Vegetation changes in beech and spruce stands in the Orlické hory Mts. in 1951–2001

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ABSTRACT: Plant cenological surveys on the basis of Braun-Blanquet's seven-point scale were made on 34 research plots in the course of studies of vegetation changes in beech and spruce stands in the Orlické hory Mts. over period of 1951–2001. The acquired data were processed not only by traditional plant coenological methods but also by numerical analyses (agglomerative and divisive classification, ordination, species diversity). The results document marked changes that occurred in species-rich spruce communities of the association *Athyrio alpestre-Piceetum* (Aa-P) as well as in species-poorer communities of the associations *Vaccinio myrtilli-Piceetum* (Vm-P), *Calamagrostio villosae-Piceetum* (Cv-P) and *Deschampsio flexuosae-Piceetum* (Df-P). The developmental trend of these communities in 1971–1991 converged on types very poor in species (Df-P association). On the contrary, the period 1991–2001 was characterised by a marked increase in the number of species, especially in the herb layer. An increase in coverage and number of tree species seedlings was very high after the productive seed years 1992 and 1995. The acceleration of changes in beech stands in 1971–1991 led to a species number diminution in herb-rich types of the association *Dentario enneaphylli-Fagetum* (De-F), and/or to their transition to species-poorer acidophilous types *Calamagrostio villosae-Fagetum* (Cv-F). Similarly like in spruce stands the number of species in beech stand relevés increased in 1991–2001. But a majority of typical species of herb-rich beech stands returned to the communities under study very slowly.

Keywords: mountain forests; beech and spruce stands; plant cenology; classification; ordination; species diversity; air pollution

Before anthropic activities started to change the landscape in the 13th century, the vegetation of the Orlické hory Mts. was a result of development of plant communities in the Quaternary. Mikyška's and Zlatník's vegetation reconstructions show that follows phytocenoses were the natural basis of forest stands at that time: meadows and alder stands, scree stands, herb-rich beech stands, beech stands with wood-rush, acidophilous mountain beech stands, mountain spruce stands, waterlogged spruce stands, raised bogs and transient peat bogs. A major portion of the mountain range (about 90%) was originally covered by beech stands with admixed fir and sycamore maple, and spruce at higher locations. Mountain spruce stands covered about 3% of the area of discontinuous locations of the mountains (ca. up 1,020 m above sea level), mainly in the areas of Malá Deštná, Velká Deštná, Maruša, Jelenka, Koruna and Tetřevec as well as Kunštátská kaple, Šerlich and Vrchmezí (MIKYŠKA et al. 1968). Contrary to this information, ZLATNÍK (archival materials) identified climax spruce stands only in the area of Malá and Velká Deštná. Table 1 shows the present identification of forest vegetation zones and their characteristics. Remnants of natural vegetation types have been conserved until now. The species composition of forests is dominated by spruce (85.4%) at present, while dominant beech accounts for

Table 1. Characteristics of forest vegetation zones of the Orlické hory Mts.

Forest vegetation zones		Area	Proportion	Altitude	Average temperature	Annual precipitation	Growing season
		(ha)	(%)	(m)	(ºC)	(mm)	(days)
5	Beech with Fir	5,174	23.4	500–700	5.5–6.5	800–980	125–140
6	Beech with Spruce	12,537	56.7	600–900	4.5–5.5	900–1,050	110–130
7	Spruce with Beech	4,157	18.8	900–1,050	4.0–4.5	1,050–1,200	90–110
8	Spruce	243	1.1	1,050–1,115	4.0	1,200–1,300	80–90

Source: FMI at Brandýs nad Labem

Table 2. Comparison of natural, present and target species composition in the Orlické hory Mts.

Tree species	Species composition					
	Natural		Present		Target	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Spruce	7,392	36.0	17,542	85.4	14,393	70.1
Fir	5,133	25.0	131	0.6	596	2.9
Pine	0	+	36	0.2	205	1.0
Larch	0	0.0	286	1.4	575	2.8
Other conifers	0	0.0	237	1.2	164	0.8
Conifers total	***12,525***	***61.0***	***18,232***	***88.8***	***15,933***	***77.6***
Oak	+	+	8	+	40	0.2
Beech	7,187	35.0	1,018	5.0	3,100	15.1
Hornbeam	0	0.0	0	+	0	0.0
Ash	62	0.3	36	0.2	165	0.8
Maple	246	1.2	151	0.7	514	2.5
Elm	20	0.1	0	+	20	0.1
Birch	62	0.3	342	1.6	165	0.8
Linden	40	0.2	6	+	328	1.6
Alder	144	0.7	504	2.5	185	0.9
Other broadleaves	246	1.2	235	1.2	82	0.4
Broadleaves total	***8,007***	***39.0***	***2,300***	***11.2***	***4,599***	***22.4***
Total	**20,532**	**100.0**	**20,532**	**100.0**	**20,532**	**100.0**

Source: Summary Forest Management Plan 2000 – FMI at Brandýs nad Labem

5.0% only (cf. Table 2). The autochthonous mountain spruce stands have not been conserved until now. Remnants of spruce stands of natural type are currently encountered in the Šerlich kettle only. Fragments of autochthonous beech stands have been conserved mostly in preserves (Bukačka National Nature Reserve, Trčkov NNR, Pod Vrchmezím Nature Reserve, Sedloňovský vrch NR, Komáří vrch NR and Černý důl NR). The objective of the paper was to describe the present state and phytocenose changes of beech and spruce stands in the Deštenská mountainous formation in 1951–2001.

PROBLEM ANALYSIS

Vegetation research consists of two stages: data collection and data processing. With respect to the objective of the study a comparison of some data collection methods and evaluation are presented by KUBÍKOVÁ and REJMÁNEK (1973), SLAVÍKOVÁ (1986), DYKYJOVÁ et al. (1989).

Semi-quantitative estimations of coverage are the most expeditious method of data collection, Braun-Blanquet's seven-point scale of abundance and dominance is employed most frequently; it was used for the study of beech stands e.g. by MATUSZKIEWICZ (1950), MÁLEK (1955), SAMEK (1957), KOPECKÝ (1958), NEUHÄUSL (1959), MORAVCOVÁ-HUSOVÁ (1964), SÝKORA (1967), MIKYŠKA (1972), MORAVEC (1974), VIEWEGH (1987), VACEK et al. (1998, 1999a,b), HLAVÁČOVÁ (1990), VACEK and LEPŠ (1991). This method was applied to study spruce stands by KRAJINA (1933), SILLINGER (1933), SAMEK (1957), SAMEK and PLÍVA (1957), KUČERA (1966), MATUSZKIEWICZ et al. (1960, 1967), STÖCKER (1968), MIKYŠKA (1972), MÁLEK (1970, 1973), PIŠTA (1972, 1978), KRAHULEC (1975), ŠOLTÉS (1976) and MAREŠOVÁ (1990). More detailed is Domin's eleven-point scale of abundance and dominance which was modified by HADAČ; it was used for plant cenological studies of climax spruce stands by HADAČ et al. (1969), SÝKORA (1971), SOFRON (1981), VACEK (1983, 1984), VACEK and MATĚJKA (1999) and VACEK and LEPŠ (1999).

The use of semi-quantitative method does not eliminate further processing of cenological relevés and determination of floristic similarity or developmental changes in populations. A semi-quantitative method is suitable for more extensive studies of phytocenoses because its time consumption is low and it surveys a much larger area as a whole compared to quantitative methods.

In the course of data processing either recurrent types of vegetation are identified (this common task is resolved by classification) or the relations of changes in vegetation to environment gradients are searched (using methods of gradient analysis). This two method groups can be applied on an empirical or numerical basis. The first approach is older and traditional (its typical example is Zurich-Montpellier phytosociological classification or the Czech school of forest typology); numerical methods

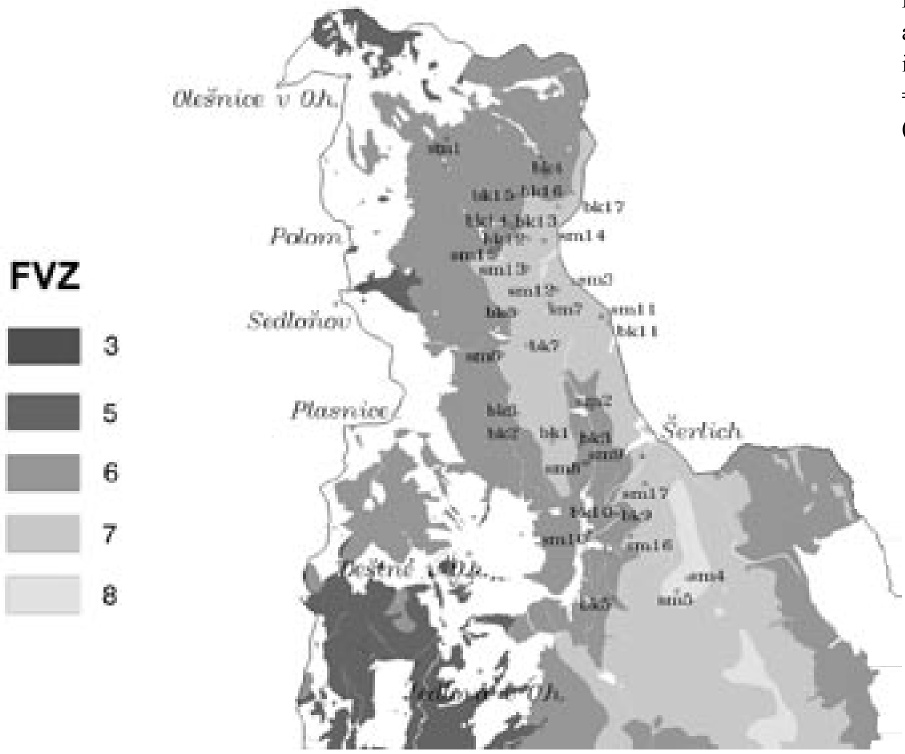


Fig. 1. Map of forest vegetation altitudinal belts with research plots in beech stands (beech1–beech17 = bk1–bk17) and spruce stands (spruce1–spruce17 = sm1–sm17)

are modern approaches and are considered as an objective alternative of subjective classification methods. In recent time the myth of objectivity of numerical classification methods has been abandoned; nevertheless, they are an important tool of vegetation research and their development continues (JONGMAN et al. 1987). VIEWEGH (1987), HLAVÁČOVÁ (1990), VACEK and LEPŠ (1991, 1992, 1999) and VACEK and MATĚJKA (1999) used classification and ordination methods to study beech and spruce stands; they compared these two approaches and examined a suitability of different input data for a numerical analysis.

The study of changes through the time that are reflected by change of the species number, entry of invasive or alien species into the community, exchange of dominants, recession of less abundant species, and finally sometimes a complete extinction of original community, that is a very important part of vegetation study. Causes of these changes should be analysed separately in each case, but a uniform method can be used for their recording (KUBÍKOVÁ 1986). One of the oldest methods of investigation into changes in the internal structure of vegetation is repeated phytosociological relevés of permanent research plots. SAMEK (1986) considered the evaluation of identified changes and their interpretation as the most critical problem of phytocenological monitoring. He stated that the evaluation of the anthropogenic influence share should be based on comparison and quantification of the examined influence. These conditions are not often satisfied in phytocenological monitoring. Therefore this type of monitoring should be used where other experimental measurements or auto-ecological assessments are carried out.

MATERIAL AND METHOD

Description of studied area

The conditions of plant cenological monitoring in spruce and beech stands were relatively satisfied on 34 research plots established in 1951 by Prof. A. Zlatník and Prof. J. Pelíšek from the Forestry Faculty of Agricultural University at Brno, and renewed in 1971 by RNDr. J. Gregor from the Forest Management Institute, branch at Hradec Králové. These plots were sampled repeatedly in 1991 and 2001 in order to record their present state and particularly the vegetation dynamics in 1951–2001.

The studied area with remnants of evaluated beech and spruce stands (Fig. 1) lies in Olešnice, Vrchmezí, Malá and Velká Deštná localities of the Orlické hory mountain range, which is a part of the Deštenská mountainous formation. Formerly it was Olešnice and Deštné forest districts, currently it is Rychnov nad Kněžnou forest administration.

Geologically, the area is built of igneous and metamorphic rocks – mica-schist gneisses, granitic mica schists, and also orthogneisses, paragneisses and migmatites (MARTINEC 1977). Oligotrophic and mesotrophic Cambisols occur in the lowest and medium-high locations of the area, entic Podzols are in higher locations and haplic Podzols developed in the highest locations. Soils influenced by water are encountered on plateaus or on moderate slopes: Stagnosols, Gleysols and Histosols.

The area is situated in a moderately warm region (moderately warm district), only the highest locations belong to a cold region (moderately cold district). The climate is harsh, of continental nature, with low temperatures, abun-

Table 3. Basic data on research plots in beech stands in the Orlické hory Mts.

Research plot No.	Altitude	Exposure	Slope (degrees)	Stand	Forest site type*	Age (years)	Mean height (m)	Mean diameter at b.h. (cm)	Site class	Stocking	Tree canopy cover – E_3 (%)			
											1951	1971	1991	2001
01	970	W	2	$133B_{13}$	$7N_3$	124	18	28	9	8	80	80	90	90
02	920	W	15	$135B_{12}$	$7N_1$	120	19	31	6	8	90	90	90	85
03	900	E	25	$133D_{13}$	$7K_6$	127	21	30	7	9	80	90	90	85
04	875	NE	25	$107B_{12}$	$6K_6$	116	25	33	5	9	75	80	90	85
05	900	SW	25	$113D_{12}$	$7N_2$	120	23	34	5	9	85	90	90	85
06	950	SW	25	$135B_{12}$	$7N_1$	120	19	31	6	8	70	80	75	70
07	1,020	SW	15	$121D_{11/7}$	$7Z_1$	110	16	20	9	8	60	80	80	75
08	1,010	W	25	$120B_{17/6}$	$7Z_2$	186	18	38	8	7	75	80	90	85
09	950	SW	20	$126B_9$	$6N_1$	82	21	26	8	10	60	80	90	85
10	990	NW	2	$126B_9$	$6N_1$	82	21	26	8	10	80	70	60	65
11	1,015	SW	5	$123B_{10}$	$7Z_2$	100	16	31	6	8	60	80	50	60
12	935	W	15	$109B_{13}$	$7K_6$	130	19	36	5	7	70	70	70	75
13	780	SW	25	$110C_{16}$	$6K_6$	151	27	40	5	7	80	80	100	95
14	860	SW	25	$110C_{16}$	$6K_6$	151	27	40	5	7	70	80	70	75
15	940	W	15	$109A_{16}$	$7K_6$	160	20	38	6	8	85	90	85	85
16	980	SW	2	$109A_{16}$	$7K_6$	160	20	38	6	8	75	80	65	65
17	970	NW	25	$108C_{17/4}$	$7F_1$	161	23	36	6	10	60	60	50	55

*Site type classification according to Forest Management Institute – first number indicate forest altitudinal zone (6 – beech with fir, 7 – beech with spruce), character is used for edaphic category (Z – scrub, N – stony-acidic, K – acidic, F – slope-stony, nutrient-medium), last number indicate the type

dant precipitation, frequent fogs forming horizontal precipitation and with occasional destructive winds (PRŮŠA 2001). Average annual temperature ranges from 4 to 7°C and sum of precipitation varies between 800 and 1,300 mm per year. The number of days with snow cover is from 60 to 160. The length of the growing season is 132 days at an altitude of 600 m, 107 days at 900 m and 83 days at 1,100 m a.s.l. Western air flows are prevailing, destructive north-eastern winds blow locally. Icing causes great damage in the highest parts. A marked climax climatic phenomenon reduces tree species growth in these locations.

According to the Czech Hydrometeorological Institute, present average annual SO_2-concentrations amount to about 5 μg/m³. Besides this toxic component, air-pollution contain high level of ozone and nitrogen oxides. During the air-pollution disaster in the middle of 80s, average SO_2-concentrations fluctuated around 20 μg/m³.

Based on vegetation reconstructions species-rich beech stands and beech stands with fir of the alliance *Fagion* (Luquet 1926) were largely dominant in the area of the Deštenská mountainous formation. Poor-in-species acidophilous beech stands, beech stands with spruce and fir stands of the alliance *Luzulo-Fagion* Lohmeyer et Tüxen 1954 occurred in the highest ridge locations from Šerlich Mt. to Vrchmezí Mt. Natural spruce stands of the alliance *Vaccinio-Piceion* Br.-Bl. in Br.-Bl., Sissingh et Vlieger 1939 were encountered only in the highest ridge locations (up 1,050 m a.s.l.). The other phytocenoses covered very small areas (MIKYŠKA et al. 1968).

Research in forest stands

Studies of dynamics of vegetation changes in beech and spruce stands on 34 research plots (permanent research plots PRP beech 01–17, PRP spruce 01–17) in Rychnov forest district were based on plant cenological relevés and pedological records of Prof. A. Zlatník and Prof. J. Pelíšek from 1951 and RNDr. J. Gregor from 1971. In 1991 and 2001 these plots 490 m² in size were sampled again using Braun-Blanquet's seven-point scale, air-pollution environmental conditions were described and soil pits were restored on selected plots (PRP beech 04, 14, 10 and 17, PRP spruce 01, 10, 13 and 16) and soil samples were taken from the genetic horizons. Table 3 shows basic data on PRP beech 01–17, Table 4 documents PRP spruce 01–17.

Processing and evaluation of relevés

Data were transcribed for computer processing into a programmed system DBreleve (specialised software for records of data on communities including environmental conditions and other data that facilitates to arrange data in tables, print tables, select relevés according to various attributes, compute characteristics of species diversity, export selected data for further processing and carry out some other operations with data; for programme description see Internet pages at *http://www.infodatasys.cz*).

Taxonomic nomenclature was unified in all relevés according to KUBÁT et al. (2002), and PILOUS and DUDA (1960). Particular relevés were included in relevant associations according to Zurich-Montpellier School of Phytosociology (MORAVEC et al. 1983): *Dentario enneaphylli-Fagetum* (De-F), *Aceri-Fagetum* (A-F) and *Calamagrostio villosae-Fagetum* (Cv-F). Numbers of phytocenological relevé: the first two digits designate PRP beech or PRP spruce (01–17), the third digit (1, 2 or 3) indicates the year of survey, e.g. the relevé designated by 093 was recorded on PRP 09 in 1991.

Changes in floristic similarity in 1951, 1971, 1991 and 2001 were evaluated by Sörensen's coefficient of floristic similarity as modified by Schmidt (KUBÍKOVÁ 1986). Constancy was calculated for the particular species and they were included in respective classes I–V (KUBÍKOVÁ 1971).

Three numerical analytical methods were used:

1. Agglomerative hierarchic classification (ORLÓCI 1978) – Ward's method of hierarchic agglomerative classification with Euclidean distance as the measure of dissimilarity was used.
2. Divisive hierarchic classification by TWINSPAN (two-way indicator species analysis) (HILL 1979a).
3. Ordination by detrended correspondence analysis – DCA (HILL 1979b), detrending by 2nd order polynoms. The axes of ordination correspond to the trends of highest variability in the whole data set. The ordination of species and relevés correspond to each other (JONGMAN et al. 1987).

Species diversity and its components (total species diversity was evaluated as Shannon-Wiener index of diversity, total number of spe-

Table 4. Basic data on research plots in spruce stands in the Orlické hory Mts.

Research plot No.	Altitude	Exposure	Slope (degrees)	Stand	Forest site type*	Age (years)	Mean height (m)	Mean diameter at b.h. (cm)	Site class	Stocking	Tree canopy cover – E_3 (%)			
											1951	1971	1991	2001
01	725	SW	25	$111C_{13}$	$6K_6$	125	25	37	5	9	70	80	75	60
02	870	SW	15	$124C_{13}$	$6K_6$	125	27	40	4	8	60	50	60	50
03	1,080	NE	2	$122F_{13}$	$8Z_4$	123	17	30	9	8	70	70	80	0
04	1,110	SW	2	$130A_{16}$	$8Z_2$	160	18	30	9	8	70	80	25	0
05	1,110	–	0	$130A_{16}$	$8Z_4$	160	18	30	9	8	70	70	0	0
06	960	W	20	$120E_{11}$	$7K_1$	108	23	32	5	9	70	70	70	60
07	980	SE	10	$123D_{13}$	$7V_1$	125	25	39	5	7	70	60	70	70
08	840	E	30	$132A_8$	$6A_5$	78	21	26	5	8	90	70	70	60
09	830	E	20	$132A_8$	$6N_1$	78	21	26	5	8	80	70	70	65
10	750	SW	25	$126C_{12}$	$6N_1$	119	28	40	4	10	80	80	80	0
11	750	SW	30	$123A_{12}$	$7Z_1$	120	16	23	9	8	70	70	65	60
12	1,025	SW	10	$122F_{13}$	$8Z_4$	123	17	30	9	8	70	70	50	40
13	1,040	–	0	$122E_9$	$8Z_4$	87	15	24	8	8	75	60	30	0
14	1,020	W	20	$109C_{13}$	$7Z_2$	128	15	34	7	7	65	60	50	0
15	940	NW	20	$116A_{11}$	$7N_1$	109	24	29	6	10	75	75	70	70
16	920	W	20	$127C_{10}$	$7K_1$	98	21	27	6	8	90	80	90	80
17	990	W	10	$128A_{11}$	$7P_1$	109	22	28	6	8	80	70	0	0

*Site type classification according to Forest Management Institute – first number indicate forest altitudinal zone (6 – beech with fir, 7 – beech with spruce, 8 – spruce), character is used for edaphic category (Z – scrub, N – stony-acidic, K – acidic, A – stony-colluvial, V – moist to wet, P – acidic gleyic), last number indicate the type cies and species equitability on the basis of these variables) were computed in DBreleve software system for the herb layer of forest stands.

Plant cenological relevés and some other results are published via Internet at address *http://www.infodatasys.cz/public/orlh2001/zprava.htm.*

RESULTS AND DISCUSSION

Overview of syntaxa

Beech stands

Phytocenological classification of beech stand syntaxa was interpreted in a very different way. The following overview presents the syntaxa of natural beech stands according to MORAVEC et al. (1983) that were identified in the examined forest stands. These are one vegetation class and one order, two alliances and suballiances and three associations:

Class: *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937
- Order: *Fagetalia sylvaticae* Pawlowski in Pawlowski, Sokolowski et Wallisch 1928
  - Alliance: *Fagion* Luguet 1926
    - Suballiance: *Eu-Fagenion* Oberdorfer 1957 em. Tüxen in Tüxen et Oberdorfer 1958
      - As. *Dentario enneaphylli-Fagetum* Oberdorfer ex W. et A. Matuszkiewicz 1960
    - Suballiance: *Acerenion* Oberdorfer 1957
      - As. *Aceri-Fagetum* J. et M. Bartsch 1940
  - Alliance: *Luzulo-Fagion* Lohmeyer et Tüxen in Tüxen 1954
    - As. *Calamagrostio villosae-Fagetum* Mikyška 1972

Dentario enneaphylli-Fagetum Oberdorfer ex W. et A. Matuszkiewicz 1960

Fagus sylvatica is a dominant tree species in the relatively closed tree layer, *Acer pseudoplatanus* and *Picea abies* are admixed species that can be included in constancy class V (const. cl. V). *Fagus sylvatica* (const. cl. III) is abundant in the mostly open shrub layer.

Dentaria enneaphyllos and *Dentaria bulbifera*, whose coverage have slightly decreased in the course of time, are characteristic of the herb layer. On the contrary, the coverage of *Calamagrostis villosa* and *Calamagrostis arundinacea* increases. *Lamium galeobdolon, Moehringia trinervia, Prenanthes purpurea* and *Polygonatum verticillatum* contribute to the pattern of the association. The coverage of the moss layer is low, with dominant *Polytrichum formosum* and *Mnium affine*.

Athyrium filix-femina, Calamagrostis villosa, Moehringia trinervia, Oxalis acetosella, Polygonatum verticillatum, Prenanthes purpurea and *Senecio ovatus* are included in const. cl. V in the herb layer, *Asperula odorata, Calamagrostis arundinacea, Dentaria bulbifera, Dryopteris carthusiana, Maianthemum bifolium, Petasites albus* and *Stellaria nemorum* in const. cl. IV, *Actea spicata, Aegopodium podagraria, Ajuga reptans, Chrysosplenium alternifolium, Crepis paludosa, Daphne mezereum, Impatiens noli-tangere, Mercurialis perennis* and *Solidago virgaurea* in const. cl. III. The moss layer comprises *Polytrichum formosum* and *Mnium affine* in const. cl. IV, and no species has been included in const. cl. III.

A characteristic combination of species consists of *Fagus sylvatica, Dentaria bulbifera, Dentaria enneaphyllos, Lamium galeobdolon, Moehringia trinervia, Prenanthes purpurea, Polygonatum verticillatum, Senecio ovatus, Rubus idaeus, Asperula odorata, Carex sylvatica, Dryopteris carthusiana, Petasites albus, Polytrichum formosum* and *Mnium affine*.

Ninety-five species in total were recorded in this association, the number of species in relevés ranged between 22 and 60. The average number of species in relevés was 44 in 1951, 42 in 1971, 24 in 1991 and 49 in 2001, i.e. 100%, 95%, 55% and 111%, respectively. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the communities of this association (the values of the coefficient below 70%).

The communities occurred on loam-sandy to sand-loamy mesotrophic Cambisol at an altitude of 780 to 1,015 m. In all four periods of observation (1951, 1971, 1991 and 2001) this association was described only on plots 12 and 13, with marked acerose elements. It was identified on plots 09 and 11 in 1951 only, these plots were included in the association Cv-F in subsequent years.

In the Orlické hory Mts. the communities of this association are considerably endangered by soil acidification and by conversion to spruce monocultures. In the years 1971–1999 the development of these herb-rich communities tended towards the association Cv-F relatively rapidly. A reversal occurred in 1991–2001, when some revitalisation of these communities was observed manifested by an increase in the species number.

Aceri-Fagetum J. et M. Bartsch 1940

The open tree layer is dominated by *Acer pseudoplatanus* and *Fagus sylvatica*, *Picea abies* is interspersed, their const. cl. is V. *Fagus sylvatica* (const. cl. III) is dominant in the sporadic shrub layer, the occurrence of *Acer pseudoplatanus* is scarce.

Athyrium distentifolium dominates in the herb layer, but its coverage has considerably decreased in the course of years, high coverage was found in *Oxalis acetosella* and *Stellaria nemorum*. *Dryopteris filix-mas, Dryopteris carthusiana, Gymnocarpium dryopteris, Prenanthes purpurea* and *Polygonatum verticillatum* contribute to the pattern of this association. The relatively well-developed moss layer is dominated by *Polytrichum formosum*, *Plagiothecium curvifolium* and *Mnium spinosum* are abundant.

In the herb layer *Dryopteris filix-mas, Dryopteris carthusiana, Oxalis acetosella, Polygonatum verticillatum, Prenanthes purpurea, Stellaria nemorum* and *Veratrum album* are included in const. cl. V, *Athyrium* *distentifolium, Deschampsia flexuosa, Gymnocarpium dryopteris, Rubus idaeus* and *Solidago virgaurea* in const. cl. IV, there is no species in const. cl. III. In the moss layer *Mnium spinosum, Plagiothecium curvifolium* and *Polytrichum formosum* belong to const. cl. V, *Dicranum scoparium* to const. cl. IV, no species has been included in const. cl. III.

A characteristic combination of species consists of *Fagus sylvatica, Acer pseudoplatanus, Stellaria nemorum, Dryopteris filix-mas, Dryopteris carthusiana, Gymnocarpium dryopteris, Polygonatum verticillatum, Prenanthes purpurea, Vaccinium myrtillus, Oxalis acetosella, Polytrichum formosum* and *Plagiothecium curvifolium*.

Thirty-four species in total were recorded in this association, the number of species in relevés ranged between 17 and 31. The average number of species in relevés was 23 (100%) in 1951, 33 (143%) in 1971, 19 (83%) in 1991 and 33 (143%) in 2001. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the community of this association.

The communities occurred on fresh sand-loamy mesotrophic Cambisol on the slope deposits at an altitude of 970 m a.s.l. It is plot 17 where this association was identified in all periods of observation.

The communities of the association A-F in the Orlické hory Mts. are very endangered phytocenoses as a result of long-term anthropic activities.

Calamagrostio villosae-Fagetum Mikyška 1972

Fagus sylvatica is dominant in the relatively closed tree layer, with admixture of *Picea abies* (const. cl. V) and scarcely interspersed *Sorbus aucuparia*, *Acer pseudoplatanus* and *Abies alba* (const. cl. I). The sparse shrub layer is dominated by *Fagus sylvatica* (const. cl. III), the other tree species of the herb layer are represented exceptionally.

Physiognomically, high coverage of *Calamagrostis villosa* forming an almost continuous layer locally is typical of this association. Very high values of coverage were also found for *Calamagrostis arundinacea, Deschampsia flexuosa* and *Vaccinium myrtillus. Maianthemum bifolium, Oxalis acetosella* and *Vaccinium myrtillus* are abundant species, in const. cl. IV they are: *Calamagrostis arundinacea, Polygonatum verticillatum* and *Fagus sylvatica*, in const. cl. III: *Athyrium filix-femina* and *Prenanthes purpurea*. In the moss layer *Polytrichum formosum* is included in const. cl. V, *Dicranum scoparium* in const. cl. IV and *Plagiothecium curvifolium* in const. cl. III.

A characteristic combination of species consists of *Fagus sylvatica, Calamagrostis villosa, Calamagrostis arundinacea, Deschampsia flexuosa, Dryopteris carthusiana, Athyrium filix-femina, Maianthemum bifolium, Oxalis acetosella, Polygonatum verticillatum, Prenanthes purpurea, Vaccinium myrtillus, Polytrichum formosum* and *Dicranum scoparium*.

Eighty-eight species in total were recorded in this association, the number of species in relevés ranged between 12 and 52 while their constancy was not very high except diagnostic species. The average number of species in relevés was 22 (100%) in 1951, 20 (91%) in 1971, 14 (64%) in 1991 and 23 (105%) in 2001.

The communities occurred on loam-sandy to sand-loamy oligotrophic to mesotrophic Cambisol and Entic Podzols at an altitude of 860–1,020 m a.s.l. In all four periods of observation (1951, 1971, 1991 and 2001) they were recorded on plots 01–08, 10 and 14–16. They were described on plots 09 and 11 only in 1971, 1991 and 2001, in previous years these plots were classified into the association De-F. The value of Sörensen's coefficient also indicates that more important changes than simple fluctuations in time took place in the communities of this association.

Communities of this association are the most frequent vegetation types of beech stands in the Orlické hory Mts.

Spruce stands

Plant cenological classification of syntaxa of spruce stands was interpreted in a very different way. The syntaxa of spruce stands are presented below. In the studied material we identified one vegetation class, two orders, two alliances, one suballiance and four associations (HUSOVÁ et al. 2002 identified only two associations):

Class: *Vaccinio-Piceetea* Br.-Br. in Br.-Bl., Sissingh et Vlieger 1939
- Order: *Athyrio-Piceetalia* Hadač 1962
  - Alliance: *Athyrio-Piceion* Sýkora 1971
    - As. *Athyrio alpestre-Piceetum* Hartmann 1959
- Order: *Vaccinio-Piceetalia* Br.-Bl. in Br.-Bl., Sissingh et Vlieger 1939
  - Alliance: *Vaccinio-Piceion* Br.-Bl. in Br.-Bl., Sissingh et Vlieger 1939
    - Suballiance: *Eu-Vaccinio-Piceenion* Oberdorfer 1962
    - As. *Calamagrostio villosae-Piceetum* (Tx. 1937) Hartmann 1953
    - As. *Deschampsio flexuosae-Piceetum* Hadač et al. 1969
    - As. *Vaccinio myrtilli-Piceetum* Szafer, Kulcz. et Pawl. 1923

Athyrio alpestre-Piceetum Hartmann 1959

Picea abies is dominant in the relatively closed to open tree layer (canopy 40–90%), with interspersed *Acer pseudoplatanus* (constancy class V) and locally occurring *Fagus sylvatica* (const. cl. III). The sporadic shrub layer (coverage 0–30%) consists of *Picea abies, Fagus sylvatica, Acer pseudoplatanus* and *Sorbus aucuparia*, which can be included in const. classes II–III.

Physiognomically the association is dominated by the ferns *Athyrium distentifolium*, *Athyrium filix-femina, Dryopteris carthusiana* and *Polystichum lobatum* in the herb layer. The pattern of this association is also characterised by the elements of tall-grass meadows – *Streptopus amplexifolius* and *Veratrum album. Polytrichum formosum, Catharinea undulata* and *Plagiothecium curvifolium* are important mosses. The coverage of moss layer is from 5 to 30%.

In the herb layer *Athyrium filix-femina, Calamagrostis villosa, Dryopteris carthusiana, Lamium galeobdolon, Maianthemum bifolium, Oxalis acetosella, Polygonatum verticillatum, Prenanthes purpurea, Rubus idaeus, Stellaria nemorum, Streptopus amplexifolius* and *Vaccinium myrtillus* are included in const. cl. V, *Actea spicata, Calamagrostis arundinacea, Carex pilulifera, Deschampsia flexuosa, Homogyne alpina, Impatiens noli-tangere, Polystichum lobatum* and *Senecio ovatus* in const. cl. IV, *Ajuga reptans, Chaerophyllum hirsutum, Milium effusum, Rumex arifolius, Senecio nemorensis* and *Veratrum album* in const. cl. III. In the moss layer *Polytrichum formosum* belongs to const. cl. V, *Dicranum scoparium* to const. cl. IV and *Catharinea undulata* and *Plagiothecium curvifolium* to const. cl. III.

A characteristic combination of species consists of *Picea abies, Athyrium distentifolium, Athyrium filix-femina, Dryopteris carthusiana, Calamagrostis villosa, Stellaria nemorum, Homogyne alpina, Oxalis acetosella, Polytrichum formosum, Dicranum scoparium* and *Sphagnum girgensohnii*.

Ninety-nine species in total were identified in this association, the number of species in relevés ranged between 21 and 58. The average number of species in relevés was 50 in 1951, 35 in 1971, 27 in 1991 and 41 in 2001, i.e. 100%, 70%, 54% and 82%, respectively. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the communities of this association; these changes are most marked on plot 08 (the coefficient from 62 to 35%).

The communities occurred on sand-loamy pseudogleyic mesotrophic Cambisols, entic Podzols and pseudogleyic haplic Podzol at an altitude of 840–1,025 m a.s.l. In all four periods of observation (1951, 1971, 1991 and 2001) this association was described only on plot 08. It was identified on plot 02 in 1951, on plot 12 in 1951 and 1971, and these plots were classified in the association Cv-P in subsequent years.

The communities of this association are endangered in the Orlické hory Mts., probably by changes in light conditions, soil moisture and acidity. In 1971–1991 the development of these fern communities with elements of tall-grass meadows tended to the association Cv-P relatively quickly.

Calamagrostio villosae-Piceetum (Tx. 1937) Hartmann 1953

Picea abies (const. cl. V) is dominant in the closed and open tree layer, with interspersed *Acer pseudoplatanus*, *Fagus sylvatica* and *Sorbus aucuparia* (const. cl. III and II). The tree layer did not exist on plots 5 and 14 in 1991 and 2001 any longer. The shrub layer is sporadic and sparse (coverage 0–20%), its species composition is identical to the tree layer.

Physiognomically, the association is characterised by high coverage of *Calamagrostis villosa*, which often forms the continuous upper herb layer. *Deschampsia flexuosa* is usually concentrated in the lower herb layer. The moss layer with typical *Polytrichum formosum* and *Dicranum scoparium* is developed on all plots (coverage 5 to 40%).

In the herb layer *Calamagrostis villosa* and *Vaccinium myrtillus* are included in const. cl. V, *Deschampsia flexuosa*, *Dryopteris carthusiana*, *Maianthemum bifolium*, *Oxalis acetosella* and *Trientalis europaea* in const. cl. IV, *Athyrium filix-femina*, *Homogyne alpina*, *Polygonatum verticillatum* and *Streptopus amplexifolius* in const. cl. III. In the moss layer *Dicranum scoparium* and *Polytrichum formosum* belong to const. cl. V, no species belongs to const. cl. IV and *Plagiothecium curvifolium* belongs to const. cl. III.

A characteristic combination of species consists of *Picea abies*, *Calamagrostis villosa*, *Deschampsia flexuosa, Dryopteris carthusiana, Maianthemum bifolium, Oxalis acetosella, Trientalis europaea, Homogyne alpina, Polytrichum formosum*, *Dicranum scoparium* and *Plagiothecium curvifolium*.

Eighty-six species in total were identified in this association, the number of species in relevés ranged between 14 and 43. The average number of species in relevés was 25 in 1951, 21 in 1971, 19 in 1991 and 24 in 2001, i.e. 100%, 84%, 76% and 96%, respectively. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the communities of this association (the coefficient mostly below 70%).

The communities occurred on (loam-sandy, sand-loamy and pseudogleyic) haplic Podzols and pseudogleyic mesotrophic Cambisols at an altitude of 870–1,110 m a.s.l. In all four periods of observation (1951, 1971, 1991 and 2001) this association was described on plots 05, 07 and 14. In 1951 it was identified on plots 12 and 17, on 1971 on plots 02, 03, 13 and 15, in 1991 and 2001 on plots 02 and 12. In most cases these communities involve many transient elements from the community Df-P.

The communities of this association have been the most frequent vegetation type in the Orlické hory Mts. until now, even though their development in 1971–1991 tended towards the association Df-P relatively rapidly.

Deschampsio flexuosae-Piceetum Hadač et al. 1969

Picea abies (const. cl. V) is dominant in the differently closed to open tree layer, with scarcely interspersed *Fagus sylvatica* and *Sorbus aucuparia* (const. cl. I and II). In 2001 the tree layer did not occur on about a third of the plots any longer. The shrub layer is sporadic, mostly sparse (coverage 0–30%) and its species composition is identical with the tree layer (const. cl. I and II).

The herb layer is poor in species, and it is markedly dominated by *Deschampsia flexuosa*, which locally covers continuous areas. *Dryopteris carthusiana* and *Vaccinium myrtillus* are present everywhere. The site dryness considerably restricts the occurrence of *Calamagrostis villosa*. The moss layer is always developed, with regularly lower coverage. It is dominated by *Polytrichum formosum*.

In the herb layer *Calamagrostis villosa, Deschampsia flexuosa, Dryopteris carthusiana* and *Vaccinium myrtillus* are included in const. cl. V, *Sorbus aucuparia* in const.

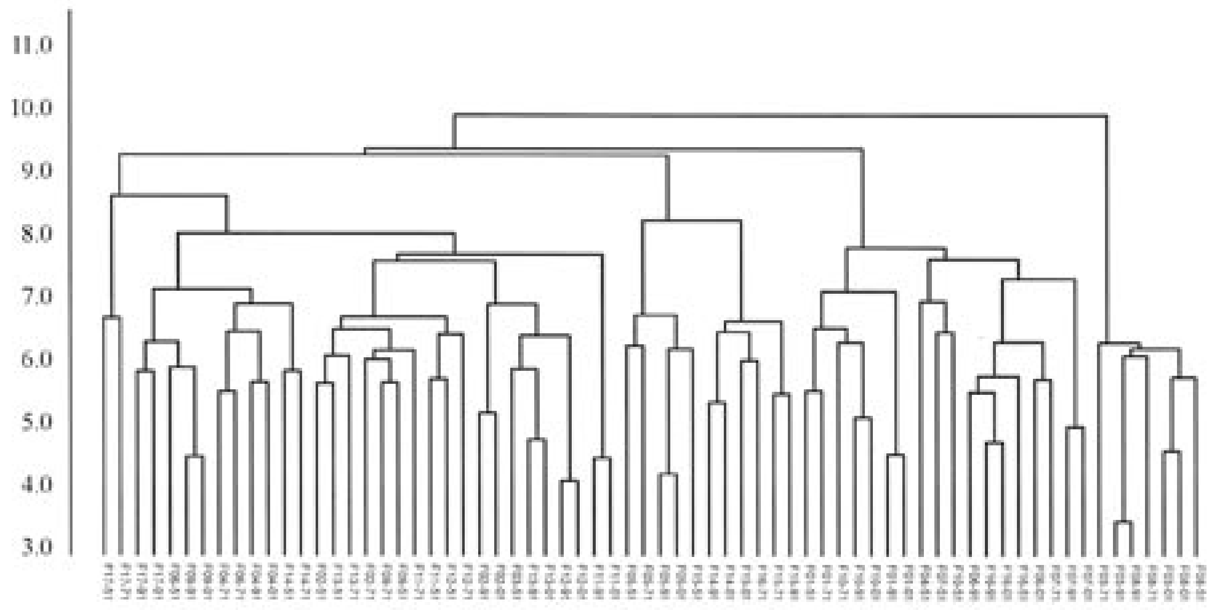


Fig. 2. Classification of phytocenological relevés according to the composition of herb and moss layers – beech stands. Ward's method of hierarchic classification and Euclidean distance as the rate of dissimilarity were used; logarithm values on vertical axis

cl. IV and *Maianthemum bifolium* in const. cl. III. In the moss layer *Polytrichum formosum* belongs to const. cl. V, *Dicranella heteromalla, Dicranum scoparium* and *Plagiothecium curvifolium* to const. cl. IV, and no species has been included in const. cl. III.

A characteristic combination of species consists of *Picea abies, Deschampsia flexuosa, Calamagrostis villosa, Dryopteris carthusiana, Vaccinium myrtillus, Polytrichum formosum, Dicranella heteromalla, Dicranum scoparium* and *Plagiothecium curvifolium*.

Forty-eight species in total were identified in this association, the number of species in relevés ranged between 10 and 22. The average number of species in relevés was 16 (100%) in 1951, 15 (94%) in 1971, 13 (81%) in 1991 and 17 (106%) in 2001. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the communities of this association (the coefficient mostly below 70%).

The communities occurred on loam-sandy entic Podzols and haplic Podzol at an altitude of 725–1,110 m a.s.l. In all four periods of observation (1951, 1971, 1991 and 2001) this association was recorded only on plots 01, 04 and 16. In 1951 it was identified on plots 03, 06 and 15, in 1971 on plot 17, and in 1991 and 2001 on plots 03, 06, 09, 10, 11, 13, 15 and 17. The communities of this association became markedly dominant in the ridge locations of the Orlické hory Mts. in 1971–1991. A trend of succession

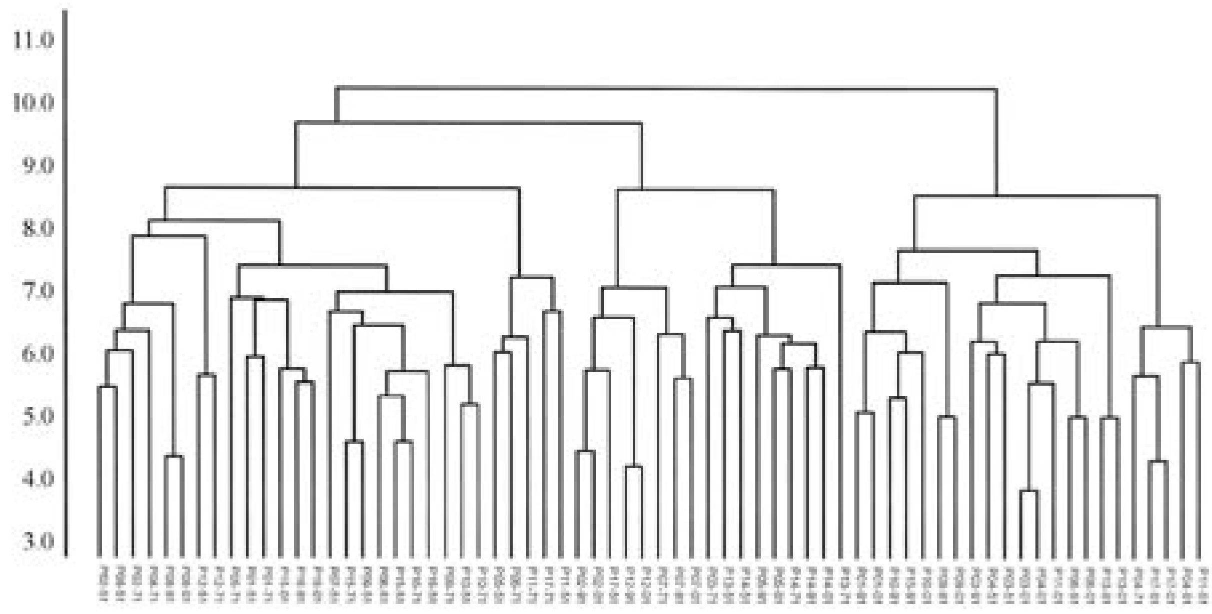


Fig. 3. Classification of phytocenological relevés according to the composition of herb and moss layers – spruce stands. Ward's method of hierarchic classification and Euclidean distance as the rate of dissimilarity were used; logarithm values on vertical axis

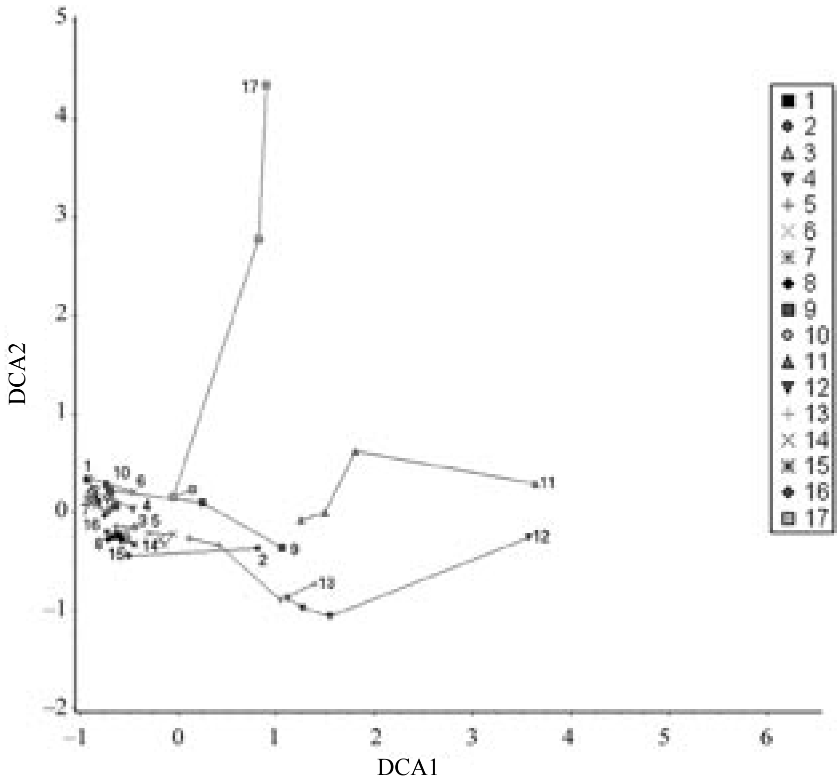


Fig. 4. Relevés ordination according to the herb layer composition in beech stands (axes 1 and 2). DCA ordination was used; vegetation development at the localities is documented for the period 1951–2001 (plot designation is on the trajectory corresponding to the first year)

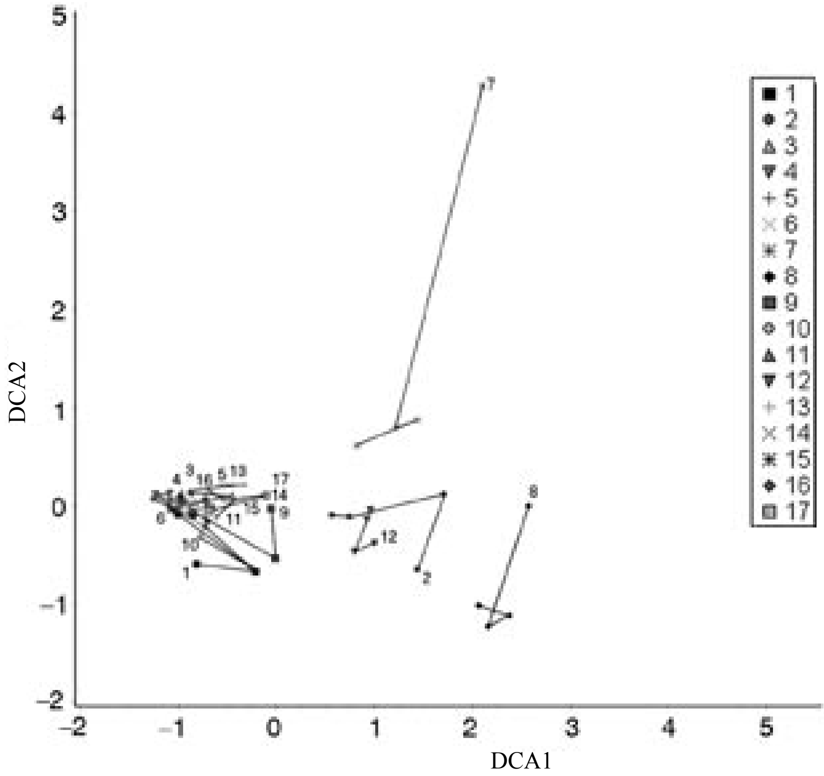


Fig. 5. Relevés ordination according to the herb layer composition in spruce stands (axes 1 and 2). DCA ordination was used; vegetation development at the localities is documented for the period 1951–2001 (plot designation is on the trajectory corresponding to the first year)

of most communities in spruce monocultures gradually tends towards these communities at that time. They are highly dominated by *Deschampsia flexuosa* as a result of canopy opening, it replaces some species less resistant to soil acidification, particularly *Vaccinium myrtillus*. The recession of other species, mainly of *Calamagrostis villosa*, was caused by a change in water regime – overall drying of the ecotope. These changes can be explained as a consequence of pollutant impacts on vegetation. But some revitalisation processes were observed in this association in 1991–2001.

Vaccinio myrtilli-Piceetum Szafer, Kulcz. et Pawl. 1923

Picea abies (const. cl. V) is dominant in the relatively closed tree layer, with interspersed *Fagus sylvatica* and

Table 5. Communities of beech stands: TWINSPAN classification of relevés. A list of species-indicators is given with the designation of each classification group (name abbreviations are used similarly like in ordination results; see Table 7). The last column shows a list of phytocenological relevés included in the given group

*0 Ave fle 1	*00	*000 Mai bif 1	*0000 Cal vil 4 Pol ver 3	*00000 Gym dry 2 Sor auc 1	*000000 Tri eur 1			F02-91 F07-51 F08-51
					*000001	*0000010		F03-71
						*0000011 Pol ver 1	*00000110	F03-91 F03-01 F08-91 F08-01
							*00000111 Car pil 1	F03-51
				*00001 Vac myr 4 Ave fle 4	*000010 Ath fil 1			F10-51 F10-71 F10-91 F10-01
					*000011	*0000110	*00001100 Fag syl 1	F06-91 F07-71 F16-51 F16-71
							*00001101	F08-71 F15-91
						*0000111 Ave fle 5		F16-91 F16-01
			*0001 Pic abi 1 Car pil 1 Rub ida 1 Pre pur 1 Dry car 4	*00010 Oxa ace 3 Hom alp 1	*000100 Ble spi 1			F05-51 F06-51 F06-71 F06-01
					*000101	*0001010 Vac myr 4	*00010100 Hom alp 1	F01-51 F01-71 F01-91 F01-01
							*00010101	F05-71 F09-91
						*0001011		F05-91 F05-01 F07-91 F07-01
				*00011 Ath fil 3 Car pal 1 Gym dry 1				F04-51 F04-71 F04-91 F04-01
		*001 Rub ida 2 Pre pur 2 Dry fil 1	*0010	*00100 Ave fle 1				F15-51 F15-71 F15-01 F09-01
				*00101				F14-51 F14-71 F14-91 F14-01
			*0011 Ver alb 1					F17-51 F17-91 F17-01
	*01 Gal lut 1 Tit dul 1 Pul obs 1	*010 Ave fle 1						F02-51 F02-71 F02-01
		*011						F09-51 F09-71
*1 Gal lut 1 Sen nem 1 Moe tri 3 Pet alb 1	*10	*100	*1000 Aco nap 1					F17-71
			*1001					F13-51 F13-71 F13-91 F13-01
		*101 Dap mez 1						F12-51 F12-71 F12-91 F12-01
	*11 Tha aqu 1							F11-51 F11-71 F11-91 F11-01

Sorbus aucuparia (const. cl. II). The shrub layer has developed sporadically – *Picea abies* and *Fagus sylvatica* (const. cl. I). The herb layer is basically dominated by *Vaccinium myrtillus*. *Deschampsia flexuosa* and *Calamagrostis villosa* are present everywhere. *Dicranum scoparium*, *Plagiothecium curvifolium* and *Polytrichum formosum* are always represented in the relatively well-developed moss layer.

In the herb layer *Calamagrostis villosa, Deschampsia flexuosa* and *Vaccinium myrtillus* are included in const. cl. V, *Dryopteris carthusiana* in const. cl. IV, *Carex pilulifera, Fagus sylvatica, Maianthemum bifolium, Picea abies,*

Table 6. Communities of spruce stands: TWINSPAN classification of relevés. A list of species-indicators is given with the designation of each classification group (name abbreviations are used similarly like in ordination results; see Table 8). The last column shows a list of phytocenological relevés included in the given group

*0	*00 Tri eur 1 Cal vil 4	*000 Hom alp 2 Cal aru 1 Tri eur 1 Cal vil 5 Oxa ace 3	*0000 Mol aru 1				P03-51 P04-51
			*0001	*00010 Pol ver 1			P03-71 P04-01 P05-91 P05-01
				*00011			P05-51 P05-71 P13-71 P14-51
		*001 Dry car 3 Rub fru 1	*0010 Tri eur 1 Mai bif 2 Rub fru 1 Pol ver 2 Cal vil 5	*00100 Pol ver 1	*001000 Rub fru 1		P11-91 P11-01 P13-91 P13-01
					*001001		P04-91 P11-51 P11-71 P17-51
				*00101 Sor auc 2			P13-51 P14-71 P14-91 P14-01
			*0011 Car pil 1	*00110 Car pil 1			P03-91 P03-01 P17-71 P17-01
				*00111	*001110		P04-71 P06-51 P16-51
					*001111 Fag syl 1		P06-71 P06-91 P06-01
	*01 Cal aru 1 Fag syl 1 Pre pur 2	*010 Pic abi 1 Fag syl 3 Pre pur 1	*0100	*01000 Abi alb 1			P09-51
				*01001	*010010		P09-91 P09-01
					*010011 Fag syl 1	*0100110 Cal aru 1	P10-91 P10-01 P15-01
						*0100111	P16-91 P16-01
			*0101 Sam rac 1				P01-91 P01-01 P10-51
		*011 Car pil 3	*0110	*01100			P15-51 P15-91 P17-91
				*01101 Vac myr 4			P09-71 P10-71 P15-71 P16-71
			*0111 Hie mur 1				P01-51 P01-71
*1 Ste nem 1 Ath fil 1 Str amp 1 Rub ida 1	*10 Ver alb 1	*100					P12-91 P12-01
		*101 Aju rep 1					P07-51 P07-71 P07-91 P07-01
	*11 Car pil 1 Gal lut 1	*110 Oxa ace 1	*1100 Aco var 1				P08-51
			*1101	*11010			P08-71 P08-91 P08-01
				*11011 Ace alp 1			P12-51 P12-71
		*111					P02-51 P02-71 P02-91 P02-01

Rubus idaeus and *Sorbus aucuparia* in const. cl. III. In the moss layer *Dicranum scoparium, Plagiothecium curvifolium* and *Polytrichum formosum* belong to const. cl. V, *Dicranella heteromalla* to const. cl. IV, *Plagiothecium curvifolium* and *Pohlia nutans* to const. cl. III.

A characteristic combination of species consists of *Picea abies, Vaccinium myrtillus, Calamagrostis villosa, Deschampsia flexuosa, Dryopteris carthusiana, Maianthemum bifolium, Polytrichum formosum, Dicranum scoparium* and *Plagiothecium curvifolium*.

Thirty-eight species in total were identified in this association, the number of species in relevés ranged from 26 to 10. The average number of species in relevés was 20 in 1951 and 15 in 1971 (i.e. 100% and 75%), in the years 1991 and 2001 this association was not identified any longer. The values of Sörensen's coefficient also indicate that more important changes than simple fluctuations in time took place in the communities of this association.

The communities occurred on sand-loamy oligothrophic Cambisols, entic Podzols and haplic Podzols at an altitude

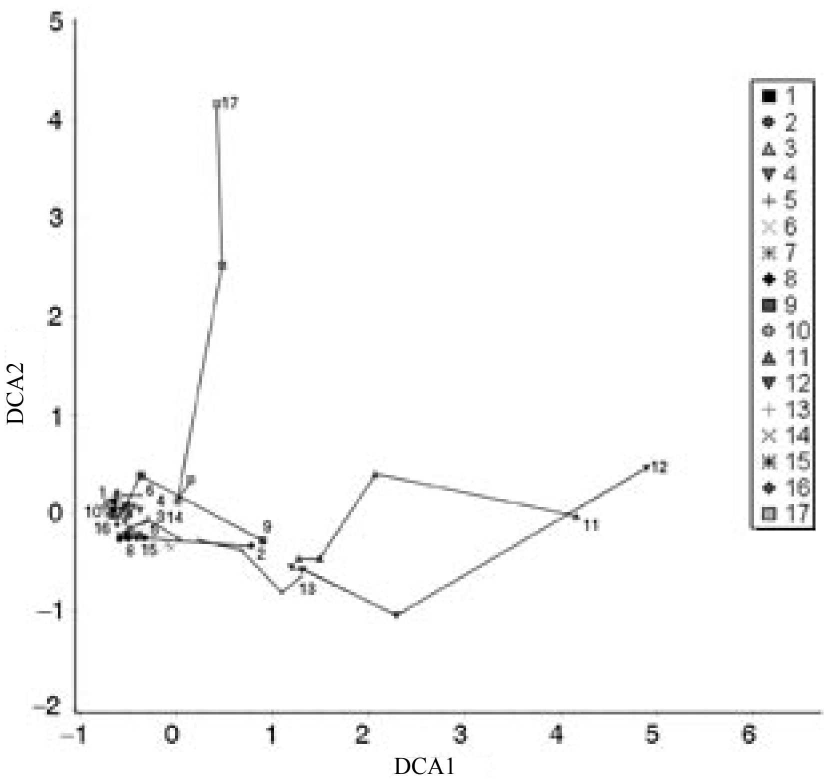


Fig. 6. Relevés ordination according to the composition of herb and moss layers in beech stands (axes 1 and 2). DCA ordination was used, such data transformation was used that the sum of significances for the species of the given layer will equal the total coverage of this layer; vegetation development at the localities is documented for the period 1951–2001 (plot designation is on the trajectory corresponding to the first year)

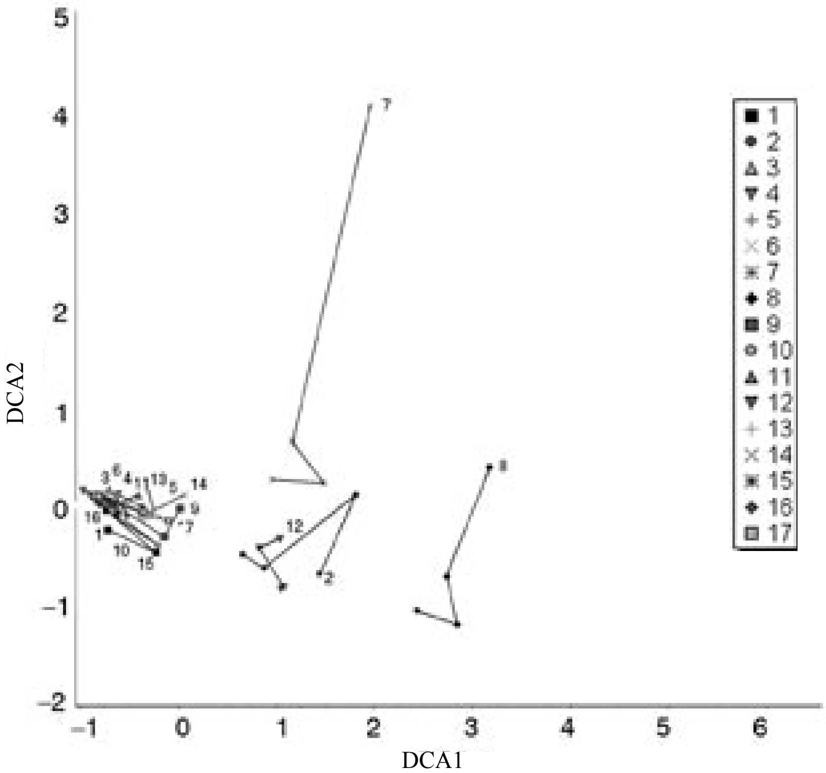


Fig. 7. Relevés ordination according to the composition of herb and moss layers in spruce stands (axes 1 and 2). DCA ordination was used, such data transformation was used that the sum of significances for the species of the given layer will equal the total coverage of this layer; vegetation development at the localities is documented for the period 1951–2001 (plot designation is on the trajectory corresponding to the first year)

of 750–830 m a.s.l. They were described only in 1951 and 1971 on plots 09, 10 and 11. In 1991 and 2001 the association Df-P was recorded on these plots. The communities of this association have almost disappeared from the Orlické hory Mts. although they used to be the most frequent vegetation type in this zone of spruce stands.

This classification corresponds to a system formulated by SOFRON (1981); HUSOVÁ et al. (2002) combined the associations Cv-P, Df-P and Vm-P into the aggregative association Cv-P. It is consistent with the relatively low number of species in these associations that are differentiated mainly on the basis of dominant species.

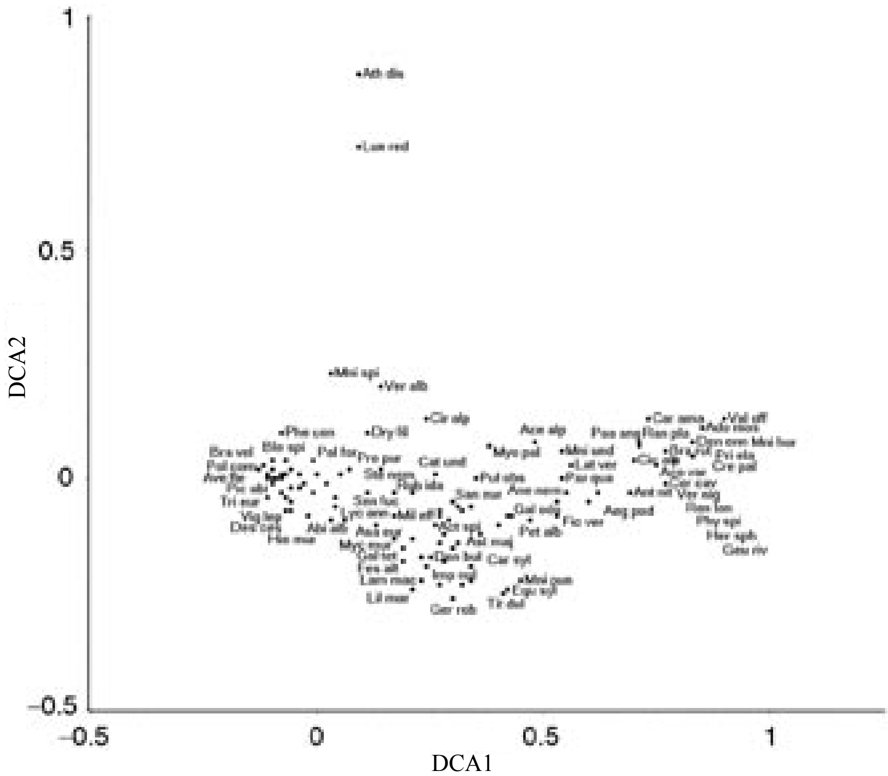


Fig. 8. Ordination of the species of herb and moss layers in beech stands (axes 1 and 2). DCA ordination was used, such data transformation was used that the sum of significances for the species of the given layer will equal the total coverage of this layer. The position of each species is marked, selected species are designated by an abbreviation of their name

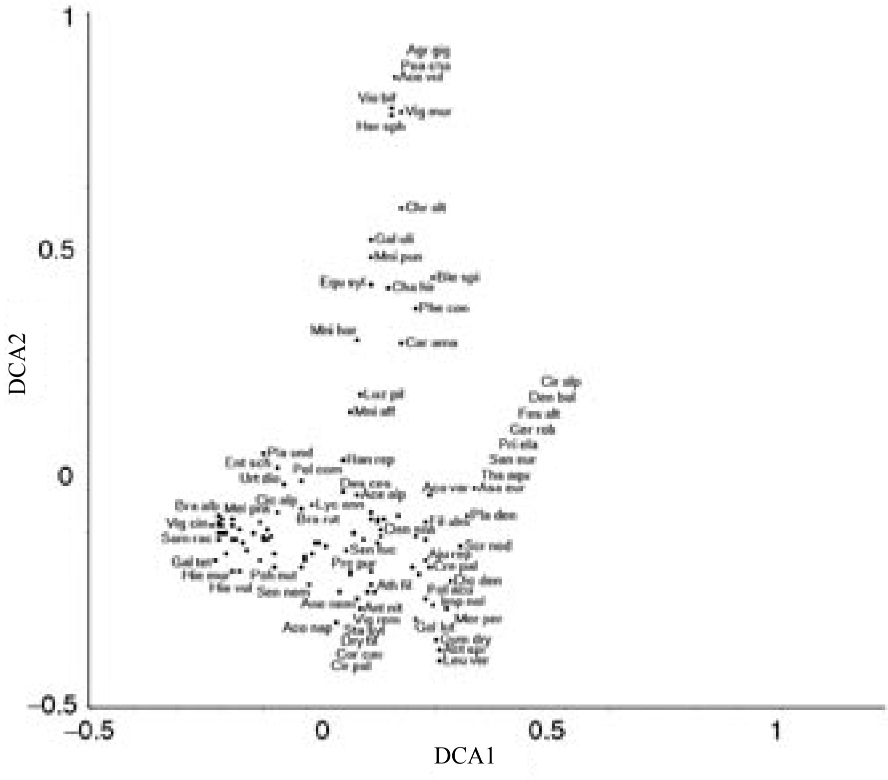


Fig. 9. Ordination of the species of herb and moss layers in spruce stands (axes 1 and 2). DCA ordination was used, such data transformation was used that the sum of significances for the species of the given layer will equal the total coverage of this layer. The position of each species is marked, selected species are designated by an abbreviation of their name

Numerical classification of plant communities

The traditional classification based on the principles of Zurich-Montpellier school of phytosociology used in the preceding section was compared with the results of numerical classification. Its goal is to classify a set of relevés in mathematical terms by help of a given algorithm into the particular groups of relevés similar to each other. Two types of classification, i.e. agglomerative and divisive classification, were applied for this purpose.

Agglomerative classification

Dendrograms in Figs. 2 and 3 illustrate the results of numerical classification. Ward's method of hierarchic classification and Euclidean distance as the measure of dis-

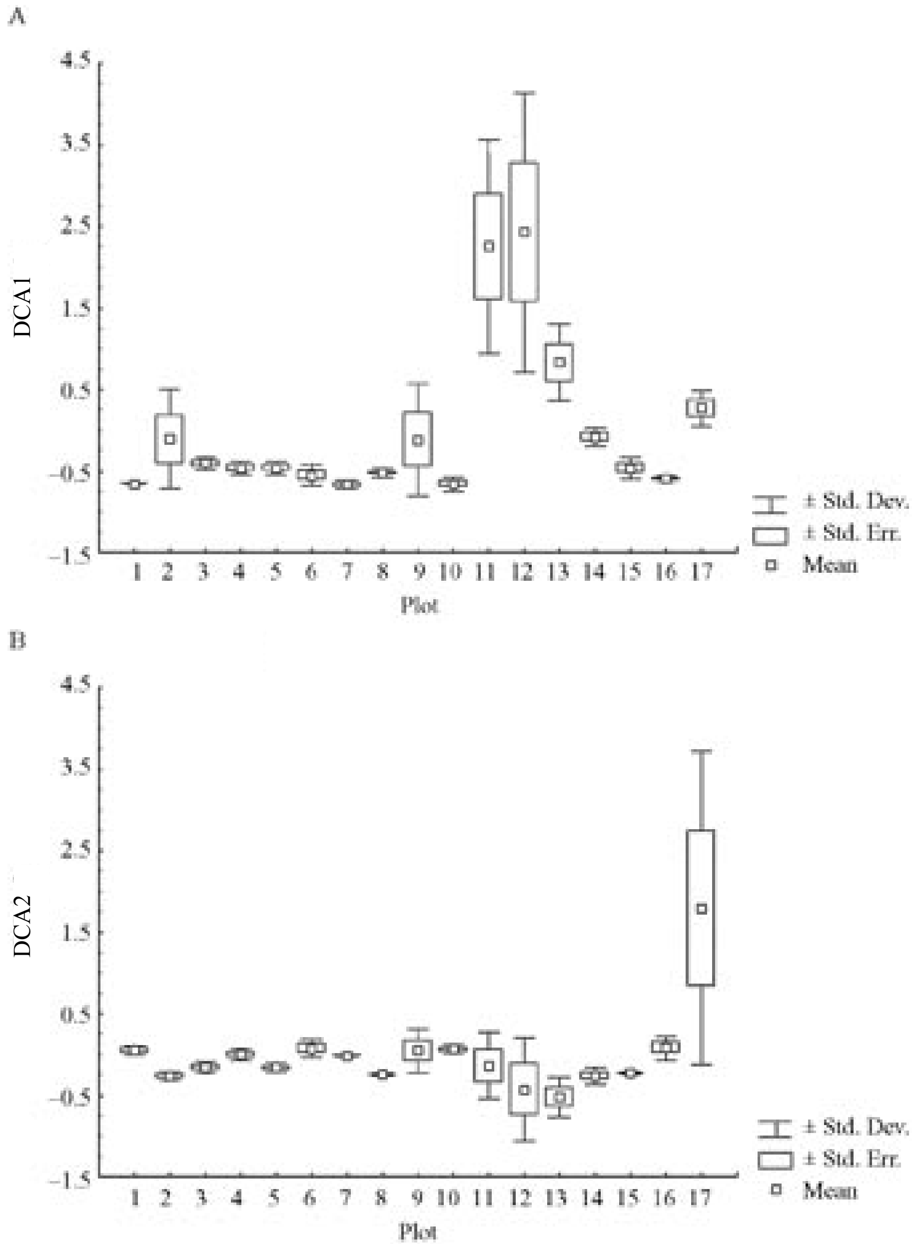


Fig. 10 A–B. Standard deviations, standard errors and averages of the values of DCA ordination of relevés on the particular plots in beech stands – ordination axis 1 (A) and ordination axis 2 (B)

similarity were used for the computation. In general it is to state that the occurrence of the particular clusters in the assessed dendrograms corresponds to the classification of evaluated communities by the traditional classification method.

Divisive classification

The results of TWINSPAN classification are given in Table 5 for beech stands and in Table 6 for spruce stands. TWINSPAN procedure was used to describe the classification of vegetation on each plot during the period of observations (1951–2001). A classification level on which the vegetation of the plot remained in the same classification class can be defined in this way; in other words, changes in the vegetation of the plot can be described in the course of time. A lower number of the classification level indicates important change of the community, a higher one occurs by a stable composition of the community:

Classification level	Plots with beech stands	Plots with spruce stands
1	17	
2	2, 9	12, 16, 17
3	15	1, 3, 4, 9, 10, 13, 14, 15
4	6, 7	8
5	8	5
6	5	6, 11
7	3, 16	
Unchanged classification	1, 4, 10, 11, 12, 13, 14	2, 7

It is obvious that the changes in beech stands were often minimum or small, on the contrary, the changes in spruce stands were frequently great.

Table 7. Species ordination in beech stands (DCA axis 1)

		DCA1
Avenella flexuosa	Ave fle	–0.11
Sambucus racemosa	Sam rac	–0.11
Trientalis europaea	Tri eur	–0.11
Blechnum spicant	Ble spi	–0.10
Homogyne alpina	Hom alp	–0.10
Luzula pilosa	Luz pil	–0.10
Sorbus aucuparia	Sor auc	–0.10
Carex pallescens	Car pal	–0.08
Carex pilulifera	Car pil	–0.08
Phegopteris connectilis	Phe con	–0.08
Picea abies	Pic abi	–0.08
Vaccinium myrtillus	Vac myr	–0.08
Deschampsia cespitosa	Des ces	–0.07
Fagus sylvatica	Fag syl	–0.07
Hieracium vulgatum	Hie vul	–0.07
Calamagrostis arundinacea	Cal aru	–0.06
Calamagrostis villosa	Cal vil	–0.06
Dryopteris carthusiana	Dry car	–0.06
Maianthemum bifolium	Mai bif	–0.06
Vignea leporina	Vig lep	–0.06
Gymnocarpium dryopteris	Gym dry	–0.04
Streptopus amplexifolius	Str amp	–0.04
Hieracium murorum	Hie mur	–0.02
Athyrium filix-femina	Ath fil	–0.01
Oxalis acetosella	Oxa ace	0.00
Abies alba	Abi alb	0.03
Acer pseudoplatanus	Ace pse	0.04
Solidago virgaurea	Sol vir	0.04
Polygonatum verticillatum	Pol ver	0.05
Lycopodium annotinum	Lyc ann	0.06
Prenanthes purpurea	Pre pur	0.07
Athyrium distentifolium	Ath dis	0.09
Lunaria rediviva	Lun red	0.09
Dryopteris filix-mas	Dry fil	0.11
Senecio ovatus	Sen fuc	0.11
Asarum europaeum	Asa eur	0.13
Stelaria nemorum	Ste nem	0.14
Veratrum album	Ver alb	0.14
Milium effusum	Mil eff	0.17
Mycelis muralis	Myc mur	0.17
Rubus idaeus	Rub ida	0.17
Festuca altissima	Fes alt	0.19
Galeopsis tetrahit	Gal tet	0.19
Lilium martagon	Lil mar	0.21
Scrophularia nodosa	Scr nod	0.21
Senecio nemorensis	Sen nem	0.21
Lamium maculatum	Lam mac	0.23
Stachys sylvatica	Sta syl	0.23
Circaea alpina	Cir alp	0.24
Ranunculus repens	Ran rep	0.24
Dentaria bulbifera	Den bul	0.25
Actaea spicata	Act spi	0.26
Acetosella vulgaris	Ace vul	0.27
Galeobdolon luteum	Gal lut	0.27
Impatiens noli-tangere	Imp nol	0.27
Astrantia major	Ast maj	0.28
Thalictrum aquilegiifolium	Tha aqu	0.28
Veronica montana	Ver mon	0.28
Moehringia trinervia	Moe tri	0.29
Aconitum napellus	Aco nap	0.30

		DCA1
Geranium robertianum	Ger rob	0.30
Sanicula europaea	San eur	0.30
Daphne mezereum	Dap mez	0.31
Chaerophyllum hirsutum	Cha hir	0.31
Allium ursinum	All urs	0.32
Epilobium montanum	Epi mon	0.32
Tephroseris crispa	Tep cri	0.32
Carex sylvatica	Car syl	0.34
Lysimachia nemorum	Lys nem	0.34
Urtica dioica	Urt dio	0.34
Pulmonaria obscura	Pul obs	0.35
Ajuga reptans	Aju rep	0.36
Viola reichenbachiana	Vio rei	0.36
Myosotis palustris	Myo pal	0.38
Galeopsis pubescens	Gal pub	0.40
Tithymalus dulcis	Tit dul	0.41
Equisetum sylvaticum	Equ syl	0.42
Mercurialis perennis	Mer per	0.42
Galium odoratum	Gal odo	0.43
Petasites albus	Pet alb	0.47
Acetosa alpestris	Ace alp	0.48
Ficaria verna	Fic ver	0.53
Chrysosplenium alternifolium	Chr alt	0.53
Paris quadrifolia	Par qua	0.54
Anemonoides nemorosa	Ane nem	0.55
Lathyrus vernus	Lat ver	0.56
Aegopodium podagraria	Aeg pod	0.60
Poa chaixii	Poa cha	0.62
Anthriscus nitida	Ant nit	0.69
Cicerbita alpina	Cic alp	0.70
Poa angustifolia	Poa ang	0.71
Ranunculus platanifolius	Ran pla	0.71
Cardamine amara	Car ama	0.73
Aconitum variegatum	Aco var	0.75
Corydalis cava	Cor cav	0.77
Geum rivale	Geu riv	0.77
Heracleum sphondylium	Her sph	0.77
Phyteuma spicatum	Phy spi	0.77
Ranunculus lanuginosus	Ran lan	0.77
Veratrum nigrum	Ver nig	0.77
Crepis paludosa	Cre pal	0.79
Dentaria enneaphyllos	Den enn	0.83
Primula elatior	Pri ela	0.83
Adoxa moschantellina	Ado mos	0.85
Valeriana officinalis	Val off	0.90
Polytrichum commune	Pol com	–0.13
Brachythecium velutinum	Bra vel	–0.12
Pohlia nutans	Poh nut	–0.11
Plagiothecium roeseanum	Pla roe	–0.09
Dicranum scoparium	Dic sco	–0.07
Plagiothecium curvifolium	Pla cur	–0.03
Polytrichum formosum	Pol for	–0.01
Dicranella heteromalla	Dic het	0.02
Mnium spinosum	Mni spi	0.03
Catharinaea undulata	Cat und	0.26
Mnium affine	Mni aff	0.27
Mnium punctatum	Mni pun	0.45
Mnium undulatum	Mni und	0.54
Brachythecium rutabulum	Bra rut	0.77
Mnium hornum	Mni hor	0.83

Table 8. Species ordination in spruce stands (DCA axis 1)

		DCA1
Vignea cinerea	Vig cin	–0.15
Galeopsis tetrahit	Gal tet	–0.14
Epilobium montanum	Epi mon	–0.13
Melampyrum pratense	Mel pra	–0.13
Molinia arundinacea	Mol aru	–0.13
Rubus fruticosus	Rub fru	–0.13
Sambucus racemosa	Sam rac	–0.13
Avenella flexuosa	Ave fle	–0.12
Vaccinium vitis-idaea	Vac vit	–0.12
Luzula luzuloides	Luz luz	–0.11
Sorbus aucuparia	Sor auc	–0.11
Hieracium murorum	Hie mur	–0.09
Picea abies	Pic abi	–0.09
Trientalis europaea	Tri eur	–0.09
Vaccinium myrtillus	Vac myr	–0.08
Dryopteris carthusiana	Dry car	–0.07
Fagus sylvatica	Fag syl	–0.07
Hieracium vulgatum	Hie vul	–0.07
Calamagrostis arundinacea	Cal aru	–0.06
Solidago virgaurea	Sol vir	–0.05
Carex pilulifera	Car pil	–0.01
Abies alba	Abi alb	0.00
Acer pseudoplatanus	Ace pse	0.00
Calamagrostis villosa	Cal vil	0.00
Melandrium sylvestre	Mel syl	0.01
Maianthemum bifolium	Mai bif	0.02
Cicerbita alpina	Cic alp	0.04
Urtica dioica	Urt dio	0.06
Rubus idaeus	Rub ida	0.11
Athyrium distentifolium	Ath dis	0.12
Senecio nemorensis	Sen nem	0.13
Lycopodium annotinum	Lyc ann	0.14
Polygonatum verticillatum	Pol ver	0.14
Homogyne alpina	Hom alp	0.15
Oxalis acetosella	Oxa ace	0.16
Streptopus amplexifolius	Str amp	0.18
Aconitum napellus	Aco nap	0.21
Deschampsia cespitosa	Des ces	0.23
Ranunculus repens	Ran rep	0.23
Senecio ovatus	Sen fuc	0.24
Aegopodium podagraria	Aeg pod	0.25
Prenanthes purpurea	Pre pur	0.25
Veratrum album	Ver alb	0.26
Acetosa alpestris	Ace alp	0.27
Anemonoides nemorosa	Ane nem	0.27
Anthriscus nitida	Ant nit	0.28
Cirsium palustre	Cir pal	0.28
Corydalis cava	Cor cav	0.28
Dryopteris filix-mas	Dry fil	0.28
Luzula pilosa	Luz pil	0.28
Stachys sylvatica	Sta syl	0.28
Vignea remota	Vig rem	0.28
Poa angustifolia	Poa ang	0.29
Stelaria nemorum	Ste nem	0.30
Athyrium filix-femina	Ath fil	0.31
Equisetum sylvaticum	Equ syl	0.31
Galium uliginosum	Gal uli	0.31
Ranunculus lanuginosus	Ran lan	0.31
Phyteuma spicatum	Phy spi	0.32
Lysimachia nemorum	Lys nem	0.33
Milium effusum	Mil eff	0.33
Pulmonaria obscura	Pul obs	0.33
Dentaria enneaphyllos	Den enn	0.34

		DCA1
Veronica montana	Ver mon	0.35
Chaerophyllum hirsutum	Cha hir	0.36
Heracleum sphondylium	Her sph	0.37
Viola biflora	Vio bif	0.37
Acetosella vulgaris	Ace vul	0.38
Agrostis gigantea	Agr gig	0.38
Poa chaixii	Poa cha	0.38
Carex sylvatica	Car syl	0.39
Cardamine amara	Car ama	0.40
Chrysosplenium alternifolium	Chr alt	0.40
Vignea muricata	Vig mur	0.40
Carex pallescens	Car pal	0.43
Galeobdolon luteum	Gal lut	0.44
Galium odoratum	Gal odo	0.44
Phegopteris connectilis	Phe con	0.44
Petasites albus	Pet alb	0.45
Ajuga reptans	Aju rep	0.47
Filipendula ulmaria	Fil ulm	0.47
Polystichum aculeatum	Pol acu	0.47
Tithymalus dulcis	Tit dul	0.47
Aconitum variegatum	Aco var	0.48
Crepis paludosa	Cre pal	0.48
Blechnum spicant	Ble spi	0.49
Impatiens noli-tangere	Imp nol	0.49
Gymnocarpium dryopteris	Gym dry	0.50
Actaea spicata	Act spi	0.51
Leucojum vernum	Leu ver	0.51
Mercurialis perennis	Mer per	0.53
Scrophularia nodosa	Scr nod	0.57
Asarum europaeum	Asa eur	0.61
Circaea alpina	Cir alp	0.61
Dentaria bulbifera	Den bul	0.61
Festuca altissima	Fes alt	0.61
Geranium robertianum	Ger rob	0.61
Primula elatior	Pri ela	0.61
Sanicula europaea	San eur	0.61
Thalictrum aquilegiifolium	Tha aqu	0.61
Brachythecium albicans	Bra alb	–0.13
Campylopus pyriformis	Cam pyr	–0.13
Lophozia ventricosa	Lop ven	–0.13
Dicranella heteromalla	Dic het	–0.12
Plagiothecium silesiacum	Pla sil	–0.12
Cephalozia bicuspidata	Cep bic	–0.09
Plagiothecium curvifolium	Pla cur	–0.03
Dicranum scoparium	Dic sco	–0.01
Plagiothecium undulatum	Pla und	0.00
Polytrichum formosum	Pol for	0.01
Pohlia nutans	Poh nut	0.03
Sphagnum girgensohnii	Sph gir	0.03
Entodon schreberi	Ent sch	0.04
Brachythecium rutabulum	Bra rut	0.11
Polytrichum commune	Pol com	0.11
Lepidozia reptans	Lep rep	0.12
Brachythecium starkei	Bra sta	0.22
Mnium affine	Mni aff	0.25
Mnium hornum	Mni hor	0.27
Calypogeia trichomanis	Cal tri	0.31
Catharinaea undulata	Cat und	0.31
Mnium punctatum	Mni pun	0.31
Mnium undulatum	Mni und	0.34
Dicranodontium denudatum	Dic den	0.54
Plagiothecium denticulatum	Pla den	0.59

Table 9. Standard deviations of DCA ordination of relevés in beech stands. The values for each of the first four ordination axes are given in separate columns. The value "Total" shows total variance expressed by the first four ordination axes

Plot	DCA1	DCA2	DCA3	DCA4	Total
8	0.044	0.017	0.055	0.156	0.172
16	0.032	0.150	0.050	0.080	0.180
4	0.075	0.065	0.112	0.162	0.221
1	0.005	0.057	0.071	0.213	0.232
10	0.090	0.051	0.108	0.190	0.242
5	0.085	0.052	0.088	0.210	0.248
7	0.050	0.008	0.129	0.216	0.256
14	0.112	0.107	0.233	0.121	0.305
15	0.129	0.017	0.306	0.113	0.351
3	0.084	0.070	0.158	0.302	0.358
6	0.133	0.119	0.358	0.275	0.485
13	0.475	0.247	0.538	0.185	0.781
9	0.682	0.276	0.255	0.546	0.951
2	0.606	0.057	0.537	0.863	1.185
11	1.316	0.412	1.037	0.103	1.728
12	1.716	0.637	0.232	0.301	1.870
17	0.221	1.924	0.310	0.217	1.973
All groups	1.071	0.663	0.569	0.568	1.494

Table 10. Standard deviations of DCA ordination of relevés in spruce stands. The values for each of the first four ordination axes are given in separate columns. The value "Total" shows total variance expressed by the first four ordination axes

Plot	DCA1	DCA2	DCA3	DCA4	Total
6	0.082	0.051	0.183	0.133	0.246
4	0.160	0.043	0.152	0.178	0.287
13	0.245	0.107	0.087	0.097	0.297
11	0.183	0.046	0.189	0.182	0.323
15	0.228	0.079	0.188	0.187	0.358
16	0.119	0.057	0.232	0.240	0.359
14	0.288	0.090	0.225	0.126	0.397
5	0.089	0.048	0.335	0.230	0.419
3	0.264	0.101	0.188	0.363	0.497
17	0.360	0.127	0.227	0.228	0.499
9	0.387	0.161	0.526	0.286	0.731
10	0.306	0.225	0.646	0.558	0.934
2	0.529	0.367	0.472	0.865	1.178
8	0.310	0.728	0.698	0.717	1.276
1	0.238	0.195	1.335	0.185	1.382
12	0.115	0.262	1.576	0.655	1.731
7	0.431	1.855	0.597	0.257	2.012
All groups	1.022	0.600	0.604	0.536	1.434

Ordination of plant communities

Relevé ordination

A graphical output of relevés ordination (Figs. 4–7) illustrates the arrangement (trajectories) of the particular plots in the ordination space constructed by connecting four points. The co-ordinates of these points correspond to the relevés recorded in 1951, 1971, 1991 and 2001 on the same research plot. Dynamics of vegetation changes in the given years is derived from the lengths of trajectories. It is to state in general, that the smaller distance of the four points from each other on one plot documents the lower the vegetation dynamics in the years of observation, and vice versa. In beech stands accelerated vegetation dynamics was recorded in rich-in-species communities in the years of observation (Fig. 4), namely on PRP 17 (association A-F), PRP 12 (De-F), PRP 9, 11 (De-F in 1951, later Cv-F) and on PRP 2 (Cv-F). These changes were most marked on the above-mentioned plots in 1951–1971, and also partly in 1971–1991 (PRP 17). The vegetation dynamics decelerated as the time proceeded. In spruce stands accelerated vegetation dynamics was also described in relatively rich-in-species communities in the course of years (Fig. 5), namely on PRP 7 (association Cv-P), PRP 8 (Aa-P), 2 and 12 (Aa-P in 1951, later Cv-P). The time trends of vegetation dynamics in spruce stands and in beech stands were similar.

Species ordination

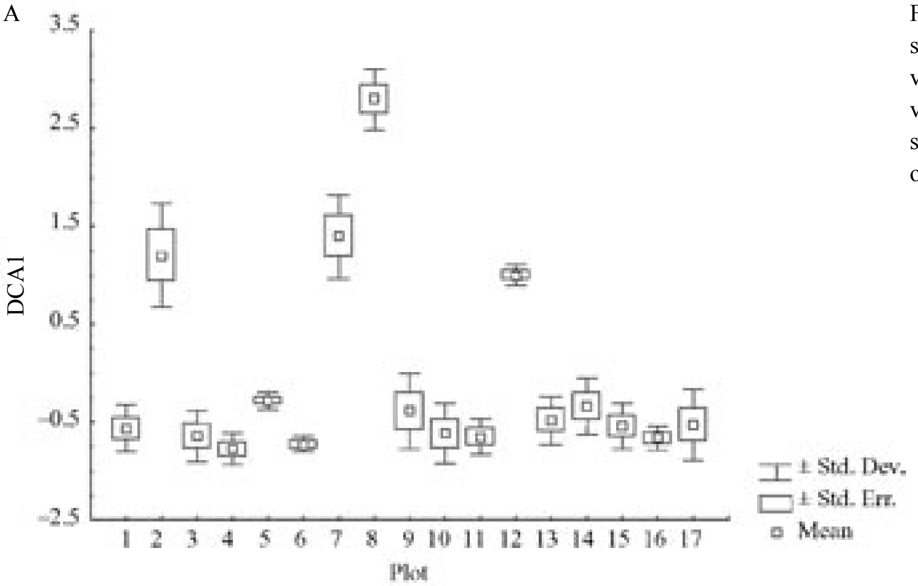
An output of ordination of the species – their position in the ordination space (axis 1 of DCA) is shown in Table 7 and Fig. 8 for beech stands and in Table 8 and Fig. 9 for spruce stands. Interpretation of the axis meaning is possible using stand richness (correlation of first ordination axis by both beech and spruce stands). The second axis represents relation to altitude by beech stands and relation to the degree of water saturation by spruce stands.

Statistical analyses of relevés ordination

Statistical analysis was used to process the results of DCA ordination of relevés. Tables 9 and 10 show standard deviations of DCA ordination of relevés in beech and spruce stands, respectively. Figs. 10 and 11 illustrate standard deviations, standard errors and means of the values of DCA ordination of relevés on the particular plots according to the ordination axes in beech and spruce stands. Minimum and maximum values of ordination, quartiles 25%, 75% and 50% (medians) of the values of DCA ordination of relevés in the particular years (1951, 1971, 1991 and 2001) according to the ordination axes in beech and spruce stands are represented in Figs. 12 and 13, respectively.

The results of these statistical analyses in beech stands document a higher variability of relevés along ordination axis 1 for plots 11, 12, 13 and 17, along ordination axis 2 for plot 17, along ordination axis 3 for plot 11 and along ordina-

A



B

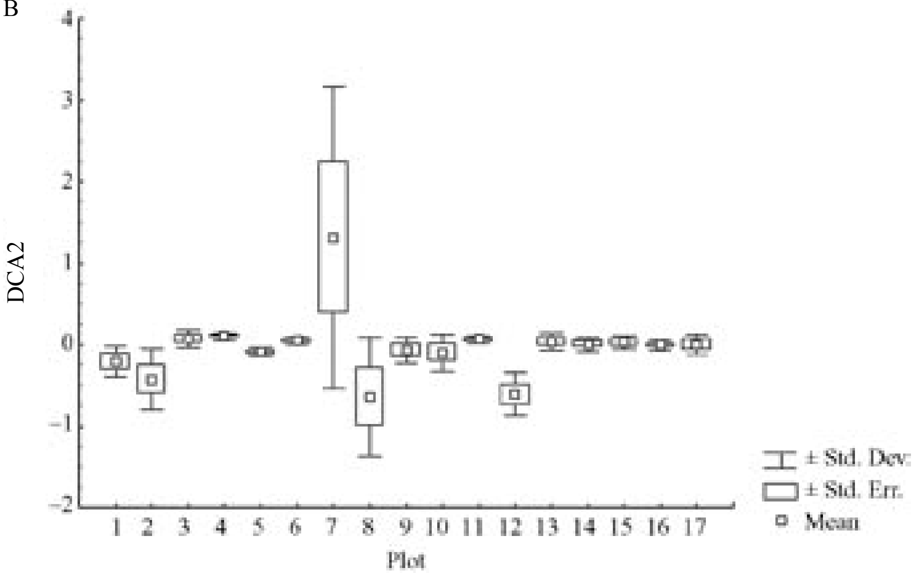


Fig. 11 A–B. Standard deviations, standard errors and averages of the values of DCA ordination of relevés on the particular plots in spruce stands – ordination axis 1 (A) and ordination axis 2 (B)

tion axis 4 for plot 2. In the course of time the variability of relevés along ordination axes 1 and 2 decreases while the variability along axes 3 and 4 is more or less balanced.

In spruce stands the variability of relevés is higher along ordination axis 2 on plots 7 and 8, and along axis 3 on plots 1 and 12. The decrease in variability of relevé ordination in time is not so marked in spruce stands as in beech ones.

Results of DCA ordination:

– There is not a large difference in the results when data on the herb layer only or data on the herb and moss layer jointly were used for analysis. Similarly, data standardisation for the sum of species significance in the vegetation layer equalling total coverage of the layer is of low significance.
– Data variability described by the first four ordination axes is similar in beech and spruce stands. The eigenvalues of analysed matrices were 0.538 – 0.340 – 0.249 – 0.214 for beech stands and 0.520 – 0.309 – 0.256 – 0.213 for spruce stands.
– Vegetation dynamics was more significant only on some plots: plots 17, 11, 12 (and possibly 13, 2 and 9) out of beech plots, and plots 7 and 8 (and possibly 12 and 1) out of spruce plots.
– The indication of dynamic changes by the ordination analysis need not always be reflected in the results of classification. As stated for the evaluation by TWINSPAN procedure, significant differences in the classification of relevés from various years were observed on plots 17, 2 and 9 for the above-mentioned beech plots, and on plots 1 and 12 for spruce stands.
– A majority of plant communities had the stable species composition.
– Dynamics in beech stands seems to be higher.
– Differences between the plots considerably diminished in the course of time.
– Groups of species that receded on the plots in time can be identified as the species with high values of the scores along the first and second ordination

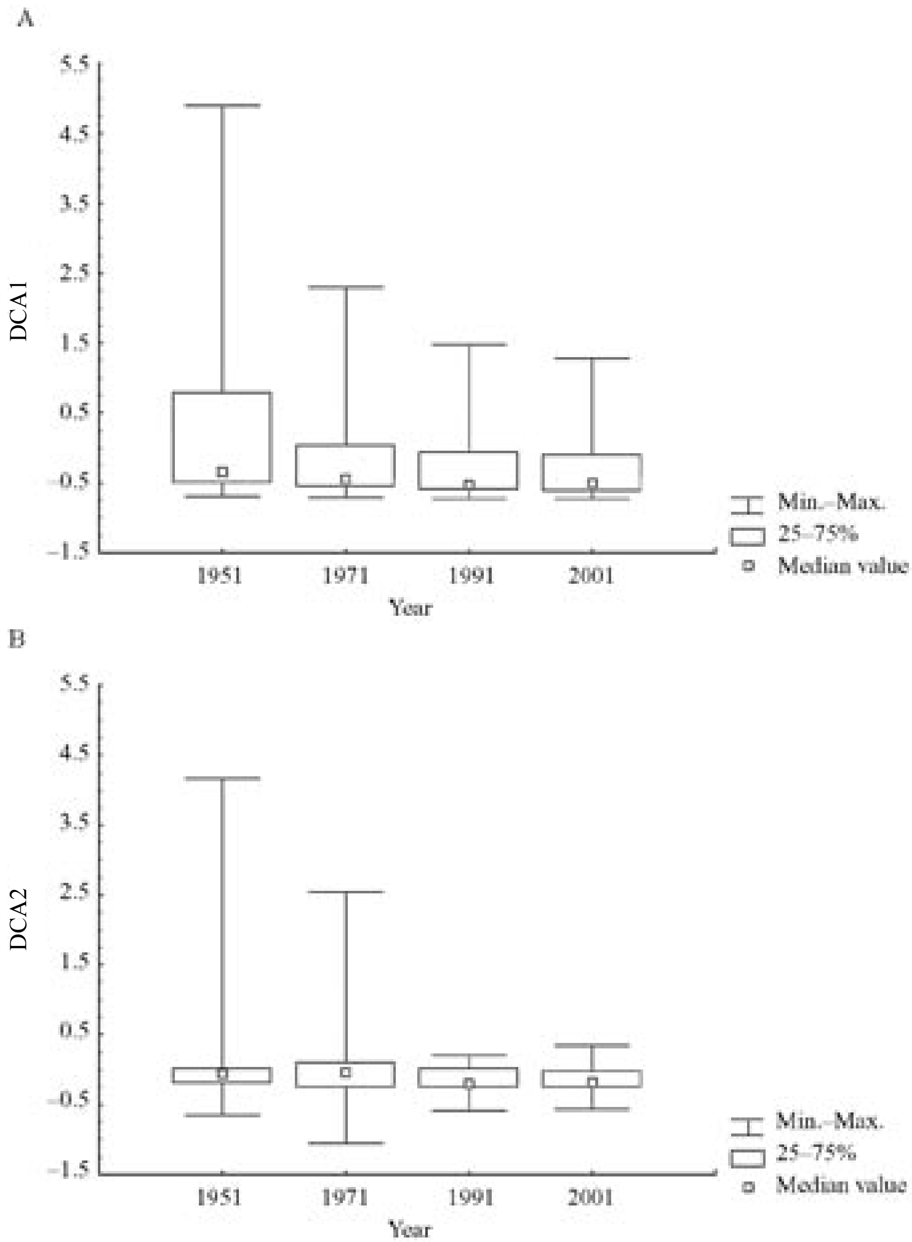


Fig. 12 A–B. Minimum and maximum values of ordination, quartiles (25%, 75%) and median of the values of DCA ordination of relevés in the years of observation (1951, 1971, 1991 and 2001) in beech stands – ordination axis 1 (A) and ordination axis 2 (B)

axis. In beech stands they involve e.g. *Aconitum variegatum*, *Corydalis cava*, *Geum rivale*, *Heracleum sphondylium*, *Phyteuma spicatum*, *Ranunculus lanuginosus*, *Veratrum nigrum*, *Crepis paludosa*, *Dentaria enneaphyllos*, *Primula elatior*, *Adoxa moschantellina*, *Valeriana officinalis*, *Lunaria rediviva* and *Athyrium distentifolium*, the species of the moss layer are *Brachythecium rutabulum* and *Mnium hornum*. The number of analogical species identified in spruce stands was lower: *Galium uliginosum*, *Chrysosplenium alternifolium*, *Heracleum sphondylium*, *Vignea muricata*, *Viola biflora*, *Acetosella vulgaris*, *Agrostis gigantea*, *Poa chaixii* and *Mnium punctatum*.

Characteristics of species diversity

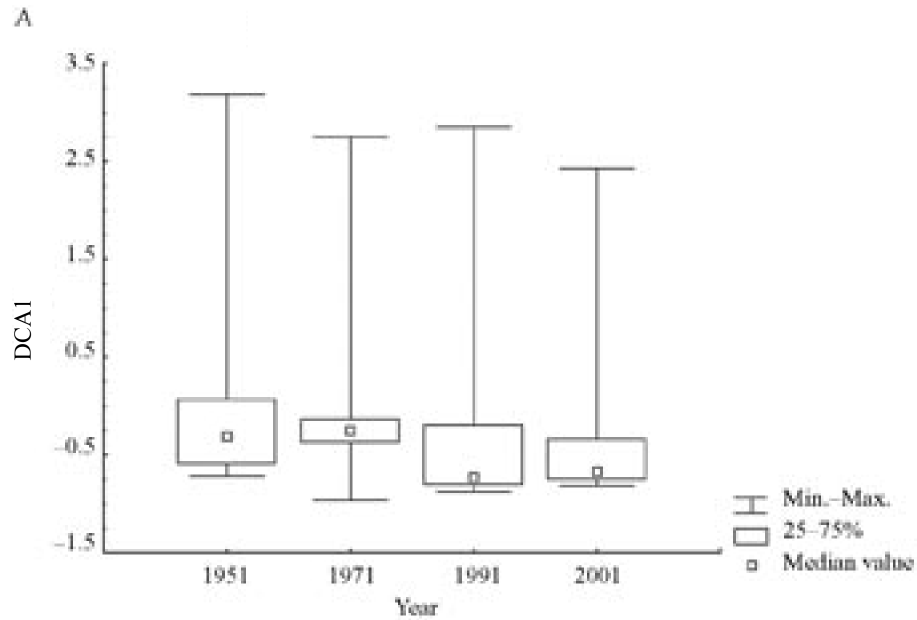
Results of the analysis of the herb layer species diversity are drawn on Figs. 13–18.

Fig. 14 shows the values of total species diversity index on the particular plots in the years of observation. The values ranged from 1.7 to 4.9 in beech stands and from 1.1 to 4.7 in spruce stands. In general, the highest species diversity was recorded in 1951, the lowest in 1991. In subsequent years the original higher values returned. This trend is also obvious from Fig. 15.

Total number of species in the herb layer per relevé was significantly different on the particular plots.

In beech stands a majority of records contained 10 to 20 species, significantly higher numbers of species were recorded on plots 2 and 13 (ca. 20–30 species; the plots are classified as forest site types $7N_1$ and $6K_6$, respectively), and on plots 11 and 12 (ca. 30–50; the respective forest site types are $7Z_2$ and $7K_6$).

There were mostly 5 to 15 species in the herb layer of spruce stands, higher numbers occurred on plots 1 and 12 (15–25 species; FST $6K_6$ and $8Z_4$, resp.), and on plots 2,



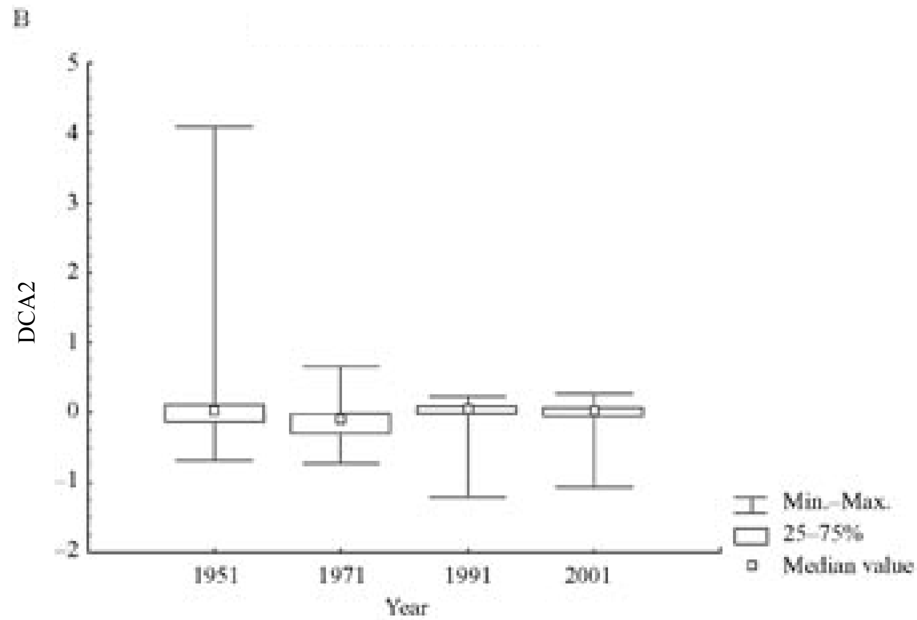


Fig. 13 A–B. Minimum and maximum values of ordination, quartiles (25%, 75%) and median of the values of DCA ordination of relevés in the years of observation (1951, 1971, 1991 and 2001) in spruce stands – ordination axis 1 (A) and ordination axis 2 (B)

7 and 8 (20–40 species; respective forest site types $6K_6$, $7V_1$ and $6A_5$).

The level of total species diversity is consistent with the number of species (Fig. 16). Slightly higher species diversity was recorded in beech stands (the values mostly ranged from 2.5 to 3.5; the values higher than 3.7 were recorded on plots 11, 12 and 13) compared to spruce stands (the range was 2.0 to 2.5; the values higher than 2.7 were recorded on plots 1, 2, 7, 8 and 12).

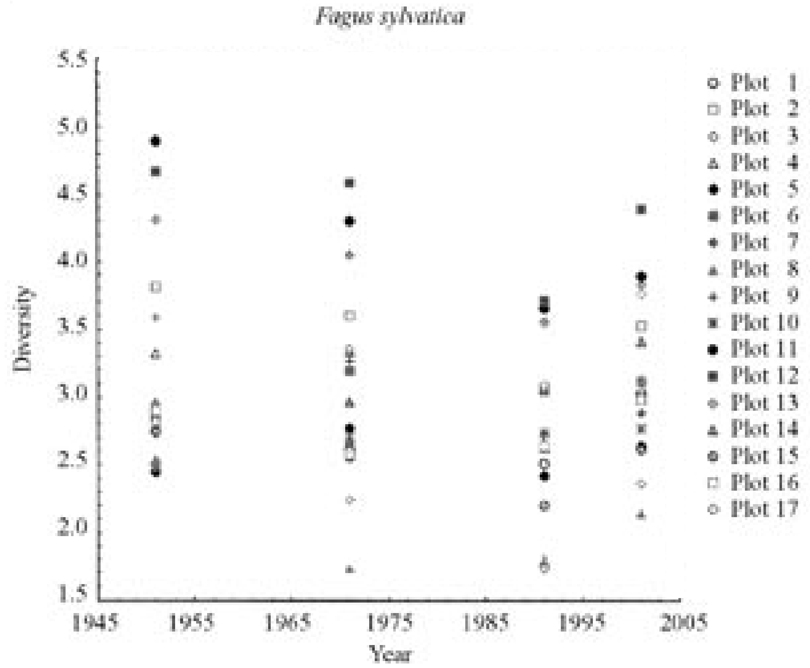
Relatively smaller differences between the plots were found in species equitability (Fig. 18) where the values for beech stands ranged from 0.7 to 0.85, for spruce stands from 0.65 to 0.8. The highest species dominance (i.e. the lowest equitability) was recorded in beech stands on plots 3 (FST $7K_6$) and 8 ($7Z_2$), in spruce stands on plots 4 ($8Z_2$), 13 ($8Z_4$) and 17 ($7P_1$) – all sites had some extreme edaphic characteristics.

CONCLUSION

The results of studies of phytocenoses on 34 plots (beech and spruce stands) in 1951–2001 demonstrate relatively accelerated vegetation dynamics, particularly in the period of great air-pollution environmental stress in the mountains in the seventies and eighties, last century (VACEK, LEPŠ 1991, 1992), and on the contrary, important revitalisation processes in 1991–2001 that are evident from a comparison of the characteristics of species diversity.

Great changes took place particularly in richer-in-species spruce communities of the association *Athyrio alpestre-Piceetum* (Aa-P), and also in poorer-in-species communities of the associations *Vaccinio myrtilli-Piceetum* (Vm-P), *Calamagrostio villosae-Piceetum* (Cv-P) and *Deschampsio flexuosae-Piceetum* (Df-P). The developmental trend of these communities in 1971–1991

A



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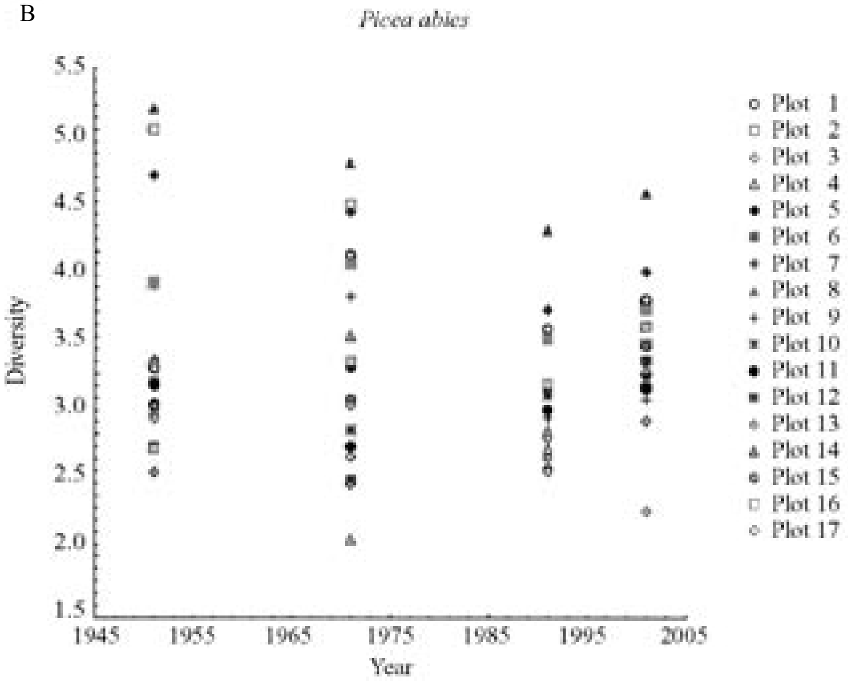
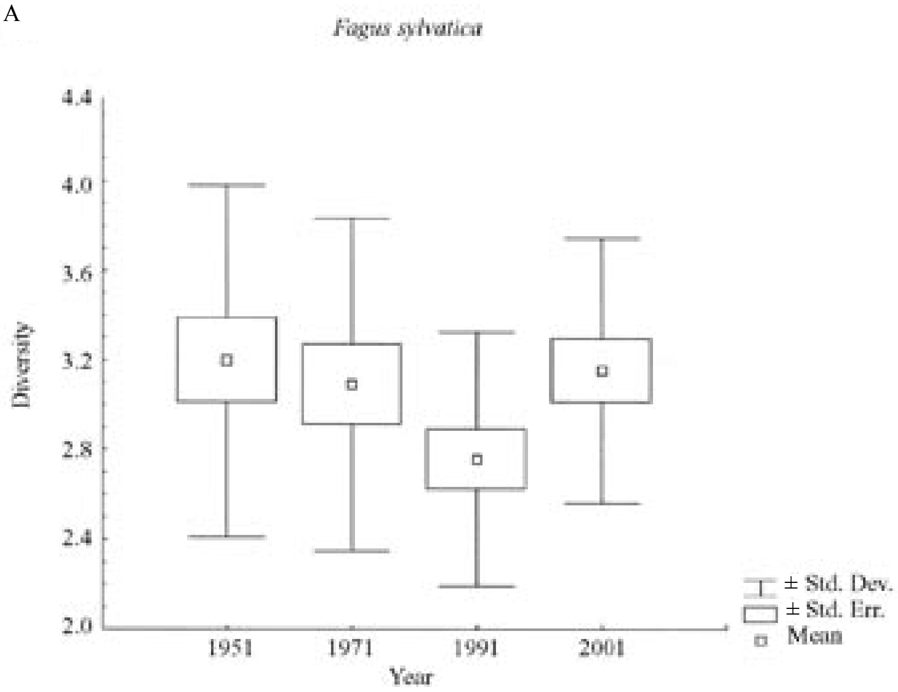


Fig. 14 A–B. Development of total species diversity on the plots in 1951–2001

tended towards the type very poor in species (association Df-P). *Deschampsia flexuosa* became a marked dominant as a result of canopy opening that was caused by the air-pollution environmental stress, and replaced some species less resistant to site acidification, mainly *Vaccinium myrtillus*. On the contrary, the number of species considerably increased in the years 1991–2001, especially in the herb layer. The increase in coverage and number of tree species seedlings was remarkable after the productive seed years 1992 and 1995. The average number of species in the relevés of the community Aa-P was 50 (100%) in 1951, 35 (70%) in 1971, 27 (54%) in 1991 and 41 (81%) in 2001, in the relevés of the community Cv-P 25 (100%), 21 (84%), 19 (76%) and 24 (96%) in the respective years, in the relevés of Df-P it fluctuated around 16 (100%), 15 (94%), 13 (81%) and 17 (100%). The average number of species in the relevés of the community Vm-P was 20 (100%) in 1951, 15 (75%) in 1971 and in 1991 and 2001 this association was not identified any longer. Regardless classification of the communities the average number of species in relevés from spruce stands was 25 (100%) in 1951, 20 (80%) in 1971, 16 (64%) in 1991 and 21 (84%) in 2001.

The acceleration of changes in beech stands in 1971–1991 led to a diminution of the species number in

A



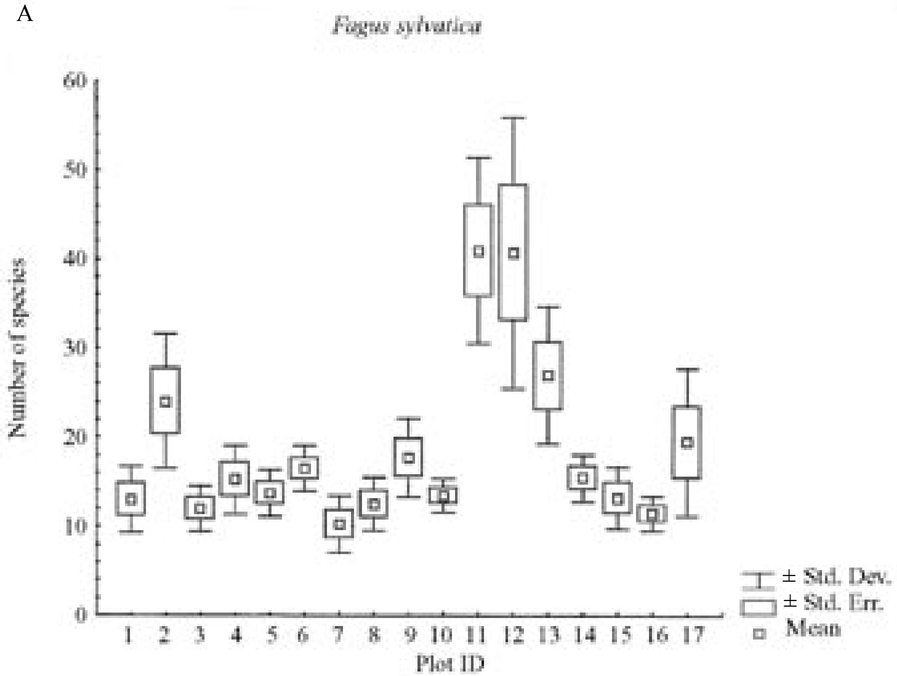
B

Fig. 15 A–B. Average values (arithmetic mean, standard error and standard deviation) of total species diversity in the years of observation in beech (A) and spruce (B) stands

rich-in-species and herb-rich types of the association *Dentario enneaphylli-Fagetum* (De-F), or to their transition to acidophilous types of *Calamagrostio villosae-Fagetum* (Cv-F) with a lower number of species. Similarly like in spruce stands the number of species in relevés from beech stands increased in 1991–2001. But a majority of typical species of herb-rich beech stands returned slowly to the studied communities. The average number of species in relevés of the community De-F was 44 (100%) in 1951, 42 (95%) in 1971, 24 (55%) in 1991 and 49 (111%) in 2001; in relevés of the community A-F 23 (100%), 33 (143%), 19 (83%), 33 (143%) in the respective years and in the community Cv-F the average number of species in relevés from the years of observation fluctuated about 22 (100%), 20 (91%), 14 (64%) and 23 (105 %). Without classification of the communities into associations the average number of species in relevés from beech stands was 27 (100%) in 1951, 23 (85%) in 1971, 17 (63%) in 1991 and 26 (96%) in 2001.

The great acceleration of vegetation dynamics in spruce stands (mainly on PRP spruce 02, 06, 12, 15 and 17) and in beech stands (PRP beech 01, 02, 09, 15 and 16) in 1971–1991 was probably caused by the increased air-pollution environmental stress. On the contrary, important revitalisation processes took place in the nineties as a result of more favourable environmental conditions, basically in

A



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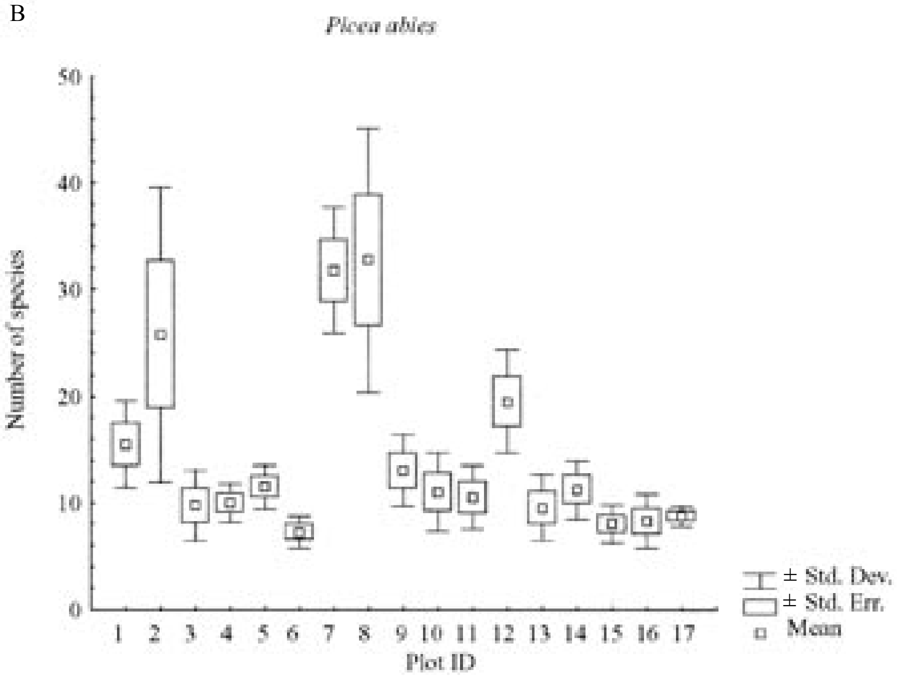


Fig. 16 A–B. Average numbers of species (arithmetic mean, standard error and standard deviation) on the plots in beech (A) and spruce (B) stands in 1951–2001

all vegetation layers (E_3–E_0). These processes were most evident in the herb layer.

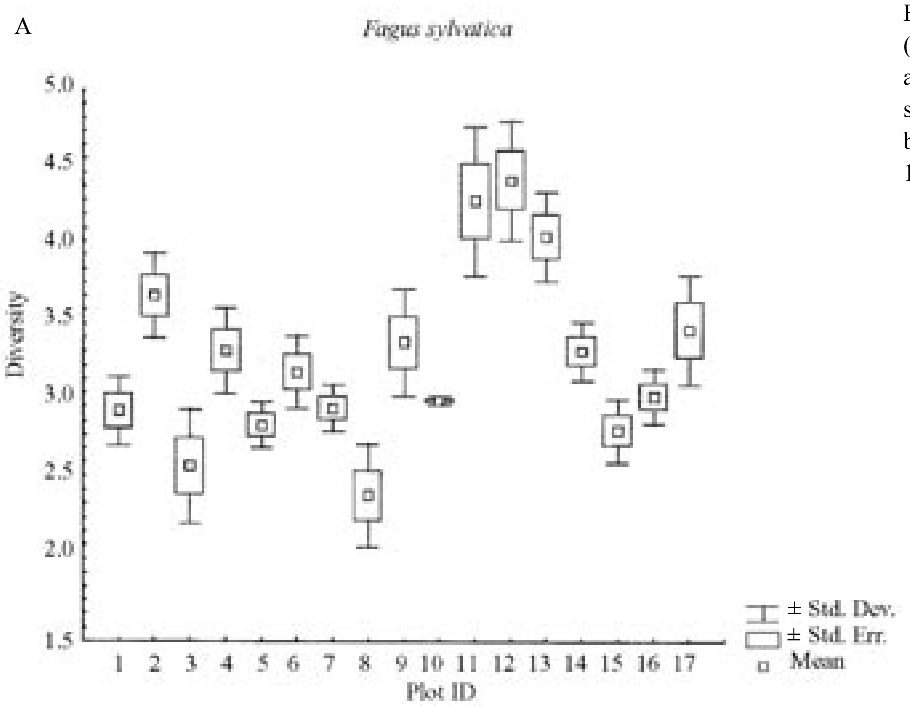
DCA ordination indicated that:

– There is not a large difference in the results obtained by the analysis of data on the herb layer only or data on the herb and moss layer jointly.
– Variability of data described by the first four ordination axes is similar in beech and spruce stands. The eigenvalues of analysed matrices were 0.538 – 0.340 – 0.249 – 0.214 for beech stands and 0.520 – 0.309 – 0.256 – 0.213 for spruce stands. There are probably two main environmental factors determining composition of these plant communities.
– More significant vegetation dynamics was recorded only on some plots with specific community composition: on beech plots 17, 11, 12 (and possibly 13, 2 and 9) and on spruce plots 7 and 8 (possibly 12 and 1).

The values of the index of total species diversity on the particular plots ranged from 1.7 to 4.9 in beech stands and from 1.1 to 4.7 in spruce stands. In general, the highest species diversity was recorded in 1951, the lowest in 1991.

It is to draw a conclusion on the basis of the above characteristics that after the air-pollution environmental disaster that had markedly negative effects on the plant cenoses of spruce stands and beech stands these com-

A



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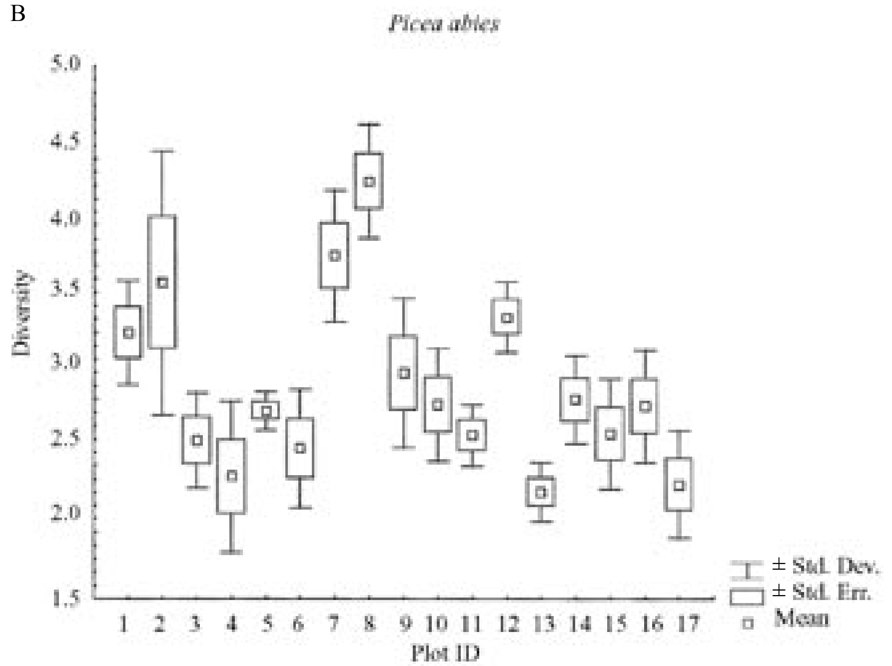


Fig. 17 A–B. Average values (arithmetic mean, standard error and standard deviation) of total species diversity on the plots in beech (A) and spruce (B) stands in 1951–2001

munities have undergone marked regeneration in recent years. From the aspect of species diversity in general in 2001 they returned to the values from 1951 or 1971 (i.e. before the start of air-pollution environmental disaster) on a majority of the evaluated plots.

References

AMBROS Z., 1985. Bioindikace abiotického prostředí lesních ekosystémů. Sbor. Vys. Šk. Zeměd. Lesn. Fak. Brno, Ser. C, *54* (3–4): 367–392.

DYKYOVÁ D. et al., 1989. Metody studia ekosystémů. Praha, Academia: 690.

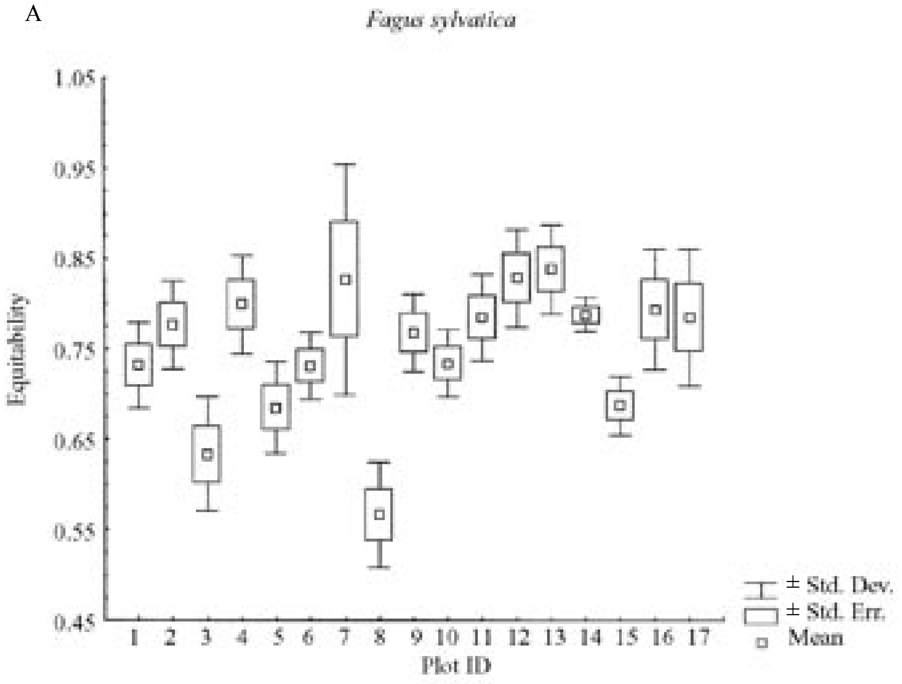
HADAČ E. et al., 1969. Die Pflanzengesellschaften des Tales „Dolina Siedmich prameňov“ in der Belaer Tatra. Vegetácia ČSSR B2. Bratislava: 343.

HILL M.O., 1979a. TWINSPAN – a FORTRAN program for arranging multivariate data in an ordered two way tabe by classification of the individuals and attributes. Ecology and Systematics, Ithaca, Cornell Univ.: 90.

HILL M.O., 1979b. DECORANA – a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Ithaca, Cornell Univ.: 52.

HLAVÁČOVÁ R., 1990. Vegetační změny v bukových porostech Orlických hor. [Diplomová práce.] Hradec Králové, Pedagogická fakulta: 68.

A



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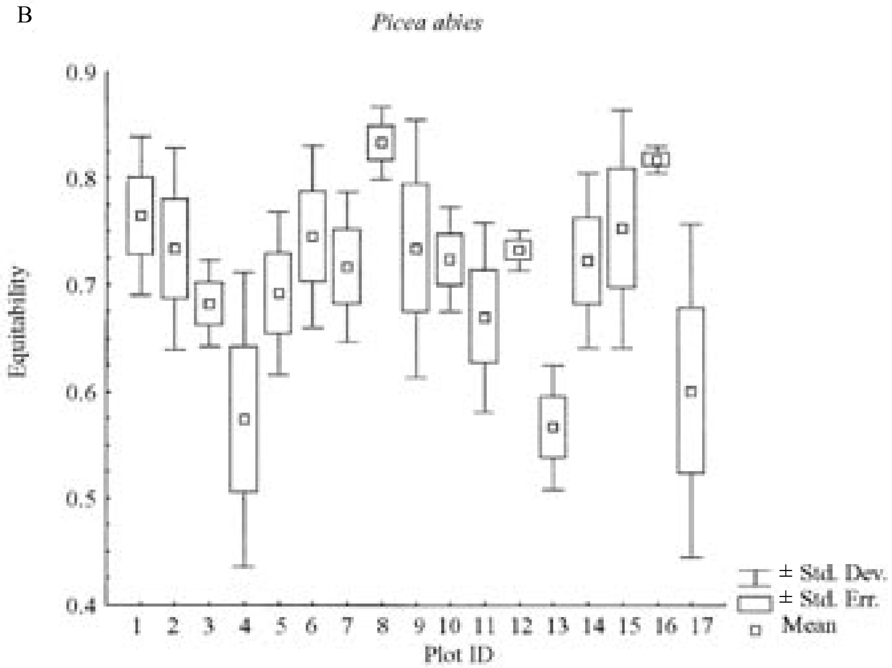

Fig. 18 A–B. Average values (arithmetic mean, standard error and standard deviation) of species equitability on the plots in beech (A) and spruce (B) stands in 1951–2001

HUSOVÁ M., JIRÁSEK J., MORAVEC J., 2002. Jehličnaté lesy. In: MORAVEC J., Přehled vegetace České republiky č. 3. Praha, Academia: 128.

JONGMAN R.H. et al., 1987. Data analysis in community and landscape ecology. Wageningen, Pudor: 299.

KOPECKÝ K., 1958. Fytocenologická studie bukových porostů jevanské vyvýšeniny. Lesnictví, *31*: 1065–1096.

KRAHULEC F., 1975. Vegetace kulminační části Králického Sněžníku. [Diplomová práce.] Praha, PřF UK: 119.

KRAJINA V., 1933. Die Pflanzengesellschaften des Mlynica-Tales in den Vysoké Tatry (Hohe Tatra). Beih. Bot. Cbl., 50B: 774–957, 51B: 1–224.

KUBÁT K. et al., 2002. Klíč ke květeně České republiky. Praha, Academia: 926.

KUBÍKOVÁ J., 1971. Geobotanické praktikum. Praha, SPN: 186.

KUBÍKOVÁ J., 1986. Jak poznáme ohroženou fytocenózu. In: Preventivní a nápravná opatření v ohrožených fytocenózách. ČSVTS – lesnické společnosti SSPPOP Středočeského kraje, Praha, Botanický ústav ČSAV: 45–55.

KUBÍKOVÁ J., REJMÁNEK M., 1973. Poznámky k některým kvantitativním metodám studia struktury rostlinných společenstev. Preslia, *45*: 154–164.

KUČERA S., 1966. Fytocenologický a fytogeografický rozbor vegetace Novohradských hor. [Diplomová práce.] Praha, PřF UK: 275.

MÁLEK J., 1955. Bučiny v Roštýnské oboře u Telče. Sbor. Lesn. Fak. Vys. Šk. Zeměd. (Brno): 103–128.

MÁLEK J., 1970. Rašelinné jedlové smrčiny (*Abieto-Piceetum sphagnosum*) na Českomoravské vysočině. Vlastiv. Sbor. Vysočiny, Odd. Věd přír., č. 6: 61–70.

MÁLEK J., 1973. Jedliny a smrčiny jižní části Českomoravské vrchoviny. Lesnictví, *19*: 37–58.

MAREŠOVÁ H., 1980. Vegetační změny ve smrkových porostech Orlických hor. [Diplomová práce.] Hradec Králové, Pedagogická fakulta: 84.

MARTINEC P., 1977. Geologické poměry. In: Příroda Orlických hor a Podorlicka. Praha, SZN: 105–215.

MATUSZKIEWICZ W., 1950. Badania fitosocjologieczne nad lasami bukowymi w Sudetach. Ann. Univ. M. Curie-Sklod., Lublin, Suppl. 5: 1–196.

MATUSZKIEWICZ W. et al., 1960. Pflanzensoziologische Untersuchungen der Waldgesellschaften des Riesengebirges. Acta Soc. Pol., *29*: 499–530.

MATUSZKIEWICZ W. et al., 1967. Zespoly roslinne Karkonoskiego Parku Narodowego. Scésc 1. Zbiorowiska lesne. Groupments végétaux du Parc national Karkonosze (Sudétes occidentales). Partie 1. Groupments forestiers. Prace Wroclaw Tow. Nauk., Ser. B, č. 135: 1–100.

MIKYŠKA R., 1972. Die Wälder der böhmischen mittleren Sudeten und ihrer Vorberge. Rozpr. Českoslov. Akad. Věd, Řada MPV, *82*, č. 3: 162.

MIKYŠKA R. et al., 1968. Geobotanická mapa ČSSR. 1 Česká země. Vegetace ČSSR, A2. Praha, Academia: 204.

MORAVCOVÁ-HUSOVÁ M., 1964. Die Fagetalia-Gesellschaften der Gebirges Branschuer Wald (Branžovský hvozd) in Westböhmen. Preslia, *36*: 272–288.

MORAVEC J., 1974. Zusammensetzung und Verbreitung der *Dentario enneaphylli-Fagetum* in der Tschechoslowakei. Folia Geobot. Phytotax. Bohemoslov., *9*: 113–152.

MORAVEC J. et al., 1983. Rostlinná společenstva České socialistické republiky a jejich ohrožení. Sev.-čes. Přír., Litoměřice, č. 1: 110.

NEUHÄUSL R., 1959. Die ostsudetischen krautreichen Buchenwälder und ihre Beziehungen zum *Fagetum boreatlanticum*. Preslia, *31*: 385–393.

ORLÓCI L., 1978. Multivariate analysis in vegetation research. 2nd ed. The Hague, Junk: 392.

PILOUS Z., DUDA J., 1960. Klíč k určování mechorostů ČSR. Praha, Academia: 568.

PIŠTA F., 1972. Lesní společenstva šumavského pralesa. Lesnictví, *18*: 415–437.

PIŠTA F., 1978. Smrkové bučiny jižní části Šumavy. Lesnictví, *24*: 219–236.

PRŮŠA E., 2001. Pěstování lesů na typologických základech. Praha, Lesn. Práce, s. r. o.: 593.

SAMEK V., 1957. Lesní společenstva Krušných hor. Zpr. Lesn. Výzk., č 3/1: 11–15.

SAMEK V., 1957. Smíšené bučiny Brdských hřebenů. Lesnictví, *3*: 537–546.

SAMEK V., 1986. Problematika a typizace monitorování vlivů lidské činnosti na fytocenózy a problematika experimentálního ověřování fytotechnických protiopatření. In: Preventivní a nápravná opatření v ohrožených fytocenózách. ČSVTS – lesnické společnosti SSPPOP Středočeského kraje, Praha, Botanický ústav ČSAV: 10–16.

SAMEK V., PLÍVA K., 1957. Rozšíření smrku a fytocenologická charakteristika smíšených smrčin v Brdech. Práce VÚLHM, č. 1: 93–102.

SILLINGER P., 1933. Monografická studie o vegetaci Nízkých Tater. Knih. Sboru pro Výzk. Slov. a Podkarp. Rusi při Slovan. Úst. v Praze. Praha: 339.

SLAVÍKOVÁ J., 1986. Ekologie rostlin. Praha, SPN: 366.

SOFRON J., 1981. Přirozené smrčiny západních a jihozápadních Čech. Studie Českoslov. Akad. Věd, č. 7: 127.

STÖCKER G., 1968. Das *Anastrepto Piceetum* im Harz und Riesengebirge (Krkonoše). Opera Corcont., *5*: 135–155.

SÝKORA T., 1967. Příspěvek ke studiu horských bučin v Krkonoších. Opera Corcont., *4*: 43–53.

SÝKORA T., 1971. Lesní rostlinná společenstva Jizerských hor. Liberec, Severočes. Muz.: 60.

ŠOLTÉS R., 1976. Phytozönotische Analyse der Verbandes *Vaccinio-Piceion* BR-BL. 1938 in den Westkarpaten. Acta Fac. Rer. Natur. Univ. Comen., Bot., *24*: 139–167.

VACEK S., 1984. Analýza fytocenóz na Strmé stráni v Krkonoších. Opera Corcont., *21*: 67–101.

VACEK S., 1983. Výzkum struktury, růstu a vývoje ochranných lesů v horských polohách. [DÚ 02 výzkumného úkolu Obhospodařování horských lesů, PEŘINA V. (koord.), Souborná závěrečná zpráva.] VÚLHM, VS Opočno: 12–25.

VACEK S., LEPŠ J., 1991. Analýza vegetačních změn v bukových porostech Orlických hor. Lesnictví, *37*: 993–1007.

VACEK S., LEPŠ J., 1992. Analýza vegetačních změn ve smrkových porostech Orlických hor. Lesnictví, *38*: 773–749.

VACEK S., LEPŠ J., 1999. Vegetační dynamika v lesních ekosystémech Krkonoš. Praha, Zpr. Čs. Bot. Společ., Materiály 17: 89–101.

VACEK S., MATĚJKA K., 1999. The state of forest stands on permanent research plots in the Krkonoše Mts. in years 1976–1997. J. For. Sci., *45*: 291–315.

VACEK S., VAŠINA V., BALCAR Z., 1998. Analýza autochtonních bukových porostů SPR Rýchory a Boberská stráň. Opera Corcont., *25*: 13–55.

VACEK S., PODRÁZSKÝ V., SOUČEK J., 1999a. Dynamika poškození smrkových a bukových porostů v CHKO Orlické hory. VIII. Analýza změn v PR Pod Vrchmezím a PR Sedloňovský vrch. In: KIRSCHNEROVÁ L., Příroda. Sbor. prací z ochrany přírody, sv. 14. Monitoring vybraných přirozených společenstev a populací rostlinných indikátorů v České republice V. Praha, Agentura ochrany přírody a krajiny ČR: 145–167.

VACEK S., BASTL M., LEPŠ J., 1999b. Vegetation changes in forests of the Krkonoše Mts. over a period of air pollution stress (1980–1995). Plant Ecol., Kluver Academic Publishers, *143*: 1–11.

VIEWEGH J., 1987. Změny ve struktuře bylinné vegetace vlivem antropogenního působení v různých lesních společenstvech Moravskoslezských Beskyd. [Kandidátská dizertační práce.] Brno, VŠZ: 86.

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Vegetační změny v bukových a smrkových porostech Orlických hor v letech 1951–2001

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ABSTRAKT: Při studiu vegetačních změn v bukových a smrkových porostech v Orlických horách v letech 1951–2001 bylo 34 výzkumných ploch osnímkováno pomocí sedmičlenné Braun-Blaunquetovy stupnice. Získaná data byla hodnocena nejen pomocí klasických fytocenologických metod, ale i metod numerické analýzy (aglomerativní a divizivní klasifikace, ordinace, druhová diverzita). Z výsledků vyplývá, že k výrazným změnám dochází zejména v druhově bohatších smrkových společenstvech asociace *Athyrio alpestre-Piceetum* (Aa-P), ale i v druhově chudších společenstvech asociací *Vaccinio myrtilli-Piceetum* (Vm-P), *Calamagrostio villosae-Piceetum* (Cv-P) i *Deschampsio flexuosae-Piceetum* (Df-P). Vývojový trend těchto společenstev v letech 1971–1991 směřuje k druhově velmi chudým typům (asociace Df-P). Léta 1991–2001 jsou naopak charakteristická výrazným přibýváním počtu druhů, zejména pak v bylinném patře. Markantní je zejména nárůst pokryvnosti i početnosti semenáčků dřevin po silných semenných letech 1992 a 1995. Zrychlující se změny v bučinách v letech 1971–1991 vedou především k ochuzování druhově bohatých květnatých typů asociace *Dentario enneaphylli-Fagetum* (De-F), případně k jejich přechodu na druhově chudší acidofilní typy *Calamagrostio villosae-Fagetum* (Cv-F). V letech 1991–2001 obdobně jako ve smrčinách stoupl počet druhů ve snímcích z bučin. Většina charakteristických druhů květnatých bučin se však do sledovaných společenstev navracela velmi pomalu.

Klíčová slova: horské lesy; bukové a smrkové porosty; fytocenologie; klasifikace; ordinace; druhová diverzita; imise

Při studiu dynamiky vegetačních změn v bukových a smrkových porostech na Lesní správě Rychnov v Orlických horách bylo na 34 výzkumných plochách (TVP BK 01–17, TVP SM 01–17) navázáno na fytocenologické a pedologické záznamy prof. A. Zlatníka a prof. J. Pelíška z r. 1951 a RNDr. J. Gregora z r. 1971. V r. 1991 a 2001 byly tyto plochy o velikosti 490 m^2 opět snímkovány pomocí sedmičlenné Braun-Blaunquetovy stupnice.

Změny ve floristické podobnosti v letech 1951, 1971, 1991 a 2001 byly hodnoceny Sörensenovým koeficientem floristické podobnosti. U jednotlivých druhů byla vypočítána konstance. Dále byly použity tři následující numerické analytické metody:

– Aglomerativní hierarchická klasifikace (Orlóci 1978) – byla užita Wardova metoda hierarchické klasifikace s Euklidovskou distancí jako mírou nepodobnosti.

– Divizivní hierarchická klasifikace metodou TWINSPAN (two-way indicator species analysis, Hill 1979a).

– Ordinace metodou korespondenční analýzy (detrended correspondence analysis – DCA, Hill 1979b). Jednotlivé osy ordinace odpovídají směrům největší variability v celém souboru dat. Ordinace druhů a snímků si vzájemně odpovídají (Jongman et al. 1987).

Druhová diverzita a její složky (celková druhová diverzita byla hodnocena jako Shannon-Wienerův index druhové diverzity, celkový počet druhů a na základě těchto veličin druhová vyrovnanost) byla počítána v programovém systému DBreleve pro bylinné patro porostů.

Z výsledků studia fytocenóz na 34 plochách (bukové a smrkové porosty) v letech 1951–2001 vyplývá relativně urychlená vegetační dynamika, a to především v období výrazného imisně ekologického zatížení pohoří v průběhu sedmdesátých a osmdesátých let (Vacek, Lepš 1991, 1992) a naopak významné revitalizační procesy v letech 1991–2001, které jsou patrné zvláště při srovnání charakteristik druhové diverzity.

K markantním změnám dochází zejména v druhově bohatších smrkových společenstvech asociace *Athyrio alpestre-Piceetum* (Aa-P), ale i v druhově chudších společenstvech asociací *Vaccinio myrtilli-Piceetum* (Vm-P), *Calamagrostio villosae-Piceetum* (Cv-P) i *Deschampsio flexuosae-Piceetum* (Df-P). Vývojový trend těchto společenstev v letech 1971–1991 směřuje k druhově velmi chudým typům (asociace Df-P). *Deschampsia flexuosa* se stává výraznou dominantou díky vyššímu prosvětlení porostů, způsobenému převážně imisně ekologickým zatížením, a nahrazuje některé druhy méně odolné vůči okyselení stanoviště, zejména pak *Vaccinium myrtillus*. Léta 1991–2001 jsou naopak charakteristická výrazným přibýváním počtu druhů, zejména pak v bylinném patře. Markantní je zejména nárůst pokryvnosti i početnosti semenáčků dřevin po silných semenných letech 1992 a 1995. Průměrný počet druhů ve snímcích společenstva Aa-P v r. 1951 činil 50 (100 %), v r. 1971 35 (70 %), v r. 1991 27 (54 %) a v r. 2001 41 (81 %), ve snímcích společenstva Cv-P v uvedených letech byl 25 (100 %), 21 (84 %), 19 (76 %) a 24 (96 %), ve snímcích Df-P kolísal okolo 16 (100 %), 15 (94 %), 13 (81 %) a 17 (100 %). Průměrný počet druhů ve snímcích společenstva Vm-P v r. 1951 činil 20 (100 %), v r. 1971 15 (75 %) a v r. 1991 a 2001 již tato asociace vylišena nebyla. Bez členění společenstev do asociací průměrný počet druhů ve snímcích ze smrkových porostů v r. 1951 činil 25 (100 %), v r. 1971 20 (80 %), v r. 1991 16 (64 %) a v r. 2001 21 (84 %).

Zrychlující se změny v bučinách v letech 1971–1991 vedou především k ochuzování druhově bohatých květnatých typů asociace *Dentario enneaphylli-Fagetum* (De-F), případně k jejich přechodu na druhově chudší acidofilní typy *Calamagrostio villosae-Fagetum* (Cv-F). V letech 1991–2001 obdobně jako ve smrčinách stoupl počet druhů ve snímcích z bučin. Většina charakteristických druhů květnatých bučin se však do sledovaných společenstev navracela velmi pomalu. Průměrný počet druhů ve snímcích společenstva De-F v r. 1951 činil 44 (100 %), v r. 1971 42 (95 %), v r. 1991 24 (55 %) a v r. 2001 49 (111 %), ve snímcích společenstva A-F v uvedených letech byl 23 (100 %), 33 (143 %), 19 (83 %), 33 (143 %) a ve společenstvu Cv-F průměrný počet druhů ve snímcích ve studovaných letech kolísal okolo 22 (100 %), 20 (91 %), 14 (64 %) a 23 (105 %). Bez členění společenstev do asociací průměrný počet druhů ve snímcích z bučin v r. 1951 činil 27 (100 %), v r. 1971 23 (85 %), v r. 1991 17 (63 %) a v r. 2001 26 (96 %).

Je pravděpodobné, že výrazné urychlení vegetační dynamiky jak ve smrkových porostech (zejména na TVP SM 02, 06,12,15 a 17), tak i v bukových porostech (TVP BK 01, 02, 09, 15 a 16) v letech 1971–1991 bylo způsobeno zvýšeným imisně ekologickým zatížením. Naopak díky příznivějším ekologickým poměrům zejména pak v průběhu devadesátých let dochází k významným revitalizačním procesům, a to v podstatě ve všech vegetačních patrech (E_3–E_0). Nejzřetelnější jsou tyto jevy v bylinném patře.

Z ordinace metodou DCA vyplývá že:

- Není příliš velký rozdíl mezi výsledky, kdy k analýze bylo použito dat pouze o bylinném patře nebo dat o bylinném a mechovém patře společně.
- Variabilita dat popsaná prvními čtyřmi ordinačními osami je obdobná u bukových i smrkových porostů. Vlastní hodnoty analyzovaných matic byly pro bukové porosty 0,538 – 0,340 – 0,249 – 0,214 a pro smrkové porosty 0,520 – 0,309 – 0,256 – 0,213.
- Pouze na některých plochách byla významnější dynamika vegetace: z bukových to byly plochy 17, 11, 12 (případně i 13, 2 a 9), ze smrkových pak plochy 7 a 8 (případně i 12 a 1).
- Hodnoty indexu celkové druhové diverzity na jednotlivých plochách se pohybují v rozmezí 1,7 až 4,9 v bukových porostech a 1,1 až 4,7 ve smrkových porostech. Obecně byla nejvyšší druhová diverzita zaznamenána v roce 1951, nejnižší pak v roce 1991.
- Na základě uvedených parametrů lze konstatovat, že po imisně ekologické kalamitě, která měla výrazně negativní vliv na fytocenózy smrčin i bučin, tato společenstva v posledních letech výrazně regenerují. Ve většině hodnocených ploch v r. 2001 již z hlediska druhové diverzity rámcově dochází k návratu k hodnotám z r. 1951 či z r. 1971 (tj. před nástupem imisně ekologické kalamity).

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