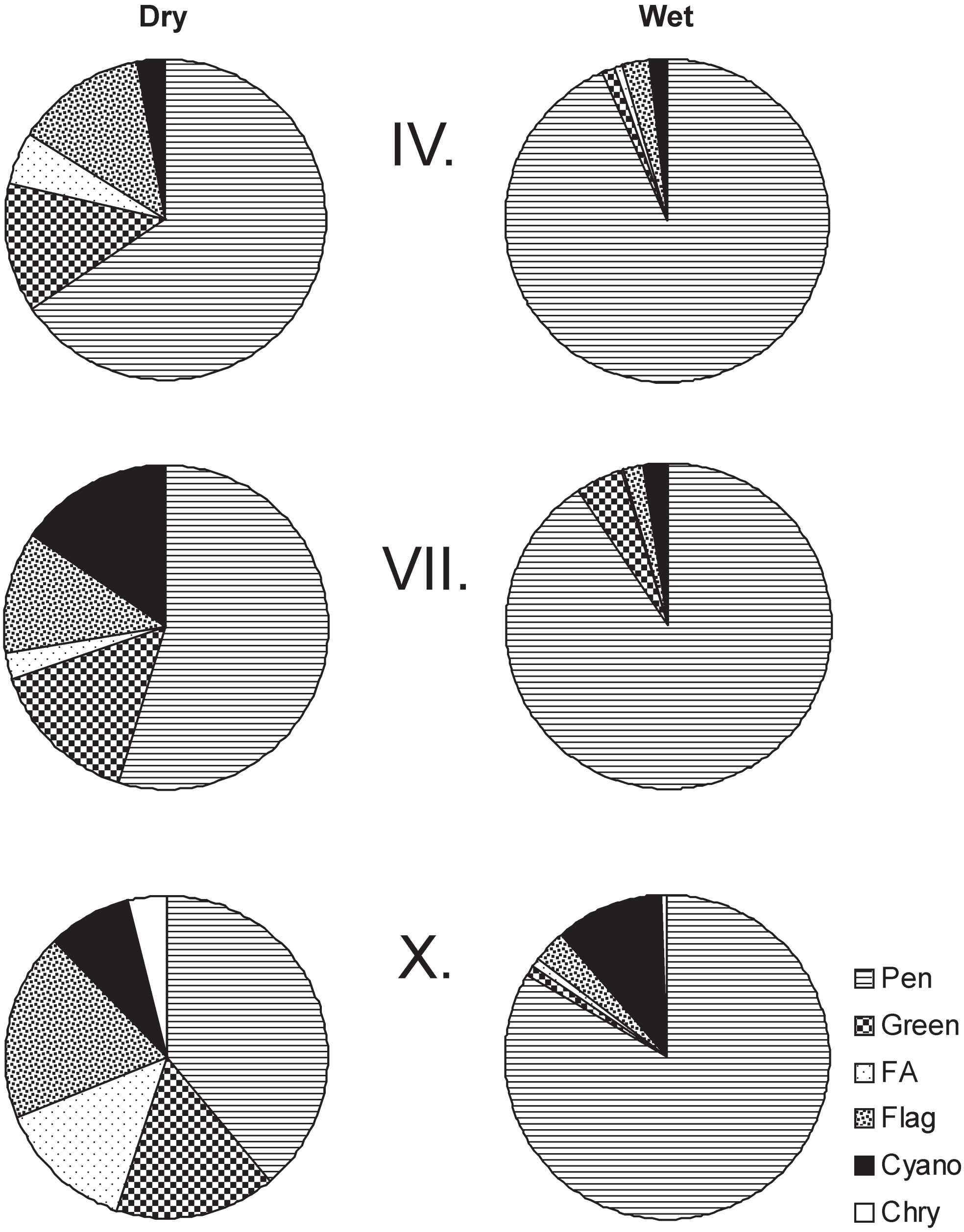
Figure 3: Vertical distribution (depth in cm) of algal groups at shaded (A) and unshaded (B) places of the locality Obidová. Pen – living cells of pennate diatoms, Pen+ - dead frustules, Green – Chlorophyta, Cyano – Cyanobacteria, Chry – Chrysophyceae.





The representation of cyanobacteria is higher at dry places than at wet sites and increases in summer and autumn. Chrysophyte resting stages were observed mostly in autumn. The representation of different algal groups in general show wider variability at dry places that at wet places (Fig. 4).

Figure 4: Seasonal changes in representation of algal groups at dry and wet places, averages from 14 permanent localities (localities indicated in bold in Tab. 1, Chapter 1). Pen – pennate diatoms, Green – Chlorophyta, FA – colourless flagellates, Flag – green flagellates, Cyano – Cyanobacteria, Chry – Chrysophyceae.



The list of diatoms identified during 1999 – 2004

Localities according to Chapter 1; nomenclature according to Krammer & Lange-Bertalot (1986, 1988, 1991) without any respect to later changes (except of the genus *Sellaphora*); some data were collected by MSc. students (see p. 6; Křenková 2001, Jarošová 2004, Luxová 2006).

Achnanthes biasolettiana Grunow A 7, 13, 20, H 90,
Achnanthes exigua Grunow D 52, 53
Achnanthes flexella A 1, 4, 7,
Achnanthes fragilaroides Petersen H 90
Achnanthes laevis Oestrup A 7, 10, 12, 13, 14, 20, G 75, 77
Achnanthes lanceolata (Brébisson) Grunow A 1, 5, 6, 10, 13, 20, C 39, 40, 41, 42, D 52, 55 G 77, H 90, I 98
Achnanthes laterostrata Hustedt B 29, D 54
Achnanthes minutissima Kützing A 1, 4, 5, 6, 7, 9, 10, 11,12, 13, 14, 20, B 26, 27, 28, 29, 32, 33, 34 C 38, 39, 40, 41, 42, 44, 45, 46, 47, 48, D 51, 52, 53, 54, 55, 56, 57, 58 G 75, 77 F 65, H 90, 92, I 97, 98, 103, 104, 105, 114, 116 K 129, 130
Amphora commutata Grunow H 90
Amphora inariensis Krammer A 20
Amphora libyca Ehrenberg A 7
Amphora montana Krasske F 63
Amphora normannii Rabenhorst A 5, 7, 13, 20, 21, 23, E 62, F 65, G 72, 75, 77, 79, H 90, I 98, 103
Amphora ovalis (Kützing) Kützing A 1, 5, 7, 14
Amphora veneta Kützing A 20, B 27
Anomoeoneis brachysira (Brébisson) Grunow H 94, I 104, 109, 113
Anomoeoneis serians (Brébisson) Cleve I 103, 104, 105
Anomoeoneis styriaca (Grunow) Hustedt I 103, 104, 105
Anomoeoneis vitrea (Grunow) Ross A 4, 13, 20, H 86, 90, 94, 95, I 100, 103, 104, 105, 109, 113
Caloneis aerophila Bock A 20
Caloneis alpestris (Grunow) Cleve A 1, 6, 7, 13, 14, 20, B 27, 29, C 38, D 53, 55, 56, 57, 58, G 75, 77, I 98, K 129,
Caloneis bacillum (Grunow) Cleve A 5, 6, 8, 10, 18
Caloneis clevei (Lagerstedt) Cleve B 32, F 63
Caloneis molaris (Grunow) Krammer A 19
Caloneis pulchra Messikommer C 42, D 56, G 77, I 98
Caloneis schumanniana (Grunow) Cleve A 6, 12, B 29, D 58, H 90
Caloneis silicula (Ehrenberg) Cleve A 7, 10, 11, G 75, H 90
Caloneis sublinearis (Grunow) Krammer A 11, C 41, F 64
Caloneis tenuis (Gregory) Krammer A 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, B 25, 26, 28, 29, 30, 31, 32, 33, 35 E 62, C 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, D 51, 52, 53, 54, 55, 56, 57, 58, F 63, 65, G 72, 75, 77, H 86, 90, 96, I 97, 98, 102, 105, J 121-126, K 129, 130
Caloneis undulata (Gregory) Krammer A 1, 8, 9, 16, 17, 21, E 62, F 63, 65, I 98, 102, J 122, 126,
Campylodiscus hibernicus Ehrenberg A 1, 13, 14, 18, 20, G 75, 77,
Cocconeis placentula Ehrenberg A 6, 7, 13, 14, C 39, 40, 42, 45, 46, D 52, 53, G 75, K 129
Cocconeis neodiminuta Krammer A 12

Cocconeis pediculus Ehrenberg A 9
Cymbella affinis Kützing A 7, 10, 12, 20, F 65, G 75, 77, I 98, 104
Cymbella amphicephala Nägeli A 9, 13, 21, D 52, 53, 54, F 65, 70, 71 G 73, 77, H 90, I 98, 103, 105, 114, J 124, 126
Cymbella aspera (Ehrenberg) Cleve A 9, 11, 13, 16, B 26, 30, F 64, 66, G 72, 77, H 90, 96, I 98, J 121, 122
Cymbella austriaca Grunow A 7, 13, 20, F 65, G 75, 77, I 98
Cymbella cesatii (Rabenhorst) Grunow B 26, 28, 29, 32, C 40, 47, D 51, 53, 54, 55, 56, 57, 58, K 129, 130,
Cymbella cistula (Ehrenberg) Kirchner A 13, F 65
Cymbella cymbiformis Agardh A 1, 9, 10, 12
Cymbella delicatula Kützing A 7, 13, B 25, 26, 27, 28, C 39, 47, 48, D 52, 53, 58, G 77, F 65, I 97, K 129
Cymbella elginensis Krammer H 90, K 129
Cymbella falaisensis (Grunow) Krammer et Lange-Bertalot A 7, C 38, 39, D 52, 53, 55, 58, H 90, 92, I 97, 116
Cymbella gaeumannii Meister B 27, 29, 32, C 42, D 51, F 65
Cymbella gracilis (Ehrenberg) Kützing A 1, 6, 7, 8, 9, 11, 13, 22, B 29, 35, C 45, F 65, 70, G 72, 77 H 86, 90, 92, 95, I 98, 103, 105, 109, 105, 113, 114, J 121, 123
Cymbella hebridica (Grunow) Cleve A 21, 23
Cymbella helvetica Kützing A 1, 5, 7, 12, 13, 16, 20, 22, B 26, 27, 32, 34, C 39, 40, 41, 45, 47, 48, D 51, 52, 57, F 65, G 75, I 98, K 130,
Cymbella hungarica (Grunow) Pantocsek A 1, 5, 6, 7, 9, 10, 12, 13, 14
Cymbella hustedtii Krasske B 25, 26, C 38, 46, H 90, 92, I 114
Cymbella incerta (Grunow) Cleve A 13
Cymbella laevis Nägeli A 8, D 56,
Cymbella lanceolata (Ehrenberg) Kirchner D 55
Cymbella leptoceros (Ehrenberg) Kkützing C 40
Cymbella mesiana Cholnoky B 28, C 39, 46, D 51, 53, 54, I 97
Cymbella microcephala Grunow B 29, C 38, 39, 41, 44, 47 D 51, 58, I 97
Cymbella minuta Hilse A 7, 13, 20, 21, B 32, C 39, 41, 44, 45, 48, F 64, G 75, 77, H 90, 92, F 65, I 98, 103, 104, 105,
Cymbella naviculiformis Auerswald A 4, 7, 10, 13 H 90, I 98
Cymbella perpusilla Cleve-Euler A 7, 13, 20, B 30, G 75, 77, H 90, I 98, 103
Cymbella proxima Reimer A7
Cymbella pusilla Grunow A 13, 20, C 41 G 75, 77, H 90
Cymbella reichardtii Krammer C 39
Cymbella schimanskii Krammer I 97
Cymbella silesiaca Bleisch A 1, 5, 6, 7, 8, 9, 10, 12, 13, 14, 16, 19, 22, 23, C 41, 44, H 90, I 98
Cymbella subaequalis Grunow A 7, 13, 20, 21, B 26, C 40, D 52, 54, 55, 56, 58, G 75, 77, I 98, K 129,
Cymbella tumidula Grunow I 97
Denticula elegans Kützing A 13
Denticula kuetzingii Grunow A 13, 20, B 29, K 129
Denticula tenuis Kützing A 13
Diatoma mesodon (Ehrenberg) Kützing A1,12
Diatoma moniliformis Kützing B 32,
Diatoma tenuis Agardh C 39
Diatoma vulgaris Bory A 13, F 65, I 104

Diploneis cf. *parma* Cleve J 124

Diploneis elliptica (Kützing) Cleve A 1, 5, 6, 7, 9, 10, 11, 12, 13,14, 16,17, 18, 19, 20, 21, 22, 23, B 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, C 38, 39, 40, 41, 44, D 51, 52, 53, 54, 55, 56, 57, 58, F 62, 63, 64, 65, 66 G 72, 73, 75, 77, H 90, 96, I 98, 102, J 121, 122, 123, 124, 126, K 129, 130

Diploneis minuta Petersen A 7, 13, 20, F 65, G 75, 77, H 90, 92, I 98, 103

Diploneis oblongella (Nägeli) A. Cleve A 1, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 18, 20, 21, 22 B 25, 26, 27, 28, 29, 30, 31, 32, 34, 35, C 39, 42, 44, 45, D 52, 53, 55, 56, 57, 58, E 62, F 63, 64, 65, 66, 70, G 75, 79, 73, 72, H 86, 90, 94, 95, 96, I 98, I 116, K129, 130

Diploneis oculata (Brébisson) Cleve A 7, 13, 20, G 75, 77, H 90, I 98

Diploneis ovalis (Hilse) Cleve A 6, 7, 8, 9, 13, 20, B 33, C 42, 46, 47, F 65, G 75, 77, H 90, 92, I 98, 104, 105

Diploneis petersenii Hustedt C 39, D 54, I 98

Diploneis pseudovalis Hustedt I 98

Epithemia adnata (Kützing) Brébisson A 6, 7, 10, C 45, 46, B 25, 26, D 51, 52, 53, 58, F 65, G 75, 77, I 98, I 103

Epithemia argus (Ehrenberg) Kützing A 6, 8, 9, B 26, 29, 30, 31, 32, 33 D 51, 52, 55, 57, 58, I 97

Epithemia argus var. *alpestris* (W. Smith) Grunow A 1, 6, 7, 8, 9, B 31, 35 E 62, G 75, 77, I 98

Epithemia cf. *frickei* Krammer F 64

Epithemia goeppertiana Hilse C 44

Epithemia sorex Kützing C 44, I 98

Eunotia arcus Ehrenberg A 1, 4, 7, 9, 12, 13, 14, 20, 21, 23, B 26, 28, 29, 33, 34 C 38, 39, 46, 48, D 51, 52, 53, 54, 56, 58, G 75, H 84, 86, 90, I 97, 103, 104, 105, 113, 114 K 129

Eunotia bilunaris (Ehrenberg) Mills A6, 10, 11, D 56, H 90, 92, I 103, 105

Eunotia cf. *rhynchocephala* Hustedt I 116

Eunotia cf. *silvahercynia* Nörpel et al. H 96

Eunotia diodon Ehrenberg A 7, H 90

Eunotia exigua (Brébisson) Rabenhorst G 77, 82, H 90, I 103, 104, 105, 114, 116

Eunotia glacialis F. Meister C 44, F 71, I 116

Eunotia implicata Nörpel et al. H 88, 90, I 103, 104, 105,114, 116

Eunotia incisa Gregory A 18 B 32 H 90, 92, G 75, 77, I 103, 104, 105, 114, 116

Eunotia minor (Kützing) Grunow H 90

Eunotia monodon Ehrenberg G 77, I 104

Eunotia muscicola var. *tridentula* Nörpel & Lange-Bertalot H 90

Eunotia nymanniana Grunow I 116

Eunotia paludosa Grunow A 8, 9, 10, 11, 13, 14, 15, 16, 19, 21, 23, B 29, 30, 31, 32, 35 F 63, 65, G 72, 75, 77, G 82, H 88, 90, 92, 95, 96, I 98, 103, 104, 105, 106, 107, 108, 109, 113, 114, 116, J 124

Eunotia pectinalis (Dillwyn) Rabenhorst H 90, 92,

Eunotia praerupta Ehrenberg A 13, 20, B 29, F 71, H 84, 90, 92, 94, 95, I 103, 105, 114

Eunotia serra Ehrenberg I 105, 109, 114

Eunotia serra var. *tetraodon* (Ehrenberg) Nörpel H 90

Eunotia soleirolii (Kützing) Rabenhorst I 114

Eunotia steineckei Petersen F 64, 70, 71, G 73, 77, 82 H 86, 88, 90, 92, 94, 95, I 98,100,102,103, 104, 105, 106, 107, 108, 109, 113, 114, 116, J 126,

Eunotia sudetica O. Müller F 70, 71 H 86, 90, 94, 96 I 109,113

Eunotia tenella (Grunow) Hustedt B 32, H 90, 92, I 103, 105, 114, 116

Fragilaria brevistriata Grunow I 98

Fragilaria capucina Desmaziéres B 33, C 38, 39, 41, 43, 44,47, D 58
Fragilaria construens (Ehrenberg) Grunow C 40, D 58, K 129
Fragilaria delicatissima (W. Smith) Lange-Bertalot C 44
Fragilaria fasciculata (C.Agardh) Lange-Bertalot B 29, I 98
Fragilaria inkognita Reichardt C 47
Fragilaria pinnata Ehrenberg D53, I 98, 105.
Fragilaria tenera (Smith) Lange-Bertalot F 65
Fragilaria ulna (Nitzsch) Lange-Bertalot A 1, 6, 14, F 71
Fragilaria virescens Ralfs I 114
Frustulia rhomboides (Ehrenberg) de Toni A 10, 21, H 84, 86, 90, 92, 94, F 64, 66, 70, G 73, 77, I 103, 104, 105, 114,116,
Frustulia vulgaris (Thwaites) de Toni A 1, 5, 10, 12, 13, 14, 20, H 90, I 103, 104, 105, 113
Gomphonema acuminatum Ehrenberg A 6
Gomphonema angustatum (Kützing) Rabenhorst A 10, 14, 15, 19, 22, B 29, 31, 35, C 38, 39, 40, 42, F 63, 71, G 73 J 121, 126
Gomphonema angustum Agardh A 13, 20, B 25, 26, 28, 29, 34, C 39, 41, 45, 47, D 51, 52, 53, 54, 55, 56, 57, 58 G 75, 77, H 90, I 97, 98, K 129, 130
Gomphonema augur Ehrenberg C 40
Gomphonema clavatum Ehrenberg A 7, 8, 11, 13, 20, 22, C 41, E 62, F 70, 71, G 73, 75, 77, H 86, 90, 96, I 98, 103, 105, 114, 116, J 121, 125
Gomphonema gracile Ehrenberg A 1, 4, 5, 6, 7, 8, 10, 12, 13, 14, 20, B 26, 29, 30, 35, C 38, 40, 48, F 63, G 72, 75, 77, H 86, 90, 95 I 98, 102, 105 ,114, J 122, 124, 126
Gomphonema hebridense Gregory I 98
Gomphonema minutum (C. Agardh) C. Agardh A 13, B 25
Gomphonema olivaceum (Hornemann) Brébisson A 1, 5, 6, 7, 9, 10, 13, 14, G 77, I 98
Gomphonema parvulum (Kützing) Kützing A 7, 8, 11, 13,16, 20, 21, 23 B 25, 26, 27, 30,32, 34, C 39, 41, 47, D 51, 52, 54, 55, 56, F 64, 65, 66, G 72, 75, 77, 79, H 90, 92, I 97, 98, 104, 105, 114, 116, J 124, 126, K 129, 130,
Gomphonema truncatum Ehrenberg C 40, D 52,
Gyrosigma acuminatum (Kützing) Rabenhorst A 1, 5, 6
Gyrosigma attenuatum (Kützing) Rabenhorst D 54
Hantschia amphioxys (Ehrenberg) Grunow A 7, 20, B 27, 33, C 43, F 65, G 77, I 98, 105, 114
Mastogloia elliptica Agardh B 29
Mastogloia grevillei W. Smith D 57, 58
Mastogloia smithii Thwaites B 26, D 51, 57, 58
Meridion circulare (Grevile) C. Agardh A 11, 12, 20, C 42, F 71, G 73, H 95, 96 I 98, 100, 105, 114
Navicula angusta Grunow A 7, 19, 20, 22 B 26, G 73, H 90, 92, I 98, 103, 105, K 129
Navicula bryophila Petersen A 7, 13, 20 B 25, 29, C 38, 44, 47, D 52, 53, 57, F 65, G 75, 77, H 90, 92, I 97, 98, 103, 104, 105, 114, K 130
Navicula capitata Ehrenberg H 92
Navicula cari Ehrenberg A 6, 7, 13, 15, 20, B 25, 27, F 64, 65, G 75, 77, H 90, 92, I 98, 103, 105
Navicula cincta (Ehrenberg) Ralfs A 7, 13, 20, G 73, 75, 77, H 90, I 98,
Navicula cocconeiformis Gregory H 90, I 114
Navicula contenta Grunow G 75
Navicula cryptocephala Kützing A 1, 5, 6, 7, 8, 9, 10, 12, 13, 14,15, 16, 20, 23, C 39, 40, 41, 44, 46, 48, D 52, 55, 56, 57, 58, F 65, 70, 71, G 75, 77, H 86, 90, 92, I 98, 103, 106, 114, 116 J 121, 123, 125, K 130

Navicula cryptotenella Lange - Bertalot A 7, 11, 13, 21, 22, 23, B 27, 28, 29, 30, C 38, 40, 41, 42, 44, 48, D 51, 52, 53, 54, 55, 56, 57, E 62 F 64, 65,G 73, H 90, I 105
Navicula cuspidata (Kützing)Kützing H 90
Navicula elginensis (W. Gregory) Ralfs A 5, 7, 9, 10, 13, C 42, H 90, 96 I 98, J 121,
Navicula erifuga Lange - Bertalot B 30 F 66 I 98,
Navicula exilis I 116
Navicula festiva Krasske A 6, H 90
Navicula gallica (Schmidt) Lagerstedt A 13, 20, G 75, 77, F 65, H 90, I 98, 114
Navicula gastrum (Ehrenberg) Kützing A 13
Navicula goeppertiana (Bleisch) Smith H 90
Navicula gracilis Ehrenberg B 32
Navicula gregaria Donkin A 1, 4, 7, 12
Navicula halophila (Grunow) Cleve C 47, D 57,
Navicula hambergii Hustedt C 42
Navicula lanceolata (C. Agardh) Ehrenberg A 6, 7, 9, 10, 14, D 53, G 73 I 114
Navicula libonensis Schoemann B 27, 33, 34, C 39, K 130
Navicula mediocris Krasske A 13, 20, H 90, I 103, 105, 116
Navicula menisculus Schumann A 1, 5, 6, 10, 12, 13, 14
Navicula minima Grunow G 75, 77, H 90, I 98,
Navicula minuscula Grunow C 41
Navicula modica Hustedt A 7, 13, 20, F 65, G 75, 77, H 92, I 98, 105
Navicula mutica Kützing A 20, F 70 I 116
Navicula oblonga Kützing A 6
Navicula phyllepta Kützing A 14, 19, B 35, G 73
Navicula placenta Ehrenberg H 90
Navicula praeterita Hustedt H 90
Navicula pseudobryophila Hustedt H 90, I 98
Navicula pseudolanceolata Lange-Bertalot B 29
Navicula pusilla W. Smith B 29
Navicula pygmaea Kützing F 70
Navicula radiosa Kützing A 1, 6, 11, 13, 14, B 29, C 41, 42, D 52, 55, 56, 57, H 92, J 121, 122, 123
Navicula rhynchocephala Kützing I 103
Navicula subtilissima A. Cleve A 8, 9, 10, 13, 16, 19, B 29, 30, 31, 32, 35, E 62, F 65 H 90, I 98
Navicula tenella Brébisson A 13
Navicula tripunctata (O.F. Müller) Bory A 5, 7, 10
Navicula trivialis Lange-Bertalot A 6, 7, 9, 10, 14
Navicula utermoehlii Hustedt H 90
Navicula veneta Kützing A 21, C 39
Navicula viridula (Kützing) Ehrenberg var. *viridula* A 7, C 39, D 54, 58 G 73
Neidium binodeforme Krammer C 41
Neidium binodis Ehrenberg G 75, H 90
Neidium hercynicum A. Mayer H 90
Neidium opulentum Hustedt A 13
Nitzschia acidoclinata Lange-Bertalot C 38, D 58
Nitzschia acicularis (Kützing) W. Smith A 6
Nitzschia amphibia Grunow A 1, 5, 6, 7, 10, 12, 13, 14, 20, B 25, 26, 29, 32, 33, C 38, 41, F 65, G 75, 77 H 90, I 98, 103, 114, K 130
Nitzschia amphibioides Hustedt A 10

Nitzschia angustata Grunow A 6, 14
Nitzschia archibaldii Lange – Bertalot A1, 8, 10, 19, 21, 22, B 35, E 62, F 64, 65, 70, G 73, 79, H 86, I 105, J 121, 123, 124, 125, 126
Nitzschia capitellata Hustedt H 86
Nitzschia cf. *tubicola* Grunow A 22
Nitzschia commutata Grunow A 6, 10, G 79
Nitzschia dissipata (Kützing) Grunow A 10, 14
Nitzschia dubia W. Smith A 14
Nitzschia fonticola Grunow G 77
Nitzschia frustulum (Kützing) Grunow A 7, 8, 9, 10, 11, 13, 14, 15, 17, 18, 19, 20, 22, 23, B 25, 28, 35, D 57, E 62, F 63, 64, 66, G 72, 73, 75, 77, 79, I 98, J 121, 122
Nitzschia linearis (C. Agardh) W. Smith A 1, 5, 6, 7, 10, 12, 13, 14, 20, F 66 H 90
Nitzschia microcephala Grunow C 44
Nitzschia palea (Kützing) W. Smith A 15, B 32, C 43, F 66, G 72, 79, J 121, 122,
Nitzschia paleacea (Grunow) Grunow F 71, I 98, J 124
Nitzschia perminuta (Grunow) Peragallo A 13, 20, B 25, 27, 29, 33, C 38, 42, 45, 46, 47, D 52, 57, G 75, 77, H 90, I 98, 105, K 130
Nitzschia sigmoidea (Nitzsch) W. Smith A 8,18, 22, D 52, F 64, 66, G 72, 73, 79
Nitzschia sinuata (Thwaites) Grunow A 4, 6, 7, 9, 10, 13, 20, B 25, 29, 31, 32, C 38, 39, 46, D 51, 53, 54, 55, 58, G 72, 75, 77, I 97, 98, K 129,
Nitzschia sinuata var. *delognei* (Grunow) Lange - Bertalot A 10, F 63
Nitzschia sociabilis Hustedt H 95
Nitzschia tubicola Grunow B 27
Nitzschia valdecostata Lange-Bertalot & Simonsen C 39
Pinnularia appendiculata (C. Agardh) A. Cleve H 84
Pinnularia borealis Ehrenberg A15, H 90, 96, I 100, 108, 114,
Pinnularia brevicostata Cleve I 98
Pinnularia gibba Ehrenberg A 7, 13, 20, E 62, G 70, 73, 75, 77, H 84, 90, 92, 94, 95, I 98, 103, 113, 114, 116, J 121
Pinnularia gibba var. *linearis* Hustedt H 90
Pinnularia hemiptera (Kützing) Cleve H 90
Pinnularia interrupta W. Smith A 13, H 90
Pinnularia karelica Cleve C 41
Pinnularia maior (Kützing) Rabenhorst A 1, 13, D 57, H 90
Pinnularia microstauron (Ehrenberg) A. Cleve A 1, 6, 7, 13, 15, 19, 20, F 65, G 75, 77, H 90, I 98, 104, 105, J 124
Pinnularia nodosa (Ehrenberg) W. Smith F 71
Pinnularia obscura Krasske H 90
Pinnularia pulchra Oestrup C 39, H 95
Pinnularia rupestris Hantzsch A 8, B 32, G 75, 77, I 98, 114, 116, K 129
Pinnularia schroederi (Hustedt) Krammer A18, I 98
Pinnularia streptoraphe Cleve G 77
Pinnularia subcapitata Gregory. A 10, 13, 14, 17, 19, B 28, C 39, 40, 41, F 63, 65, G 77, H 84, 86, 88, 90, 92, 95, I 98, 100, 103, 104, 105, 108, 114, 116
Pinnularia sudetica (Hilse) Peragallo A 7, B 29, 33, 34, 39, 40, D 56, H 90
Pinnularia viridis (Nitzsch) Ehrenberg A 1, 5, 6, 7, 10, 11, 13, 14, 15, 19, 21, 22, B 29, 31, 35, C 42, 48, D 51, 55, F 63, 64, 66, 70, 71, G 72, 73, 75, 77, 79, H 84, 86, 90, 94, 95, I 98, 102, 103, 104, 105, 108, 109, 113, 114, 116, J 123, 124, 126,
Rhopalodia cf. *brebissonii* Krammer I 98

Rhopalodia gibba (Ehrenberg) O. Müller A 1, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, B 25, 26, 28, 29, 30, 31, 32, 33, 35, 38, C 39, 40, 41, 42, 44, 45, 46, 47, 48 D 51, 52, 53, 55, 56, 57, 58, F 63, 65, G 72, 75, 77, I 97, 98, 102 J 121, 122, 124, K 129
Rhopalodia gibberula (Ehrenberg) O. Müller A 6, 7, 10
Rhopalodia operculata (C. Agardh) Håkansson A 9
Rhopalodia rupestris (W. Smith) Krammer A 6, 7, 8, 9, 10, 11, 13, B 25, 26, 29, 30, 35, C 41, 44, 46, D 56, 57, 58, F 65, G 75, 77 H 92, I 97, 98, 102, J 121, 122, 123, 124, 125 K 129
Sellaphora bacillum Ehrenberg A 14 E 62 F 71 J 121, 122, 123
Sellaphora pupula (Kützing) Mereschkowsky A 5, 6, 12, 15, 21, B 26, F 70, G 73, H 90
Stauroneis acuta W. Smith G 77
Stauroneis anceps Ehrenberg A 1, 5, 6, 13, 14, H 90
Stauroneis gracillima Hustedt H 88, I 104,108
Stauroneis kriegeri Patrick B 32, I 103, 106, 107, 109
Stauroneis phoenicenteron (Nitzsch) Ehrenberg A 1, 5, 14, D 54, 55, F 66, 70, 71, H 90
Stauroneis producta Grunow D 56
Stauroneis smithii Grunow A 7, 13, 19, 20, B 32, C 39, D 54, F 70, G 77, H 90, 92
Surirella brebissonii Krammer et Lange-Bertalot A 1, 6, 14, H 92
Surirella linearis W. Smith A 5, 6, 7, 13, 14, 22, B 31
Surirella spiralis Kützing A 1, 8, 10, 13, 14, 20, B 26, C 39, 40, 44, F 63,G 75, 77, K 129, 130
Surirella splendida (Ehrenberg) Kützing G 77
Tabellaria cf. *ventricosa* Kützing H 86, 94, 95, I 105, 113, 114
Tabellaria flocculosa (Roth) Kützing F 65, G 77, H 90, 92, I 104, 105, 114, 116

The list of cyanobacteria identified during 1999 – 2004

Anabaena sphaerica Bornet et Flahault F 67
Aphanocapsa parietina Nägeli A 13, B 22, 26, 32, C 39, 41, 44, 46, 45
Aphanocapsa cf. *parietina* Nägeli D 57
Aphanothece castagnei (Brébison) Rabenhorst A 7, K 130
Aphanothece cf. *castagnei* (Brébison) Rabenhorst D 54, G 77
Aphanothece pallida (Kützing) Rabenhorst A 7, C 47, K129
Aphanothece saxicola Nägeli A 7, 13, 23, B 29, 33,C 46, D 56, I 97, K 129,
Calothrix stellaris Bornet et Flahault C 48
Chamaesiphon cf. *incrustans* Grunow B 29, 33,C 47
Chamaesiphon minutus (Rostafinski) Lemmermann C 40, 42,47
Chamaesiohon cf. *minutus* (Rostafinski)Lemmermann D55
Chamaesiphon polonicus (Rostafinski) Hansgirg A 13,C 41, 44, 48, G 75, 77
Chamaesiphon cf. *polonicus* (Rostafinski)Hansgirg C 45
Chroococcus helveticus Nägeli A 7, C 46, 47, D 52, 54
Chroococcus lithophilus Ercegović C 38, 39, 40, 41, 44, 46
Chroococcus minor Kützing A 7, B 25, 28, 29,C 43, 47, D 51, 55, H 90, K 129
Chroococcus cf. *minor* Kützing B 29
Chroococcus minutus Kützing B 22, 32, C 42, F 67, I 97
Chroococcus cf. *minutus* Kützing A 7, 13,B 34,K 130
Chroococcus tenax (Kirchner) Hieronymus B 28, C 38, C 47, D 52, K 129
Chroococcus turgidus (Kützing) Nägeli A 7, C 39, D 56, 57, 58, I 97, 100
Cyanobacterium cf. *notatum* (Skuja) Komárek C 44
Cyanobium diatomicola (Geitler) Komárek A 13
Cyanothece aeruginosa (Nägeli) Komárek B 28, C 44, D 56, I 97

Gloeocapsa alpina (Nägeli) Braend A 7, G 77, K 129
Gloeocapsa cf. *alpina* (Nägeli) Braend I 97
Gloeocapsa atrata Kützing C 40,D 51, 54, 58, G 77
Gloeocapsa compacta Kützing C 44, D 55
Gloeocapsa sanguinea (Agardh) Kützing A 7, C 48
Gloeocapsa cf. *puctata* Nägeli A 7
Gloeothece fusco-lutea Nägeli C 39, 40,45, 46, D 55,I 97
Gloeothece palea (Kützing) Rabenhorst C 38, 39, 43, 44, 45, D 53, G 77
Gloeothece cf. *palea* (Kützing) Rabenhorst B 25
Komvophoron minutum Skuja F 67, I 104
Leptolyngbya boryana (Gomont) Anagnostidis et Komárek C 38, 40, 41, 42, 43,46, K 130
Leptolyngbya cf. *boryana* (Gomont) Anagnostidis et Komárek B 26, 29, C 45, D 57
Leptolyngbya cf. *fragilis* (Gomont) Anagnostidis et Komárek K 130
Leptolyngbya cf. *langerheimii* (Gomont) Anagnostidis et Komárek B 22, 28, C 43, I 103
Lyngbya intermedia Gardner G 75
Microchaete tenera Thuret ex Bornet et Flahault C 43,G 75
Nostoc calcicola Brébison ex Bornet et Flahault A 7, 13, C 39, F 67
Nostoc caerulem Lynbye ex Bornet et Flahault H 91
Nostoc cf. *carneum* Agardh ex Bornet et Flahault A 7
Nostoc commune Vaucher ex Bornet et Flahault B 27, C 42, 44, 45, 46, 47, 48,
D 51, 54, 58, G 75, I 97, 104, K 129, 130
Nostoc microscopicum Carmichael ex Bornet et Flahault A 7, B 22, 32, D 57, F 67
Nostoc cf. *microscopicum* Carmichael ex Bornet et Flahault A 7
Nostoc muscorum Agardh ex Bornet et Flahault A 7, 13, B 27, C 38, 40, 41, 44,
D 52, 55, K 130
Nostoc cf. *muscorum* Agardh ex Bornet et Flahault B 25, C 45, 48, D 52
Nostoc paludosum Kützing ex Bornet et Flahault F 67, I 100
Nostoc cf. *paludosum* Kützing ex Bornet et Flahault C 40
Nostoc sphaeroides Kützing ex Bornet et Flahault C 42, I 100
Oscillatoria brevis (Kützing) Gomont A 7, G 77
Oscillatoria granulata Gardner C 42, H 90
Oscillatoria simplicissima Gomont D51, B25
Oscillatoria tenius Agardh D55
Oscillatoria terebriformis Agardh F 67, K 129
Phormidium amoenum Kützing B 26, 29, 33, C 40, D 55, 58
Phormidium cf. *animale* (Agardh ex Gomont) Anagnostidis et Komárek C 46
Phormidium autumnale Kützing C 41, D 53, 56
Phormidium cortianum (Menegh. ex Gomont) Anagnostidis et Komárek B 26, D 52, 57
Phormidium cf. *crouanii* Gomont I 103
Phormidium formosum (Bory ex Gomont) Anagnostidis et Komárek C 40, 42, 43, 45, 47,D 54, K 129
Phormidium interruptum Kützing C 45, D 58, F 67
Phormidium cf. *interruptum* Kützing A 13, B 27, D 51, 54
Phormidium ionicum Skuja C 45, D 55, I 100
Phormidium irriguum (Kützing ex Gomont) Anagnostidis et Komárek B 26, 28, C 41, D 52
Phormidium cf. *irriguum* (Kützing ex Gomont) Anagnostidis et Komárek B 28
Phormidium retzii (Agardh) Gomont B 34,C 42, D 53, 56, F 67, G 75, H 91, I 103
Phormidium cf. *tenue* (Agardh ex Gomont) Anagnostidis et Komárek C 4
Phormidium tenuissimum Woronichin A 7, 13, 23, C 38, D 53, F 67, H 91, K 130
Pleurocapsa minor Hansgirg C 43, 46, G 77,

Pleurocapsa cf. *minor* Hansgirg B 26
Pseudocapsa cf. *dubia* Ercegović C 40, 41, D 58
Schizothrix aurantiaca Kützing I 100
Scytonema hofmanii Agardh ex Bornet et Flahault B 29, D 53
Synechococcus cf. *elongatus* (Nägeli) Nägeli A 7, G 77, H 90
Tolypothrix cf. *tenuis* Kützing ex Bornet et Flahault C 45
Trichormus variabilis (Kützing ex Bornet et Flahault) Anagnostidis et Komárek C 40, F 67

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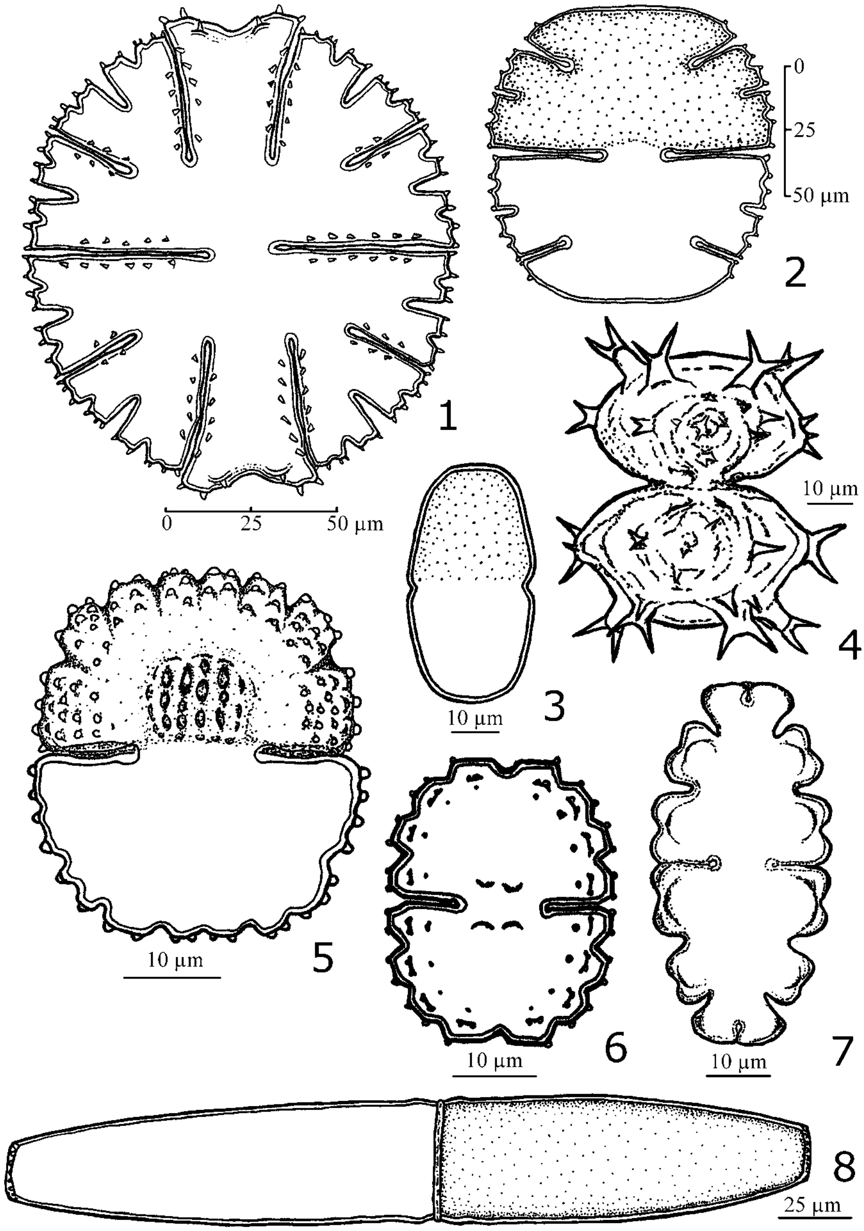


Table 1: 1 *Micrasterias papillifera*, 2 *M. truncata*, 3 *Actinotaenium cucurbitinum*, 4 *Staurastrum senarium*, 5 *Cosmarium caelatum*, 7 *Euastrum oblongum*, 6 *C. nasutum* f. *granulata*, 8 *Pleurotaenium crenulatum*

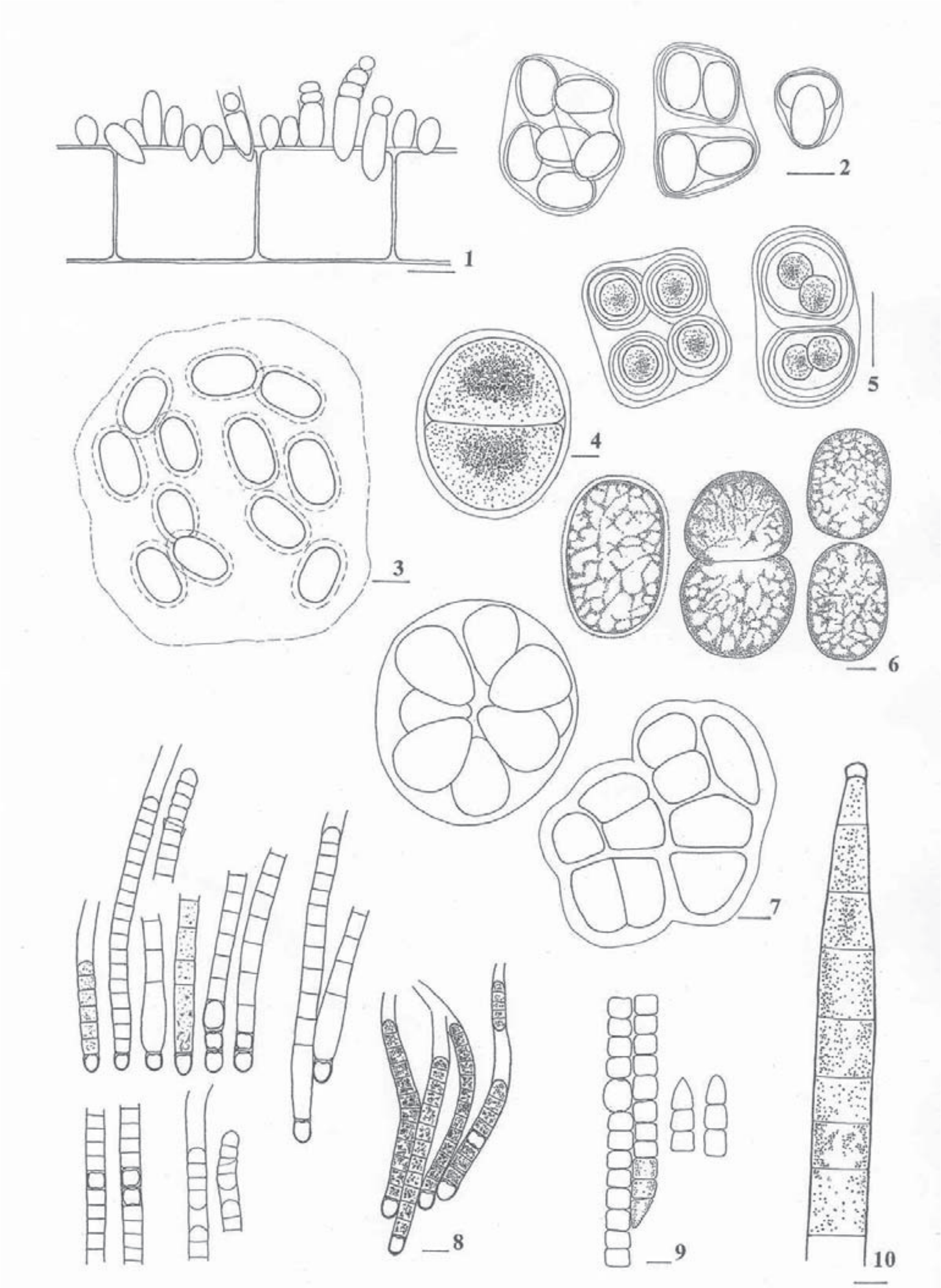


Table 2: 1. *Chamaesiphon minutus*, 2. *Gloeothece palea*, 3. *Aphanothece pallida*, 4. *Chroococcus turgidus*, 5. *Gloeocapsa atrata*, 6. *Cyanothece aeruginosa*, 7. *Pseudocapsa* cf. *dubia*, 8. *Microchaete tenera*, 9. *Trichormus variabilis*, 10. *Phormidium amoenum*; scale bar = 5 µm.

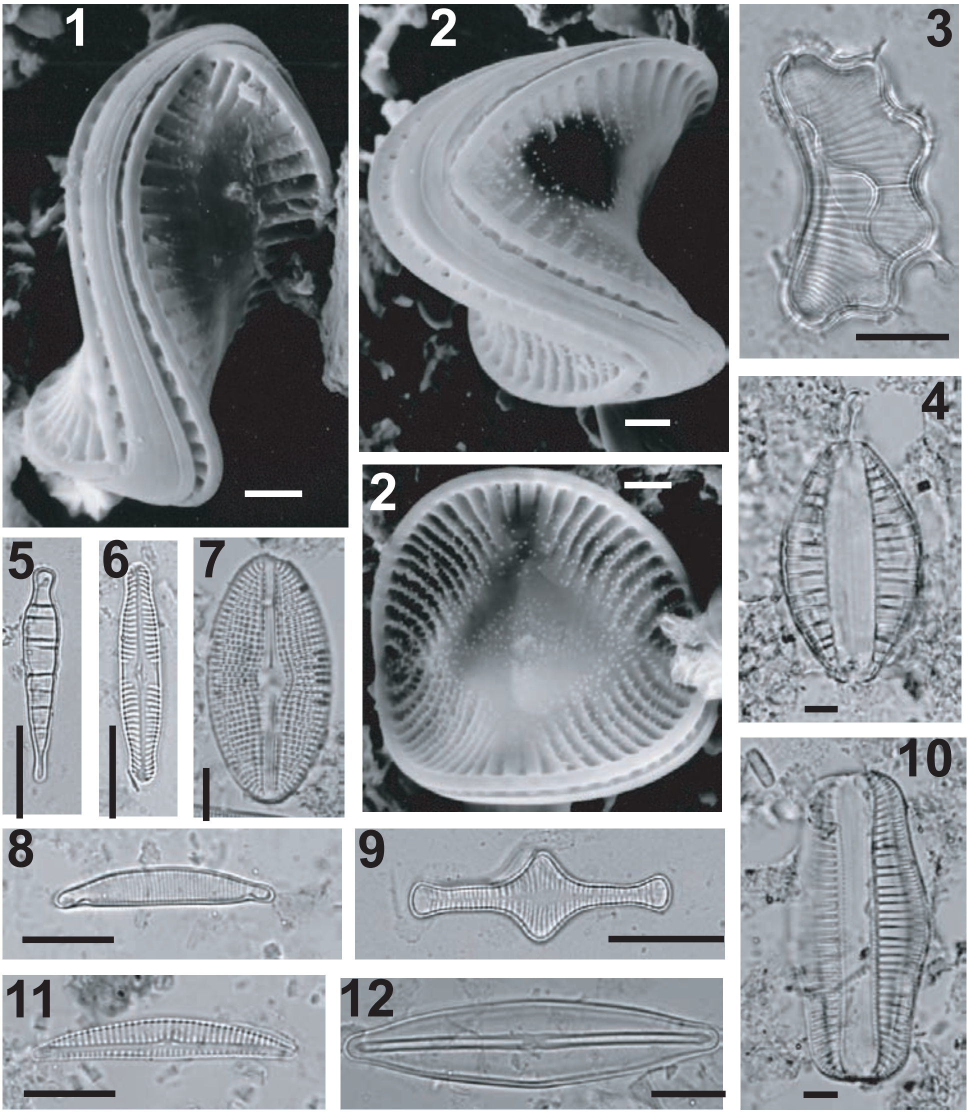


Table 3: 1. *Surirella spiralis*, 2. *Campylodiscus hibernicus*, 3. *Eunotia serra*, 4. *Rhopalodia rupestris*, 5. *Meridion circulare* var. *constrictum*, 6. *Pinnularia subcapitata,* 7. *Diploneis ovalis,* 8. *Eunotia incisa,* 9. *Tabellaria flocculosa,* 10. *Rhopalodia gibba* 11. *Cymbella gracilis,* 12. *Frustulia rhomboides.* Scale bar =10µm. Photos 1,2: R. Novotný; 3,5,6,8,11 P. Křenková; 4,7,9,10,12: A. Poulíčková.

Chapter 7

Macrofungi

M. Vašutová

Introduction

Fungi as decompositors, symbionts and parasites represent an irreplaceable part of ecosystems. They are variously bound to their symbiotic partners, hosts or the substrates they utilize. If there has been a reduction of biotopes in which substrates and fungi hosts occur, fungi certainly start disappearing as well. As already mentioned in previous chapters, wetlands and in particular small spring fens are endangered in the present landscape. Therefore, it is likely that some fungi restricted to such areas are potentially highly endangered, too. Although there has been a fairly long tradition of mycofloristical studies on bogs and raised bogs in the Czech Republic, detailed knowledge about fungi species associated with small spring fens is still missing.

The aim of this part of the project focusing on fungi was to map the occurrence, species diversity and the composition of ecological groups of fungi in spring fens. Another goal was to find out if there are fungi strictly bound to these habitats.

Since the sites are located in a mycofloristicaly little known area (Adamčík et al. 2003), this paper presents complete floristic–ecological data that have been obtained during the project GACR 206/02/0568. The comments on the occurrence of species in different fen types, temporal and spatial distribution of their sporocarps, and the correlation between species occurrence and selected environmental variables are involved in the particular chapters below. Detailed results will be published elsewhere.

Historical overview

The fundamental research projects on mire species were carried out in southern Bohemia at Soběslavská Blata (Kotlaba 1952, 1953a, 1953b, 1954) and Červené Blato u Šalmanovic (Kotlaba 1955, Kotlaba & Kubička 1960). J. Veselský (1968) studied the mycocoenology of the peat bog Hutě pod Smrkem in northern Moravia. Later, Šteklová (1979) continued mycofloristical studies of mycorrhizal fungi of raised bogs and bog spruce forests in the Krušné Hory Mts. R. Fellner (Fellner in Kuthan 1989) investigated subalpine raised bogs in the Krkonoše Mts, L. Hruška (Hruška in Kuthan 1989) studied the Nature Reserve Březina in the České Středohoří Mts. Mycofloristical notes from raised bogs and bog spruce forests in the Vysoké Tatry Mts were published by J. Kuthan et al. (1989). Several peat bogs have been studied recently in the Novohradské Hory Mts (Beran 2005), in Šumava Mts (Holec 1997) and Třeboňská pánev (Kotlaba 2003). Compared to raised bogs, much less attention has been paid to transitional mires. More complex data were published only from Skalské rašeliniště by Rýmařov in northern Moravia (Veselský 1966).

Small fen habitats have been studied only from mycofloristical point of view. Kubička (1958, 1960), M. Svrček (1960), Kubička & Svrček (1983) published some records from pond surroundings and spring alder stands near Třeboň. M. Kotilová–Kubičková (Kotilová-Kubičková et al. 1990a, 1990b, 1990c) followed their preliminary research, and carried out an ecological study of mycoflora of mire willow scrubs. Moravec

(1989) published a contribution to the mycoflora of forest springs and petasites fringes.

Very little is known about the mycoflora of calcareous fens. Šebek (1957) published some observations of mycoflora from *Caricion davallianae* meadow in the Polabí area. A more detailed study was carried out in the Nature Reserve Abrod (the *Caricion davallianae* and *Molinion* alliance; Adamčík & Hagara 2003).

Two studies became fundamental for the knowledge of mycoflora of raised bogs in Europe, i. e. the ecological study of bogs in northern Denmark (Lange 1948) and the study of subalpine raised bogs in the Swiss Jura Mts and their surroundings (Favre 1936, 1937, 1939, 1948). A minor floristic contribution (Kraft 1978) and the study of B. Senn–Irlet (Senn–Irlet et al. 2000) dealt with raised bogs in Switzerland.

Einhellinger (1976, 1977, 1982) carried out mycofloristic-ecological observation in bogs in Bavaria. Kreisel (1954, 1957) and Augustin & Runge (1968) studied bog communities in northern Germany, Krisai (1987) in Austria. C. Perini and her colleagues (Perini et al. 2002) have studied peat bogs in Tuscany (Italy). In Poland, mycoflora of bogs has been studied only marginally as a part of mycofloristical or mycocoenological studies of bog spruce forests and alder stands (Flisinska 1988, Domanski 1993). Kalamees (1982) published a contribution to the knowledge of Estonian bogs.

A crucial study for the methodology of studies on fungi of non-forest habitats was Arnolds´s dissertation (Arnolds 1981, 1982) from the Netherlands. Unfortunately, he dealt only with the *Calthion* and *Molinion* alliances of marsh habitats.

Methods

Altogether, 14 localities were observed in the years 2001–2004 (numbers 7, 13, 20, 67, 75, 77, 91, 92, 98, 103, 104, 105, 114, 115 in Table 1, Chapter 1) in order to cover all fen types in the Moravian-Slovakian borderland area. At these localities, permanent plots of the dimensions 1 x 1 m and 3 x 3 m were regularly monitored in 2001-2004. Occasionally, 4 other localities were observed (numbers 32, 81, 85, 106 in Table xxxx), and 28 localities were visited only once (numbers 4, 15, 33, 52, 57, 68, 71, 80, 82, 86, 87, 88, 94, 99, 109, 117, 118, 124, 125, 134, 135, 136, 141, 144 in Table 1, Chapter 1 and in a supplement bellow).

Results

List of additional localities
(not involved in Table 1, Chapter 1)

I:Kuk – Kúkoľanka – Turzovská vrchovina uplands, Raková – Kúkoľanka village, 2 km NNW from Prielačský hill (649.6 m a. s. l.), 590 m a. s. l., longitude 18°42´17´´, latitude 49°29´07´´

I: Kop – Kopčiská – Turzovská vrchovina uplands, Korcháňovci – Kopčisko village, opposite to the cottage n. 572, 2.5 km SE from Veľký Polom hill, longitude 18°41´84´´, latitude 49°29´08´´

K:OrV – Oravské Veselé, the valley of the Veselianka brook, between Oravské Veselé and Oravská Jasenica villages, 680 m

K:Klr – Klinské rašelinisko: the peat bog in the Klinské rašelinisko Nature Reserve, between Námestovo town and Klin village, 630 m

The occurrence of macromycetes, i.e. fungi with sporocarps greater than 5 mm, was studied. The studied macromycetes belonged to the following taxonomical groups (according to Kirk et al. 2001): *Agaricales*, *Russulales* (p.p.), *Boletales* (p.p.), *Polyporales* (excl. small corticioid fungi), *Cantharellales*, *Pezizales*, *Xylariales* (p.p.), *Sordariales* (p.p.), *Hypocreales* (p.p.), and *Helotiales* (p.p.). They were collected by the author with cooperation of P. Hájková, M. Hájek, J. Wolfová et M. Beran. The nomenclature of macromycetes follows Index of fungorum. Herbarium specimens are deposited in the author's private herbarium. More detailed comments and descriptions of some rare species are being prepared for publishing.

The species were divided according to Arnolds (1981) to those belonging to the studied biotope (directly dependent on organisms living within the community) and those alien to the communities, i.e. dependent on organisms living outside the studied community (mycorrhizal, lignicolous and coprofilous). The species that belong to the studied community are classified among those linked to plant remains (herbicolous), *Sphagnum* (sphagnicolous), mosses (muscicolous), sporocarps and terrestrial fungi.

The list of collected species

In total, 592 records from 46 spring fens sites are presented. Altogether, 171 macrofungi species were found (73 of them were not definitely identified); of these according to our observation 20 (3 not definitely identified) were sphagnicolous, 1 sphagnicolous-muscicolous, 18 (9) muscicolous, 30 (15) herbicolous, 13 (5) species were found in *Sphagnum* bog or mosses and on herbs remains, 24 (14) terrestrial, 52 (24) mycorrhizal, 2 (1) coprophilous, 9 (2) lignicolous and 2 others.

The numbers behind 1x1 and 3x3 express the occurrence and number of fungi sporocarps on permanent plots. The numbers in brackets represent the numbers of specimens in the author's herbarium. Unidentified sporocarps that appeared to be separate taxa were labelled by numbers. For explanations of locality abbreviations see the list of the studied fens at the beginning of this monograph (Chapter 1).

o. = sporocarps occurred outside a permanent plot

Sphagnicolous species

Entoloma cetratum (Fr.) M.M.Moser
G:81: 7.VII.2002 (02/259); **H:91**: 1.VII.2001 (01/121); **I:103**: 1.VII.2001 (01/137), all records were found in *Sphagnum* bog.

Entoloma conferendum (Britzelm.) Noordel.
H:91: 8.VI.2002 (02/140); 10.X.2003 (03/359), (03/362); 14.IX.2004; **I:103**: 10.X.2003 – 3x3: 4 (03/389); **105**: 10.X.2003 – 3x3: 4 (03/397, 03/400); 28.VIII.2004; 13.IX.2004 (04/314) – 3x3: 3; **115**: 10.X.2003 (03/371); all records were found in *Sphagnum* bog

Galerina calyptrata P.D.Orton
I:105: 12.X.2002 (02/478), in *Sphagnum* bog

Galerina cf. *mniophila* f. *cephalotricha* (Kühner) A. de Haan et Welleyn
I:104: 10.X.2003, 3x3: 3 (03/402); **114**: 5.10.2001 (01/409), 10.VI.2003 (03/087); all records were found in *Sphagnum* bog

Galerina paludosa (Fr.) Kühner
G:81: 29.IV.2002 (02/035); 10.VI.2003 (03/076); **H:85**: 10.VI.2003; 28.VIII.2004; **87**: 10.VI.2003; **91**: 29.IV.2002 – 3x3: 12, o. (02/046); 12.VII.2002 – 3x3: 4, o. (02/195); 10.VI.2003 – 1x1: 1, 3x3: 5; 28.VIII.2003; 25.VI.2004;

14.IX.2004; **92**: 29.IV.2002 – 3; **I:103**: 12.VII.2002 – 3x3: 1; 25.VI.2004; **104**: 25.VI.2004; **105**: 1.VII.2001 (01/135d); 10.VI.2003 – 3x3: 1; 5.VI.2002 (02/109b); 28.VIII.2003 – 3x3 (03/160); 25.VI.2004 – 3x3; 28.VIII.2004; **106**: 5.VI.2002 (02/105); 10.VI.2003; **114**: 1.VII.2001 (01/126); 29.IV.2002 – 2; 10.VI.2003 – 3x3: 2, o.; 25.VI.2003 (04/157); 28.VIII.2003 (03/149b), 28.VIII.2004; **115**: 1.VII.2001 (01/122); 29.IV.2002 – 1x1: 2, o.; 10.VI.2003 – 1x1: 1, o.; 25.VI.2004: 1x1: 2 (04/118); **117**: 10.VI.2003; **118**: 7.VI.2002 (02/132); **Kop:** 1.VI.2002 (02/074), in *Sphagnum warnsdorfii, S. flexuosum*; **Kuk**: 7.VI.2002; all records were found in *Sphagnum* bog

Galerina sect. *Mycenopsis* stirps *Hypnorum* 3

K:OrV: 28. IX. 2002 (02/312)

Galerina sphagnorum (Pers.) Kühner – in *Sphagnum* bog

H:85: 10.X.2003 (03/383), 13.IX.2004 (04/291); **I:105**: 13.IX.2004 (04/313b); **115**: 10.X.2003 – 3x3: 3 (03/366); all records were found in *Sphagnum* bog

Galerina tibiicystis (G.F.Atk.) Kühner

H:85: 28.VIII.2004 (04/230); 13. IX. 2004; **88**: 10.VI.2003; **91**: 5.X.2001 (01/380); 8.VI.2002 (02/139); 12.VII.2002; 12.X.2002 (02/464); 10.X.2003 (03/358) – on submerged *Sphagnum* near a stream; 25.VI.2004; 14.IX.2004 (04/345); **92**: 5.X.2001 (01/382); 12.X.2002 – 1x1: 3, 3x3: 1 (02/470); 10.X.2003: 1x1; 2 (03/365), o.; **93**: 10.VI.2003; **I:103**: 5.X.2001 (01/425); 5.VI.2002 (02/118); 12.VII.2002; 12.X.2002 (02/473); 10.VI.2003; 10.X.2003 (03/390); 25.VI.2004 – 3x3: 2; **104**: 5.VI.2002 (02/115); 12.X.2002 (02/480); 10.VI.2003; **105**: 1.VII.2001 (01/135b); 12.VII.2002 (02/175); 12.VII.2002 – 3x3: 2; 10.VI.2003 – 1x1: 2, 3x3: 15, o; 28.VIII.2003 (03/162); 25.VI.2004 – 1x1: 4, 3x3: 48 (04/129); 28.VIII.2004 – o.; 13.IX.2004, **109**: 13.IX.2004; **114**: 1.VII.2001 (01/125); 12.VII.2002– 3x3: 4, o. 02/186); 25.VI.2003; 10.X.2003 (03/373); 28.VIII.2004 (04/226); 13.IX.2004 (04/301); **115**: 1.VII.2001 (01/123); 12.VII.2002– 1x1, o.; 12.XI.2002 (02/458); 10.X.2003 (03/370); 25.VI.2004; **117**: 10.VI.2003; **118**: 7.VI.2002 (02/130) – in *Polytrichum commune* bog; **K:135**: 18.IX.2002 (02/280), in mosses; **144**: 19.IX.2002; most records were found in *Sphagnum* bog

Geoglossum cf. *glabrum* Pers.

H:91: 28.VIII.2003 (03/155); **105**: 28.VIII.2003 – 3x3 (03/161); **115**: 13.IX.2004 (04/299);

K:Klr: 28.IX.2002 (02/319); all records were found in *Sphagnum* bog

Hygrocybe coccineocrenata (P.D. Orton) M. M. Moser

H:91: 1.VII.2001 (01/119), 12.VII.2002– 3x3: 5; o.; **92**: 12.VII.2002; 28.VIII.2003 – 1; **I:103**: 1.VII.2001 (01/138); 12.VII.2002– 1x1: 3, 3x3: 6; o.; 10.VI.2003; **104**: 1.VII.2001 (01/139); 5.VI.2002– 3x3 (02/114); 12.VII.2002– 3x3: 7 (02/178, rev. H. Deckerová); 25.VI.2004; 13.IX.2004; **105**: 10.X.2003 – 3x3: 1 (03/399); 28.VIII.2003 – 3x3 (03/163); **106**: 5.VI. 2002 (02/106); **115**: 12.VII.2002; 10.X.2003 (03/369); 13.IX.2004; **K:135**: 18.IX.2002 (02/282), under *Salix* sp., *Picea abies, Pinus sylvestris*; all records were found in *Sphagnum* bog

Hypholoma udum (Pers.) Kühner

H:91: 10.X.2003 (03/355), among grasses and *Sphagnum* sp. div.

Hypholoma elongatum (Pers.) Ricken

H:85: 10.X.2003 (03/387); 28.VIII.2004; 13.IX.2004; **91**: 5.X.2001 (01/378); 8.VI.2002; 12.X.2002 – 3x3: 11 (02/462); 12.X.2002 – 3x3: 2 (02/465); 10.X.2003 – 1x1: 7; 3x3: 8, 14.IX.2004 – 1x1: 1; **92**: 5.X.2001 (01/384); **I:103**: 5.X.2001

(01/428); 10.X.2003 – 3x3: 5; o.; **105**: 5.X.2001 (01/414); 12.X.2002; **109**: 13.IX.2004; **114**: 12.X.2002 – 3x3: 4 (02/471); **115**: 5.X.2001 (01/401); 12.XI.2002 (02/459); 10.X.2003 (03/368); 3.IX.2004 – 3x3: 4, o.; **K:136**: 28.IX.2002; **144**: 19.IX.2002; **Klr**: 28.IX.2002; all records were found in *Sphagnum* bog

Mitrula paludosa Fr.

G:81: 29.IV.2002 (02/037), on *Sphagnum* sp. and herb remains; 10.VI.2003 (03/078), on leaves and twig remains, in *Sphagnum* bog; **H:93:** 10.VI.2003, in *Sphagnum* bog; **I:104**: 10.VI.2003 – 1x1: 5; o.; 25.VI.2004, on *Sphagnum*; **105**: 5.VI.2002 (02/112), on *Sphagnum fallax*

Mycena galopus (Pers.) P.Kumm.

H:85: 10.X.2003 (03/386); 28.VIII.2004; **91**: 5.X.2001; **I:105**: 28.VIII.2004; **114**: 1.VII.2001; 5.X.2001; 28.VIII.2003 (03/150); all records were found in *Sphagnum* bog

Mycena megaspora Kauffman

I:115: 12.XI.2002 (02/461), in *Sphagnum* bog

Omphalina oniscus (Fr.) Quél.

I:105: 10.X.2003 – 3x3: 1 (03/395)**,** in *Sphagnum* bog

Phaeogalera stagnina (Fr.) Pegler et T.W.K. Young

H:85: 10.VI.2003 (03/089)**,** on submerged *Sphagnum* in a stream

Psathyrella sphagnicola (Maire) J. Favre

K:Klr: 28.IX.2002 (02/318)*,* in *Sphagnum* bog

Tephrocybe palustris (Peck) Donk

A:4: 12.V.2002 (02/073); **G:81**: 29.IV.2002 (02/036); 4.VIII.2002 (02/198); 10.VI.2003 (03/077); **85**: 10.VI.2003; **87**: 10.VI.2003; **H:91**: 1.VII.2001 (01/120); 29.IV.2002; 29.IV.2002b– 3x3: 23; 8.VI.2002; 10.VI.2003 – 1x1: 1; 3x3: 13; 25.VI.2004 – 3x3: 10; o.; **92**: 29.IV.2002; **93**: 10.VI.2003; **I:103**: 5.VI. 2002; 10.VI.2003 – 3x3: 3; **104**: 5.X.2001 (01/424); **105**: 1.VII.2001 (01/137; 01/145); 5.VI.2002 (02/108); 12.X.2002 (02/479); 10.VI.2003; 25.VI.2004 – 1x1: 3; 3x3: 5; 28.VIII.2004; **114**: 29.IV.2002; 10.VI.2003 – 3x3: 1; o.; 25.VI.2003; 28.VIII.2004; **115**: 29.IV.2002– 3x3: 3; o.; 10.VI.2003 – 3x3: 7; 25.VI.2004 – 3x3: 4; **117**: 10.VI.2003; **118**: 7.VI.2002; all records were found in *Sphagnum* bog; **I:Kop**: 1.VI.2002 (02/075)

Trichoglossum hirsutum (Pers.) Boud.

H:91: 5.X.2001 (01/379) – on remains of *Sphagnum* and grasses; 12.VII.2002– 3x3: 1; 10.X.2003 – 1x1: 1; 3x3: 6 (03/352), in *Sphagnum* bog; **I:115**: 10.X.2003 (03/372), in *Sphagnum* bog; **K:141**: 28.IX.2002 (02/308), in *Sphagnum flexuosum* bog

Sphagnicolous/muscicolous

Rickenella fibula (Bull.) Raithelh.

F:71: 1.VII.2001 (01/133), in mosses; **G:77**: 1.VII.2001 (01/131) – in *Dicranum bonjeanii*, 6.X.2001 (01/433) – in mosses; 25.VI.2004, 14.IX.2004 – 3x3: 19 (04/325), in mosses; **80**: 6.VI.2002, in *Sphagnum* bog; **81**: 29.IV.2002: (02/038), in mosses; 10.VI.2003 (03/075), in *Aulacomnium palustre;* **82**: (99/011), in mosses; **H:86**: 10.VI.2003, in mosses; **88**: 10.VI.2003 (03/094), in mosses; **91**: 1.VII.2001 (01/121b); 29.IV.2002 – 2; 10.VI.2002 (03/083); 10.VI.2003 (03/083); 28.VIII.2003 – 3x3: 2 (03/156) 10.X.2003 – 3x3: 1; 25.VI.2004; 14.IX.2004 – 3x3: 1, in *Sphagnum* bog; **92**: 8.VI.2002 (02/137); 12.VII.2002– 1; 10.X.2003; 25.VI.2004;

I:99: 11.VII.2002; in mosses; **104**: 5.VI.2002 (02/114b); 12.VII.2002 – 3x3: 3; 10.VI.2003 in *Sphagnum* bog and mosses; **105**: 13.IX.2004 – 3x3: 4 (03/311); in *Sphagnum* bog; **106**: 5.VI.2002 (02/107); 10.VI.2003, in mosses; **J:124**: 6.VI.2002 (02/127), in mosses

Muscicolous species

Arrhenia lobata (Pers.) Kühner & Lamoure ex Redhead
G:77: 6.X.2001 (01/435), on *Calliergonella cuspidata*; 1.V.2003 (03/014), on *Calliergonella cuspidata*, *Aulacomnium palustre, Cratoneuron commutatum*; **I:98**: 5.VI.2002 (02/103), on *Calliergonella cuspidata*
Arrhenia retiruga (Bull.) Redhead
D:52: 24.VIII.2002 (02/565); **F:65**: 13.IV.2001 (01/011); all records were found on *Calliergonella cuspidata*
Arrhenia sp.
F:65: 14.IX.2004 – 3x3: 1 (04/326**)**, on remains of mosses and *Cyperaceae*
Cantharellula umbonata (J. F. Gmel.) Singer
K:136: 18.IX.2002 (02/285), in *Polytrichum commune* bog
Clitocybe sp.
K:Klr: 28.IX.2002 (02/317), in *Polytrichum strictum* bog
Cystoderma amiantinum (Scop.) Fayod.
H:91: 5.X.2001 (01/376); 12.X.2002 (02/463); 10.X.2003 (03/354); all records were found in *Polytrichum commune* bog
Galerina pumila (Pers.) M.Lange
G:75: 6.X.2001 (01/440), in mosses; **I:105**: 5.X.2001 (01/418), in *Polytrichum commune* bog; 13.IX.2004 (04/313), in Sphagnum bog.; **K:141**: 28.IX.2002 (02/297), in *Polytrichum strictum* bog
Galerina pumila (Pers.) M.Lange agg.
I:114: 28.VIII.2004, on soil and among mosses
Galerina mniophila (Lasch.) Kühner agg.
K:Klr: 28. IX. 2002 (02/314), in *Polytrichum strictum* bog
Galerina cf. *mniophila* (Lasch) Kühner
H:92: 10.X.2003 (03/361), under *Salix* sp., in mosses
Galerina subsect. *Calyptrospora* 1
K:144: 19.IX.2002 (02/291), in *Polytrichum strictum* bog
Galerina heterocystis (G.H.Atk.) A.H.Sm. et Singer
A:13: 6.X.2001 (01/448), in mosses; **B:32**: 3.VI.2002 (02/081), in *Carex paniculata* bog; **F:65**: 9.X.2003 (03/339c), in mosses; **G:75**: 2.VII.2001 (01/141) – 1, in mosses (esp. *Bryum pseudotriquetrum*) on bank of a stream; **77**: 11.X.2002 (02/452); **H:92**: 5.X.2001 (01/381), on remains of grasses and mosses; **I:98**: 5.X.2001 (01/430); 11.X.2002 (02/456); 9.X.2003 – 3x3: 4 (03/345), 14.IX.2004 (04/317), in mosses
Galerina cf. *hypnorum* (Schrank) Kühner
F:65: 1.VII.2001 (01/130); 14.IX.2004 (04/327) – all records were found in mosses
Galerina subgen. *Mycenopsis* str. *Hypnorum* 1
F:65: 6.X.2001 (01/441**)**, in mosses
Galerina subgen. *Mycenopsis* str. *Hypnorum* 2
I:105: 1.VII.2001 (01/135c)
Galerina annulata (J.Favre) Singer

G:77: 25.VI.2004 – 3x3 (04/150), in mosses, 14.IX.2004 – 1x1: 2, 3x3: 14 (04/324), on *Aulacomnium palustre*; **I:98** – 11.VII.2002 (02/172) – in mosses; 14.IX.2004 (04/316), on *Drepanocladus cossonii*

Galerina vittaeformis (Fr.) Sing.

F:65: 9.X.2003 – 3x3: 2 (03/339), in mosses; **G:77**: 6.X.2001 (01/436), in mosses; 11.X.2002 (02/453), in mosses; 9.X.2003 (03/340a, b); **80**: 6.VI.2002 (02/123), on *Calliergonella cuspidata*; **91**: 10.VI.2002 (03/086); on *Drepanocladus cossonii*, 10.VI.2003 (03/086), in mosses; **92**: 12.X.2002 (02/467) – *Galerina vittaeformis* f. *pachyspora* Sm.et Sing.; **I:104**: 13.IX.2004, in mosses; **117**: 10.VI.2003, in mosses

Rickenella setipes (Fr.) Raitheld

I:98: 5.X.2001, in mosses

Terrestrial/herbicolous/muscicolous/sphagnicolous species

Agrocybe paludosa (J.E.Lange) Kühner et Romagn.

A:7: 3.VI. 2002 (02/078), terrestrial; **13**: 24.VI.2004 (04/102), terrestrial; **15**: 1.VI.2002 (02/072), on *Caliergonella cuspidata;* **F:65**: 9.X.2003 – 3x3: 1 (03/339b), terrestrial; **77**: 9.VI.2003 (03/071), in *Aulacomnium palustre*; **G:80**: 6.VI.2002 (02/122), in *Sphagnum* bog; **91**: 10.VI.2002 (03/084),; 10.VI.2003 (03/084); 25.VI.2004, in *Sphagnum* bog; **92**: 29.IV.2002 (02/040); 8.VI.2002 (02/138, det. V. Antonín); 12.X.2002: 3x3 (02/468); 25.VI.2004 – 3x3 (04/133), in *Sphagnum* bog; **H:94:** 10.VI.2003; **I:98**: 5.VI.2002– 3x3: 2 (02/100), in *Drepanocladus cossonii*; 10.VI.2003 – 1x1: 1; 3x3: 1; 25.VI.2004: 3x3 (04/148), in mosses; **J:125**: 6.VI.2002 (02/124), in mosses

Galerina jaapii A.H.Sm. et Singer

G:81: 27.VII.2003 (03/127)**,** on grasses remains

Hemimycena pseudocrispata (Valla) Maas Geest. agg.

G:77: 25.VI.2004 (04/151, det. V. Antonín) – terrestrial

Mycena adonis (Bull.) Gray

G:81: 6.IX.2001 (01/567)

Mycena cf. *acicula* (Schaeff.) P.Kumm.

G:77: 9.VI.2003 (03/072)

Mycena cf. *citrinomarginata* Gillet

G:77: 1.VII.2001 (01/132), terrestrial, in mosses

Mycena epipterygia (Scop.) Gray

A:13: 5.X.2001 (01/370), in herb and grass remains; 6.X.2001 (01/443); 11.X.2002 – 3x3: 13 (02/442); 9.X.2003 (03/323); **G:75**: 11.X.2002 (02/448); **I:98**: 9.X.2003 (03/348), terrestrial; **103**: 10.X.2003 – 3x3: 4 (03/392); **K:136**: 18.IX.2002; **Klr**: 28.IX.2002

Mycena metata (Fr.) P.Kumm.

A:13: 6.X.2001 (01/444), in mosses; **G:77**: 6.X.2001 (01/434); 11.X.2002 (02/451), in moss; **H:91**: 5.X.2001 (01/374), on remains of grasses and sedges; 10.X.2003 (03/353), in *Sphagnum*, among sedges; **92**: 5.X.2001, on remains of grasses and sedges; 12.X.2002 (02/466), in *Sphagnum* bog; **I:103**: 5.X.2001 (01/426), in *Sphagnum* bog; **115**: 5.X.2001, in *Sphagnum palustre* bog; 5.X.2001 (01/385); 12.XI.2002 (02/460); **K:134**: 19.IX.2002 (02/287), in *Sphagnum warnstorfii.*

Panaeolus acuminatus (Schaeff.) Gillet agg.

G:77: 11.X.2002 (02/455), 9.X.2003 (03/341), terrestrial; **H:91**: 5.X.2001 (01/375), on grass remains; 10.X.2003 (03/350), terrestrial among *Deschampsia cespitosa*, grasses, mosses, in the margin of locality

Psilocybe xeroderma Huijsman

A:13: 24.VI.2004 (04/107) terrestrial; **20**: 9.VI.2003 – 1x1: (03/065), on *Carex paniculata* bog; **G:75**: 24.VI.2004 (04/092) terrestrial; **77**: 25.VI.2004 (04/152) terrestrial; **I:98**: 5.VI.2002 (02/101), on remains of *Drepanocladus cossonii* and *Carex panicea*; 11.VII.2002 – 3x3: 1 (02/171, det. V. Antonín et M. Vašutová), terrestrial

Psilocybe semilanceata (Fr.) P.Kumm.

H:91: 10.X.2003 (03/349), terrestrial, among *Deschampsia cespitosa*, grasses and mosses; **I:103**: 5.X.2001 (01/427); 10.X.2003, in *Deschampsia cespitosa* tuft

Stropharia albonitens (Fr.) P.Karst.

A:20: 6.X.2001 (01/460); 11.X.2002 (02/443); 9.X.2003 (03/334), on top of *Carex paniculata* bogs; **I:98**: 9.X.2003 – 3x3: 4 (03/344), terrestrial

Psathyrella prona (Fr.) Gillet

A:13: 9.VI.2003 (03/062) on remains of branches and mosses (*Cratoneuron*); 24.VI.2004 (04/106), in mosses; **20**: 9.VI.2003 (03/067), in mosses, in streams; **B:32**: 12.IV.2001 (01/001), 3.VI.2002 (02/082) – *P. prona* f. *utriformis* Kits van Wav. agg., solitary, on remains of sedges (*Carex davalliana*); 1.V.2003 (03/006), on *Cratoneuron commutatum*

Herbicolous

Clavaria asterospora Pat.

A:20: 6.X.2001 (01/456, rev. O. Jindřich); 14.IX.2004 (04/335), both records were found in *Carex paniculata* bog

Coprinus subsect. *Alachuani*

A:13: 9.VI.2003 – 1x1: 1 (03/060); 24.VI.2004 – 3x3: 1 (04/100), on remains of grasses and sedges; 14.IX.2004 – 3x3: 1 (04/336); **20**: 14.IX.2004 – 3x3: 1, on remains of *Carex paniculata*; **B:32**: 2.VII.2001 (01/153), on remains of *Carex paniculata;* **F:65**: 4.VI.2002 – 3x3 – on remains of leaves (*Scirpus sylvatica* or *Eriophorum* sp.); **G:77**: 4.VI.2002 – 3x3 (02/099), on *Homalothecium nitens* or *Carex* sp.; 9.VI.2003 (03/073), on herb remains; **I:98**: 5.VI.2002 (02/102) – on remains of grasses and sedges; 25.VI.2004 – 1x1 (04/145), on leaves of *Carex*; **J:125**: 6.VI.2002 (02/126), on *Eriophorum latifolium* leaves.

Coprinus cf. *narcoticus* (Batsch) Fr.

A:20: 14.IX.2004 (04/334), in *Carex paniculata* bog

Coprinus cf. *plagioporus* Romagn.

A:13: 9.VI.2003 (03/064), on herb remains in mire

Crepidotus variabilis (Pers.) P.Kumm.

A:7: 6.X.2001 (01/453, det. S. Ripková), on leaves of *Festuca rubra*

Cudoniella sp.

H:94: 10.VI.2003 (03/093), on herb remains in a stream

Delicatula integrella (Pers.) Fayod

H:92: 12.VII.2002 (02/197), on roots on clay bank of a stream

Entoloma cyanulum (Lasch.: Fr.) Noordel.

H:92: 28.VIII.2003 – 3x3: 1 (03/158), on herb remains

Entoloma cyanulum (Lasch) Noordel. agg.

A:20: 2.VII.2001 (01/142), on *Carex paniculata* bog; 11.VII.2002 (02/166), on roots of *C. paniculata*

Entoloma byssisedum (Pers.) Donk

A:20: 2.VII.2001 (01/143), on *Carex paniculata* bog

Entoloma sp.2

I:104: 25.VI.2004 – 1x1 (04/136)**,** on leaves (*Cyperaceae*)

Entoloma cf. *sericellum* (Fr.) P. Kumm.

A:20: 6.X.2001 (01/457); 14.IX.2004 (04/340), on herb remains (*Carex*?)

Entoloma incanum (Fr.) Hesler

B:32: 3.VI.2002 (02/080), on *Carex paniculata* bog

Galerina sect. *Marginatae*

A:20: 9.X.2003 (03/335), on *Carex paniculata* bog

Hemimycena pseudogracilis (Kühner et Maire) Singer agg.

A:7: 24.VI.2004 (04/109, det. V. Antonín), on stalk of *Carex* sp., **I:98**: 25.VI.2004, 1x1 (04/146, det. V. Antonín), on leaf of *Carex* sp.

Hemimycena pseudocrispula (Kühner) Singer agg.

A:20: 6.X.2001 (01/458, det. V. Antonín), on herb remains

Hemimycena mauretanica (Maire) Singer

A:20: 2.VII.2001 (01/144), (01/151); 11.VII.2002 – 1x1 (02/162, det. V. Antonín); 9.X.2003, 1x1, 3x3 (03/328); 14.IX.2004 – 1x1 (04/329); all records were found on *Carex paniculata* roots

Marasmiellus vaillantii (Pers.) Sing.

F:65: 11.VII.2002 – 3x3 (02/167), **I:104**: 12.VII.2002 (02/182, det. V. Antonín); 25.VI.2004 – 1x1 (04/135); all records were found on remains of grasses

Marasmius curreyi Berk et Broome

F:65: 24.VI.2004: 3x3 (04/088); **G:75**: 24.VI.2004 – 1x1 (04/090); **I:98**: 11.VII.2002 – 1x1: 15 (02/170); o.; 25.VI.2004 – 1x1: 12; 3x3: 9 (04/144); 13.IX.04 (04/318) – 1x1: 4; 3x3: 9; **104**: 12.VII.2002: 3x3 (02/183); **J:125**: 6.VI.2002 (02/125), all records were found on *Carex* remains (leaves)

Marasmius limosus Boud. et Quél.

A:20: 6.X.2001 (01/451); 11.X.2002 (02/444); 9.X.2003: 3x3 (03/329); all records were found on leaves of *Carex paniculata*

Mycena cf. *leptocephala* (Pers.) Gillet

A:20: 11.X.2002 (02/445); 9.X.2003 (03/333); 24.VI.2004 (04/094); 14.IX.2004 – 1x1: 1 (04/328); all records were found on *Carex paniculata* bog

Mycena cf. *rorida* (Scop.) Quél.

A:20: 6.X.2001 (01/442), on herb remains

Mycena cf. *bulbosa* (Cejp.) Kühner

A:20: 14.IX.2004 – 3x3: 1 (04/331); **H:91**: 25.VI.2004 – 1x1 (04/123), on leaf of *Carex* sp.; **92**: 1.VII.2001 (01/117), on leaves of *Carex nigra*

Mycena speirea (Fr.) Gillet

A:13: 9.VI.2003 (03/063) on twig of decidous tree; 24.VI.2004 (04/105), on wood, leaf and herb remains; **20**: 2.VII.2001 (01/147); 9.X.2003 – 3x3 (03/330), on herb remains; **I:98**: 9.X.2003 (03/347), terrestrial

Mycena sect. *Fragilipedes* 2

I:103: 10.X.2003 (03/391), on remains of *Nardus stricta*

Peziza sp. 1

F:68: 29.IV.2002 (02/034), on herb remains

Psathyrella typhae (Kalchbr.) A.Pearsoon et Dennis

A:13: 3.VI.2002 – 3x3 (02/084), on herb remains in peaty soil; 3.VI.2002 (02/085), on basis of *Carex flacca*; 11.VII.2002 – 3x3: 1 (02/161), on peaty soil; 9.VI.2003 – 3x3 (03/061), on leaves of *Eriophorum angustifolium*; 24.VI.2004 – 3x3 (04/099), on leaf of *Eriophorum*; **13** – *Calthion*: 3.VI.2002 (02/086), on leaves of *Eriophorum angustifolium*

Rustroemia aff. *henningsiana* (Plöttn.) Dennis

A:15: 03/004, **B:32**: 1.V.2003 (03/008); **I:103**: 2. V. 2003 – 3x3 (03/022); all records were found on herb remains

Sclerotinia cf. *vahliana* Rostr.

A:15: 03/003; **H:92**: 2. V. 2003 – 3x3 (03/029); **I:104**: 2. V. 2003 – 3x3 (03/018); all records were found on leaves of *Eriophorum* sp.

Typhula sp. div.

A:7: 3.VI.2002 – 3x3 (02/077), on remains of *Carex* sp.; **20**: 14.IX.2004 – 1x1 (04/330); **G:75**: 6.X.2001, on soil (with grass remains)

Terrestrial species

Bolbitius lacteus J.E.Lange

B:33 (02/569); **F:65**: 9.X.2003 – 3x3: 1 (03/336), det. A. Hausknecht

Bolbitius vitellinus (Pers.) Fr.

I:98: 25.VI.2004 (04/147)

Clitocybe cf. *dealbata* (Sow.: Fr.) Kumm. ss. Fr.

A:7: 6.X.2001 (01/452)

Conocybe anthracophila (Maire & Kühner) Singer

G:77: 9.X.2003 (03/343), det. A. Hausknecht

Entoloma subgen. *Leptonia,* sect. *Cyanula*

I:98: 14.IX.04 (04/319)

Entoloma cf. sericeum (Bull.) Quél.

I:103: 10.X.2003 – 3x3: 1 (03/393)

Entoloma mougeotii (Fr.) Hesler

G:77: 25.VI.2004 (04/153)

Entoloma longistriatum (Peck) Noordel.

G:81: 27.VII.2003 (03/128); **I:104**: 12.VII.2002 – 3x3: 3 (02/179)

Entoloma sp. 1

H:85: 10.X.2003 (03/382)

Entoloma subgen. *Leptonia* sect. *Cyanula* 1

I:105: 10.X.2003 – 1x1: 1 (03/401)

Entoloma subgen. *Leptonia* sect. *Cyanula* 2

I:98 – *Calthion*: 11.VII.2002 (02/173)

Entoloma subgen. *Nolanea* sect. *Papillata* 1

A:13: 24.VI.2004 (04/103)

Entoloma cf. *neglectum* (Lasch) Arnolds

G:77: 25.VI.2004 – 1 x1 (04/149)

Gymnopus aquosus (Bull.) Antonín et Noordel.

I: 103: 25.VI.2004 (04/143); **114**: 25.VI.2004 (04/117), under *Betula* sp.

Gymnopus dryophilus (Bull.) Murrill

I:115: 8.VI.2002 (02/136, det. V.Antonín), in Sphagnum, near snowberry

Hygrocybe conica var. *conicopalustris* (R. Haller Aar.: Bon) Arnolds

D:57: 29.IX.2002 (02/327, det. H. Deckerová), under *Salix purpurea*

Hygrocybe virginea (Wulfen: Fr.) P.D.Orton et Watling

G:77: 9.X.2003 (03/342, det. H. Deckerová); **I:98**: 9.X.2003 (03/346, det. H. Deckerová)

Hygrocybe virginea var. *fulvescens* (Bres.) Ardolds – in *Sphagnum* and mosses

K:135: 18.IX.2002 (02/279, det. H. Deckerová)

Lycoperdon sp. – in the margin of locality

H:91: 10.X.2003 (03/362c)

Marcelleina sp

A:20: 6.X.2001 (01/454)**,** on soil

Mycena sect. *Fragilipedes* 1

A:13: 24.VI.2004 (04/104)

Peziza sp. 2

A:13: 3.VI.2002 – 3x3 (02/083), on peaty soil

Psathyrella sect. *Pennatae*

A:20: 9.X.2003 (03/327)

Scutellinia sp. div.

A:13: 11.X.2002 – 3x3 (02/441); 9.VI.2003; 24.VI.2004 (04/107b); 1x1 (03/059); **20**: 24.VI.2004 (04/096, 04/098), on soil; **H:91**: 10.VI.2002 (03/085); 10.VI.2003 (03/085); **92**: 12.X.2002 – 3x3 (02/469); 10.VI.2003 (03/091), on soil; 25.VI.2004 – 1x1 (04/124), on soil with herb remains; **I:103**: 5.VI.2002 (02/119), on soil and remains of *Eriophorum angustifolium*

Mycorrhizal species

Boletus piperatus Bull.

H:91: 25.VI.2004, under *Picea abies*

Cantharellus lutescens (Pers.) Fr.

K:134: 19.IX.2002 (02/288), in Sphagnum, under *Picea abies*, *Salix* sp.

Cantharellus tubaeformis (Bull.) Fr.

I:105: 28.VIII.2004 – 1

Cortinarius acutus (Pers.) Fr. agg.

I:114: 5.X.2001 (01/411), in *Sphagnum*, among *Nardus stricta* and *Carex nigra*, under *Picea abies*; 25.VI.2004 (04/116, det. M. Beran), under *Picea abies*; **K:134**: 19.IX.2002 (02/289), in *Sphagnum*

Cortinarius bataillei J. Favre

H:85: 10.X.2003 (03/379); 28.VIII.2004 (04/233, 04/236); 13.IX.2004 (04/346, det. M. Beran); **I:114**: 28.VIII.2004 (04/225); **109**: 13.IX.2004, in *Sphagnum*

Cortinarius brunneus (Pers.) Fr.

H:85: 13.IX.2004, det. M. Beran, under *Picea abies*

Cortinarius croceoconus Fr.

H:85: 28.VIII.2004 (04/234), under *Picea abies*; **I:114**: 28.VIII.2003 (03/149); in *Sphagnum*, under *Picea abies*

Cortinarius chrysolithus Kauffman

I:105: 5.X.2001 (01/421); 13.IX.2004 (04/300, det. M. Beran)**,** in *Sphagnum*, under *Picea abies*

Cortinarius flexipes var. *flabellus* (Fr.) Lindstr. et Melot

H:85: 13.IX.2004, det. M. Beran, under *Picea abies*

Cortinarius muscigenus Peck

H:85: 10.X.2003 (03/388); 28.VIII.2004; 13.IX.2004 (04/298, det. M. Beran) – all records were found under *Picea abies*, in *Sphagnum*

Cortinarius cf. paleaceus Fr.

H:85: 28.VIII.2004 (04/240, det. M. Beran), under *Picea abies*

Cortinarius stillatitius Fr.

I:114: 10.X.2003 (03/376); 13.IX.2004 (04/310, det. M. Beran), under *Picea abies*, in *Sphagnum*

Cortinarius tubarius Ammirati & A.H. Sm.

H:85: 10.X.2003 (03/378), (03/380); 28.VIII.2004 (04/235); 13.IX.2004 (det. M. Beran), in *Sphagnum* bog, under *Picea abies*; **I:105**: 28.VIII.2004 (04/227); **114**: 13.IX.2004 (04/309, det. M. Beran), in *Sphagnum* bog, under *Picea abies*

Cortinarius subgen. *Sericeocybe* 1

I:105: 5.X.2001 (01/422), under *Picea abies*, on dryer part of locality

Cortinarius subgen. *Sericeocybe* 2

H:91: 14.IX.2004 (04/321), under *Picea abies*

Cortinarius subgen. *Telamonia* cf. sect. *Pulchelii*

I:114: 5.X.2001 (01/403), in *Sphagnum* bog, under *Picea abies*

Cortinarius subgen. *Telamonia* 1

A:13: 6.X.2001 (01/447), 9.X.2003 (03/322), under *Betula pendula*

Cortinarius subgen. *Telamonia* 2

I:114: 5.X.2001 (01/410), in *Sphagnum* bog, under *Picea abies*; 25.VI.2004 (04/115), under *Picea abies*

Cortinarius subgen. *Telamonia* 3

I:114: 5.X.2001 (01/406), in *Sphagnum* bog, under *Picea abies*; 10.X.2003 (03/374), under *Picea abies, Betula pendula*

Cortinarius subgen. *Telamonia* 4

I:105: 5.X.2001 (01/420); **114**: 25.VI.2004 (04/114); 28.VIII.2004 (04/222) – in *Sphagnum* bog, under *Picea abies*

Cortinarius subgen. *Telamonia* 5

H:85: 10.X.2003 (03/381), under *Picea abies*

Cortinarius subgen. Telamonia 6

H:85: 28.VIII.2004 (04/237); 13.IX.2004, under *Picea abies*

Cortinarius subgen. *Dermocybe* sp. div.

H:91: 12.X.2002 (02/462), under *Picea abies*; **I:105**: 1.VII.2001 (01/135), under *Betula pendula*; 5.X.2001 (01/408), in *Sphagnum* sp., under *Betula pendula*; 5.X.2001 (01/413), in *Sphagnum* bog, under *Betula pendula, Picea abies*; 12.X.2002 (02/477), in *Sphagnum* bog, under *Picea abies*; **114**: 5.X.2001 (01/402), in *Sphagnum* bog, under *Picea abies*

Hebeloma circinans (Quél.) Sacc. agg.

A:13: 6.X.2001 (01/446); 9.X.2003 (03/321), under *Betula pendula*

Inocybe dulcamara (Alb. et Schwein.) P. Kumm. agg.

E:57: 29.9.2002 (02/328), under *Salix purpurea*

Inocybe cf. *lanuginosa* (Bull.) P. Kumm.

I:105: 1.VII.2001 (01/136); **114**: 1.VII.2001 (01/128); 28.VIII.2003 (03/148; 28.VIII.2004 (04/221) – all records were found in *Sphagnum* bog, under *Picea abies*

Inocybe sect. *Marginatae* 1

A:13: 11.X.2002 (02/439), under *Betula pendula, Corylus avellana*

Inocybe sp. 1

I:114: 1.VII.2001 (01/127), under *Picea abies*

Laccaria affinis (Sing.) Bon

I:105: 5.X.2001 (01/416); 12.X.2002 (02/476); **K:OrV**: 28.IX.2002 (02/310); in *Sphagnum* bog, under *Betula pendula*

Laccaria pumila Fayod agg.

H:92: 10.X.2003 (03/360), under *Salix* sp.; **I:105**: 10.X.2003 – 3x3: 1 (03/398); **114**: 28.VIII.2004 (04/223)

Laccaria laccata (Scop.) Fr.

K:Klr: 28.IX.2002 (02/315)

Lactarius sp.1

A:13: 11.X.2002 (02/438), under *Betula pendula*

Lactarius tabidus Fr.

H:85: 10.X.2003 (03/385); 13.IX.2004 (04/303, det. M. Beran); **I:105**: 28.VIII.2004 (04/228), under *Picea abies*; **115**: 5.X.2001 (01/388), in *Sphagnum*, under *Betula pendula*; 12.XI.2002 (02/457); 13.IX. 2004, under *Betula pendula, Picea abies*; 10.X.2003 (03/367), under *Salix* sp.; 25.VI.2004 (04/119) under *Betula pendula*

Lactarius deterrimus Gröger.

H:91: 1.VII.2001, under *Picea abies*

Lactarius glyciosmus (Fr.) Fr.

I:105: 5.X.2001 (01/412), in *Sphagnum* bog, under *Betula pendula, Picea abies, Pinus sylvestris*

Lactarius helvus Fr.

H:85: 28.VIII.2004; 13.IX.2004; **I:114**: 5.X.2001; 28.VIII.2003 (03/152); all records were found under *Picea abies*

Lactarius picinus (Fr.) Fr.

I:114: 13.IX.2004 (04/308), under *Picea abies*

Lactarius pubescens (Fr.) Fr.

A:13: 9.X.2003, 14.IX.2004, **K:OrV** : 28.IX.2002 (02/311)**,** under *Betula pendula*

Lactarius rufus (Scop.) Fr.

H:85: 28.VIII.2004 (04/231); 13.IX.2004, det. M. Beran, under *Picea abies*

Lactarius sphagnetii (Fr.) Neuhoff.

I:105: 28.VIII.2004 (04/229); 13.IX.2004, det. M. Beran, under *Picea abies*

Lactarius torminosus (Schaeff.) Gray

A:13: 14.IX.2004, under *Betula pendula*

Leccinum variicolor Watling

A:13: 14.IX.2004, under *Betula pendula*; **I:105**: 5.X.2001 (01/415), in *Sphagnum* bog, under *Betula pendula, Picea abie*s; 13.IX.2004, under *Picea abies*; **114**: 13.IX.2004 (04/306, det. M. Beran), under *Picea abies, Betula pendula*

Leccinum brunneogriseolum Lannoy et Estadès

I:114: 13.IX.2004 (04/307, det. M. Beran), under *Picea abies, Betula pendula*; **109**: 13.IX.2004, under *Picea abies*

Leccinum sp. div.

A:13: 9.X.2003, under *Betula* sp.; **H:92**: 5.X.2001 (01/383), in *Sphagnum* bog, under *Betula pendula*; **I:114**: 5.X.2001 (01/405), in *Sphagnum* bog, under *Betula pendula*; 10.X.2003 (03/377)

Naucoria cf. *escharioides* (Fr.) P. Kumm.

A:20: 6.X.2001 (01/459), under *Alnus glutinosa*, on soil

Rozites caperatus (Pers.) P. Karst

I:105: 1.VII.2001, under *Betula pendula*

Russula cf. sect. *Tenellae* 1

A:13: 9.X.2003 (03/320)**,** under *Betula pendula*

Russula cf. sect. *Tenellae* 2

H:92: 25.VI.2004 (04/128)**,** under *Betula pendula, Picea abies*

Russula cf. *sphagnophila* Kauffman

G:81: 27.VII.2003 (03/126), under *Betula pendula, Picea abies*

Russula emetica (Schaeff.) Pers.
G:81: 4.VIII.2002 (02/200); **H:85**: 10.X.2003 (03/384); 28.VIII.2004; **I:105**: 12.X.2002 (02/475); 10.X.2003 – 3x3: 1; 28.VIII.2004 – *Russula emetica* var. *betularum* Hora; all records were found under *Betula pendula, Picea abies*
Russula paludosa Britzelm.
H:85:13. IX. 2004; **I:114**: 28.VIII.2004, both records were found under *Picea abies*
Tricholoma flavobrunneum (Fr.) P. Kumm.
A:13: 5.X.2001 (01/371); 11.X.2002; 9.X.2003 (03/319); 14.IX.2004, under *Betula pendula*

Coprophilous species

Panaeolus acuminatus (Schaeff.) Quél. agg.
A:13: 11.X.2002 (02/440), on remains of cow excrement
Coprinus sp.
G:75: 24.VI.2004 (04/091) – on roebuck excrement

Lignicolous species

Daedaleopsis confragosa (Bolton) J. Schröt.
A:20: 13.IV.2001, on *Alnus glutinosa* log
Oudemansiella radicata (Relhan) Singer
G:75: 11.X.2002 (02/449)
Panellus stipticus (Bull.) P. Karst.
A:20: 2.VII.2001**,** on *Alnus glutinosa* stem
Peniophora sp.
A:20: 13.IV.2001 (01/010), on bark of *Alnus glutinosa* stem
Pluteus romellii (Britzelm.) Lapl.
G:75: 6.X.2001 (01/438), on twig of decidous tree
Polyporus sp.
A:20: 13.IV.2001 (01/007), on *Alnus glutinosa* log
Stereum hirsutum (Willd.) Gray
G:75: 2.VII.2001 (01/140), old sporocarp, on ground
Stereum rugosum (Pers.: Fr.) Fr.
A:20: 13.IV.2001, on *Alnus glutinosa* stem
Strobilurus esculentus (Wulfen) Singer
F:65: 9.X.2003 – 3x3: 10 (03/338), **G:77**: 13.IV.2001, both records were found on *Picea abies* cone

Other species

Collybia tuberosa (Bull.) P. Kumm.
H:85: 13.IX.2004; **I:114**: 28.VIII.2003 (03/154); **K:136**: 18.IX.2002; all records were found on remains of sporocarp
Sclerotinia tuberosa (Hedw.) Fuckel
F:65: 13.IV.2001 (01/011), on rootsock of *Anemone nemorosa*

Fungal communities of different types of fens

The variability in the composition of fungal communities corresponded more or less with different vegetation types of fens. The greatest differences were between poor *Sphagnum* fens and spring *Calthion* meadows. Correlation between species richness and pH was not significant (Fig. 2; r= -0.24, P>0.05,).

The total number of species belonging to studied community in the poor *Sphagnum* fens (91, 115, 114, 103, 105) varies from 7 to 19 per locality. Sphagnicolous fungi (*Galerina paludosa, G. tibiicystis, Tephrocybe palustris*, *Hypholoma elongatum, Mycena metata, Entoloma conferendum,* and *Hygrocybe coccineocrenata*), usually very rich in the number of sporocarps, represent a very important group here. Only in this type of fens do the following sphagnicolous members of the *Geoglossaceae* occur: *Trichoglossum hirsutum,* and *Geoglossum cf. glabrum*; they are both rare and endangered in the Czech Republic. In poor *Sphagnum* fens, there are no characteristic muscicolous or herbicolous macromycetes species. Only in spring is a mass occurrence of *Lachnum* and *Mollisia* species observed on the basis of leaves of herbs (rush, sedge and matgrass) growing in *Sphagnum* bogs.

The number of macromycetes species in poor *Sphagnum* fens increases with an increasing presence of trees and their mycorrhizal fungi. Members of *Cortinarius* subgenus *Dermocybe* (mainly *Cortinarius croceoconus*, *C. batailleii* and *C. tubarius*) and Cortinarius subgen. *Telamonia*, genus *Lactarius* (*L. tabidus*, *L. pubescens*), genus *Russula* (*R. emetica*), and genus *Leccinum* occur there most of all.

In comparison with data from larger raised bogs, here in small *Sphagnum* fens the members of *Omphalina* genus, and the species *Psathyrela sphagnicola* and *Clavaria argillacea* f. *sphagnicola* are missing.

Mycoflora of rich *Sphagnum* fens (104, 92; 13 and 15 species) is similar to mycoflora of poor *Sphagnum* fens because of presence of mire species dependent on *Sphagnum* (*Galerina paludosa, G. tibiicystis, Tephrocybe palustris,* and *Hygrocybe coccineocrenata*). Moreover species common to calcareous fens (*Galerina heterocystis, Agrocybe paludosa, Marasmius curreyi,* and *Galerina vittaeformis*) occur there. Characteristic species for rich *Sphagnum* fens are: *Entoloma* subg. *Leptonia* sect. *Cyanula*, *Rickinella fibula*, and *Mitrula paludosa*.

The mycoflora of basic spring fens is more variable than of *Sphagnum* fens; there are greater differences between localities. Characteristic species for these fens are *Coprinus* subsect. *Alachuani, Psilocybe xeroderma, Galerina heterocystis,* and *Psathyrella prona.* Even more common but less ecologically restricted species were e.g. *Marasmius curreyi, Mycena speirea, M. epipterygia, Galerina vittaeformis*. Muscicolous species are less dominant in calcareous spring fens and spring *Calthion* meadows fens than in poor *Sphagnum* fens; more herbicolous and terrestrial species occur here.

Figure 1: Box and whiskers plot of species richness in the sites within the four different structural habitat types. Abbreviations: psf – poor *Sphagnum* fens; rsf – rich *Sphagnum* fens; scm – spring *Calthion* meadows; csf – calcareous spring fens.

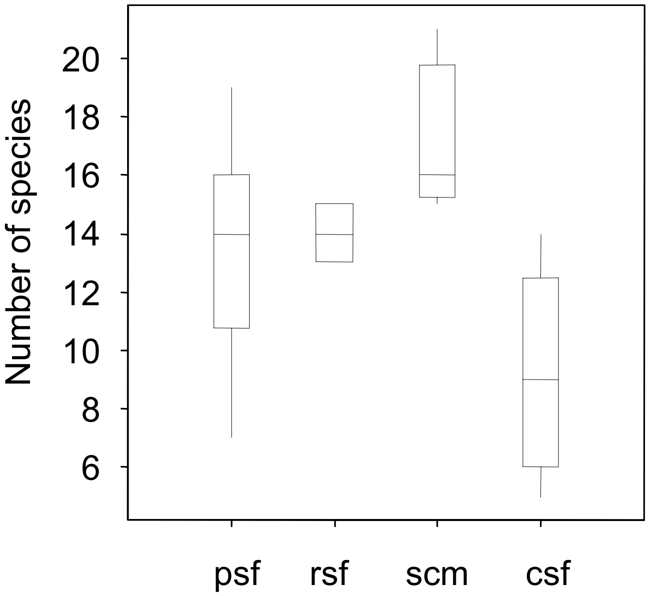
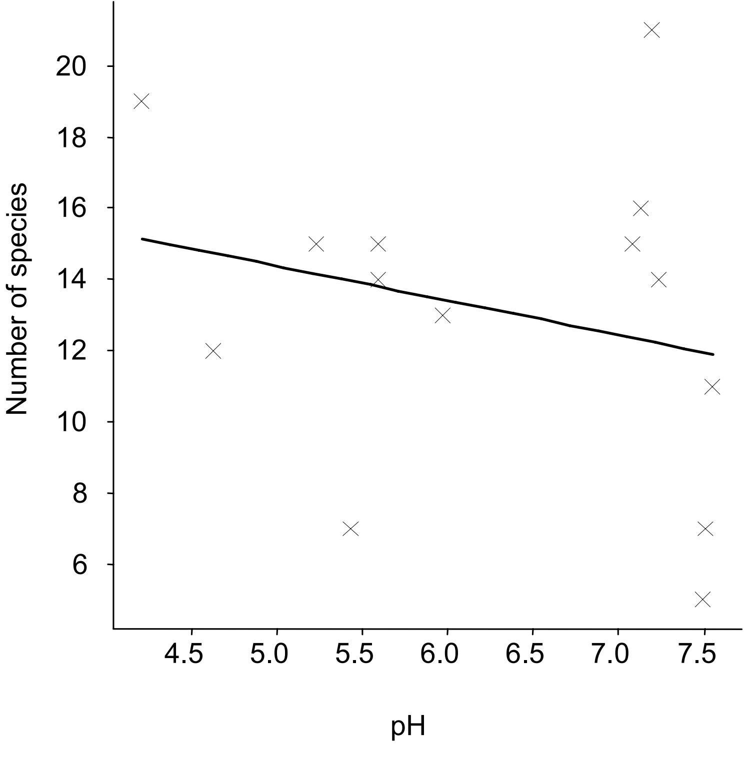


Figure 2: Correlation between water pH and macrofungi species richness in the fens.



The calcareous spring fens (7, 13, 67 and 98) are very species poor (7–14 species), characteristic species are *Mycena epipterygia* and *Galerina heterocystis*, on the other hand spring *Calthion* meadows (20, 75, 77) belong to species richest localities (13–19 species) in studied communities, typical species for spring calthion meadows are *Coprinus* subsect. *Alachuani*, *Galerina annulata*, *Arhenia lobata*, and *Stropharia albonitens*.

The highly productive meadow calcareous fen Kloboucký potok (20) is very interesting from the mycological point of view. The highest number of macromycetes was found here, probably due to the mass of *Carex paniculata, Equisetum telmateia,* and *Fillipendula* stems. Approximately two thirds of the recorded species were bound to *Carex paniculata* bogs that represent key microbiotopes for fungi communities. The high groundwater level in the springs may be the reason for the absence of muscicolous species.

It seems that none of the above-mentioned species, important in the studied biotopes, is a strict specialist in any of these habitats. Sphagnicolous species can occur in raised bogs or even in bog spruce forests. Muscicolous species *Galerina vitaeformis* is abundant in mossy meadows and suitable moist forests (Einhellinger 1977). *Marasmius curreyi* is a species that can occur on decaying remnants of *Cyperaceae*, *Juncaceae* and *Poaceae*, on dry to moist places, in both natural and man-made habitats (Antonín & Noordeloos 1993). Members of *Coprinus* subsect. *Alachuani* also occur on various herb remnants in moist localities, regardless of their origin. According to Einhellinger (1977, 1978), *Galerina heterocystis* has a wide ecological valence as well; it was found in an open fen, in alder stands, in a birch forest, and even in communities of *Phragmition* alliance.

Only *Agrocybe paludosa, Psilocybe xeroderma,* and *Stropharia albonitens* (see Senn–Irlet et al. 2000) seem to be more strictly connected with fen habitats, but there is little information about the ecology of these species. According to Einhellinger (1977) *Agrocybe paludosa* was also found in a degraded raised bog under birch.

Phenology

The growth of fungal sporocarps starts in the studied mires and fens in early spring, shortly after the snow melts. The early-spring species are mostly ascomycete fungi from the genus *Sclerotinia*, *Rustroemia*, *Lachnum* sp. div, and *Mollisia palustris* agg. At this time of year, there are almost no basidiomycete fungi, only sporocarps of *Arhenia retiruga* and *A. lobata* are present. No more than 2 macrofungi species were found at a locality per visit in spring.

The early summer aspect starts when sporocarps of common sphagnicolous fungi such as *Galerina* sp. div., *Tephrocybe paludosa* and *Hygrocybe coccineocrenata* appear. This period is very rich in species of calcareous fens. *Agrocybe paludosa*, *Rickenella fibula*, *Coprinus*, and *Psathyrella typhae* can be found. Approximately 0-9 macrofungi species were found at a locality per visit in early summer.

The growth of mycorrhizal fungi indicates the beginning of the summer aspect. Other typical summer species are *Entoloma* sp. div., *Marasmiellus vaillantii*, *Hemimycena* sp. div. (0-5 macrofungi species per visit). Several species of the genus *Dermocybe* are typical for the late summer. Calcareous fens were not monitored at this period due to the lack of precipitation in late summer.

The autumnal aspect is very species-rich in most localities (0-11 macrofungi species per one locality and visit). The occurrence of the representatives of genus *Tricholoma*, *Clitocybe*, and *Psilocybe semilanceata* species characterize this period.

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Chapter 8

Bryophytes

P. Hájková

Introduction

Bryophytes, and *Sphagnum* species in particular, form an important part of mire vegetation and participate significantly in the formation of its structure, the determination of mire development and peat accumulation (Andrus 1986, Vitt 2000, Hájková & Hájek 2004). Recent studies demonstrated that bryophytes are more sensitive to acidity-alkalinity gradients than vascular plants, which are influenced rather by nutrient supply (Bragazza & Gerdol 2002) or behave more ubiquitously (Miserere et al. 2003). In addition, various *Sphagnum* species have even the ability to control succession by means of pH regulation (Glime et al. 1982, Andrus 1986). For all these reasons, bryophytes are useful for the classification of mire vegetation and mire habitats (see Pakarinen 1979, Rybníček et al. 1984, Mullen et al. 2000, Valachovič 2001, Hájek 2002) and in fact any mire study cannot be complete without the identification of bryophytes.

Therefore, attention was given to bryophytes, which were recorded in all of the phytosociological relevés sampled during vegetation and ecological research over the last 7 years. Thus, we have a good deal of information about bryophytes' affinity for particular vegetation types (for ecological description of vegetation types see Chapter 5.1) and about their ecological demands. In fifteen vegetation types of wet meadows, rich calcareous and poor acidic noncalcareous fens, we recorded, among 110 cryptogams, 92 species of mosses (19 of them are *Sphagnum* species), 18 liverworts, 1 lichen and 1 species of *Chara* (Table 1). For some purposes, the moss species were classified into families following the system of Smith (1980). Nomenclature unified according to Frey et al. (1995).

Results and discussion

Bryophyte biomass and species richness in vegetation types

There are great differences among mire vegetation types in bryophyte contribution to total biomass and to species composition in our study area. High quantities of bryophyte biomass, mainly *Sphagnum* species, are generally observed both in acidic fens and bogs (Malmer 1986). In Carpathian mires, high quantities of bryophyte biomass were detected not only in acidic fens of the *Sphagno recurvi-Caricion canescentis* all. (maximum 1046 $g.m^{-2}$), but also in some rich calcareous fens dominated by brown mosses of *Amblystegiaceae* (maximum 1043 $g.m^{-2}$; Hájková & Hájek 2003). In the case of calcareous fens, the most important factor for the development of a dense bryophyte layer is the decrease in vascular plant biomass due to mowing which increases the amount of light available.

Further, particular vegetation types differ in bryophyte species diversity. The relationship between bryophyte species richness and water pH was generally confirmed to be unimodal (Hájková & Hájek 2003); this means that moderately-rich fens were the species-richest types (Fig. 1). This finding also corresponds to the results obtained from the boreal zone (e.g. Vitt et al. 1995). With respect to vegetation types, the highest α-diversity (average number of species per relevé), and also β-diversity (number of all species recorded in the vegetation type in total) were recorded in the moderately-rich fens with calcitolerant *Sphagnum* species of the *Sphagno warnstorfii-Tomenthypnion* all., where 47 bryophyte species were recorded. The other species-rich vegetation types were: the relic communities of the *Caricion lasiocarpae* all., the waterlogged meadows combining meadow and fen species (*Cirsietum rivularis eriophoretosum*, *Angelico-Cirsietum palustris*) and the Outer-Carpathian calcium-rich peat forming fens with brown mosses (*Valeriano-Caricetum flavae*) (Fig. 1). On the contrary, very low bryophyte species diversity (both α and β diversity) were found in three different habitat types: first, in vegetation types having an extreme water chemistry (alkaline *Glauco-Trichophoretum pumili*, several communities of acidic *Sphagno recurvi-Caricion canescentis* all.), second, in highly productive types with strong competition from vascular plants (*Scirpetum sylvatici, Filipendulenion* suball.) and, third, in vegetation which suffers from significant disturbances (*Junco inflexi-Menthetum*). The latter exhibits also the most distinct difference between α- and β-diversity. It is caused by a relatively high species pool of bryophyte immigrants, which prefer disturbed places. This process is stochastic and, therefore, different species occur at particular cases and β-diversity increases. By contrast, just the same α- and β-diversity were found in the extremely species-poor subhalofytic vegetation of *Glauco-Trichophoretum pumili*, in which only 5 bryophyte species were recorded.

Role of bryophytes in the characterisation of vegetation types

Some bryophyte species reveal high fidelity to particular vegetation types and, therefore, they can be of good differential value. This is connected with the grade of their representation in the total species composition and total biomass. The vegetation types with high productivity of vascular plants, low bryophyte biomass and low species diversity (*Scirpetum sylvatici, Filipenduletum* s.l.) have no moss species of significant fidelity to this particular type. However, most other mire vegetation types are well characterised by bryophyte species of high fidelity and high constancy, playing an important role in their differentiation (for details see Table 1).

The coenological amplitude of selected bryophyte species is expressed by various circle sizes at the locations of syntaxa in DCA ordination diagram (Fig. 2 A-N). Among wet meadow species, *Brachythecium rivulare* has its optimum in *Chaerophyllo hirsuti-Calthetum* growing in habitats with running water, but it commonly occurs also in other types of waterlogged meadows (*Angelico-Cirsietum palustris, Cirsietum rivularis, Scirpetum sylvatici* and *Junco inflexi-Menthetum*). This species avoids peat soils and, therefore, it overlaps only weakly to fen types (Fig. 2A). On the contrary, *Climacium dendroides*, which is not able to grow directly in running water, overlaps clearly from wet meadows to extremely-rich (*Carici flavae-Cratoneuretum*) and moderately-rich (*Caricion fuscae, Sphagno warnstorfii-Tomenthypnion*) fens (Fig. 2B). Fen mosses differ also in their affinities with particular vegetation types. For example, *Cratoneuron commutatum* and *C. filicinum* are both restricted to extremely-rich fens with tufa formation (*Carici flavae-Cratoneuretum, Caricetum davallianae, Cirsietum rivularis eriophoretosum*) (Fig. 2C,E), but *Cratoneuron filicinum* tolerates better the high degree of disturbance in *Junco inflexi-Menthetum* and soil salination in *Glauco-Trichophoretum pumili*. *Drepanocladus cossonii* and *Campylium stellatum* have their optimum both in extremely-rich and moderately-rich fens (Figs 2F,D), but the former does not occur so commonly in tufa (*Carici flavae-Cratoneuretum*). *Calliergon giganteum* and *Aulacomnium palustre* represent typical species of moderately-rich fens without any tufa formation (Fig. 2G,H), but *Aulacomnium palustre* is more common having a wider coenological amplitude. It also grows in waterlogged meadows (*Angelico-Cirsietum palustris*), poor fens (*Sphagno recurvi-Caricion canescentis*) and even in ombrotrophic bogs. The most acidic and calcium-poorest stands are occupied by *Sphagnum* species. *Sphagnum warnstorfii* belongs among the most *Ca*-tolerant *Sphagnum* species, having its optimum in communities of the *Sphagno warnstorfii-Tomenthypnion* all. (Fig. 2I). The closely related species *Sphagnum capillifolium* s.s. occasionally occurs also in moderately-rich fen vegetation, but its optimum is shifted to acidic poor fens (Fig. 2J). Similar difference is apparent between niches of *Sphagnum fallax* and *S. flexuosum* (both belonging to the *S. recurvum* agg.). *Sphagnum flexuosum* tolerates higher levels of calcium and can grow also in moderately-rich fens (Fig. 2L), whereas *Sphagnum fallax* occurrence is clearly bound to *Ca*-poor fens (Fig. 2K). *Sphagnum palustre* has very similar coenotical affinity with *Sphagnum flexuosum* (Fig. 2N). The lawn species *Sphagnum magellanicum* was recorded only in poor acidic fens (Fig. 2M), but its optimum is in ombrotrophic bog communities (Rybníček et al. 1984), which are scarce in our study area.

Major ecological factors determining bryophyte distribution

Base saturation is the major ecological factor controlling the distribution of both bryophytes and vascular plants not only in the Carpathian mires (Hájek 2002, Hájek et al. 2002) but in the entire northern hemisphere (Sjörs 1952, Persson 1962, Mörnsjö 1969, Malmer 1986, van Baaren 1988, Gerdol 1995, Tahvanainen et al. 2003). The bryophytes receive water containing nutrients over the entire surface unlike vascular plants, which absorb nutrients by different root systems. Most mire mosses, especially the *Sphagnum* species, also have an ability to control directly habitat conditions through acidification (Glime et al. 1982, Rybníček et al. 1984, Andrus 1986, Hájková & Hájek 2004 etc.). For both these reasons, bryophytes reflect the character of water chemistry more exactly than vascular plants. The occurrence of vascular plants is, therefore, more complicated and it is often determined by a whole complex of different ecological factors (Hájková & Hájek 2004b). In order to verify the major gradients in bryophyte species composition on the regional level, we subjected vegetation data on bryophytes from all our relevés to indirect ordination (Detrended Correspondence Analysis) (Fig. 3). DCA analysis shows the major poor-rich water chemistry gradient as the first ordination axis, along which the species composition changes from the most calcifilous species (*Cratoneuron commutatum, Campylium stellatum*) to the calcifuge *Sphagnum* species (e.g. *S. fallax, S. palustre*). The second principal gradient is clearly connected with the degree of meadow character and of nutrient supply, and it is obvious only in the *Ca*-rich part of the first gradient. The typical rich fen species are located in the upper part, the species of waterlogged and fen meadows are concentrated in the bottom part (Fig. 3). Wet meadow species like *Cirriphyllum piliferum, Climacium dendroides* and *Plagiomnium elatum* do not occur in the acidic *Sphagnum*-dominated stands nor in extremely *Ca*-rich fens and, therefore, they occupy the middle part of the first axis.

All meadow mosses (e.g. *Climacium dendroides, Plagiomnium elatum, Cirriphyllum piliferum*) seemed to prefer higher values of water pH. They occured most often at sites with pH between 6.5 and 7.5, only *Scleropodium purum* grew more often under pH above 7.5 (Fig 4), but never directly in alkaline water. The majority of meadow species occupies the habitats with water conductivity between 300 and 500 $\mu S.cm^{-2}$, while only *Hypnum pratense* and *Rhytidiadelphus squarrosus* occurred more often in mineral-poorer stands with conductivity below 200 $\mu S.cm^{-2}$. Two latter species also prefer habitats with lower values of calcium content (ca 50 $mg.l^{-1}$). Habitats of *Brachythecium rivulare* exhibited the highest mean values of water conductivity (500 μS.cm^{-2}) as well as calcium content (200 mg.l^{-1}). *Aneura pinguis* and *Chiloscyphus polyanthos* s.l., the most common liverworts, are also diversified in their ecological demands in our study area (Fig. 4), where *Aneura pinguis* prefers more alkaline and calcareous water than does *Chiloscyphus polyanthos* s.l. The above mentioned species were recorded in habitats with iron content below 50 mg.l^{-1}.

Species from the *Amblystegiaceae* belong generally among the most typical fen species, and their niches are clearly differentiated according to the grade of mineral supply (Hedenäs & Kooiman 1996). *Calliergonella cuspidata* is a species with a broad niche for water pH, conductivity and calcium content, and it was distributed in many of vegetation types (Fig. 5). *Campylium stellatum, Drepanocladus cossonii, Cratoneuron commutatum* and *C. filicinum* were recorded under the highest mean values of water pH (ca 7), water conductivity (400 – 500 μS.cm^{-2}) and calcium content (ca 150 mg.l^{-1}). However, the variation among all factors was rather high. *Calliergon giganteum* and *Drepanocladus vernicosus* represent species of semineutral and moderately-rich habitats with pH between 6 and 7, water conductivity between 100 – 300 μS.cm^{-2} and calcium content below 100 mg.l^{-1}. *Calliergon stramineum* and *Drepanocladus exannulatus* are the most acidofilous and calcifuge from all species of this group (Fig. 5). *Calliergon giganteum* tolerates relatively high content of iron in water (up to 100 mg.l^{-1}) and thus it differs from other *Amblystegiaceae* species.

Other fen mosses belong to several families of *Bryales. Philonotis calcarea, Bryum pseudotriquetrum* and *Fissidens adianthoides* have demands similar to the calciphilous species of *Amblystegiaceae* (Fig. 6). Some differences among them have been found in the water calcium content. Two latter species have their optimum in less calcareous waters than the first one. *Aulacomnium palustre, Philonotis fontana* and a rare relic species *Paludella squarrosa* occurred in the moderately-rich sites with water of pH 6 – 7, water conductivity 100 – 300 μS.cm^{-2} and calcium content less than 50 mg.l^{-1}. *Aulacomnium palustre* habitats have the mean values of calcium content lower than those of *Philonotis fontana*. Both species probably have a higher tolerance for iron in water since they occurred in fens with a Fe concentration over 50 mg.l^{-1}. *Polytrichum commune* preferred the most acidic and calcium poor habitats (Fig. 6), where it formed dry hummocks in patches with shallow layers of fen peat.

Sphagnum species can be divided into two basic groups, the calcitolerant species and the calcifuge ones. The first group involves species from the sections *Subsecunda* (*S. contortum, S. subsecundum*), *Squarrosa* (*S. teres*) and *Acutifolia* (*S. warnstorfii*). All calcitolerant *Sphagnum* species can grow in water with calcium content between 10 - 15 mg.l^{-1} (Fig. 7). The highest values of pH, conductivity and calcium content were found for *Sphagnum warnstorfii*. This species, together with *Sphagnum teres,* often occurred in habitats with calcium content over 20 mg.l^{-1}, where they are the first *Sphagnum* species indicating the succession towards the acidophilous vegetation. *Sphagnum warnstorfii* and *S. teres* tolerated high pH values and calcium content also in the boreal peatlands of Europe (Persson 1961, Daniels & Eddy 1985) and North America (Vitt & Slack 1984, Janssens & Glaser 1986).

An extremely high iron content in water was observed in habitats with the occurrence of *Sphagnum subsecundum* (Fig. 7). We found this species at sites with Fe concentration mostly between 50 – 100 mg.l^{-1}. In some cases its content even reached as high as 150 mg.l^{-1}. *Sphagnum subsecundum* behaves similarly also in other regions but sometimes it is reported from more acidic and calcium-poor sites (Anderson et al. 1995, Bragazza & Gerdol 1999, Dünhofen & Zechmeister 2000). The strong tolerance of *Sphagnum subsecundum* to free iron can be the crucial feature responsible for its different ecology in the Carpathian mires. As peat mosses preferentially absorb cations with higher valences (Andrus 1986), the presence of free iron in water can limit the absorption of calcium cations. Therefore, the high supply of dissolved iron seems to be the reason for higher calcitolerance of *Sphagnum subsecundum* in the studied fens.

Sphagnum flexuosum has a transitional position between calcitolerant and calcifuge species. It occupies habitats with similar calcium content as for example *Sphagnum contortum*, but *Sphagnum flexuosum* has a stronger ability to acidify the environment (Hájková & Hájek 2005). This fact is manifested by lower pH values (Fig. 7) compared to habitats of other calcitolerant *Sphagnum* species. In addition, enhanced nutrient input increases the competitive ability of *Sphagnum recurvum* agg. even in mineral-rich habitats, as several studies from West Europe demonstrate as well (Kooijman & Kanne 1993; see Chapter 5).

The luxuriant growth of *Sphagnum recurvum* agg. in nutrient-enriched fens results in an extreme acidification of such habitats (Kooijman & Bakker 1994) and in changes of species composition and species richness. Most *Sphagnum flexuosum*-dominated habitats were at the same time the species-poorest ones (Hájková & Hájek 2003; Chapter 5). *Sphagnum capillifolium* s.s. also occupies habitats with water pH similar to that of *S. flexuosum* (Fig. 7), but *S. capillifolium* does not tolerate such a high conductivity and calcium content (Fig. 7). *Sphagnum palustre* and *S. fallax* prefer fens with pH around 5 and conductivity below 50 $\mu S.cm^{-2}$. Similar affinity was found for *Sphagnum magellanicum*, which occurs in the most acidic and calcium-poorest fens. Since any typical ombrotrophic bog with a very low total supply of nutrients is absent in our study area, the niche breadths of *Sphagnum magellanicum* and *S. fallax* are narrow and do not cover the most acidic part of the poor-rich gradient. In other areas with ombrotrophic bogs, these two *Sphagnum*-species grow in acidic waters with pH even below 4 (cf. Gerdol & Tomaselli 1997).

Endangered species of bryoflora in the West Carpathian mires

Some endangered mosses had already been reported from the West Carpathians before our study. Rybníček et Rybníčková (1972) mentioned rare, mostly relic bryophytes in the Orava region. Some of their localities are still preserved and are also documented in our research, but many of them exist no longer. Older data about the threatened mosses and glacial relics *Meesia triquetra* and *Paludella squarrosa* were also published by Šmarda (1954). Some new findings of these mosses have been reported recently from the central and northern Slovakia (Blanár & Šoltés 2000, Šoltés 1999, 2000, Šoltés & Dítě 2002, Šoltés & Novák 1999, Šoltés et al. 1998, 2002), and from the flysch borderland between the Czech and Slovak Republics (Hájková & Hájek 2001) recently.

In total, 29 moss and 2 liverwort species of some threat status in the Czech Republic (Kučera & Váňa 2003) or Slovak Republic (Kubinská et al. 2001) were recorded during our investigarions (Table 2). Four of them were found in the Czech territory only, 16 species only in the Slovak part and the remaining number of species occurred in both states. Eight species belong to the highest categories of threat (critically threatened and endangered). A majority of these bryophyte species occurs in our rich or moderately-rich fens of the *Caricion lasiocarpae*, *Caricion davallianae,* and *Sphagno-Tomenthypnion* alliances, being generally the species-richest vegetation types. *Calliergon trifarium* is critically endangered in both republics, but it was recorded only in the Slovak part, in the Liptov and Spiš Basins and in Polish Podhale (locality L: 146). Two other glacial relics *Meesia triquetra* and *Paludella squarrosa*, classified as endangered species in the Slovak Republic, have a similar distribution pattern. *Scorpidium scorpioides*, a critically endangered species in Slovakia, was confirmed in the historical and sole present locality in

Kubinská hola Mt (Migra & Šoltés 1998). *Philonotis caespitosa*, the most common *Philonotis* species in the Czech Republic (Buryová 1996), is endangered in Slovakia. Only three of its localities were found in the Liptov and Spiš basins. *Campylium elodes* is another endangered moss, which was found only in the salt-rich fen of the *Glauco-Trichophoretum pumili* in the Spiš basin. The *Sphagnum* species with a suboceanic distribution character, namely *Sphagnum denticulatum, S. inundatum* and *S. papillosum*, are rather common in the Czech Republic, but not in Slovakia (only a few localities) and, therefore, we classify them among endangered or vulnerable species. All these *Sphagna* were recorded in poor fen communities of the *Sphagno recurvi-Caricion canescentis* all. in the Kysuce region (region I), where several suboceanic vascular plants were also recorded (see Chapter 9). Ombrotrophic bogs are generally rare in Slovakia; therefore, bog species, namely *Sphagnum cuspidatum*, are not widely distributed there. Nevertheless, we surprisingly found *Sphagnum cuspidatum* in two poor spring fens in slightly calcium-rich and less acidic habitats than used to be typical for this species (localities I: 114, 115). These populations have been recently described as *Sphagnum viride,* whose position in the taxonomic system is not entirely clear (herbarium material was revised by K. I. Flattberg).

Some endangered or almost threatened species in the Czech Republic (*Calliergon giganteum, Drepanocladus vernicosus, Cratoneuron decipiens, Tomenthypnum nitens*) are without any marked threat in Slovakia, and we recorded them rather often in the West Carpathian moderately-rich fens, especially in the Slovak part of our study area. Since the fen sites are generally endangered by human activities, many fen bryophyte species, which are still rather common, are regarded as potentially threatened species. They are denoted as LR-nt and LC-att in the Czech Red List (e.g. *Dicranum bonjeanii, Bryum weigelii, Hypnum pratense,* and *Drepanocladus cossonii*); however, some species belonging to these categories might be only overlooked (*Brachythecium mildeanum*, *Physcomitriella patens*). This concerns also the species listed in the category DD (data deficient). However, it is probably not the case with *Drepanocladus revolvens* s.s. which behaves as a mountain, slightly acidophilous species not tolerating a high content of calcium (Hedenäs & Kooijman 1996). Unlike widely distributed *D. cossonii*, there are recently only two isolated localities of *Drepanocladus revolvens* s.s. in the Krkonoše Mts (Kučera & Váňa 2003) and only one known locality in our study area (H: 92).

Bryophytes form a very important biotic component of the spring fen vegetation we studied, especially because of their high species diversity, high representation of threatened species and also their function in particular communities. The niches of individual species are well differentiated with respect to habitat characteristics, namely the water quality, which makes this taxonomic group indispensable for habitat and syntaxonomic classification and bioindication.

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Table 1: Synoptic table of moss and *Chara* layer species in percentages ordered according to their fidelity values. Fidelity over 10 are marked by one asterisk (*), fidelity over 20 are marked by two asterisks (**).

1: Scir - *Scirpetum sylvatici*, 2: Fil - *Filipendulenion*, 3: Ch-Cal – *Chaerophyllo hirsuti-Calthetum*, 4: A-Cp – *Angelico-Cirsietum palustris*, 5: J-Men – *Junco inflexi-Menthetum longifoliae*, 6: Criv – *Cirsietum rivularis*, 7: Crive – *Cirsietum rivularis eriophoretosum*, 8: Cf-C – *Carici flavae-Cratoneuretum*, 9: Cdav – *Caricetum davallianae*, 10: Gl-Tp – *Glauco-Trichophoretum pumili*, 11: V-Cf – *Valeriano-Caricetum flavae*, 12: Clas – *Caricion lasiocarpae*, 13: Sp-T – *Sphagno warnstorfii-Tomenthypnion*, 14: Cfus – *Caricion fuscae*, 15: Sr-Cc – *Sphagno-recurvi-Caricion canescentis*.

Syntaxa	Scir	Fil	Ch-Cal	A-Cp	J-Men	Criv	Crive	Cf-C	Cdav	Gl-Tp	V-Cf	Clas	Sp-T	Cfus	Sr-Cc	
Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Number of relevés	77	38	16	41	74	196	43	129	36	6	42	14	35	29	67	
Plagiochila asplenioides	1*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
Brachythecium rutabulum	8	13*	.	.	3	5	.	2	.	.	.	.	.	.	.	
Plagiochila porelloides	.	3*	.	.	.	.	2	.	.	.	.	.	.	.	.	
Chiloscyphus polyanthos s.l.		.	.	31**	2	.	1	5	.	3	.	.	.	20**	3	1
Brachythecium rivulare	18	16	81**	39*	32	35*	23	14	.	.	10	.	.	7	.	
Pellia epiphylla/neesiana	.	.	12*	.	.	1	2	3	.	.	.	.	.	3	.	
Calliergon cordifolium	.	.	12*	5	.	1	.	.	.	.	5	.	.	10*	3	
Bryum weigelii	.	.	6*	.	.	1	2	.	.	.	.	.	3	.	.	
Conocephalum conicum	.	.	6*	.	.	1	.	2	3	.	.	.	.	.	.	
Rhytidiadelphus squarrosus	6	5	25	44**	.	16	16	3	.	.	26	14	17	31*	3	
Pleurozium schreberi	.	.	.	5**	.	.	.	.	.	.	.	.	.	.	.	
Climacium dendroides	10	8	19	68*	3	46**	60*	14	17	.	64*	7	40	59*	4	
Brachythecium mildeanum	.	.	.	12*	.	2	5	1	.	.	5	.	.	3	.	
Dicranum spadiceum	.	.	.	2*	.	.	.	.	.	.	.	.	.	.	.	
Atrichum undulatum	3	.	12	12*	1	2	2	.	.	.	7	.	9	14*	3	
Plagiomnium elatum	29	34	69	78*	34	72*	84*	60	64	.	81*	36	57	55	6	
Brachythecium salebrosum	.	.	.	.	5**	.	.	.	.	.	.	.	.	.	.	
Eurhynchium hians s.l.	19	11	6	.	32**	16	14	12	.	.	2	.	.	3	.	
Bryum klinggraeffii	.	.	.	.	4*	.	.	.	.	.	.	.	.	.	.	
Cratoneuron filicinum	10	.	6	10	38*	17	30	37**	17	17	10	.	3	7	.	
Physcomitrium pyriforme	.	.	.	.	3*	.	.	.	.	.	.	.	.	.	.	
Dicranella schreberiana	.	.	.	.	3*	.	.	.	.	.	.	.	.	.	.	
Dicranella staphylina	.	.	.	.	1*	.	.	.	.	.	.	.	.	.	.	
Pottia truncata	.	.	.	.	1*	.	.	.	.	.	.	.	.	.	.	
Physcomitriella patens	.	.	.	.	1*	.	.	.	.	.	.	.	.	.	.	
Fissidens taxifolius	.	.	.	.	1*	.	.	.	.	.	.	.	.	.	.	
Brachythecium glareosum	.	.	.	.	7*	1	7	3	8	.	.	.	.	.	.	

Table 1: Cont.

Syntaxa Column	Scir 1	Fil 2	Ch-Cal 3	A-Cp 4	J-Men 5	Criv 6	Crive 7	Cf-C 8	Cdav 9	Gl-Tp 10	V-Cf 11	Clas 12	Sp-T 13	Cfus 14	Sr-Cc 15
Plagiomnium undulatum	9	11	25	5	18*	13	9	7	.	.	.	.	3	.	.
Cirriphyllum piliferum	6	8	12	12	.	19*	30*	7	.	.	19	.	.	17	.
Fissidens adianthoides	1	3	.	2	3	2	49**	43**	39*	.	21	21	37*	3	.
Bryum pseudotriquetrum	6	5	6	27	20	28	86**	89**	86*	17	93**	79	69*	34	4
Calliergonella cuspidata	32	16	44	61	58	65	93*	82**	61	.	79	36	74	79	9
Funaria hygrometrica	.	.	.	.	.	.	2*	.	.	.	.	.	.	.	.
Campylium stellatum s.l.	1	3	.	15	8	9	60*	78**	83**	100*	64*	71*	71*	24	1
Lophocolea bidentata	3	6	5	.	1	7*	2	.	.	.	.	.	.	1	
Scleropodium purum	3	5	.	5	1	4	12*	6	.	.	.	.	3	3	.
Cratoneuron commutatum	3	3	.	5	19	10	28	84**	50*	.	10	14	6	.	.
Chara sp.	.	.	.	.	1	.	.	16**	14*	17	2	7	.	.	.
Philonotis calcarea	.	.	.	5	1	2	.	23**	31*	.	31*	14	9	.	.
Aneura pinguis	4	5	12	10	3	4	21	23*	36*	17	17	50*	46**	7	1
Eucladium verticillatum	.	.	.	.	.	.	.	2*	.	.	.	.	.	.	.
Ctenidium molluscum	.	.	.	.	1	1	.	4*	8*	.	.	.	.	.	.
Drepanocladus cossonii	.	.	.	2	1	.	9	21	92**	17	64**	50*	60**	7	.
Cratoneuron decipiens	.	.	.	2	.	1	2	.	8*	.	12*	.	.	3	.
Amblystegium varium	.	.	.	.	1	.	.	.	3*	.	.	.	.	.	.
Philonotis caespitosa	.	.	.	.	.	.	.	.	3*	.		.	3*	.	.
Campylium elodes	.	.	.	.	.	.	.	.	.	17**	.	.	.	.	.
Campylium chrysophyllum	.	.	.	.	.	1	2	2	.	17*	.	.	.	.	.
Calliergon giganteum	.	.	.	2	.	.	.	.	.	.	19**	21*	17*	10	3
Brachythecium oedipodium	.	.	.	.	.	.	.	.	.	.	2*	.	.	.	.
Dicranum bonjeanii	.	.	.	2	.	1	2	.	.	.	10*	.	14**	.	1
Homalothecium nitens	.	.	.	10	.	1	19	9	19	.	26*	57**	51**	10	.
Aulacomnium palustre	.	.	.	27	.	5	7	2	11	.	33*	64**	83**	41*	19
Philonotis fontana	1	.	12	7	.	1	5	2	.	.	17*	.	26**	17*	4
Hypnum pratense	1	.	6	20	.	4	7	1	6	.	24*	14	57**	34*	1
Thuidium philibertii	3	.	.	7	1	5	9	4	.	.	14*	.	11	10	1
Drepanocladus vernicosus	.	.	.	.	.	1	.	.	.	.	5	50**	6	3	3
Meesia triquetra	.	.	.	.	.	.	.	.	3	.	.	14**	.	.	.
Calliergon trifarium	.	.	.	.	.	.	.	.	3	.	.	14**	.	.	.
Scorpidium scorpioides	.	.	.	.	.	.	.	.	.	.	.	7**	.	.	.
Catoscopium nigritum	.	.	.	.	.	.	.	.	.	.	.	7**	.	.	.
Riccardia multifida	.	.	.	5	.	.	.	.	.	.	.	21**	9*	.	1
Sphagnum subnitens	.	.	.	.	.	.	.	.	.	.	.	21**	17**	.	.
Sphagnum teres	1	.	.	2	.	1	2	.	.	.	.	43**	69**	24*	12
Sphagnum warnstorfii	.	.	.	2	.	.	.	.	.	.	.	36*	77**	7	3
Sphagnum girgensohnii	.	.	.	.	.	.	.	.	.	.	.	7*	.	.	1
Sphagnum contortum	.	.	.	5	.	1	.	.	.	.	.	21*	40**	.	3
Drepanocladus exannulatus	.	.	.	2	.	1	.	.	.	.	.	21*	26**	7	9*
Sphagnum flexuosum	.	.	.	2	.	.	.	.	.	.	.	36*	26*	24*	55**
Sphagnum fallax	.	.	.	.	.	.	.	.	.	.	.	29*	9	3	52**

Table 1: Cont.

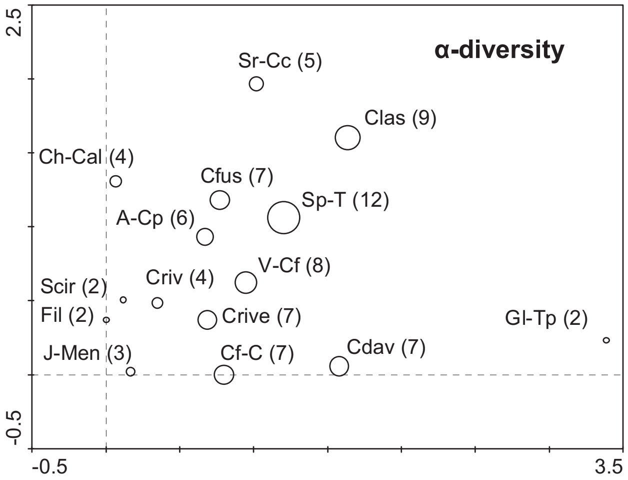
Syntaxa	Scir	Fil	Ch-Cal	A-Cp	J-Men	Criv	Crive	Cf-C	Cdav	Gl-Tp	V-Cf	Clas	Sp-T	Cfus	Sr-Cc
Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Paludella squarrosa	.	.	.	.	.	1	.	.	.	.	.	.	**14****	.	.
Calliergon stramineum	1	.	.	7	.	1	.	.	.	.	.	21	**40****	**28***	**55****
Lophocolea heterophylla	.	.	.	2	.	1	.	.	.	.	.	.	**9****	.	.
Sphagnum subsecundum	.	.	.	2	.	.	.	.	.	.	2	7	**17****	**14***	**9***
Riccardia incurvata	.	.	.	.	.	.	.	.	.	.	.	.	**3***	.	.
Philonotis tomentella	.	.	.	.	.	.	.	.	.	.	.	.	**3***	.	.
Pohlia nutans "sphagnicola"	.	.	.	.	.	.	.	.	.	.	.	.	**3***	.	.
Cephaloziella hampeana	.	.	.	.	.	.	.	.	.	.	.	.	**3***	.	.
Cephalozia bicuspidata	.	.	.	.	.	.	.	.	.	.	.	.	**3***	.	.
Hypnum lindbergii	.	.	.	2	.	1	.	.	3	.	.	.	**6***	.	1
Sphagnum palustre agg.	.	.	.	10	.	.	.	.	.	.	.	14	**17***	7	**46****
Marchantia polymorpha	1	.	.	2	.	1	.	1	.	.	2	.	3	**7***	.
Polytrichum commune	.	.	.	5	.	.	.	.	.	.	.	.	.	10	**61****
Sphagnum magellanicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**18****
Sphagnum capillifolium	.	.	.	.	.	.	.	.	.	.	.	7	6	7	**22****
Sphagnum papillosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**9****
Polytrichum strictum	.	.	.	.	.	.	.	.	.	.	.	.	3	.	**6****
Sphagnum rubellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**4****
Sphagnum squarrosum	.	.	.	.	.	.	.	.	.	.	.	.	3	3	**6***
Sphagnum angustifolium	.	.	.	.	.	.	.	.	.	.	.	.	3	.	**4***
Sphagnum denticulatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**3***
Absconditella sphagnorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Calypogeia neesiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Mylia taylorii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Sphagnum obtusum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Sphagnum inundatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Drepanocladus fluitans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Scapania irrigua	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Sphagnum cuspidatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1***
Species without fidelity to any vegetation type															
Rhizomnium punctatum	1	.	6	.	.	3	2	.	3	.	.	.	3	.	1
Rhytidiadelphus triquetrus	.	3	.	.	1	2	2	3	3	.	2	.	.	.	.
Barbula unguiculata	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Bryum capillare agg.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Dicranella varia	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.
Leptodictyum riparium	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.
Hylocomium splendens	.	.	.	2	.	1	.	.	.	.	.	.	.	3	.
Drepanocladus aduncus	.	.	.	2	.	2	.	.	3	.	5	.	3	3	.
Thuidium recognitum	.	.	.	.	.	2	2	1	3	.	2	.	.	.	.
Pellia endiviifolia	.	.	6	.	1	3	2	2	3	.	.	.	.	.	.
Preissia quadrata	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Thuidium delicatulum	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.

Table 2: List of threatened bryophytes recorded in the Carpathians mires. Category of threat follows Kučera & Váňa (2003) for the Czech Republic and Kubinská et al. (2001) for Slovakia.

Red List (common categories for CZ and SK): CR – critically endangered, EN – endangered, VU – vulnerable, DD – data deficient; SK Red List: NT – not threatened; CZ Red List: DD-va – vanished, LR-nt – lower risk – near threatened, LC-att – attention list, LC – not threatened.

Bryophyte species and number of finds	**category of threat**		**country of occurrence**
	in CZ	**in SK**	
Brachythecium mildeanum (17)	LC-att	NT	CZ, SK
Bryum weigelii (6)	LC-att	NT	CZ, SK
Calliergon giganteum (26)	VU	NT	CZ, SK
Calliergon trifarium (3)	CR	CR	SK, -
Campylium elodes (1)	DD-va	EN	SK, -
Cephaloziella hampeana (1)	DD	NT	SK, -
Cratoneuron decipiens (13)	LR-nt	NT	SK, -
Dicranum bonjeanii (15)	LR-nt	NT	CZ, SK
Drepanocladus cossonii (147)	LR-nt	NT	CZ, SK
Drepanocladus revolvens (1)	DD	NT	CZ, -
Drepanocladus vernicosus (16)	VU	NT	SK, -
Eucladium verticillatum (4)	LC-att	NT	CZ, SK
Homalothecium nitens (76)	LR-nt	NT	CZ, SK
Hypnum pratense (69)	LR-nt	NT	CZ, SK
Meesia triquetra (3)	CR	EN	SK, -
Paludella squarrosa (6)	CR	EN	SK, -
Philonotis caespitosa (3)	LC	EN	SK, -
Philonotis tomentella (1)	VU	NT	- , CZ
Physcomitriella patens (1)	LR-nt	-	- , CZ
Riccardia multifida (9)	LC-att	DD	CZ, SK
Scorpidium scorpioides (1)	VU	CR	SK, -
Sphagnum angustifolium (4)	DD	DD	SK, -
Sphagnum contortum (24)	VU	VU	CZ, SK
Sphagnum cuspidatum (2)	LC	VU	SK, -
Sphagnum denticulatum (4)	LC	EN	SK, -
Sphagnum inundatum (2)	LR-nt	EN	SK, -
Sphagnum obtusum (1)	LR-nt	CR	SK, -
Sphagnum papillosum (6)	LC	VU	CZ, SK
Sphagnum subnitens (9)	LC-att	DD	CZ, SK
Sphagnum warnstorfii (40)	LR-nt	NT	CZ, SK
Thuidium delicatulum (2)	LC-att	NT	SK, -

Figure 1. Differences among vegetation types in α-diversity (mean species number per relevé) and β-diversity (total species number recorded in vegetation type) showed by various sizes of circles dependent on number of species in vegetation types. The positions of vegetation types in DCA-ordination diagram are based on log-transformed frequency data from synoptic table. For explanation of abbreviations see Table 1.



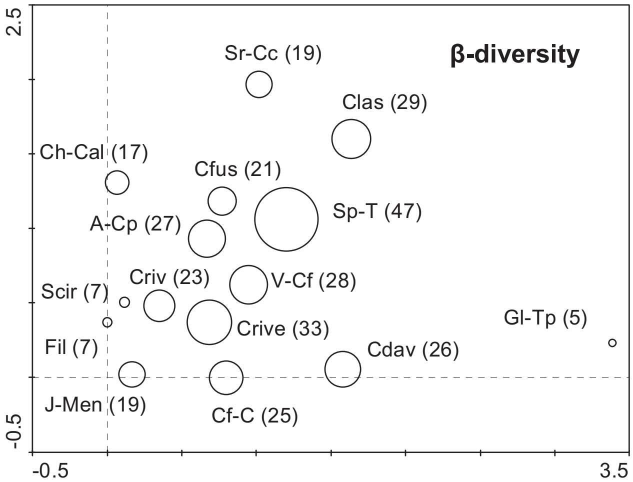


Figure 2: (A-N). The constancy of selected bryophyte species in particular vegetation types expressed by different circle sizes at the position of vegetation types in DCA ordination diagram. DCA ordination is based on log-transformed species frequency data from synoptic table (Table 1).

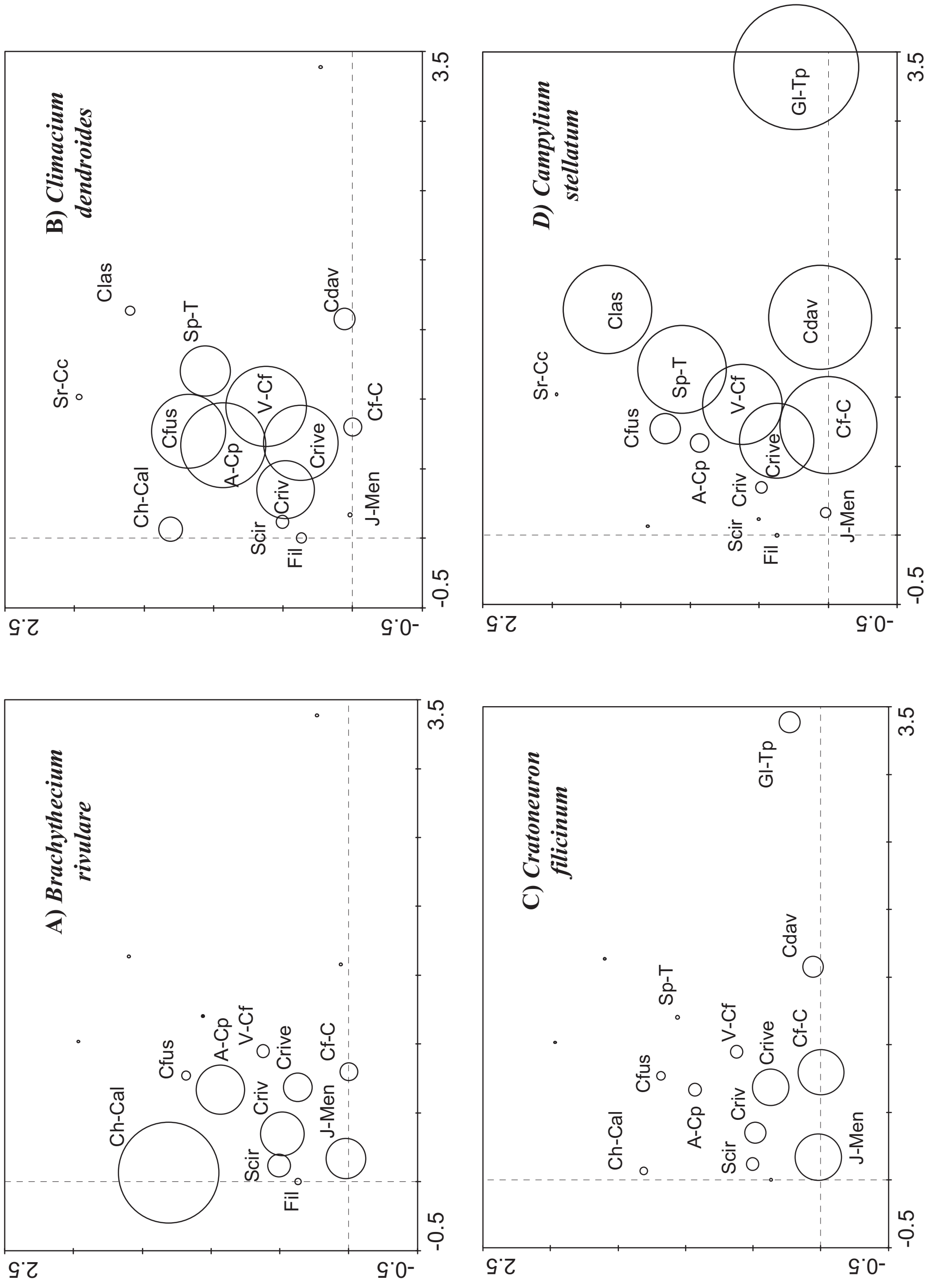


Figure 2: Cont.

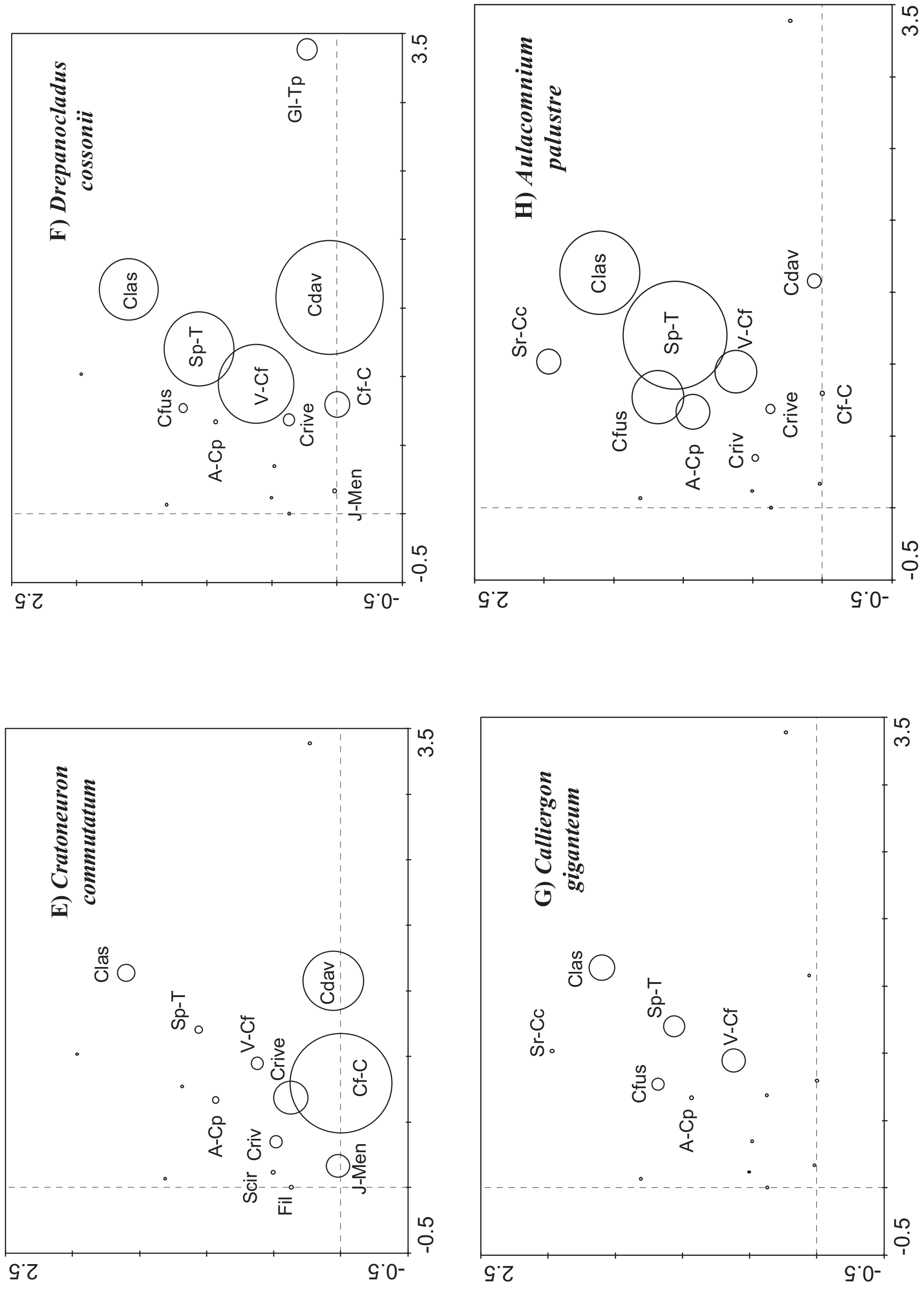


Figure 2: Cont.

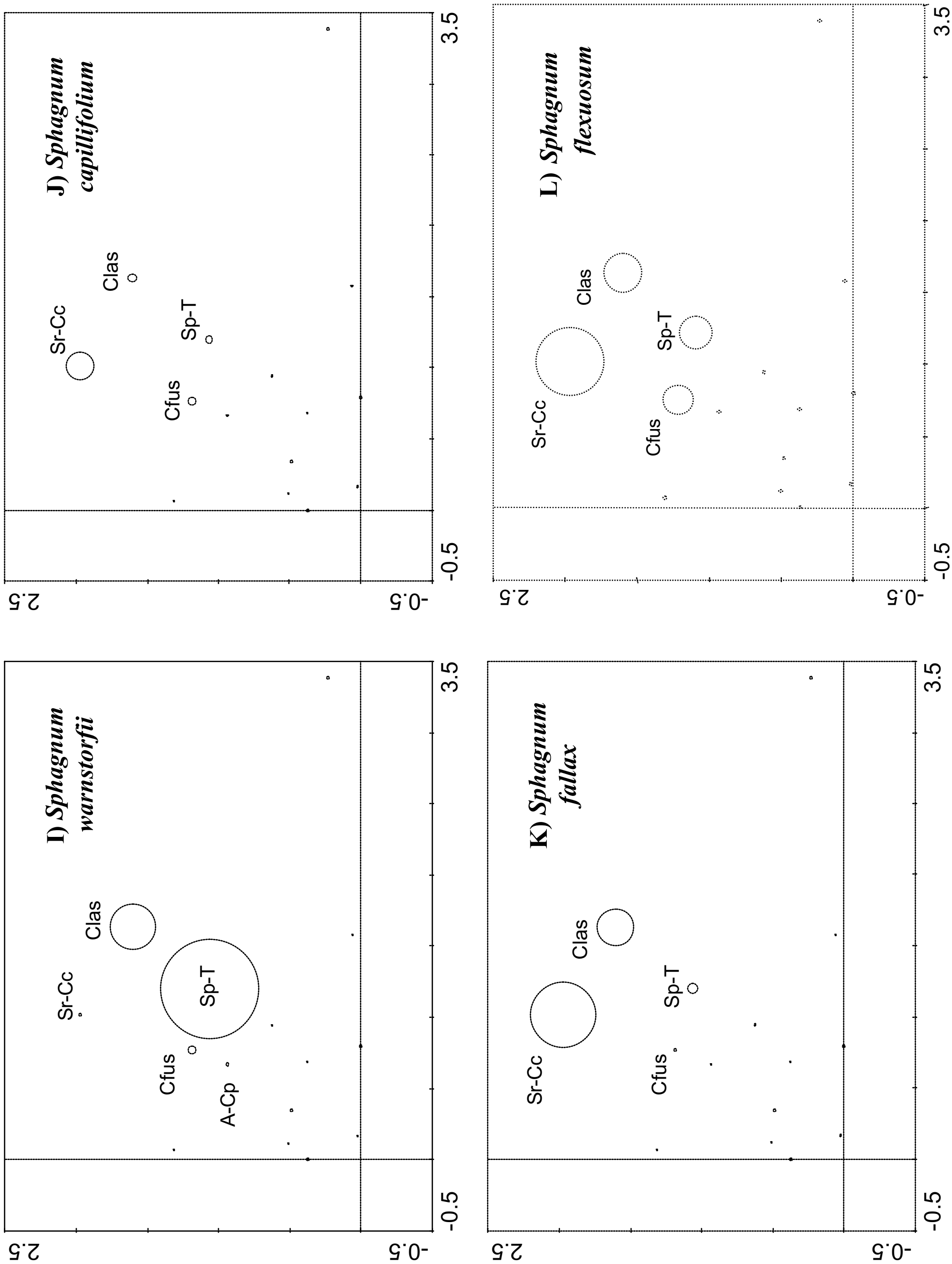


Figure 2: Cont.

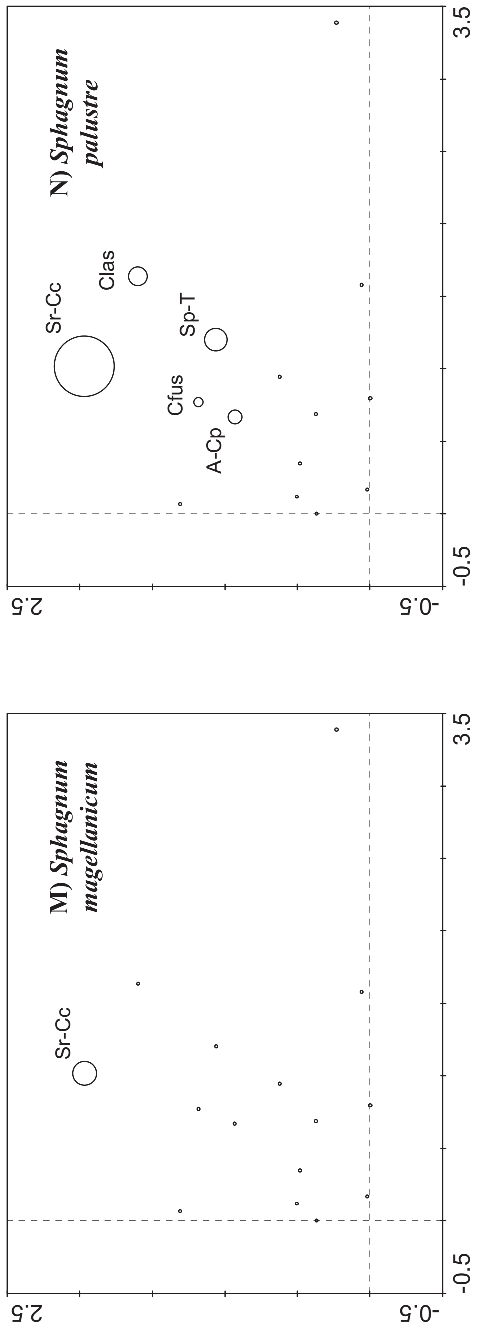


Figure 3: The position of the bryophyte and Chara species in DCA ordination diagram (eigenvalue: 1st axis 0.797, 2nd axis 0.443). Only species with the highest fit and weight are showed. Species list: Aneura pinguis, Aulacomnium palustre, Brachythecium rivulare, Bryum pseudotriquetrum, Calliergon stramineum, Calliergonella cuspidata, Campylium stellatum, Cirriphyllum piliferum, Chara species, Climacium dendroides, Cratoneuron commutatum, C. filicinum, Drepanocladus cossonii, Eurhynchium hians, Homalothecium nitens, Hypnum pratense, Fissidens adianthoides, Philonotis calcarea, P. fontana, Plagiomnium elatum, P. undulatum, Polytrichum commune, Rhytidiadelphus squarrosus, Scleropodium purum, Sphagnum fallax, S. flexuosum, S. palustre, S. teres, S. warnstorfii, Thuidium philibertii.

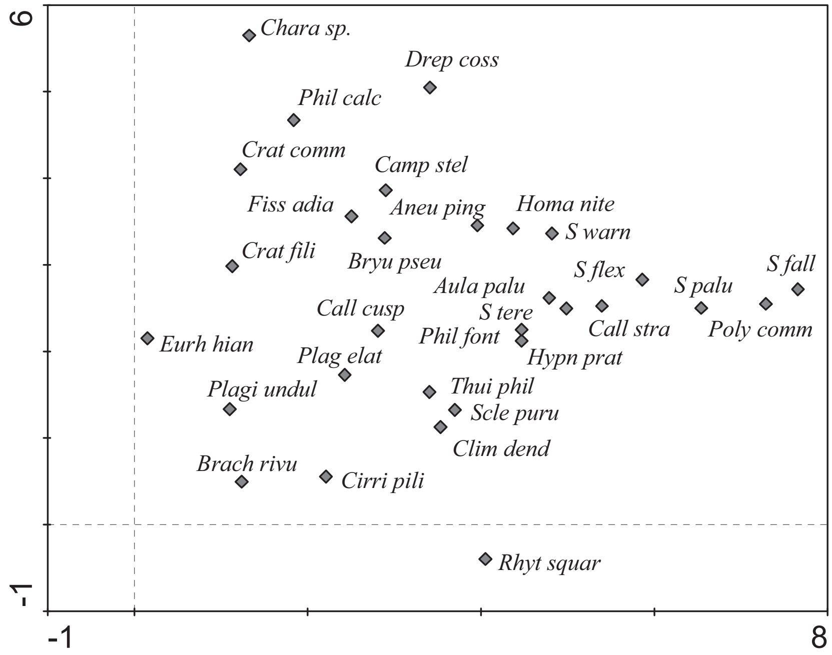
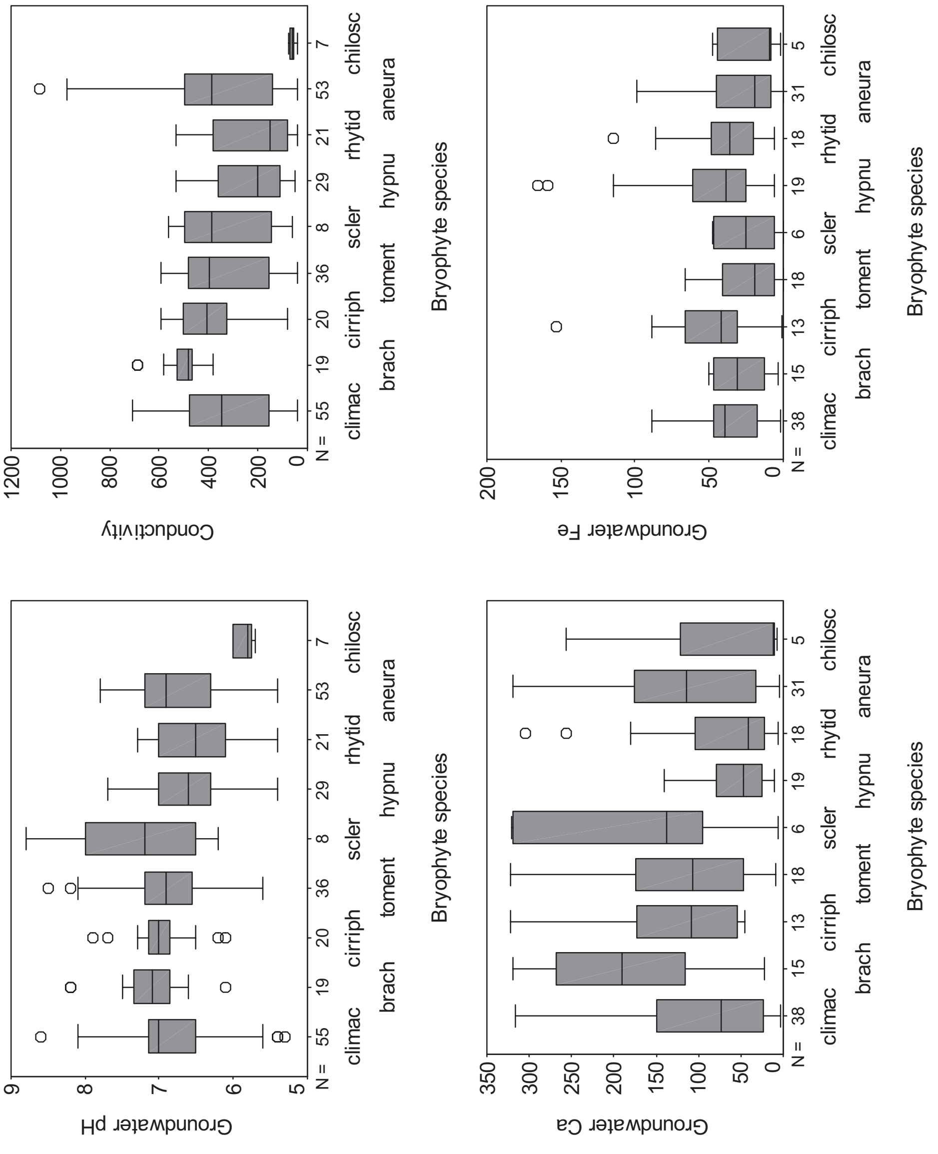


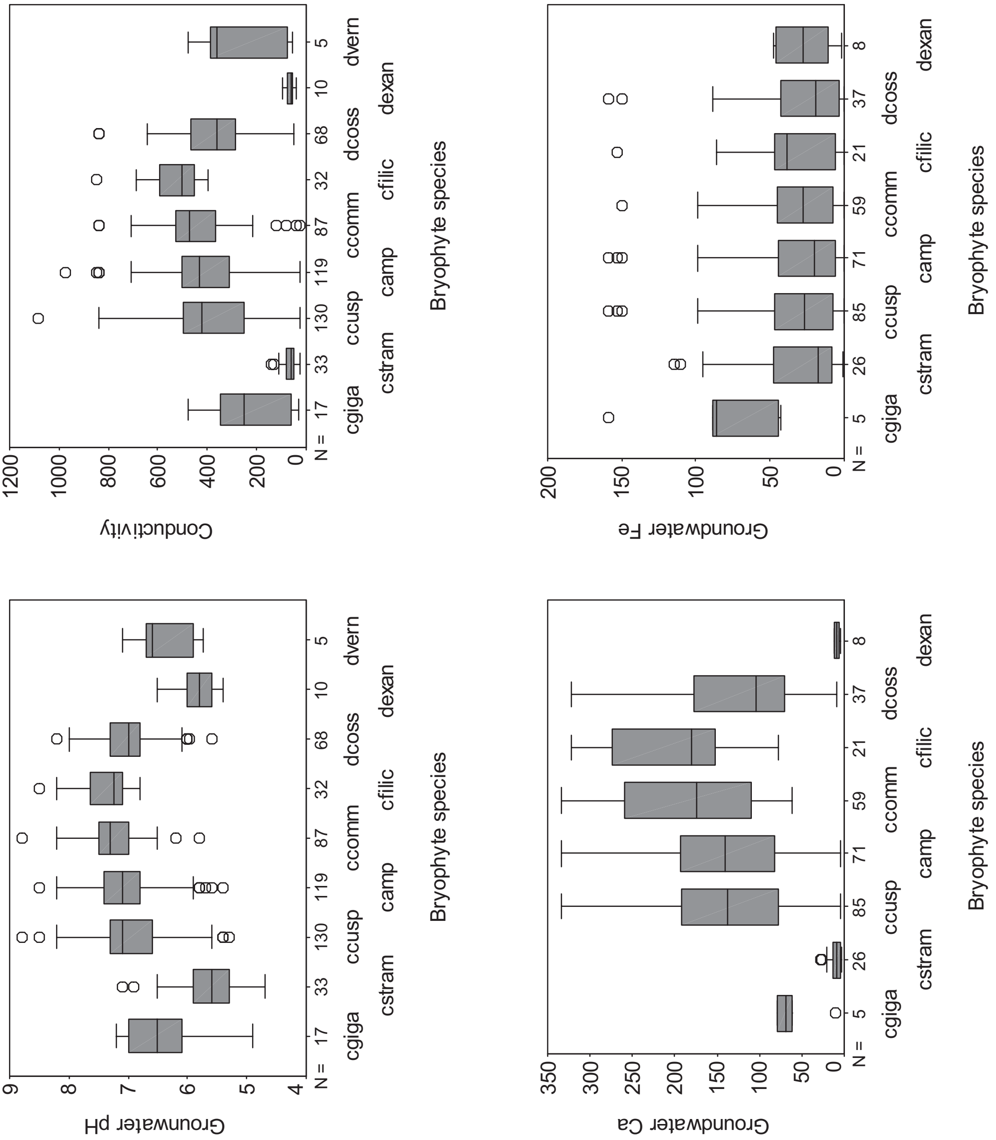
Figure 4: Box and whisker plots of the most important environmental variables (groundwater pH, conductivity in µS.cm^{-2}, Ca^{2+} and total dissolved Fe in mg.l^{-1}).

Climaciaceae: *Climacium dendroides* (climac); *Brachytheciaceae*: *Brachythecium rivulare* (brach), *Cirriphyllum piliferum* (cirriph), *Homalothecium nitens* (toment), *Scleropodium*



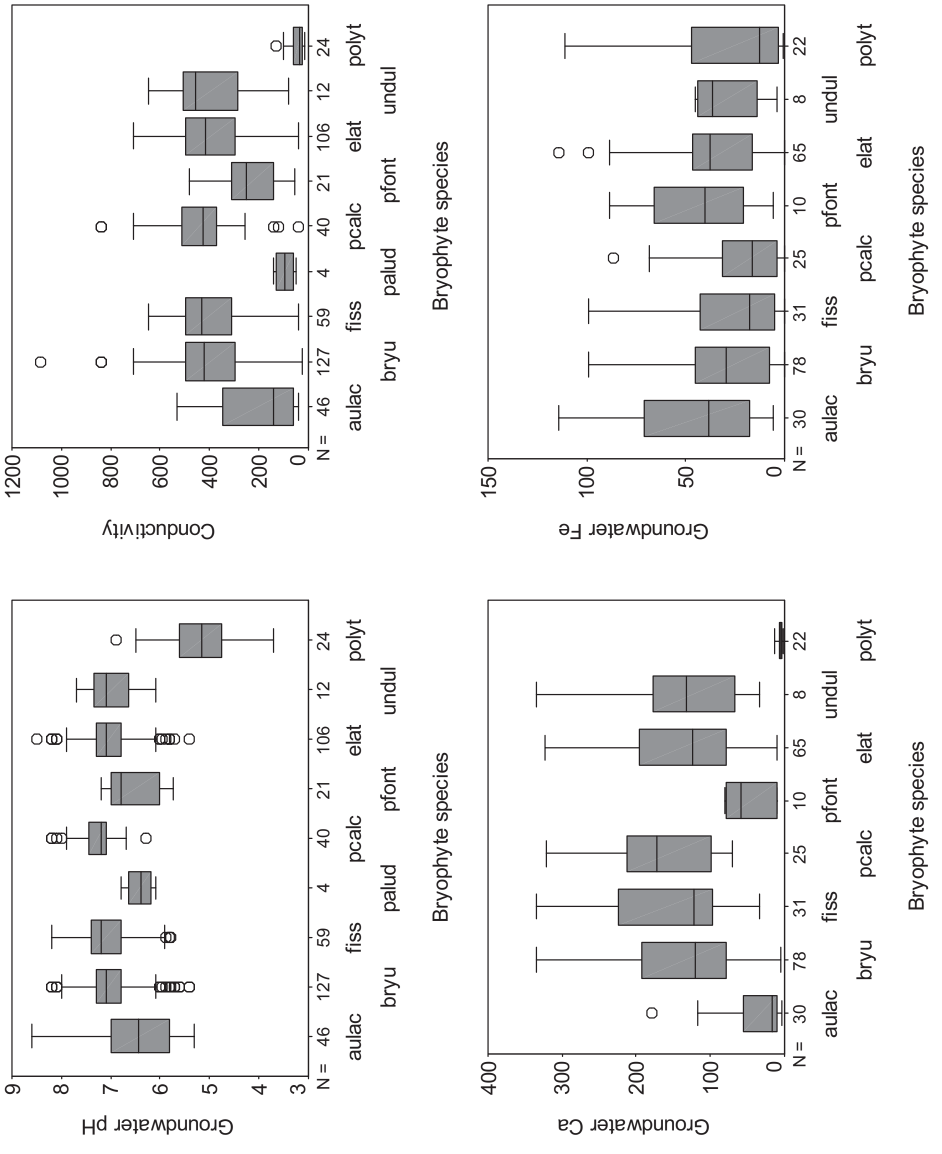
purum (scler); *Hypnaceae*: *Hypnum pratense* (hypnu), *Rhytidiadelphus squarrosus* (rhytid); liverworts: *Aneura pinguis* (aneura), *Chiloscyphus polyanthos* (chilosc).

Figure 5: Box and whisker plots of the most important environmental variables (groundwater pH, conductivity in µS.cm^{-2}, Ca^{2+} and total dissolved Fe in mg.l^{-1}).
Amblystegiaceae: *Calliergon giganteum* (cgiga), *Calliergon stramineum* (cstram), *Calliergonella cuspidata* (ccusp), *Campylium stellatum* (camp), *Cratoneuron commutatum*



(ccomm), *Cratoneuron filicinum* (cfilic), *Drepanocladus cossonii* (dcoss), *Drepanocladus exannulatus* (dexan), *Drepanocladus vernicosus* (dvern).

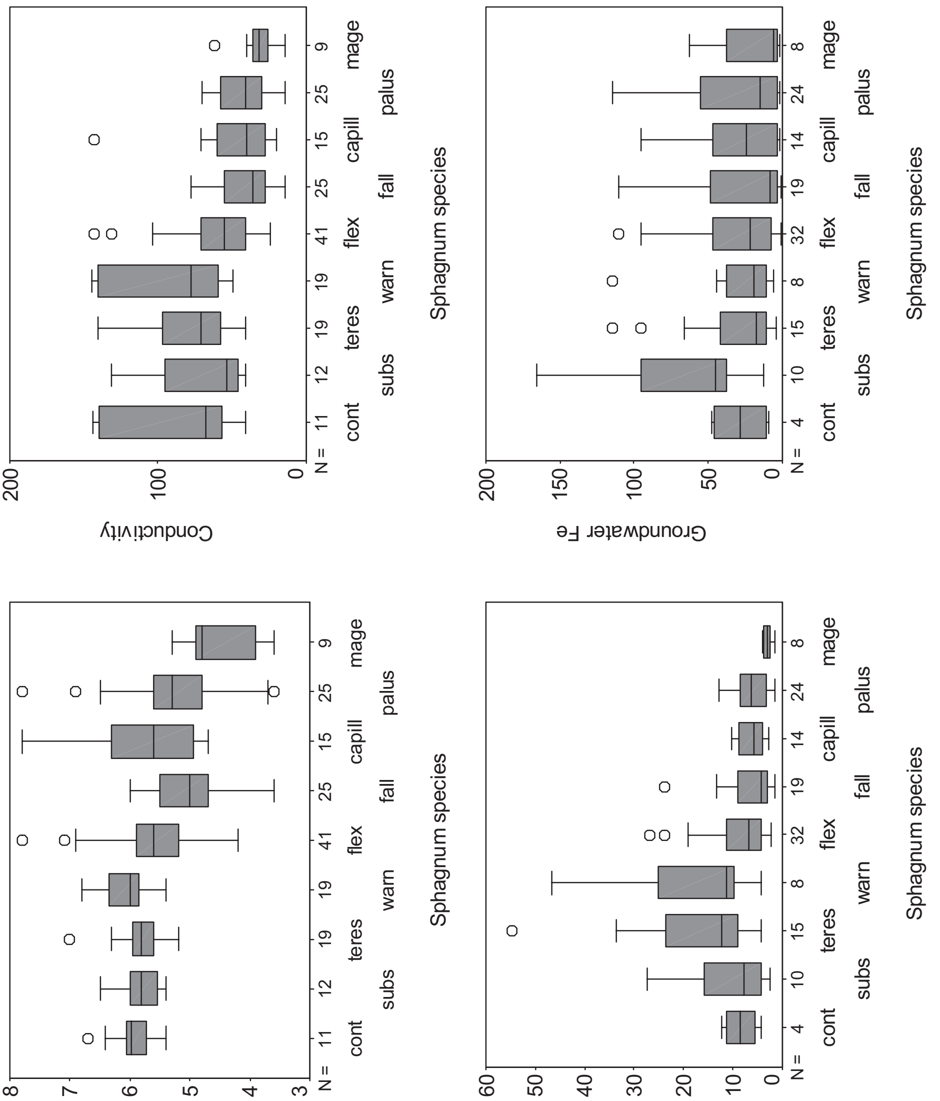
Figure 6: Box and whisker plots of the most important environmental variables (groundwater pH, conductivity in µS.cm^{-2}, Ca^{2+} and total dissolved Fe in mg.l^{-1}).
Aulacomniaceae: *Aulacomnium palustre* (aulac); *Bryaceae*: *Bryum pseudotriquetrum* (bryu); *Fissidentaceae*: *Fissidens adianthoides* (fiss); *Meesiaceae*: *Paludella squarrosa*



(palud); *Bartramiaceae*: *Philonotis calcarea* (pcalc), *Philonotis fontana* (pfont); *Mniaceae*: *Plagiomnium elatum* (elat), *Plagiomnium undulatum* (undul); Polytrichaceae: *Polytrichum commune* (polyt).

Figure 7: Box and whisker plots of the most important environmental variables (groundwater pH, conductivity in µS.cm^{-2}, Ca^{2+} and total dissolved Fe in mg.l^{-1}).

Sphagnaceae: *Sphagnum contortum* (cont), *S. subsecundum* (subs), *S. teres* (teres), *S.*



Chapter 9

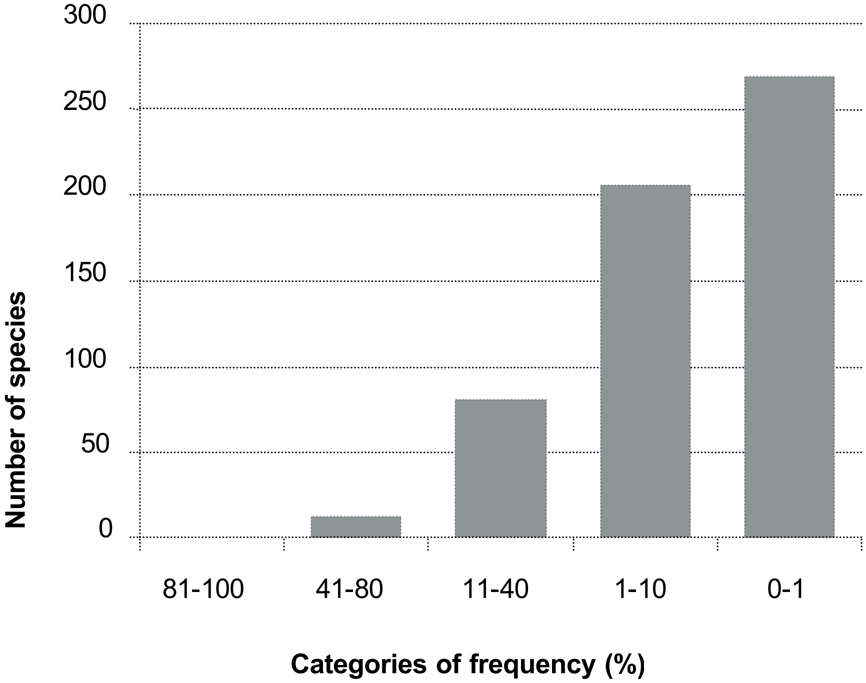
Vascular plants

M. Hájek

Introduction

Vascular plants are the most comprehensive taxonomical group studied in the Carpathian spring wetlands. In the more than eight hundred phytosociological relevés, altogether 568 species of vascular plants were recorded. However, half of this number represents rare species occurring in less than one per cent of relevés (Fig. 1). Only 93 species were recorded in more than 10% of the relevés. The high number of rare species results partly from the small areal extent of the studied fens and waterlogged meadows. Due to their small size, many species enter such communities from contact vegetation. Another reason for the high number of rare species is the low frequency of some species restricted to mire habitats. The majority of studied fens are successionally young (Chapter 3), therefore, some typical mire species are extremely rare in the study area.

Figure 1**:** Numbers of species in frequency categories. Note that categories in x-axis are not equal.



Cirsium rivulare is the most frequent species of waterlogged *Calthion* meadows, followed by several species generally overlapping between moist and mesic meadows (*Ranunculus acris*, *Poa trivialis, Rumex acetosa*, *Lathyrus pratensis, Festuca rubra*), several wetland ubiquists (*Equisetum palustre, Scirpus sylvaticus, Caltha palustris*), and *Carex panicea* (Tab. 1). *Potentilla erecta* is the most common species in fens (*Scheuchzerio-Caricetea fuscae*, see Tab. 2), followed by low sedges and cotton grasses (*Carex panicea, C. nigra, Eriophorum angustifolium, E. latifolium*). It is a gratifying fact that two threatened species, *Eriophorum latifolium* and *Dactylorhiza majalis* (Holub & Procházka 2000), are among the top ten of the most frequent fen species. Surprisingly, grassland ubiquist *Briza media* occurred in 49% of fen relevés, but it was not as frequent in the waterlogged *Calthion* meadows. This is probably because it is only weakly competitive, which limits the species to low-productive vegetation types. In general, *Potentilla erecta* and *Carex panicea* are the only species that occurred in more than 60% of all studied wetland plots (Tab. 3).

Table 1: Ten most frequent species in waterlogged *Calthion* meadows. Asterisks indicate the species with a positive fidelity to waterlogged *Calthion* meadows. * fidelity > 20; ** fidelity > 30

	species	frequency	fidelity
1.	*Cirsium rivulare*	71 %	**
2.	*Ranunculus acris*	66 %	*
3.	*Poa trivialis*	62 %	**
4.	*Equisetum palustre*	59 %	
5.	*Scirpus sylvaticus*	57 %	**
6.	*Lathyrus pratensis*	56 %	*
7.	*Rumex acetosa*	54 %	**
8.	*Carex panicea*	53 %	
9.	*Caltha palustris*	52 %	*
10.	*Festuca rubra*	52 %	

Table 2: Ten most frequent species in fen (*Scheuchzerio-Caricetea fuscae*) vegetation. Asterisks indicate the species with a positive fidelity to fen vegetation. * fidelity > 20; ** fidelity > 30

	species	frequency	fidelity
1.	*Potentilla erecta*	85 %	**
2.	*Carex panicea*	81 %	*
3.	*Eriophorum angustifolium*	78 %	**
4.	*Carex nigra*	64 %	*
5.	*Eriophorum latifolium*	56 %	**
6.	*Juncus articulatus*	55 %	*
7.	*Equisetum palustre*	53 %	
8.	*Briza media*	49 %	
9.	*Dactylorhiza majalis*	47 %	
10.	*Festuca rubra*	43 %	

Table 3: Ten most frequent species in all studied spring wetlands (total number of relevés = 843)

	species	frequency
1.	*Potentilla erecta*	65 %
2.	*Carex panicea*	65 %
3.	*Cirsium rivulare*	57 %
4.	*Equisetum palustre*	56 %
5.	*Ranunculus acris*	55 %
6.	*Carex nigra*	51 %
7.	*Eriophorum angustifolium*	50 %
8.	*Festuca rubra*	48 %
9.	*Scirpus sylvaticus*	42 %
10.	*Poa trivialis*	42 %

In contrast to the more ubiquitous species mentioned above, some boreal species (*Carex lasiocarpa*, *Oxycoccus palustris*) as well as subatlantic species *Hydrocotyle vulgaris, Lycopodiella innundata* and *Montia fontana* belong to the rarest mire and spring species. The first group of species is extremely rare especially in the westernmost flysch Carpathians across the border area between the Czech Republic and Slovakia where no relic stands occur. During our investigation, we were surprised to find *Carex lasiocarpa* in a fen meadow in the Zajacovci lonely house in the Slovak part of the Moravskoslezské Beskydy Mts (site no. I: 104). It represents the first finding of this species anywhere in this mountain range (Dítě & Hájek 2005). By analogy, *Oxycoccus palustris* and *Eriophorum vaginatum* are rare in the Moravskoslezské Beskydy Mts despite a high number of suitable habitats and despite the fact that these two species are rather common in some adjacent mountains. The former is currently known from two localities, and the latter only from one (Hájek & Malina 1998). Some species of this group reported by Duda (1950) from the Moravskoslezské Beskydy Mts (e.g. *Andromeda polifolia, Carex pauciflora*) no longer grow here as their habitats were destroyed by water reservoir "Šance".

The suboceanic species forming the second group of regionally rare species are very important from the biogeographical point of view. Several suboceanic species reach their eastern distribution limit in the study area. The following species occurring in the Slovak part of the Moravskoslezské Beskydy Mts are generally rare in Slovakia and occur only here and in the Borská nížina lowland and/or in the Orava region: *Juncus bulbosus, J. squarrosus, Hydrocotyle vulgaris, Montia fontana* (Valachovič & Hájek 2000), *Lycopodiella inundata* (Dítě et al. 2001), *Lotus uliginosus*; to a lesser degree this includes also *Carex demissa* and *Pedicularis sylvatica*. The highest concentration of these species in the Slovak part of the Moravskoslezské Beskydy Mts is in the surroundings of Hrubý Buk village. The suboceanic species enrich namely the communities of circumneutral fen meadows (Hájek & Hájková 2002).

The major geographical gradient in vascular plant distribution

The most apparent difference caused by biogeographical relationships within the West Carpathians is that between the flysch Outer-Carpathian and Inner-Carpathian rich fens. The latter belong to the *Caricetum davallianae* association and are characterised by a group of rich fen species, which do not occur in Outer-Carpathian rich fens (see Chapter 5.1.). By analogy, some mollusc species are also confined to this habitat type (Chapter 11).

This geographical gradient runs from the east to the west in our study area (Figure 1 in Chapter 3). The highest concentration of species confined to the Inner-Carpathian fens (*Carex hostiana, C. lepidocarpa, C. dioica, Primula farinosa, Sesleria uliginosa, Schoenus ferrugineus, Pinguicula vulgaris, Triglochin maritima, Equisetum variegatum, Tofieldia calyculata, Juncus alpinoarticulatus, Polygala amara, Trichophorum pumilum*) is remarkable in rich fens of the Inner-Carpathian basins, namely in the surroundings of the Velká Fatra Mts and in Liptov, Spiš and Horehron basins. Some of these species rarely penetrate westward from the regional distribution centre in the Strážovská hornatina Mts (*Carex lepidocarpa,* rarely *Pinguicula vulgaris*) and only very occasionally occur in the Outer Carpathians. *Carex lepidocarpa* was recorded only at a few sites in the Bílé Karpaty Mts (Hájek 1998); isolated historical and no longer existing localities of *Pinguicula vulgaris* and *Primula farinosa* were reported from the Moravskoslezské Beskydy Mts in the Czech Republic (Duda 1950, Kovanda 1992). On the contrary, some species of this group (*Carex lepidocarpa, C. dioica, Pinguicula vulgaris* and *Equisetum variegatum*) occur rather commonly northward in rich fens of the Orava region. *Pinguicula vulgaris* and *Equisetum variegatum* penetrate to the eastern part of the Kysucká vrchovina Mts, where they occur namely in rich fens in the Vychylovka open-air museum (site no. J: 125).

Carex davalliana, having similar ecological demands as the species of the above described group, is widely distributed in the West Carpathians. It had even more localities in the southwestern flysch region of the Bílé Karpaty Mts (Staněk et al. 1996), but recently it has been rare there. It occurs also in the Hostýnské vrchy Mts at the westernmost margin of our study area (Hájková & Hájek 2000) at present and, in addition, it has one isolated locality in a rich fen Štiavnik-Ráztoka in the Javorníky Mts (site no. I: 97).

On the other hand, other rich fen species, such as *Eriophorum latifolium, Carex flava, Parnassia palustris, Triglochin palustris, Blysmus compressus, Juncus articulatus, Epipactis palustris, Eleocharis quinqueflora, Polygala amarella,* and *Gymnadenia densiflora,* are distributed in rich fens of both regions, i.e. in the Inner as well as in the Outer West Carpathians.

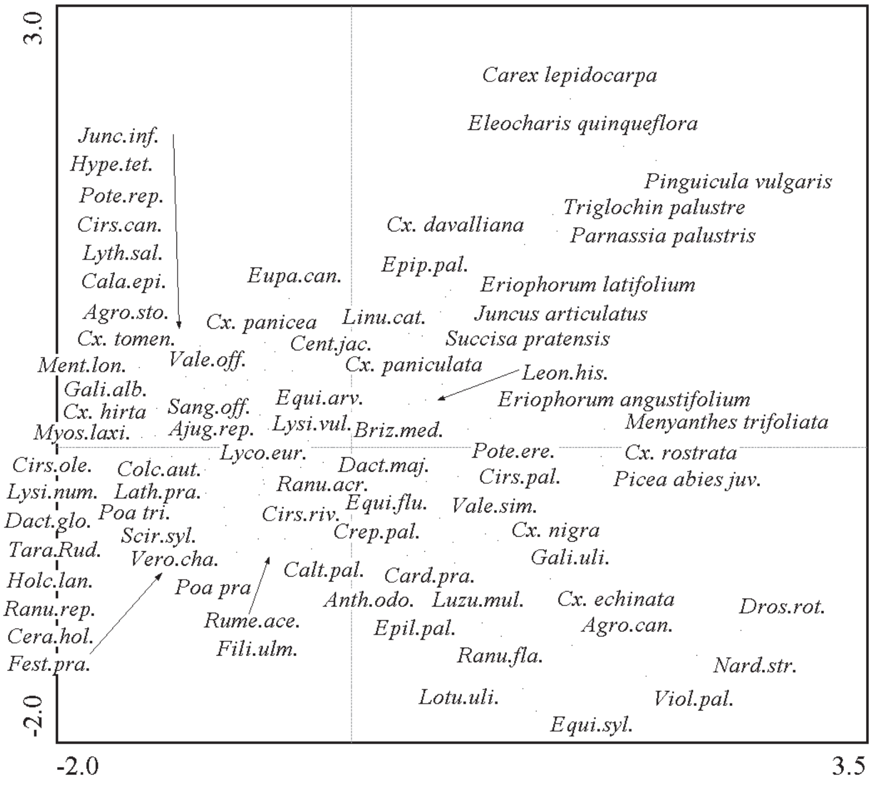
During our research, we took water samples from both the Outer- and Inner-Carpathian rich fens in order to assess whether the differences in geographical distribution of the plants can be related to the differences in water chemistry (unpublished data). We found that there is no indication of coincidence between water chemistry and geographical gradient in the above described plant distribution. We did not find any differences either in water pH or in mineral richness between the Outer- and Inner-Carpathian fens and between major vegetation types occurring there. Thus, the described differences are probably caused by other factors. The Inner-Carpathian rich fens are larger and older; the Outer-Carpathian fens are smaller and younger (Chapter 4). Higher numbers of rich fen species can live in relic and older Inner-Carpathian fens for a longer time. In addition, the larger extent of the Inner-Carpathian fen habitats reduces the negative role of the edge effect and competition. It was verified in Swiss rich fens, where Lienert & Fischer (2003) found that the population size, density, reproduction and vitality of *Primula farinosa* were significantly higher in the centres of large rich fen habitats than at their margins and at small-sized sites. This phenomenon may hold true also for the Carpathian fens.

Relations between major ecological factors and the occurrence of vascular plants

Base saturation is the major ecological factor controlling the species composition and the distribution of vegetation in our study area (Hájek 2002, Hájek et al. 2002). However, this feature concerns mostly bryophytes (Hájková & Hájek 2005, see also Chapter 8). In order to identify the major gradients in species composition solely for vascular plants, we subjected the vegetation data on vascular plants to indirect ordination (Correspondence analysis). This analysis revealed two principal gradients in the species composition of vascular plant communities (Fig. 2). The first gradient, only a little more important than the second one, is connected to soil quality and nutrient availability. The vegetation samples were ranked from nutrient- and mineral-rich clayey soils lacking fen peat to organic soils. The species characterising the extreme nutrient- and mineral-rich part of this gradient are mostly the species with a ruderal tendency (*Carex hirta, Dactylis glomerata, Taraxacum* sect. *Ruderalia*, *Agrostis stolonifera, Ranunculus repens*), which occur in disturbed and eutrophicated vegetation of the *Junco inflexi-Menthetum longifoliae* association (Table 2 in Chapter 5) and in highly productive *Calthion* vegetation (e.g. *Cirsium oleraceum, Scirpus sylvaticus, Lathyrus pratensis, Poa trivialis*). The opposite end of this gradient is characterised by species of both the calcium-rich though nutrient-limited fens (e.g. *Carex lepidocarpa, Eleocharis quinqueflora, Pinguicula vulgaris*) and the calcium-poor acidic *Sphagnum*-fens (e.g. *Drosera rotundifolia*). Low-productive *Calthion* meadows, rich in species, form the central part of this continuum.

Figure 2**:** Indirect ordination (Correspondence analysis) of vascular plant data. Only the species with the highest weight and fit are shown. Eigenvalues of the axes: 0.365 (1st); 0.295 (2nd). Arrows are used in cases of high concentration of species optima in a small area of the diagram.

List of abbreviated species: *Agrostis canina, Agrostis stolonifera, Ajuga reptans, Anthoxanthum odoratum, Briza media, Calamagrostis epigejos, Caltha palustris, Cardamine pratensis, Carex hirta, Carex tomentosa, Centaurea jacea, Cerastium holosteoides, Cirsium canum, Cirsium oleraceum, Cirsium palustre, Cirsium rivulare, Colchicum autumnale, Crepis paludosa, Cx. = Carex, Dactylis glomerata, Dactylorhiza majalis, Drosera rotundifolia, Epilobium palustre, Epipactis palustris, Equisetum arvense, Equisetum fluviatile, Equisetum sylvaticum, Eupatorium cannabinum, Festuca pratensis, Filipendula ulmaria, Galium album, Galium uliginosum, Holcus lanatus, Hypericum tetrapterum*, *Juncus inflexus*, *Lathyrus pratensis, Leontodon hispidus, Linum catharticum, Lotus uliginosus, Luzula multiflora, Lycopus europaeus, Lysimachia nummularia, Lysimachia vulgaris, Lythrum salicaria, Mentha longifolia, Myosotis palustris* subsp. *laxiflora, Nardus stricta, Poa pratensis, Poa trivialis, Potentilla erecta, Potentilla reptans, Ranunculus acris, Ranunculus flammula, Ranunculus repens, Rumex acetosa, Sanguisorba officinalis, Scirpus sylvaticus, Taraxacum* sect. *Ruderalia, Valeriana officinalis, Valeriana simplicifolia, Veronica chamaedrys, Viola palustris*.



The second principal gradient is clearly connected to the base saturation, and it differentiates in particular the “fen” part of the first gradient described above. Poor fen species (e.g. *Drosera rotundifolia, Viola palustris, Carex echinata, Agrostis canina*) are located at the bottom right of the scatter (Fig. 1), whereas rich fen species (e.g. *Carex lepidocarpa, C. davalliana, Triglochin palustris, Parnassia palustris*) occur at the upper right. The next important ecological group, which is visible in the scatter, is a group of species with the optimum in moderately mineral-rich and at the same time nutrient-poor peat soils: *Menyanthes trifoliata, Cirsium palustre, Carex nigra, Valeriana simplicifolia, Eriophorum angustifolium,* and *Carex rostrata*. However, the niches of a majority of these species are rather wide, which may be the reason why these species were ordered at medium position between the poor and rich fen indicators.

Threatened species

Altogether 97 vascular plant species found in habitats of our concern are threatened either in the Czech Republic or in Slovakia (Tab. 4). There are some differences among red lists of both neighbouring countries because lime-rich habitats are extremely rare in the Czech Republic as a whole, even though they are relatively common in Slovakia. For example, rich fen species *Eriophorum latifolium*, *Blysmus compressus* and *Polygala amarella* are listed among highly threatened species in the Czech Republic, but in Slovakia they are regarded as non-threatened species. On the contrary, acidophilous species *Eriophorum vaginatum, Trientalis europaea* and *Juncus bulbosus* are out of danger in the Czech Republic, whereas in Slovakia they belong to endangered or vulnerable species. Nevertheless, basiphilous species prevail over the acidophilous in the common red list (Tab. 4). There are several principal reasons for this. First, there are generally more calcicole than calcifuge species in the Central European vascular plant flora (Ewald 2003); second, basiphilous communities have been recently rarer than the acidophilous and, therefore, they would still be more threatened even during equal potential extinction of both acidic and alkaline habitats. The third reason is that lime-rich fens are often located at lower altitudes where the agricultural pressure is more intense than in the mountains. Fourth, rich fen species are often eliminated from the formerly moderately alkaline habitats due to *Sphagnum recurvum* agg. expansion, which causes the acidification of surface water. This process is more common at present because it is facilitated by increased ammonium and phosphorus concentrations in fen waters, which suppress rich fen mosses but not fast-growing *Sphagnum* species (Kooijman & Kanne 1993). These changes at rich fens have been observed even in our study area (Hájek et al. 2002).

From 9 to 47 threatened vascular plant species were found in the particular vegetation types, including those occurring only scarcely and randomly there. The highest number (47) concerns both the Inner-Carpathian calcareous fens and the waterlogged *Cirsietum rivularis* meadows. However, such a number of threatened species is not comparable within vegetation types, because it is influenced by the total number of relevés and by the number of accidental species entering spring wetlands from contact communities. To eliminate the effect of accidental species without any significant link to wetland communities, we calculated the fidelity of each species to each vegetation type in order to find out which threatened species are bound to a particular vegetation type. Afterwards, we counted the numbers of threatened species reaching the fidelity value above 10, separately in each vegetation type. Vegetation types were then compared and the results were quite different from those obtained by mere comparison of absolute values (Tab. 5). The results show that all *Calthion* and *Caricion fuscae* meadows are less important in terms of vascular-plant gene pool conservation than the rich fens. Both the Inner-Carpathian calcareous fens (*Caricetum davallianae*) and moderately calcium-rich fens with calcitolerant peat mosses (*Sphagno warnstorfii-Tomenthypnion*) have the highest concentration of threatened species within all the studied habitats (24-25). The latter are also noted for their high bryophyte diversity and high representation of threatened bryophyte species (Chapter 8). The high number of threatened species, as well as high sensitivity to changes in nutrient balance (Hájek et al. 2002), make this habitat type needful for conservation priority. Compared to moderately calcium rich fens, the former (*Caricetum davallianae*) is still more important from the viewpoint of the conservation of vascular plant gene pool. Despite low alpha-diversity (Tab. 3 in Chapter 5), *Caricetum davallianae* hosts 45 threatened species from which 25 are significantly linked to this habitat type. It mostly concerns diagnostic species occurring very frequently and abundantly there. Eight threatened species were recorded in more than 50% relevés (*Carex davalliana, C. lepidocarpa, Epipactis palustris, Eriophorum latifolium, Parnassia palustris, Pinguicula vulgaris, Primula farinosa,* and *Triglochin palustris*); this is twice as much as in the communities of *Sphagno warnstorfii-Tomenthypnion* all. (see Tab. 4).

The third important vegetation type is that of the Outer-Carpathian calcium-rich albeit peat-forming fens (*Valeriano-Caricetum flavae*), which is followed by four other fen types. The lowest number of threatened species is linked to the habitats of waterlogged meadows, probably due to their anthropogenic origin and short Holocene existence. Their higher production of aboveground biomass, compared to fens, probably also plays a certain role, because the majority of presently threatened species are of low competition ability. *Cirsietum rivularis* waterlogged meadows displayed the inequality between total number of recorded threatened species (47) and threatened species linked to this vegetation type (2). This inequality is partly caused by vegetation dynamics and by the influence of contact communities. In our study area, *Cirsietum rivularis* often develops at former fen habitats or at their margins after an increase in nutrient supply combined with the cessation of mowing. Threatened rich fen species only survive there from previous successional stages. The next reason for this inequality can be seen in a wide ecological niche for the threatened species, which frequently occur here (e.g. *Dactylorhiza majalis, Valeriana simplicifolia*). As a result, only two slightly threatened and not so frequent species *Listera ovata* and *Senecio subalpinus* reach notable fidelity to this vegetation type.

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Table 4: Percentage frequency of threatened species in particular vegetation types. The vascular plant species, which are threatened either in the Czech Republic or Slovakia, or in both countries, were selected from the total data set. In the brackets, the first code indicates the degree of threat in the Czech Republic and the second in Slovakia. Code "n" means that the species does not occur in the country; code "–" is used when the species is not threatened in the country. Degrees of threat, which are presented in the brackets, were taken from Holub & Procházka (2000) for the Czech Republic and from Marhold (1998) for Slovakia. For the explanation of column numbers see Tabs. X and X. If the species fidelity to the vegetation type was higher than 10, the frequency is typed in bold. Species are listed alphabetically.

Abbreviated taxa: *Centaurium littorale* subsp. *compressum*, *Ophrys holosericea* subsp. *holubyana*, *Pedicularis sceptrum-carolinum*, *Plantago maritima* subsp. *ciliata, Salix repens* subsp. *rosmarinifolia*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Arabis sudetica (C1, -)	.	.	.	.	.	.	.	.	**3**	.	.	.	.	.	.
Blysmus compressus (C2, -)	3	.	.	2	7	3	12	**20**	19	33	**26**	.	6	3	.
Calla palustris (C3, CRr)	.	.	.	.	.	.	.	.	.	.	.	**7**	**3**	.	.
Carex appropinquata (C2, VU)	.	.	.	.	.	.	.	.	.	.	.	.	.	**3**	.
Carex canescens (-, LR)	6	.	19	12	.	3	.	.	.	.	7	.	9	7	**18**
Carex davalliana (C2, VU)	.	5	.	5	3	9	19	16	**100**	17	29	7	**34**	3	1
Carex diandra (C2, EN)	.	.	.	2	.	.	.	1	.	.	5	.	.	3	**4**
Carex dioica (C1, ENr)	.	.	.	.	.	.	.	.	**19**	.	7	**36**	**40**	3	3
Carex distans (C2, VU)	.	.	.	.	11	5	9	**19**	6	**67**	.	.	.	.	.
Carex flava (C4a, -)	13	8	.	41	27	30	**65**	**62**	25	.	55	29	**60**	38	7
Carex hartmanii (C3, VUr)	.	5	.	.	.	2	.	2	.	.	7	.	3	.	.
Carex hordeistichos (C1, EN)	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Carex hostiana (C2, VU)	.	.	.	.	.	1	2	.	**44**	.	.	.	6	.	.
Carex chordorrhiza (C1, CRr)	.	.	.	.	.	.	.	.	.	.	.	**14**	**6**	.	.
Carex lasiocarpa (C2, VU)	.	.	.	.	.	.	2	.	.	.	.	**79**	.	7	1
Carex lepidocarpa (C2, -)	.	.	.	.	1	1	5	**19**	**69**	.	2	14	14	.	.
Carex limosa (C2, CRr)	.	.	.	.	.	.	.	.	3	.	.	**14**	.	.	1
Carex otrubae (C4a, -)	1	.	.	.	**7**	3	2	1	.	.	.	.	.	3	.
Carex paniculata (C4a, EN)	6	13	.	2	22	22	23	**25**	19	17	7	.	9	3	4
Carex pauciflora (C3, EN)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**4**
Carex pulicaris (C2, ENr)	.	.	.	.	.	.	.	.	.	.	.	.	**3**	.	.
Carex umbrosa (C3, VU)	.	.	.	.	.	1	.	.	.	.	2	.	.	.	.
Carex viridula (C2, ENr)	.	.	.	.	.	.	.	2	3	.	.	**7**	.	.	.
*Centaurium * compressum* (C1, CRr)	.	.	.	.	.	.	.	.	.	**50**	.	.	.	.	.
Cirsium pannonicum (C3, -)	.	.	.	.	.	1	.	2	.	.	.	.	.	.	.
Cladium mariscus (C1, CRr)	.	.	.	.	.	.	.	.	.	**17**	.	.	.	.	.
Cyperus fuscus (C3, -)	.	.	.	.	**4**	.	.	.	.	.	.	.	.	.	.
Dactylorhiza fuchsii (C4, VU)	.	.	.	2	.	1	.	.	3	.	**7**	.	**9**	3	3
Dactylorhiza incarnata (C2, EN)	4	.	.	.	4	2	2	**9**	6	17	2	7	3	.	.
Dactylorhiza maculata (C1, CRr)	.	.	.	2	.	.	.	.	.	.	.	**14**	.	.	3
Dactylorhiza majalis (C3, VU)	22	8	38	**63**	9	46	**63**	41	50	.	**83**	64	**69**	34	28
Drosera anglica (C1, CRr)	.	.	.	.	.	.	.	.	3	.	.	**7**	.	.	1
Drosera rotundifolia (C3, EN)	.	.	.	.	.	.	.	.	3	.	.	14	**49**	14	**46**
Eleocharis quinqueflora (C1, VU)	.	.	.	.	.	.	2	9	**39**	**33**	**21**	**36**	**20**	.	.
Eleocharis uniglumis (C2, DD)	.	.	.	2	.	5	.	5	.	**33**	10	.	3	7	.
Epipactis palustris (C2, VU)	.	.	.	12	5	11	**67**	**43**	**56**	50	**55**	36	34	7	.
Equisetum telmateia (C4a, -)	8	5	6	.	9	7	9	9	.	.	10	.	.	.	.
Equisetum variegatum (C1, EN)	.	.	.	5	.	1	2	2	6	.	**7**	.	.	.	.
Eriophorum latifolium (C2, -)	1	.	.	22	7	18	**91**	**80**	**81**	17	**88**	36	**63**	14	1
Eriophorum vaginatum (-, VU)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**3**
Galium boreale (C4a, -)	4	**13**	.	2	3	6	.	2	.	.	.	.	.	.	.
Gentiana asclepiadea (C4a, -)	.	**3**	.	.	.	.	.	.	.	.	.	.	.	.	.
Glaux maritima (C1, EN)	.	.	.	.	.	.	.	.	.	**50**	.	.	.	.	.
Glyceria nemoralis (C3, -)	3	.	**12**	.	1	1	2	1	3	.	.	.	.	3	.
Gymnadenia conopsea s.s. (C3, VU)	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.
Gymnadenia densiflora (C1, CRr)	.	.	.	5	.	1	5	**17**	14	.	**24**	.	.	.	.
Hydrocotyle vulgaris (C3, CRr)	.	.	.	.	.	.	.	.	.	.	**2**	.	.	.	.
Iris sibirica (C3, VU)	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Juncus alpinoarticulatus (C3, LRr)	.	.	.	.	.	1	.	2	**25**	.	.	.	.	.	.
Juncus bulbosus (-, EN)	.	.	.	.	.	.	.	.	.	.	.	.	**14**	**14**	**6**
Juniperus communis (C3, -)	.	.	.	.	.	.	.	3	3	.	**7**	.	3	.	3
Liparis loeselii (C1, CRr)	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Listera ovata (C4a. VU)	1	5	.	15	3	**15**	**21**	5	.	.	17	.	11	3	.

Lotus uliginosus(-, EN)	10	5	19	15	.	5	2	.	.	.	2	14	**34**	**45**	**25**
Lycopodiella inundata (C2, CR)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Menyanthes trifoliata (C3, EN)	.	5	6	2	.	2	2	.	**17**	.	10	**79**	9	**17**	10
Molinia caerulea (-, VU)	.	.	.	2	.	2	5	2	**42**	**50**	2	**29**	**17**	7	1
Montia fontana (C1, CR)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ophioglossum vulgatum (C2, CR)	.	**5**	.	.	.	2	.	1	.	.	.	.	.	.	.
*Ophrys * holubyana* (C1, CRr)	.	.	.	.	.	.	.	**3**	.	.	.	.	.	.	.
Oxycoccus palustris (C3, CR)	.	.	.	.	.	.	.	.	.	.	.	**57**	**20**	3	**16**
Parnassia palustris (C2, LR)	.	.	.	15	1	2	9	**21**	**67**	**100**	**40**	7	**34**	10	1
Pedicularis palustris (C2, EN)	.	.	.	7	.	1	.	1	8	17	.	**21**	**17**	.	1
P. sceptrum-carolinum (A1, CRr)	.	.	.	.	.	.	.	.	**3**	.	.	.	.	.	.
Pedicularis sylvatica (C3, VU)	.	.	.	.	.	.	.	.	.	.	.	.	.	7	**13**
Peucedanum palustre (-, LR)	.	.	.	.	.	.	.	.	.	.	.	.	.	3	**3**
Pinguicula alpina (n, VU)	.	.	.	.	.	.	.	2	**6**	.	.	.	.	.	.
Pinguicula vulgaris (C2, EN)	.	.	.	.	.	.	.	1	**69**	**50**	12	**50**	**29**	.	1
*Plantago * ciliata* (C1, EN)	.	.	.	.	.	.	.	.	.	**67**	.	.	.	.	.
Polemonium caeruleum (C3, -)	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Polygala amara (C1, -)	.	.	.	.	.	.	.	.	**17**	.	.	.	.	.	.
Polygala amarella (C2, -)	.	.	.	.	.	.	2	**11**	8	.	**14**	.	3	.	.
Potentilla palustris (C4a, VU)	.	.	.	2	.	.	2	.	.	.	.	.	.	3	**9**
Primula farinosa (A1, EN)	.	.	.	.	.	.	.	.	**72**	**83**	.	7	**26**	.	.
Pyrola rotundifolia (C2, -)	.	.	.	.	.	.	.	.	.	.	2	**21**	**6**	.	.
*Salix * rosmarinifolia* (C3, VU)	1	5	.	.	.	1	2	3	**11**	.	.	7	**11**	.	.
Scabiosa lucida (C2, -)	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.
Scorzonera humilis (C3, ENr)	.	.	.	.	.	1	.	.	.	.	**2**	.	.	.	.
Senecio subalpinus (C2, -)	.	.	.	5	.	**5**	.	.	.	.	.	7	3	.	.
Serratula tinctoria (C4a, -)	3	11	.	.	4	4	2	6	.	.	2	.	.	.	.
Sesleria uliginosa (C2, CRr)	.	.	.	.	.	.	.	.	**11**	.	.	.	.	.	.
Schoenoplectus tabernaemontani (C2, LR)	.	.	.	.	.	.	.	.	3	**100**	.	.	.	.	.
Schoenus ferrugineus (C1, ENr)	.	.	.	.	.	.	.	.	**8**	**33**	.	.	.	.	.
Taraxacum sect. *Palustria*	1	.	.	.	.	1	5	**10**	.	.	**12**	.	3	3	.
Tephroseris crispa (C4a, -)	.	3	.	.	.	2	.	2	.	.	5	.	.	.	.
Tofieldia calyculata (C1, -)	.	.	.	.	.	.	.	2	**39**	17	.	.	3	.	.
Trientalis europaea (-, VU)	.	.	.	.	.	.	.	.	.	.	.	**14**	.	3	**4**
Trifolium fragiferum (C3, LR)	.	.	.	.	.	.	.	.	.	.	**2**	.	.	.	.
Trifolium spadiceum (C3, -)	.	.	.	.	.	1	.	.	3	.	2	.	**6**	.	.
Triglochin maritima (C1, EN)	.	.	.	.	.	.	.	.	**14**	**100**	.	.	.	.	.
Triglochin palustris (C2, VU)	.	.	.	15	.	4	12	**22**	**64**	**100**	**38**	29	20	7	6
Trichophorum pumilum (n, EN)	.	.	.	.	.	1	.	.	3	**100**	.	.	.	.	.
Trollius altissimus (C3, VU)	1	3	.	.	.	2	2	1	3	.	2	.	**9**	.	.
Utricularia minor (C2, EN)	.	.	.	.	.	.	.	.	**3**	.	.	.	.	.	.
Valeriana dioica (C4a, -)	6	3	.	5	14	19	30	**40**	25	17	.	.	.	.	.
Valeriana simplicifolia (C2, VU)	10	13	25	44	.	27	30	22	42	.	**81**	50	**49**	31	6
Valeriana tripteris (C2, -)	.	.	.	.	.	.	.	.	**3**	.	.	.	.	.	.
Veronica scutellata (C4a, LR)	1	.	6	**7**	.	1	.	.	.	.	**7**	.	.	**10**	.

Table 5: Representation of threatened vascular plants in vegetation types (see Tab. X for the list of threatened plants). Only those species, which were significantly bound to a particular vegetation type with fidelity > 10, were involved. The total number of all threatened species, which were recorded at least once in the vegetation type, is in brackets. Vegetation types are ordered according to the decreasing representation of linked threatened species.

	Vegetation type	Number of threatened species
1.	*Caricetum davallianae*	25 (47)
2.	*Sphagno warnstorfii-Tomenthypnion*	24 (40)
3.	*Valeriano simplicifoliae-Caricetum flavae*	18 (40)
4.	*Caricion lasiocarpae*	16 (31)
5.	*Glauco-Trichophoretum pumili*	16 (24)
6.	*Carici flavae-Cratoneuretum*	15 (45)
7.	*Sphagno recurvi-Caricion canescentis*	12 (31)
8.	*Cirsietum rivularis eriophoretosum latifolii*	5 (33)
9.	*Caricion fuscae*	5 (32)
10.	*Filipendulenion*	3 (18)
11.	*Cirsietum rivularis*	2 (47)
12.	*Angelico-Cirsietum palustris*	2 (27)
13.	*Junco inflexi-Menthetum longifoliae*	2 (19)
14.	*Chaerophyllo hirsuti-Calthetum*	1 (8)
15.	*Scirpetum sylvatici*	0 (20)

Chapter 10

Testate amoebae

V. Opravilová

Introduction

Testate amoebae inhabit various biotopes from aquatic to terrestrial environments. In some habitats they represent a dominant group of invertebrates, e.g. in oligotrophic lakes (Schönborn 1966) or especially on raised bogs, where they form typical communities (Harnisch 1929). Testate amoebae that live in mosses and soil are mainly affected by the degree of substratum moisture, or eventually by watering, to which the shape and structure of their shell and the size of pseudostom are adapted (Schönborn 1964). In raised bogs, communities of species dependent on certain moisture degree are formed. Special conditions (low pH, nutrient deficiency) cause high densities of several species. Harnisch (1929) defined the communities according to dominant species: Amphitrema association - (*Amphitrema flavum, Amphitrema wrightianum*), Hyalosphenia association - (*Hyalosphenia papilio, Hyalosphenia elegans*) and Waldmoos association - (*Hyalosphenia subflava, Trigonopyxis arcula* and other species). Amphitrema association inhabits completely submerged *Sphagnum* ssp., Hyalosphenia association very moist *Sphagnum* ssp., and Waldmoos association occurs in marginal parts of raised bogs. Significant changes of climate during the post glacial period affected also testate amoebae of raised bogs, their shells remained preserved in turf, and hence dead turf layers analysis (the rhizopode analysis) provided a record of climate changes in given areas (e.g. Grospietsch 1953).

Only a few authors have studied testate amoebae of the Carpathian region: Hoogenraad (1944), Bartoš (1940, 1952), Ertl (1955) and Balík (1992). While Bartoš (1940, 1952) and Balík (1992) were interested in testate amoebae of mosses and soil, Hoogenraad (1944) worked on testate amoebae of raised bogs near Štrbské pleso Lake and Ertl (1955) studied testate amoebae of raised bogs in Bór (Orava).

The aim of this research was to compare species composition of testate amoebae taxocenoses in two different kinds of spring fens: calcareous fens and acidic fens, i.e. habitats, to which attention has not been paid yet.

The relation to ecological variables of some taxa will be processed in another paper (Hájek & Opravilová in prep.).

Methods and localities

Fourteen localities were sampled, seven calcareous fens and seven acidic fens. During this study, 39 samples with 35,547 individuals representing 128 taxa were collected and identified. Samples were taken 11. - 12. 7. 2002.

Several samples of mosses were taken at each locality. Sometimes also bottom sediments from pools were sampled. The samples of mosses were transported in live stage to the laboratory and identified (det. Michal Hájek); bottom sediments were preserved with 4% formaldehyde. Mosses were moistened before handling and after pressing water out,

0.1 ml of this water was analysed. Testate amoebae were identified and the number of individuals was counted.
Physico-chemical variables (see Chapter 5.1) and vegetation cover were recorded at each locality. Chapter 1 presents the list of all localities. Samples for testate amoebae study were taken from localities listed below. Their field numbers are presented in brackets: the letters indicate different microhabitats.

Calcareous fens:
1 – Hrnčárky (1a, 1b, 1c)
13 – Hrubý Mechnáč (2a)
20 – Valašské Klobouky (3a, 3b)
65 - U Sládků – Semetín (4a, 4b, 4c)
75 - Jasénka, Kotrlé (5a, 5b)
77 - Hrubé Brodské (6a, 6b)
98 - Kelčov (7a,7b)

Acidic fens:
105 - Zajacovci (8a, 8b, 8c, 8d, 8e)
104 - Zajacovci (9a, 9b, 9c)
103 - Polková (10a, 10b, 10c)
113 - Jančíkovci (11c)
114 - Jančíkovci (11a,11b)
116 - Biely Kríž (12a,12b, 12c)
91 - Obidová (13a,13b, 13c)
92 - Obidová (14a, 14b, 14c)

Results and discussion

List of all recorded taxa

A complete list of localities is given at the beginning of this monograph (Chapter 1). Total numbers of localities (TL) and specimens (TS) for individual species are given in italics. New species for the Czech Republic are marked with an asterisk *. The taxa are arranged in taxonomical order according to Aescht & Foissner (1989).

RHIZOPODA

Testacealobosia
Arcella catinus Penard, 1890 – **I**: 98,104, 105, 111, 116; **H**: 91. *TL: 6; TS: 130.*
Arcella catinus sphaerocysta Deflandre, 1928 – **I**: 98. *TL: 1; TS: 3.*
Arcella dentata Ehrenberg, 1830 – **H**: 92. *TL: 1; TS: 7.*
Arcella discoides Ehrenberg, 1871 – **A**: 7; **G**: 77; **I**: 98, 103, 104, 105; **H**: 92. *TL:7; TS: 40.*
Arcella discoides scutelliformis Playfair 1917 – **I**:103, 104, 113; **H**: 92. *TL: 4; TS;14*
Arcella hemisphaerica intermedia Deflandre 1928 – **I**: 103,104,113; **H**: 92. *TL: 4; TS:35.*
Pyxidicula cymbalum Penard, 1901 – **G**: 75; **I**: 104. *TL: 2; TS: 3.* .
Microchlamys patella Claparede & Lachmann, 1859 – **A**: 7; **F**: 65. *TL: 2; TS: 2.*
Centropyxis aculeata aculeata Ehrenberg, 1830 – **A**: 7, 13, 20; **G**: 75, 77; **I**: 98, 103, 104, 105, 113, 116; **H**: 91,92. *TL: 13; TS: 371.*

Centropyxis aculeata oblonga Deflandre, 1929 – **A**: 7,13, 20; **F**: 65; **G**: 75,77; **I**: 98, 104, 105, 116; **H**: 92. *TL: 11; TS: 169.*

Centropyxis aerophila sphagnicola Deflandre, 1929 – **A**: 20; **F**: 65; **I**: 105, 114, 116. *TL: 5; TS: 12.*

Centropyxis cassis Deflandre, 1929 – **A**: 7,13,20; **F**: 65; **G**: 75, 77; **I**: 103, 104, 105; **H**: 92. *TL: 10; TS: 767.*

Centropyxis constricta Ehrenberg, 1841 – **A**: 7, 20; **F**: 65; **G**: 75, 77; **I**: 98. *TL: 6; TS: 215.*

Centropyxis discoides Penard, 1890 – **A**: 7, 20; **G**: 75; **I**: 98. *TL: 4; TS: 34.*

Centropyxis ecornis Ehrenberg, 1841 – **A**: 7; **H**: 92. *TL: 2; TS: 32.*

Centropyxis globulosa Bonnet & Thomas, 1960 - **H**: 91. *TL: 1; TS: 80.*

Centropyxis minuta Deflandre, 1929 – **F**: 65 ; **G** : 77; **I**: 98. *TL: 3; TS: 3.*

Centropyxis orbicularis Deflandre, 1929 – **F**: 65; **G**: 75, 77; **I**: 104, 116; **H**: 91. *TL: 6; TS: 36.*

Centropyxis platystoma Penard, 1890 – **A**: 7; **F**: 65; **G**: 77; **I**: 98, 105; **H**: 92. *TL: 6; TS: 14.*

Centropyxis sylvatica Deflandre, 1929 – **A**: 7, 13, 20; **F**: 65; **G:** 75, 77; **I**: 98, 103, 104, 105, 116; **H**: 91, 92. *TL: 13; TS: 247.*

Cyclopyxis arcelloides Penard, 1902 – **A**: 7; **F**: 65; **I**: 104. *TL: 3; TS: 7.*

Cyclopyxis eurystoma Deflandre, 1929 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104, 105, 114, 116; **H**: 91, 92. *TL: 14; TS: 969.*

Cyclopyxis eurystoma parvula Bonnet & Thomas, 1960 – **A**: 7, 20; **F**: 65; **G**: 75, 77; **I**: 98, 104; **H**: 91, 92. *TL: 9; TS: 537.*

Cyclopyxis kahli Deflandre, 1929 – **A**: 7; **F**: 65; **G**: 75, 77; **I**: 98; **H**: 92. *TL: 6; TS: 85.*

Trigonopyxis arcula Leidy, 1879 – **I**: 114, 116. *TL: 2; TS: 26.*

Trigonopyxis microstoma Hoogenraad, 1948 – **I**: 103, 114. *TL: 2; TS: 6.*

Difflugia acuminata Ehrenberg, 1830 – **A**: 7. *TL: 1; TS: 1*

Difflugia angulostoma* Gauthier-Lievre & Thomas, 1958 – **A: 7; **I**: 105. *TL: 2; TS: 2.*

Difflugia bacillariarum Perty, 1849 – **A**: 104, 105; **H**: 92. *TL*: 3; *TS: 7.*

Difflufia bacillifera Penard, 1890 – **I**: 103, 104, 105, 114. *TL: 4; TS: 19.*

Difflugia bryophila Penard, 1902 – **A**: 7, 13; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104; **H**: 92. *TL: 9; TS: 46.*

Difflugia capreolata Penard, 1902 – **I**: 98. *TL: 1; TS: 1.*

Difflugia fallax Penard, 1890 – **A**: 7, 13; **F**: 65; **G**: 77; **I**: 98; **H**: 92. *TL: 6; TS: 10.*

Difflugia glans Penard, 1902 – **F**: 65; **G**: 75, 77; **I**: 98. *TL: 4; TS: 45.*

Difflugia globulosa Dujardin, 1837 – **I**: 103. *TL: 1; TS: 5.*

Difflugia globularis sphaerica* Chardez, 1957 - **G: 75. *TL: 1; TS: 1.*

Difflugia gramen Penard, 1902 -**A**: 7; **G**: 77; **I**: 98. *TL: 3; TS: 7.*

Difflugia linearis Penard, 1890 – **I**: 105; **H**: 92. *TL: 2; TS: 2.*

Difflugia lithophila (Penard) Gauthier-Lievre & Thomas, 1958 – **H**: 92. *TL: 1; TS: 1.*

Difflugia lucida Penard, 1890 – **F**: 65. *TL: 1; TS: 3.*

Difflugia mammilaris Penard, 1893 – **G**: 77. *TL: 1; TS: 1.*

Difflugia minuta Rampi, 1950 – **G**: 75, 77. *TL: 2; TS: 4.*

Difflugia penardi Cash & Hopkinson, 1909 – **G**: 65; **I**: 98. *TL: 2; TS: 3.*

Difflugia penardi ogiva Deflandre, 1926 - **I**: 98. *TL : 1; TS: 2.*

Difflugia pristis Penard, 1902 – **F**: 65. *TL: 1; TS: 1.*

Difflugia pulex Penard, 1901 – **A**: 20; **F**: 65; **I**: 98. *TL: 3; TS: 29.*

Difflugia pyriformis Perty, 1849 – **A**: 7, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104, 105. *TL: 9; TS: 29.*
Difflugia pyriformis lata Jung, 1942 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 104; **H**: 92. *TS: 29.*
Difflugia pyriformis lacustris Penard , 1899 – **A**: 7. *TL: 1; TS: 1.*
Difflugia pyriformis longicollis Gassowsky, 1936 - **F**: 65; **G**: 77; **I**: 98, 104; **H**: 92. *TL: 5; TS: 16.*
Difflugia pyriformis tenuis Penard, 1890 - **G**: 75. *TL: 1; TS: 1.*
Difflugia rubescens Penard, 1891 – **I**: 103, 104, 105, 114; **H**: 92. *TL: 5; TS: 34.*
Difflugia urceolata Carter, 1864 – **G**: 75; **I**: 105. *TL: 2; TS: 12.*
Difflugia sp.$_1$ – **G**: 75. *TL: 1; TS: 2.*
Difflugia sp.$_2$ – **I**: 98. *TL: 1; TS: 3.*
Pontigulasia biggibosa Penard, 1901 – **I**: 105; **H**: 92. *TL: 2; TS: 12.*
Pontigulasia incisa Rhumbler, 1896 – **G**: 77; **I**: 98. *TL: 2; TS: 15.*
Pontigulasia spectabilis Penard, 1901 – **A**: 7; **F**: 65; **I**: 103; **H**: 92. *TL: 4; TS 15.*
Heleopera petricola Leidy, 1879 – **I**: 103, 105, 114, 116; **H**: 91.*TL: 5; TS: 83.*
Heleopera rosea Penard, 1890 – **A**: 13; **I**: 98, 103, 104, 105, 115, 116; **H**: 91, 92. *TL: 9; TS: 273.*
Heleopera rectangularis* Bonnet, 1966 – **G: 75; **I**: 105. *TL: 2; TS: 3.*
Heleopera sphagni Leidy, 1874 – **A**: 7, 20; **F**: 65; **G**: 75, 77; **I**: 98, 105, 116; **H**: 91, 92. *TL: 10; TS: 248.*
Hyalosphenia elegans Leidy, 1874 – **A**: 7; **I**: 105, 114. *TL: 3; TS: 803.*
Hyalosphenia papilio Leidy 1874 – **A**: 20; **I**: 103, 104, 105, 113, 114; **H**: 91, 92. *TL: 8; TS: 3589.*
Hyalosphenia papilio cylindricollis* Chardez, 1962 - **I: 103, 105. *TL: 2; TS: 3.*
Nebela bohemica Taranek, 1881 – **A**: 20; **F**: 65; **I**: 98, 103, 104, 105,113, 114, 116; **H**: 91, 92. *TL: 11; TS: 1368.*
Nebela collaris Ehrenberg, 1848 – **A**: 98; **I**: 103,104,105, 113, 114, 116; **H**: 92. *TL: 8; TS: 121.*
Nebela dentistoma Penard, 1890 – **A**: 7, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104, 105; **H**: 91, 92. *TL: 11, TS: 266.*
Nebela flabellulum Leidy, 1874 – **I**: 114. *TL: 1; TS: 2.*
Nebela gracilis* Penard, 1910 – **I: 98, 105; **H**: 91, 92. *TL: 4; TS: 69.*
Nebela lageniformis Penard, 1890 – **A**: 7; **I**: 98, 104; **H**: 92. *TL: 4; TS: 7.*
Nebela marginata Penard, 1902 – **I**: 103, 105. *TL: 2; TS: 130.*
Nebela militaris Penard, 1890 – **I**: 103, 105, 114, 116; **H**: 91, 92. *TL: 6; TS: 364.*
Nebela penardiana Deflandre, 1936 – **I**: 103. *TL: 1; TS: 1.*
Nebela tincta Leidy, 1879 - **I**:103, 105, 114, 116; **H**: 91, 92 *TL: 6; TS: 1280.*
Nebela tubulata Brown, 1910 – **I**: 116; **H**: 91. *TL: 2; TS: 2.*
Paraquadrula irregularis Archer, 1877 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98. *TL: 7; TS: 775.*
Lesquereusia spiralis – Ehrenberg, 1840 – **I**: 103, 113, 114. *TL: 3; TS: 14.*
Quadrulella symmetrica Wallich, 1863 – **A**: 7; **F**: 65; **G**: 75, 77; **I**: 103, 104, 105;**H**: 92. *TL: 8; TS: 214.*
Quadrulella symmetrica longicollis Taranek, 1852 – **G**: 75; **I**: 104. *TL: 2; TS: 2.*
Plagiopyxis callida Penard, 1910 – **F**: 65. *TL: 1; TS: 1.*
Plagiopyxis declivis Bonnet & Thomas, 1955 – **F**: 65; **G**: 75; **I**: 98. *TL: 3; TS: 17.*
Plagiopyxis minuta Bonnet, 1959 – **G**: 75; *TL: 1; TS: 1.*

Plagiopyxis oblonga Bonnet & Thomas, 1955 – **A**: 20; **F**: 65, **G**: 75. *TL: 3; TS: 4.*
Plagiopyxis penardi Thomas,1955 - **F**: 65, **G**: 75. *TL: 2; TS: 8.*
Cryptodifflugia oviformis fusca Penard 1890 – **I**: 116. *TL: 1; TS: 30.*
Wailesella eboracensis Wailes & Penard, 1911 – **I**: 103. *TL: 1; TS: 60.*
Phryganella acropodia Hertwig & Lesser, 1879 – **A**: 7; **F**: 65; **G**: 75, 77; **I**: 98,103,104, 105, 113, 114, 116; **H**: 92. *TL: 12; TS: 289.*
Phryganella acropodia penardi Decloitre, 1955 – **F**: 65; **G**: 75, 77. *TL: 3; TS: 10.*

Testaceafilosia
Amphitrema flavum Archer, 1877 – **I**: 103, 105. *TL: 2; TS: 5.*
Amphitrema wrightianum Archer, 1869 – **I**: 105. *TL: 1; TS: 6.*
Campascus minutus Penard, 1899 – **G**: 77. *TL: 1; TS: 1.*
Cyphoderia ampulla Ehrenberg, 1840 – **A**: 7; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104; **H**:92. *TL: 8; TS: 51.*
Cyphoderia ampulla crassa (Husnot) Thomas, 1954 **F**: 65. *TL: 1; TS: 1.*
Cyphoderia bonneti Štěpánek, 1967 - **A**: 7, 20; **G**: 75. *TL: 3; TS: 5.*
Assulina muscorum Greeff, 1888 – **A**: 20; **I**: 103, 105, 114, 116; **H**: 91, 92. *TL: 7; TS:1587.*
Assulina seminulum Ehrenberg, 1848 – **I**: 103, 105, 114, 116; **H**: 91, 92. *TL: 6; TS:234.*
Corythion dubium Taranek,1881 – **A**: 20; **I**: 103, 104, 105, 113, 114, 116; **H**: 91, 92. *TL: 9; TS: 658.*
Corythion pulchellum Penard, 1890 – **I**: 116; **H**: 92. *TL: 2; TS: 30.*
Euglypha acanthophora Ehrenberg, 1841 – **I**: 98; **H**: 92. *TL: 2; TS: 5.*
Euglypha ciliata Ehrenberg, 1848 – **A**: 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 105, 114; **H**:91, 92. *TL: 10; TS: 1662.*
Euglypha ciliata glabra Wailes, 1915 – **F**: 65; **G**: 75. *TL: 2; TS: 345.*
Euglypha ciliata heterospina Wailes, 1912 - **A**: 7; **I**: 116. *TL: 2; TS: 19.*
Euglypha compressa Carter, 1864 – **I**: 114. *TL: 1; TS: 16.*
Euglypha cristata Leidy, 1874 – **A**: 7; **I**: 103, 104, 105, 114, 116; **H**: 91, 62. *TL: 8;TS: 1450.*
Euglypha denticulata Brown, 1912 – **A**: 13, 20; **F**: 65. *TL: 3; TS: 16.*
Euglypha filifera Penard, 1890 – **I**: 105; **H**: 92. *TL: 2 ; TS: 89.*
Euglypha laevis Perty, 1849 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104, 105, 114,116; **H**: 91, 92. *TL: 14; TS: 9992.*
Euglypha rotunda Wailes & Penard, 1911 – **A**: 13; **I**: 104. *TL: 2; TS: 5.*
Euglypha strigosa Ehrenberg, 1871 – **F**: 65; **I**: 103, 104, 105, 114, 116; **H**: 91, 92.*TL: 8 TS: 901.*
Euglypha strigosa glabra Wailes & Penard, 1911 – **I**: 105. *TL: 2; TS: 2.*
Euglypha strigosa heterospina Wailes, 1912 - **I**: 105; **H**: 91. *TL: 2; TS: 14.*
Euglypha strigosa muscorum Wailes, 1912 - **I**: 91. *TL: 1; TS: 1.*
Euglypha tuberculata Dujardin, 1841 – **A**: 13; **F**: 65; **I**: 98, 104; **H**: 91. *TL: 5; TS: 18.*
Euglyphella delicatula Valkanov, 1962 – **F**: 65. *TL: 1; TS: 5.*
Sphenoderia fissirostris Penard, 1890 – **I**: 103, 105, 114, 116; **H**: 91, 92. *TL: 6; TS: 262.*
Sphenoderia lenta Schlumberger, 1845 – **I**: 103, 104, 105; **H**: 92. *TL: 4; 259.*
Tracheleuglypha dentata Penard, 1890 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104,116; **H**: 92. *TL: 11; TS: 2362.*

Trinema complanatum Penard, 1890 – **A**: 20; **G**: 75, 77; **I**: 98, 103, 105, 114, 116; **H**: 91, 92. *TL: 10; TS: 431.*

Trinema enchelys Ehrenberg, 1838 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103, 104, 105; **H**: 92. *TL: 11; TS: 2041*

Trinema lineare Penard, 1890 – **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 98, 103,104, 105, 113,114, 116; **H**: 91, 92.*TL: 15; TS: 8632.*

Trinema lineare minuscula Chardez, 1971 - **A**: 7, 13, 20; **F**: 65; **G**: 75, 77; **I**: 105, 116;**H**: 91, 92. *TL: 10; TS: 830.*

Pseudodifflugia fulva Archer, 1869 – **A**: 13; **G**: 75, 77; **I**: 98, 103, 105, 116; **H**: 92. *TL: 8; TS: 83.*

Pseudodifflugia gracilis Schlumberger, 1845 – **A**: 13; **G**: 75, 77; **I**: 104, 105; **H**: 92. *TL: 6; TS: 63.*

Pseudodifflugia gracilis terricola Bonnet & Thomas, 1960 – **F**: 65; **G**: 75, 77; **I**: 98. *TL: 4; TS:20.*

Pseudodifflugia senartensis Couteaux, 1972 – **F**: 65. *TL: 1; TS: 2.*

We studied testate amoebae in two different kinds of spring fens: calcareous and acidic. The calcareous fens belonged to A, F, G and I regions, the acidic fens to I and H regions. We took samples of mosses and bottom sediments from pools. Dissimilarity of the two kinds of fens was expressed by the presence of different species, e.g. *Paraquadrula irregularis* in calcareous fens; species of *Amphitrema* and *Hyalosphenia* genera and some species of genus *Nebela* entirely in acidic fens. Several species were recorded in both kinds of fens, but in differing abundance, e.g. *Assulina muscorum*.

We divided samples into five groups distinguished along two major gradients in species composition (Fig. 1): acidic mosses, strongly calcareous mosses, slightly calcareous mosses, acidic sediments, and non-acidic sediments.

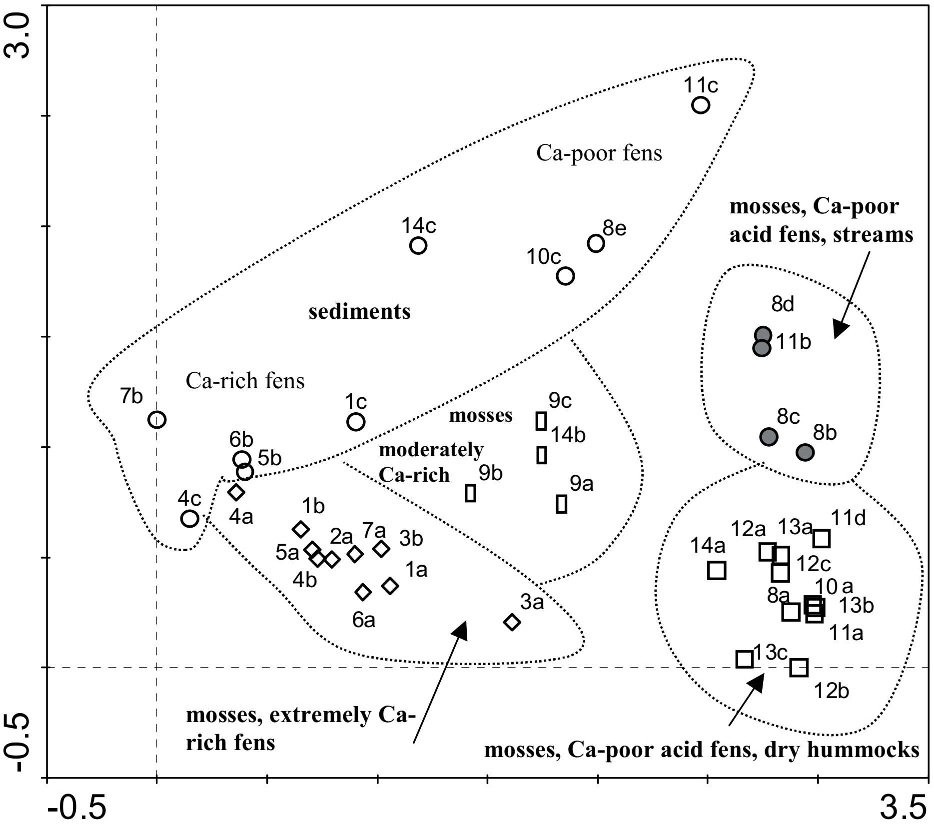
Calcareous fens

Altogether, we took fifteen samples and identified 90 taxa. Various species of mosses (Bryidae) and sediments formed the substratum.

Relatively abundant species *Paraquadrula irregularis* is associated only with calcareous environment. This species of testate amoebae has its shell formed only of calcareous idiosomata. Sometimes it occurs in such a great number that Schönborn (1966) described this species on the Spitzbergen as an indicator of calcareous waters. Also in the Canadian Arctic, a separate community of *Paraquadrula irregularis – Paraquadrula penardi* was formed at areas with high conductivity (Beyens et al. 1991). *Trinema enchelys* species, which was recorded from both kinds of fens, was densely populated in calcareous ones. *Trinema enchelys - Euglypha* sp.1 assemblage was formed in samples from lakes, pools and ponds in the River Zackenberg basin in Greenland (Trappeniers et al. 1999). Laminger (1978) studied the influence of soil moisture on population dynamics, shell size and food specialisation of *Trinema enchelys*. *Trinema enchelys* represented a very abundant species in our samples, and remarkable differences in shell size were also recorded in this current study.

The bottom sediments had significantly lower population density than mosses, because they lacked species of higher abundance.

Figure 1: Detrended correspondence analysis of testate amoebae assemblages from Western Carpathian fens. Samples are arranged according to two principal gradients in species composition. The dashed lines border the samples from one microhabitat type. Short habitat characteristics are presented for each dashed group: type of substratum (sediment or mosses), base richness and, respectively, elevation above water table. The numbers of samples are field numbers and they are explained in the Method section in the text. The number indicates the locality, the letter indicates different microhabitat.



Acidic fens

Twenty-five samples were taken and 92 taxa of testate amoebae were recorded. The substratum was formed especially of *Sphagnum* spp. and *Polytrichum commune.* The DCA analysis separated the groups of moist microhabitats near the streams, hummock microhabitats and slightly calcareous habitats (Fig. 1). We also took several samples of bottom sediments.

In samples from moist microhabitats, the sphagnophilous species *Hyalosphenia papilio* and *Hyalosphenia elegans* prevailed; on the contrary, *Amphitrema flavum* and *Amphitrema wrightianum,* and also *Nebela bohemica* and *Euglypha cristata* occured rarely. However, these species were also recorded from hummock forming mosses and it was therefore impossible to assess distinct differences between these two habitats.

Three abundant species *Assulina muscorum, Corythion dubium,* and *Cyclopyxis eurystoma* represented the group found on hummock forming mosses (*Sphagnum* spp., *Polytrichum commune*). Communities with *Assulina muscorum* and *Corythion dubium* occur in Europe in drier marginal areas of raised bogs with xerophytic vegetation (Jung 1936) and form a typical part of Waldmoos-association (Schönborn 1962).

Assulina muscorum community was also recorded on lichens and mosses from arctic and subarctic tundras (Beyens et al. 1986, 1988). A group of slightly calcareous habitats formed the transition between the group of acidic and the group of calcareous fens, with the highest abundance of *Tracheleuglypha dentata*..

Sediments were inhabited less than mosses analogous to calcareous fens.

Conclusions

Testate amoebae taxocenoses were studied in two different kinds of spring fens: calcareous and acidic. The D.C.A. analysis was the basis for dividing testate amoebae taxocenoses into five groups (Figure 1).

90 taxa were identified in calcareous and 92 in acidic spring fens. *Difflugia angulostoma*, *Difflugia globularis sphaerica, Heleopera rectangularis*, *Hyalosphenia papilio cylindricollis* and *Nebela gracilis* were recorded as new taxa in the Czech Republic.

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Table 1: l *Hyalosphaenia papilio*, 2 *Centropyxis cassis*, 3 *Quadrulella symmetrica*, 4 *Trinema enchelys*, 5 *Hyalosphenia elegans*, 6 *Cyclopyxis eurystoma,* 7 *Assulina seminulum*, 8 *Euglypha cristata;* Photos: J. Schenková.

Chapter 11

Molluscs

M. Horsák

Introduction

There is a long tradition of mollusc studies in the West Carpathians, but spring and fen ecosystems have been mostly overlooked. Only a few malacological studies have focused on extremely rich calcareous fens in order to discover populations of rare and relict snails. Thus, these studies covered only petrifying springs, which are the richest from the malacological point of view. There are only scarce previous faunistic data available from the target area (e.g. Ložek 1971, 1982, 1989, 1992; Ložek & Šteffek 1983; Kroupová 1986; Lučivjanská 1992; Šteffek 1995).

A systematic and ecological investigation of mollusc communities of the West Carpathian spring fens has been carried out since 2001. This research followed several purposes. First, malacological and vegetation data along the poor-rich gradient in springs with known water chemistry were tested. In the process, the existence of a poor-rich mire gradient in the composition of mollusc communities and the hypothesis of increasing mollusc species richness towards *Ca*-rich fens (Horsák & Hájek 2003) was tested. This study also tried to assess the possibility of predicting the mollusc assemblage quality using vegetation composition. The second interest of the study covers the geographical differences between the Outer and Inner Carpathians. This part of the research is closely related to the investigation of the historical development of fens and the autecology requirements of relict species known from the Inner Carpathians. For the time being, the analysis of distribution and habitat preferences of the most endangered exclusively fen inhabitant, snail *Vertigo geyeri*, has been carried out in detail (Horsák & Hájek in press). Other work on such themes is planned for the near future.

The main goal of this paper is to publish all data concerning records of individual species at individual sites that have been recorded so far. In larger ecological studies, it is not possible to release primary data, as was the case of previous paper (Horsák & Hájek 2003). Therefore, we consider it very useful to give all individual records to others scientists. We suppose the people engaged in the issue of nature conservation will be most interested in these data because many of the investigated sites are small reserves and many of the encountered species are regarded as endangered on an international level.

The general results achieved and involved in our ecological papers are briefly summarised and commented on in particular passages below.

Methods

Fieldwork was conducted from 1997 to 2003. Altogether, 125 sites were studied. Most were situated in the Czech Republic (39) and Slovakia (84), with only two sites in Poland.

At each site, one 12-litre sample comprising the upper soil layer with litter and herbaceous and moss vegetation was collected. The samples were washed through a bowl-shaped sieve (mesh size 0.5 mm) to wash out the fine clay particles; otherwise they would have caused all the material to stick together after drying. Any coarse plant matter was picked out, too. This method called wet washing is described in detail by Horsák (2003). After drying, the material was separated by sieving into fractions of different particle size, from which the mollusc shells were extracted by hand-sorting under a binocular microscope. Samples were not collected randomly, as the material collected was meant to reflect the same vegetation composition and structure as the vegetation relevé. The primary goal was always to detect the site's species as exhaustively as possible. The mollusc species names are given according to Juřičková et al. (2001), with the exception of *Euconulus alderi* (Gray, 1840). Its current name *E. praticola* (Reinhartd, 1883) is used (Falkner et al. 2002).

Results and discussion
List of all recorded species

In total, 2,123 records from 122 spring fen sites are presented. The remaining three investigated sites were free of molluscs. Altogether, we found 95 mollusc species; 84 of them were terrestrial and 11 were aquatic (6 snails and 5 bivalves). In total, more than 88,000 specimens were collected. The list of species follows taxonomic order; the sites where a particular species was encountered are divided into geographical regions. For explanations of locality abbreviations see the list of studied fens at the beginning of this monograph (Chapter 1). Total numbers of localities (TL) and specimens (TS) for individual species are given in italics.

To render the general use of the obtained data possible in further malacological research, all recorded species are presented, although some of them inhabit adjacent biotopes but do not live within the fens (*Orcula dolium*, *Vestia gulo* etc.). These were mostly the cases when no live specimens were found. Such species are marked with asterisks.

We calculated the sum of occurrences of individual species, their frequency and dominance (Tab.1). The species encountered at less than ten sites were not included.
A minor part of these data has already been published (Horsák 2000, 2001; Beran & Horsák 2001, 2002; Hájek et al. 2002; Horsák 2003; Horsák & Neumanová 2004; Horsák & Hájek in press).

Class: **GASTROPODA**

Subclass: **Prosobranchia**
Alzoniella slovenica* (Ložek et Brtek, 1964) - **A: 3, 7, 15; **B**: 32. *TL: 4; TS: 42.*
Bythinella austriaca s.lat. (von Frauenfeld, 1857) - **A**: 1-7, 9-10, 12-3, 15-7, 19-21, 23; **B**: 25-6, 28-30, 32-3, 35; **C**: 36-42, 45-8; **D**: 49-56, 58; **E**: 59, 60, 62; **F**: 64-6, 71; **G**: 74, 78; **H**: 92; **I**: 97-8; **J**: 122, 124-6; **K**: 129, 131-3, 137-8, 140, 145; **M**: 148, 152, 155-6. *TL: 75; TS: 20752.*
Platyla polita (Hartmann, 1840) - **A**: 1, 12, 21, 23; **B**: 29, 33, 35; **C**: 36-7, 39, 47-8; **D**: 53-4; **G**: 78; **J**: 126; **K**: 137; **N**: 163. *TL: 18; TS: 131.*

Subclass: **Pulmonata**
Galba truncatula (O.F. Müller, 1774) - **A**: 1-4, 6-13, 15, 17, 20-1, 23; **B**: 24-30, 32-5; **C**: 36-42, 46-7; **D**: 49-53, 55-6; **E**: 59, 60, 62; **F**: 64-6, 69, 71; **G**: 77, 79; **H**: 88, 92-4,

96; **I**: 97-8, 104; **J**: 121-3, 125-6; **K**: 129-131, 133, 135-9, 141, 143, 145; **L**: 147; **M**: 149-152, 154, 157; **N**: 158, 160, 162-4. *TL: 91; TS: 2676.*

Radix peregra (O.F. Müller, 1774) - **A**: 7, 10; **B**: 29, 35; **C**: 46-7; **D**: 49-55; **F**: 64, 66, 71; **H**: 88, 92; **I**: 98, 104; **J**: 121; **K**: 130-1, 133, 135, 145; **L**: 146-7; **M**: 149, 151, 153-4, 156-7; **N**: 162, 164. *TL: 36; TS: 464.*

Anisus leucostoma (Millet, 1813) - **A**: 20, **D**: 56-7; **E**: 60; **F**: 71; **J**: 121-2; **K**: 133, 135; **L**: 147; **M**: 153, 157; **N**: 158, 160, 164. *TL: 15; TS: 723.*

Gyraulus albus (O.F. Müller, 1774) - **K**: 130. *TL: 1; TS: 1.*

Carychium minimum O.F. Müller, 1774 - **A**: 1-13, 15-7, 19-21, 23; **B**: 24-30, 32-5; **C**: 36-42, 44-8; **D**: 49-53, 55-8; **E**: 59, 60, 62; **F**: 63-6, 69, 71; **G**: 74-5, 77; **H**: 96; **I**: 97, 102; **J**: 119, 121-6; **K**: 129-135, 137-9, 141-3, 145; **L**: 146; **M**: 148-153, 156-7; **N**: 158-160, 162-4. *TL: 103; TS: 9861.*

Carychium tridentatum (Risso, 1826) - **A**: 1, 3-4, 6-9, 11, 13, 15-6, 21, 23; **B**: 24, 27-30, 32-3, 35; **C**: 36-9, 47-8; **D**: 49-51, 54; **E**: 59, 60, 62; **F**: 63-6, 69; **G**: 75, 77-9; **H**: 92, 96; **I**: 97-8, 102; **J**: 122-3, 125-6; **K**: 132, 134-5, 137-140, 142; **L**: 147. *TL: 60; TS: 2232.*

Cochlicopa lubrica (O.F. Müller, 1774) - **A**: 1-2, 4, 6-13, 15-7, 19, 20-1, 23; **B**: 24-30, 32-5; **C**: 36-42, 44-8; **D**: 49-56, 58; **E**: 59, 60, 62; **F**: 63-6, 69; **G**: 74-5, 77-9; **H**: 96; **I**: 97-8, 102; **J**: 119, 121-6; **K**: 129-133, 135, 137-8, 140, 142; **L**: 146-7; **M**: 148-151; **N**: 160-2, 164. *TL: 94; TS: 3016.*

Cochlicopa lubricella (Rossmässler, 1835) - **A**: 2-4, 8, 12, 23; **B**: 30. *TL: 7; TS: 15.*

Cochlicopa nitens (M. von Gallenstein, 1848) - **D**: 51, 56; **K**: 129. *TL: 3; TS: 97.*

Orcula dolium* (Draparnaud, 1801) - **A: 15, 23; **C**: 47. *TL: 3; TS: 81.*

Sphyradium doliolum* (Bruguière, 1792) - **A: 9. *TL: 1; TS: 6.*

Granaria frumentum* (Draparnaud, 1801) - **A: 2. *TL: 1; TS: 1.*

Pupilla alpicola (Charpentier, 1837) - **D**: 50-8; **E**: 62; **K**: 129-131; **M**: 148; **N**: 159, 160, 163-4. *TL: 18; TS: 1172.*

Pupilla muscorum (Linnaeus, 1758) - **A**: 4, 8; **B**: 27, 30; **C**: 38. *TL: 5; TS: 27.*

Vallonia costata (O.F. Müller, 1774) - **A**: 4, 8, 9, 11-3, 15, 19, 21, 23; **B**: 25, 27, 29, 30, 32-3, 35; **C**: 36-9, 46; **D**: 55; **E**: 60; **F**: 65; **K**: 142. *TL: 26; TS: 277.*

Vallonia enniensis (Gredler, 1856) - **C**: 42, 44-5; **D**: 51; **E**: 60. *TL: 5; TS: 55.*

Vallonia pulchella (O.F. Müller, 1774) - **A**: 1, 2, 4-12, 15, 17, 19-21, 23; **B**: 24-30, 32-3, 35; **C**: 37-42, 47; **D**: 50-8; **E**: 59, 62; **F**: 63, 65-6, 69; **G**: 74-5, 77-9; **I**: 97, 102; **J**: 119, 121-2, 124-6; **K**: 129-133, 135, 137-8, 140, 142; **L**: 147; **M**: 148-151; **N**: 158-164. *TL: 82; TS: 1877.*

Acanthinula aculeata (O.F. Müller, 1774) - **A**: 1, 5-7, 9; **B**: 28; **C**: 36-8, 47-8; **E**: 60, 62; **G**: 74-5. *TL: 15; TS: 81.*

Columella edentula (Draparnaud, 1805) - **A**: 2, 4-6, 9, 15-6, 19, 20; **B**: 24, 27, 34-5; **C**: 36-8, 40-2, 44-8; **D**: 52-5; **E**: 60, 62; **F**: 63, 65; **G**: 74, 78-9; **I**: 98; **J**: 125; **K**: 129, 135, 137-140, 143; **M**: 152. *TL: 45; TS: 336.*

Truncatellina cylindrica (A. Férussac, 1807): **A**: 2-4, 7-9; **B**: 25, 30, 32, 34; **C**: 38. *TL: 11; TS: 98.*

Vertigo angustior Jeffreys, 1830 - **A**: 1-3, 6-9, 11-2, 20-1, 23; **B**: 24, 26-8, 30, 32; **C**: 36, 38, 41-2, 44-8; **D**: 51, 53-8; **E**: 59, 60, 62; **F**: 65, 69; **G**: 74-5; **J**: 119; **K**: 129-133, 137-8, 142; **L**: 147; **M**: 148-151; **N**: 159, 160, 162-4. *TL: 59; TS: 2944.*

Vertigo antivertigo (Draparnaud, 1801) - **A**: 1, 2, 4, 6-13, 15-7, 19-21; **B**: 24-30, 32-5; **C**: 36-42, 44-8; **D**: 49, 51-3, 56-8; **E**: 60, 62; **F**: 63-5, 69, 71; **G**: 74-5, 77; **H**: 88; **I**: 97-8; **J**: 119, 121-3, 125-6; **K**: 129-131, 133, 137-9, 141, 145; **L**: 146-7; **M**: 150-1, 157; **N**: 158-161, 164. *TL: 85; TS: 3080.*

Vertigo geyeri Lindholm, 1925 - **C**: 47-8; **D**: 51; **K**: 133, 135, 137-140, 145; **L**: 147; **M**: 148-152, 157; **N**: 162-4. *TL: 20; TS: 813.*

Vertigo moulinsiana (Dupuy, 1849) - **A**: 8, 15-7; **B**: 28-30, 32; **C**: 36-8. *TL: 11; TS: 283.*

Vertigo pusilla* O.F. Müller, 1774 - **A: 7, 9, 21; **B**: 28; **C**: 40, 46. *TL: 6; TS: 12.*

Vertigo pygmaea (Draparnaud, 1801) - **A**: 1-9, 11-3, 15, 17, 19-21, 23; **B**: 24-30, 32-5; **C**: 37-42, 44-6; **D**: 51-2, 56-8; **E**: 59, 60, 62; **F**: 63-6, 69; **G**: 74-5, 77-8; **I**: 97-8; **J**: 119, 121-5; **K**: 129-131, 142; **L**: 147; **N**: 160, 162, 164. *TL: 71; TS: 2667.*

Vertigo substriata (Jeffreys, 1830) - **A**: 1, 9, 11, 13, 15, 17, 20-1; **B**: 27, 29, 30, 33, 35; **C**: 36-7, 39, 47-8; **D**: 51-6; **E**: 62; **F**: 63-6, 69, 71; **G**: 75, 77-9; **H**: 88, 92-3, 96; **I**: 97-8, 102, 106; **J**: 119, 122, 124-6; **K**: 131-5, 137-142, 145; **L**: 146-7; **M**: 150, 152, 154, 157. *TL: 66; TS: 1131.*

Ena montana* (Draparnaud, 1801) - **A: 9. *TL: 1; TS: 7.*

Merdigera obscura* (O.F. Müller, 1774) - **A: 9, 15, 23. *TL: 3; TS: 5.*

Cochlodina laminata* (Montagu, 1803) - **A: 9, 15, 23. *TL: 3; TS: 10.*

Macrogastra plicatula* (Draparnaud, 1801) - **C: 37. *TL: 1; TS: 1.*

Macrogastra tumida (Rossmässler, 1836) - **A**: 15-6; **E**: 62; **F**: 63. *TL: 4; TS: 18.*

Macrogastra ventricosa* (Draparnaud, 1801) - **A: 9, 15, 20, 23. *TL: 4; TS: 81.*

Clausilia dubia (Draparnaud, 1805) - **N**: 163. *TL: 1; TS: 2.*

Alinda biplicata (Montagu, 1803) - **A**: 6, 15, 21, 23; **B**: 26, 34; **C**: 47-8. *TL: 8; TS: 60.*

Vestia gulo* (E.A. Bielz, 1859) - **J: 125. *TL: 1; TS: 1.*

Vestia turgida* (Rossmässler, 1836) - **A: 20, 23. *TL: 2; TS: 57.*

Succinella oblonga (Draparnaud, 1801) - **A**: 1-3, 6, 8-11, 15, 17, 19, 20; **B**: 24-9, 34; **C**: 36, 38, 41, 45; **D**: 51; **E**: 59, 62; **K**: 140, 142; **L**: 146; **M**: 148, 151; **N**: 160, 163. *TL: 33; TS: 878.*

Succinea putris (Linnaeus, 1758) - **A**: 4, 7, 10, 11, 13, 20-1, 23; **B**: 27, 33, 35; **C**: 36-7, 42; **D**: 49-51, 55-6, 58; **E**: 62; **F**: 63-6, 71; **G**: 74-5, 77; **H**: 88, 92-4, 96; **I**: 97-8, 106; **J**: 121-6; **K**: 129, 131-140, 142, 145; **L**: 146-7; **M**: 148, 150-1, 155; **N**: 160, 163. *TL: 64; TS: 1084.*

Oxyloma elegans Westerlund, 1885 - **A**: 4, 7, 9; **B**: 24, 29, 30, 32, 34; **C**: 36, 41-2, 44-8; **D**: 51-8; **E**: 59, 60, 62; **F**: 66; **G**: 75; **I**: 97; **J**: 119, 121; **K**: 129, 130, 133, 137, 140; **M**: 148-9, 151; **N**: 158-161, 163-4. *TL: 46; TS: 1748.*

Cecilioides acicula (O.F. Müller, 1774): **A**: 4; **B**: 24, 30; **C**: 38. *TL: 4; TS: 6.*

Punctum pygmaeum (Draparnaud, 1801) - **A**: 1-9, 11-3, 15-7, 19-21, 23; **B**: 24-5, 27-30, 32-5; **C**: 36-42, 44-8; **D**: 51, 53-6, 58; **E**: 59, 60, 62; **F**: 63, 65-6, 69; **G**: 74-5, 77-9; **I**: 97-8, 102; **J**: 119, 122, 126; **K**: 129, 130-1, 133, 135, 137-8, 140, 142, 145; **L**: 146-7; **M**: 148-9, 151; **N**: 162-3. *TL: 82; TS: 1811.*

Discus perspectivus* (M. von Mühlfeld, 1816): **A: 4, 9; **C**: 37; **I**: 97. *TL: 4; TS: 4.*

Discus rotundatus* (O.F. Müller, 1774): **A: 4, 15, 21; **B**: 34-5, **C**: 38; **J**: 126. *TL: 7; TS: 9.*

Zonitoides nitidus (O.F. Müller, 1774) - **A**: 10-1, 20; **B**: 24, 27-8, 32, 35; **C**: 36, 38, 42, 45; **D**: 51, 56, 58; **E**: 60, 62; **F**: 64, 71; **J**: 119, 121; **K**: 138; **M**: 148; **N**: 161, 164. *TL: 25; TS: 757.*

Euconulus fulvus (O.F. Müller, 1774) - **A**: 1-9, 11-3, 15-6, 19-21, 23; **B**: 24-5, 27-30, 32-5; **C**: 37-40, 42, 44, 46-8; **D**: 53-5; **E**: 59, 60, 62; **F**: 63, 65-6, 69, 71; **G**: 74-5, 77-9; **I**: 97-8, 102, 106; **J**: 122, 124-6; **K**: 131-2, 137-8, 140, 142; **M**: 151, 152; **N**: 156, 160. *TL: 71; TS: 1263.*

Euconulus praticola (Reinhardt, 1883) - **C**: 36-7, 42, 44-8; **D**: 49-53, 55-58; **J**: 119, 121; **K**: 129-130, 133, 135, 138-9, 142, 145; **L**: 146-7; **M**: 148-9; **N**: 161-4. *TL: 35; TS: 801.*

Vitrina pellucida (O.F. Müller, 1774) - **A**: 1-4, 11-2, 17, 21, 23; **B**: 27-8, 30; **C**: 38-9, 40, 44-5; **D**: 51-2, 55, 58; **E**: 60, 62; **F**: 64-5, 69; **G**: 74-5, 77-9; **H**: 96; **I**: 97-8; **J**: 122, **K**: 129, 130, 137-8, 142; **L**: 147. *TL: 41; TS: 99.*

Semilimax semilimax (J. Férussac, 1802) - **B**: 28; **C**: 48; **D**: 56, 58; **I**: 98; **J**: 119, **K**: 129, 130, 137. *TL: 9; TS: 58.*

Vitrea contracta (Westerlund, 1871) - **A**: 1-5, 8, 9, 12-3, 15-6, 21, 23; **B**: 32; **C**: 37-9; **D**: 58. *TL: 18; TS: 81.*

Vitrea crystallina (O.F. Müller, 1774) - **A**: 1, 7, 20-1; **B**: 30; **C**: 37, 45, 47; **D**: 55; **E**: 62; **H**: 94; **J**: 125, **K**: 132, 139, 140; **M**: 150, 152. *TL: 17; TS: 160.*

Vitrea diaphana (Studer, 1820) - **A**: 4, 7, 9, 15-6, 21; **B**: 34; **C**: 36-9, 45, 47-8; **D**: 49; **G**: 77; **J**: 126. *TL: 17; TS: 45.*

Vitrea subrimata* (Reinhardt, 1871) - **D: 54-5; **M**: 151. *TL: 3; TS: 5.*

Vitrea transsylvanica (Celssin, 1877) - **K**: 137, 140, 142-3. *TL: 4; TS: 25.*

Aegopinella epipedostoma* (Fagot, 1879) - **C: 45. *TL: 1; TS: 4.*

Aegopinella minor (Stabile, 1864) - **A**: 3-5, 7, 9, 15; **B**: 30; **E**: 59; **G**: 75; **K**: 140. *TL: 10; TS: 23.*

Aegopinella pura (Alder, 1830) - **A**: 1, 4-6, 9, 12, 15, 20-1, 23; **B**: 28, 30, 32-3, 35; **C**: 36-40, 42, 45, 47-8; **E**: 62; **F**: 63, 66, 69; **G**: 78-9; **J**: 122, **K**: 137, 140. *TL: 33; TS: 428.*

Perpolita hammonis (Störm, 1765) - **A**: 4, 8, 12-3, 15-7, 19-21, 23; **B**: 24, 28, 33-5; **C**: 36, 39, 46-7; **D**: 51-3, 55-6; **E**: 59, 60, 62; **F**: 63, 65-6, 69, 71; **G**: 74-5, 77-9; **H**: 88, 92-4, 96; **I**: 97-8, 102, 106; **J**: 119, 122-6; **K**: 129-135, 137, 139-143, 145; **L**: 146-7; **M**: 148-151, 155-6; **N**: 161-3. *TL: 78; TS: 1623.*

Perpolita petronella (L. Pfeiffer, 1853) - **D**: 50-1, 56; **K**: 135; **M**: 148, 150-1; **N**: 163. *TL: 8; TS: 58.*

Oxychilus cellarius* (O.F. Müller, 1774) - **B: 32; **C**: 36; **E**: 62. *TL: 3; TS: 6.*

Oxychilus glaber* (Rossmässler, 1835) - **A: 1, 15, **B**: 26, 29; **C**: 45; **G**: 75. *TL: 6; TS: 10.*

Daudebardia brevipes (Draparnaud, 1805) - **A**: 1, 3, 4, 6, 9, 15, 21, 23; **B**: 28, 30, 32-3; **C**: 36-7, 39, 45-6, 48; **D**: 52; **E**: 62; **G**: 74-5, 78; **I**: 98; **J**: 126. *TL: 25; TS: 74.*

Daudebardia rufa (Draparnaud, 1805) - **A**: 3, 7, 9, 12, 15, 23; **B**: 27-9, 33-4; **C**: 37-9, 40, 44-5, 47-8; **D**: 58; **E**: 60; **F**: 63, 66; **G**: 75, 78-9; **J**: 126; **K**: 137, 140. *TL: 29; TS: 95.*

Lehmannia nyctelia* (Bourguignat, 1861) - **A: 9, 15. *TL: 2; TS: 2.*

Deroceras agreste (Linnaeus, 1758) - **I**: 102, 106; **J**: 122, 126; **K**: 130. *TL: 5; TS: 6.*

Deroceras laeve (O.F. Müller, 1774) - **A**: 5, 9, 12; **C**: 41; **H**: 96; **J**: 122, 124; **K**: 138, 140, 143, 145; **M**: 155. *TL: 12; TS: 15.*

Deroceras praecox* Wiktor, 1966 - **A: 15, 23. *TL: 2; TS: 6.*

Boettgerilla pallens* Simroth, 1894 - **A: 15, 23; **K**: 142. *TL: 3; TS: 4.*

Arion fasciatus* (Nilsson, 1823) - **A: 9, 23; **K**: 130. *TL: 3; TS: 4.*

Arion silvaticus* Lohmander, 1937 - **A: 15, 23. *TL: 2; TS: 3.*

Arion subfuscus* (Draparnaud, 1805) - **A: 9; **C**: 39; **F**: 69; **I**: 102; **K**: 130; **L**: 147. *TL: 6; TS: 8.*

Fruticicola fruticum (O.F. Müller, 1774) - **B**: 33-4; **C**: 36, 39, 42, 45; **D**: 54, 56; **N**: 160, 163. *TL: 10; TS: 23.*

Helicodonta obvoluta* (O.F. Müller, 1774): **A: 9, 15; **C**: 37. *TL: 3; TS: 3.*

Euomphalia strigella* (Draparnaud, 1805) - **A: 1, 2, 5, 7; **B**: 30. *TL: 5; TS: 7.*

Trichia hispida (Linnaeus, 1758) - **B**: 28, 30, 32; **C**: 45. *TL: 4; TS: 183.*

Trichia villosula* (Rossmässler, 1838) - **K: 130-1; **N**: 160. *TL: 3; TS: 15.*

Plicuteria lubomirskii (Ślósarskii, 1881) - **A**: 1, 5-9, 12, 15, 17, 19, 21, 23; **B**: 26, 29, 34-5; **C**: 38-9, 46; **E**: 59, 60; **F**: 65; **G**: 74; **J**: 119; **K**: 133. *TL: 25; TS: 142.*

Petasina unidentata (Draparnaud, 1805) - **A**: 9, 23; **B**: 35, **C**: 39, 40, 45; **D**: 53, 55; **K**: 137. *TL: 9; TS: 40.*

Perforatella bidentata (Gmelin, 1791) - **A**: 20, 23; **B**: 33; **C**: 36, 46-8; **D**: 51, 56; **E**: 62; **F**: 65-6; **K**: 129, 138; **M**: 148-9; **N**: 162-3. *TL: 18; TS: 294.*

Monachoides incarnatus (O.F. Müller, 1774) - **A**: 3, 4, 6-9, 12-3, 15-6, 20-1, 23; **B**: 24, 26, 29, 32, 34-5; **C**: 36, 39, 40, 47-8; **D**: 53; **E**: 59, 62; **F**: 63, 65-6; **G**: 74-5, 78-9; **H**: 96; **I**: 98; **J**: 119, 126; **K**: 137, 140, 142. *TL: 41; TS: 112.*

Monachoides vicinus* (Rossmässler, 1842) - **A: 7, 20; **B**: 35; **C**: 45; **D**: 55; **E**: 62. *TL: 6; TS: 13.*

Pseudotrichia rubiginosa (Rossmässler, 1838) - **B**: 24; **D**: 51, 56; **M**: 148; **N**: 160-1, 164. *TL: 7; TS: 177.*

Arianta arbustorum (Linnaeus, 1758) - **A**: 9, 10-1, 15; **B**: 27, 34; **D**: 54; **F**: 62; **F**: 62; **G**: 78; **K**: 130. *TL: 10; TS: 29.*

Faustina faustina* (Rossmässler, 1835): **A: 9, 15, 20, 23; **B**: 26, **C**: 37. *TL: 6; TS: 7.*

Isognomostoma isognomostomos* (Schröter, 1784) - **A: 9, 15, 20. *TL: 3; TS: 3.*

Cepaea hortensis* (O.F. Müller, 1774) - **A: 1, 9. *TL: 2; TS: 3.*

Cepaea vindobonesis (A. Férussac, 1802) - **A**: 1, 5-8; **B**: 26, 29. *TL: 7; TS: 12.*

Helix pomatia* Linnaeus, 1758 - **A: 4, 7, 9, 23. *TL: 4; TS: 7.*

Class: **BIVALVIA**

Pisidium casertanum (Poli, 1791) - **A**: 2, 3, 7-10, 13, 15, 20; **B**: 24-7, 32-3, 35; **C**: 37-8, 40-2, 44-7; **D**: 49-51, 55, 58; **E**: 59, 60, 62; **F**: 64, 69, 71; **G**: 77; **H**: 92-3, 96; **I**: 97, 103-4, 106, 113-4; **J**: 119, 121-5; **K**: 129-136, 138-9, 141, 143, 145; **L**: 146-7; **M**: 148-151, 153, 154-7; **N**: 160, 162-4. *TL: 81; TS: 6412.*

Pisidium milium Held, 1836 - **D**: 51; **M**: 149, 157; **N**: 161. *TL: 4; TS: 42.*

Pisidium obtusale (Lamarck, 1818) - **D**: 56; **M**: 148-9; **N**: 158, 160-2, 164. *TL: 8; TS: 511.*

Pisidium personatum Malm, 1855 - **A**: 2, 3, 5-10, 12-3, 15-7, 20-1, 23; **B**: 24-30, 32-3, 35; **C**: 36-42, 45-6; **D**: 49-52, 54-6, 58; **E**: 59, 60, 62; **F**: 63, 64-6, 69, 71; **G**: 74-5, 77, 79; **H**: 88, 92-4, 96; **I**: 97-8, 104; **J**: 119, 121-6; **K**: 129-136, 138-9, 141, 143, 145; **L**: 146-7; **M**: 148-151, 153, 154-7. *TL: 94; TS: 14451.*

Pisidium subtruncatum Malm, 1855 - **D**: 51. *TL: 1; TS: 1.*

Mollusc communities of different types of fens

We found a clear coincidence between the composition of mollusc communities and both structural habitat type of fens and vegetation composition. We confirmed the existence of a poor-rich mire gradient in the composition of mollusc communities and the hypothesis of increasing mollusc species richness towards *Ca*-rich fens (Horsák & Hájek 2003). The site classification based on mollusc data reflects differences in water chemistry and vegetation. In general, we can divide mollusc communities of all studied fens into four basic groups distinguished along the poor-rich gradient. Fig. 1 shows the variability of species richness within these four groups.

The first group comprises exclusively rich fens with tufa formation (petrifying springs). Easily available calcium in the form of tufa is the main reason for the highest species richness (max. 32 species). Due to precipitated tufa, there are small dry patches within the fen that support xerophilous snails (e.g. *Cochlicopa lubricella*). These have not been found in other types of fens. Also *Vallonia costata* is an exclusive inhabitant of petrifying springs, besides *V. pulchella* that occurs commonly in fens without tufa formation. At least ten snail species were recorded only in rich fens. Besides the xerophilous species mentioned above, these were the species with a high demand for calcium; some of them are threatened (e.g. *Cochlicopa nitens*, *Pupilla alpicola*, *Vallonia enniensis*, *Vertigo angustior*, *V. moulinsiana*). In any case, petrifying springs represent the most variable group, and this fact is mainly caused by differences in their chemistry and geographical position. Interesting differences are obvious between Outer-Carpathian extremely rich tufa-forming fens (*Carici flavae-Cratoneuretum*) and Inner-Carpathian extremely rich fens (*Caricetum davallianae*), despite the same water chemistry. The species richness of mollusc fauna of the Outer-Carpathian petrifying springs is on average higher compared to that of the Inner-Carpathian. This is mainly caused by a higher proportion of forest species. The more important fact is the occurrence of relict snail species in Inner-Carpathian extremely rich fens. The most important of them are *Vertigo geyeri* and *Pupilla alpicola*, endangered relicts from wet glacial periods and cold periods of the Pleistocene, respectively. Differences mentioned above can be most probably explained by different historical development. The results of paleobotanical and paleomalacological investigation of selected sites in the Outer Carpathians support the hypothesis of young age of Outer-Carpathian rich fens (Hájková & Hájek 2003, Chapter 3).

The second group consists of brown-moss rich fens without tufa formation (*Valeriano simplicifoliae-Caricetum flavae* and communities of the alliance *Caricion lasiocarpae* in the Orava region). The mollusc communities in most of these sites were species-rich (max. 20 species), particularly due to high calcium concentration in water. Species-rich communities with a high proportion of meadow species (e.g. *Cochlicopa lubrica* and *Perpolita hammonis*) and a lack of many exclusive petrifying spring inhabitants are the main characteristics of this group. The fens of this group support the occurrence of many species that are not able to survive under base-poor conditions at the sites of the third and fourth group. Thus, the characteristic species of this group represent exclusive inhabitants of base-rich fens, above all the open-country snails *Vallonia pulchella* and *Vertigo pygmaea*. Some woodland and shrub snails (e.g. *Platyla polita*, *Aegopinella pura*, *Monachoides incarnatus*) can be considered similarly. It is necessary to mention that two groups of base-rich fens described above are mutually similar with respect to the composition of mollusc species. A few localities of petrifying springs (group 1) fell within this second group. However, they represent initial successional stages with low amounts of precipitated tufa.

The third group includes rich *Sphagnum*-fens with the occurrence of calcitolerant *Sphagnum* species (*Sphagno warnstorfii-Eriophoretum latifolii*). The site with the highest species richness hosted 13 species. Rich *Sphagnum*-fens are the most extreme sites hosting terrestrial snails. Only 4 aquatic molluscs occurred in the most unfavourable site. At the majority of sites, 4 terrestrial (*Carychium minimum*, *Vertigo substriata*, *Succinea putris*, *Perpolita hammonis*) and 3 aquatic molluscs (*Galba truncatula*, *Pisidium casertanum*, *P. personatum*) were encountered.

The fourth and last group consists of poor *Sphagnum*-fens (communities of the alliance *Sphagno recurvi-Caricion canescentis*), with very low calcium concentration in water. Only one single aquatic bivalve, i.e. *Pisidium casertanum,* could dwell under such conditions, which are unfavourable to molluscs in general. In fact, these fens with small water pools represent a favourable environment for *Pisidium casertanum*, which may reach high population densities there. On the other hand, if calcium concentration and water pH decreased under the limiting value, which was between 2.7-4 mg/l and pH 4.8-5.5 respectively (Horsák & Hájek 2003), no molluscs were found in the samples.

In conclusion, species composition of mollusc communities usually fits to the species composition of vegetation, with a few exceptions of successionally initial stages. In addition, the arrangement of malacological samples along the major gradient corresponds almost absolutely to the arrangement of vegetation samples (Horsák & Hájek 2003). The detailed numerical analysis (Horsák & Hájek 2003) clearly showed that vegetation composition reliably predicts the quality of mollusc communities. This is caused by the fact that vegetation reflects not only water chemistry, but also other environmental conditions such as climate and the quality of sediment.

Molluscs in relation to water chemistry

In general, the main factor determining species richness and structure of mollusc communities is the content of available calcium. Many authors (e.g. Wäreborn 1969 and 1970, Waldén 1981, Pokryszko 1993, Millar & Waite 1999) found strong positive correlations between pH value and Ca content in soil or litter and the number of mollusc species and/or individuals. Molluscs need calcium for building their shells and other physiological processes (Wäreborn 1970); lack of calcium may also restrict their reproduction (Wäreborn 1979). Molluscs are able to assimilate calcite ($CaCO_3$); Ca- and CO_3-ions are utilised to build the shell (Wäreborn 1969). Therefore, molluscs reach higher abundance and species richness in calcareous areas and sites.

Consequently, species richness of mollusc communities strongly correlates with the main mineral-trophic gradient from mineral rich to mineral poor fens; the number of species gradually decreases towards acidic fens. There is an obvious dissimilarity between fen mollusc communities and vegetation in the study area as there are only a few calcifuge mollusc species in the fens. The majority of species found in the acidic types of fens also occur in the calcium-rich ones, but some of them really have their optima at base-poor sites. A detailed study of the relation between water calcium concentration and species richness in the Outer-Carpathians yielded very interesting results (Horsák & Hájek 2003). There is a strong linearly positive correlation between base saturation and species richness on sites with lower calcium concentration. In such fens calcium is the main factor that influences the occurrence of individual species and their abundance. On the contrary, in rich fens, especially the calcareous ones, the number of species no longer correlates with the increasing calcium concentration. In petrifying springs, where calcium is over-abundant due to a high amount of tufa, other abiotic and biotic factors became more important. We found a significantly lower number of mollusc species at calcium-rich sites with high iron concentration.

Some snail species respond differently to the mineral richness and to pH within the gradient measured. The results of the study suggested that *V. geyeri* avoids fens with extremely high alkalinity and mineral richness. This fact was supported by a unimodal response of *V. geyeri* to the gradient of mineral richness measured as water conductivity. The species optimum was at the sites with intermediate mineral richness and the species was not present in extremely mineral- and salt-rich fens (Horsák & Hájek in press).

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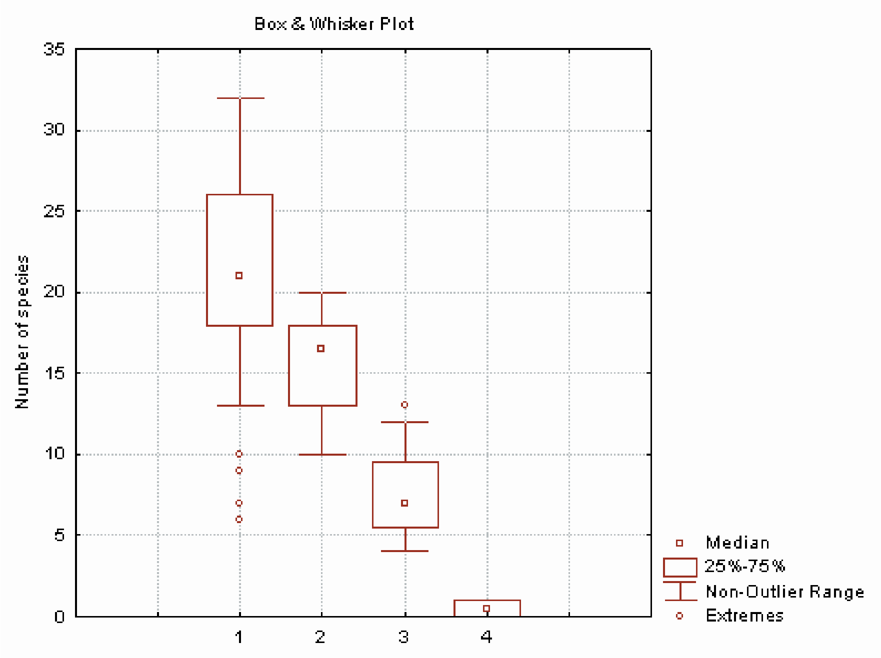
Table 1: The species recorded at least at ten sites are ranked according to their frequency. Their mean dominance (%) is calculated separately for terrestrial and aquatic molluscs.

terrestrial species	**sum of sites**	**frequency**	**dominance**
Carychium minimum	103	84.4	25.93
Cochlicopa lubrica	94	77.0	8.40
Vertigo antivertigo	85	69.7	9.25
Punctum pygmaeum	82	67.2	4.79
Vallonia pulchella	82	67.2	6.57
Perpolita hammonis	78	63.9	10.12
Euconulus fulvus	71	58.2	5.23
Vertigo pygmaea	71	58.2	7.28
Vertigo substriata	66	54.1	8.40
Succinea putris	64	52.5	12.05
Carychium tridentatum	60	49.2	11.41
Vertigo angustior	59	48.4	9.55
Oxyloma elegans	46	37.7	9.50
Columella edentula	45	36.9	2.00
Vitrina pellucida	41	33.6	0.86
Monachoides incarnatus	40	32.8	0.81
Euconulus praticola	35	28.7	5.73
Aegopinella pura	33	27.0	2.70
Succinella oblonga	33	27.0	4.85
Daudebardia rufa	29	23.8	0.91
Vallonia costata	26	21.3	2.39
Daudebardia brevipes	25	20.5	0.71
Plicuteria lubomirskii	25	20.5	1.43
Zonitoides nitidus	25	20.5	4.90
Vertigo geyeri	20	16.4	10.85
Perforatella bidentata	18	14.8	2.77
Platyla polita	18	14.8	1.82
Pupilla alpicola	18	14.8	15.75
Vitrea contracta	18	14.8	1.20
Vitrea crystallina	17	13.9	3.59
Vitrea diaphana	17	13.9	0.87
Acanthinula aculeata	15	12.3	1.13
Deroceras laeve	12	9.8	3.65
Truncatellina cylindrica	11	9.0	1.94
Vertigo moulinsiana	11	9.0	4.51
Arianta arbustorum	10	8.2	1.78
Fruticicola fruticum	10	8.2	0.76
aquatic species			
Pisidium personatum	95	77.9	41.16
Galba truncatula	92	75.4	14.47
Pisidium casertanum	82	67.2	29.74
Bythinella austriaca	75	61.5	51.24
Radix peregra	37	30.3	5.33
Anisus leucostoma	15	12.3	21.82

Figure 1: Variability of species richness at the sites within the four different structural habitat types. Abbreviations: 1 - extremely rich fens with tufa formation (petrifying springs); 2 - brown-moss rich fens without tufa formation; 3 - rich *Sphagnum*-fens with the occurrence of calcitolerant *Sphagnum* species; 4 - poor acidic fens. Note: outliers of the first group (petrifying springs) represent Inner-Carpathian travertine swards; the extremes are caused by their extreme mineral richness.



Summary

M. Hájek

Spring fens in the westernmost part of the West Carpathians are small, young and mostly scattered within a mosaic of managed grassland, but they represent one of the most important sources of biodiversity in the current landscape. The comprehensive set of threatened mire organisms had not colonised these habitats before man started to manage the landscape. However, managed spring fens are recently the only habitats where we can find mire specialists. Generally, spring fen habitats that are moderately or extremely calcium-rich were found to be more threatened than calcium-poor acidic ones.

Carpathian spring fens are unique not only for their vegetation, but also for their specific water chemistry and specific assemblages of algae, fungi and invertebrates. All the studied taxonomic groups change their species composition along the poor-rich gradient, from extremely calcium-poor acidic spring fens populated by peat mosses to extremely calcium-rich spring fens with the formation of calcareous tufa. The appearance of any, even calcitolerant, *Sphagnum* species was found to be the most important natural discontinuity in the major gradient of species composition. The second direction of the species-data variation is mostly controlled by moisture changes within sites. In all cases, vegetation composition accounted for a larger portion of species variation in the studied assemblages of lower plants, fungi and invertebrates, as compared to directly measured environmental data. The species richness generally increases from poor to moderately-rich fens with calcitolerant peat mosses, then it decreases (bryophytes, algae, fungi) or continues to rise (vascular plants, molluscs). The enhanced nutrient input and lowered nutrient export by hay removal is mostly reflected in the succession of vegetation. When nutrient input increases, calcareous fens easily change to more productive *Calthion* meadows and moderately-rich fens are rapidly overgrown by *Sphagnum* species, acidified and changed into poor fens. The successional change reflects also in the species composition of other taxonomic groups.

We believe that this monograph will turn the attention of nature-conservancy to these unique but strongly threatened habitats. All well-preserved remnants of spring-fen vegetation should be protected and, if succession or litter accumulation is observed, extensively managed. The absence of attractive vascular plant species such as orchids and the small area of fens should not be arguments for the lack of interest from conservancy authorities; the preserved spring-fens always serve as potential habitats for threatened species migrating in the landscape and very often host an “invisible” rarity of lower plants, fungi and invertebrates.

Ecology and palaeoecology of spring fens of the West Carpathians

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