State and development of phytocenoses on research plots in the Krkonoše Mts. forest stands

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ABSTRACT: The paper assesses the state and development of phytocenoses in beech, mixed and spruce stands on permanent research plots (PRP) 1–32 in the Krkonoše (Giant) Mts. in the years 1980–2005, i.e. during the air-pollution calamity and afterwards. Dynamics (the extent of change) of the vegetation structure has been expressed as the overall change of species composition in comparison with the year 1980. The change was quantified using the Euclidean distance or as the change of the several first ordination axes (DCA 1–DCA 4). Species composition was significantly changing on all 32 PRP stands in the period 1980–2005; some species completely disappeared (e.g. *Cicerbita alpina*, *Lamium maculatum, Phyteuma spicatum, Viola biflora*) or their ratio was reduced (e.g. *Blechnum spicant, Dentaria enneaphyllos, Homogyne alpina*). From the viewpoint of diversity, the most significant change is the reduction of species in the moss layer, which was observed in all types of stands; in beech and mixed forests the average number of species dropped from 4.8 to 2.7 (44%), in non-declining spruce stands the number fell from 11.6 to 5.5 (53%), and in declining spruce stands it dropped from 10.4 to 3.3 (68%). The overall reduction of species diversity ranged between 31% and 43%; the highest reduction was recorded at species with lower representation. The most significant factors influencing the species composition were altitude and exposition of plot.

Keywords: beech; mixed and spruce stands; classification; Krkonoše Mts.; ordination; state and development of phytocenoses

The state of vegetation of the Krkonoše (Giant) Mts. in the 13th century, i.e. before the impact of human activities on landscape, was the result of flora quaternary development. Mikyska in their vegetation reconstruction (Mikyška et al. 1968) reported that the natural basis of the stands in the lowest parts of the Krkonoše Mts. were flowery and woodrush meadows, followed upward by acidophilic mountain beech forests, climax spruce forests, and the highest altitudes were covered with mountain pine and subalpine communities. Alluvial plains, alder carrs, scree forests, moist spruce forests, upland moors, and valley bogs occurred in a mosaic pattern. A map of potential vegetation in the Krkonoše National Parks (Krkonošský národní park and Karkonozsky Park Narodowy) was constructed earlier (Fig. 1; see Vacek et al. 2006).

Species composition of the Krkonoše Mts. forests has changed significantly, especially during the last four centuries. Original beech, spruce-fir-beech and partly spruce forests were destroyed by human activities, such as chalet farming, mining and glass industry. The forests were slowly restored, yet, their species, genetic, age and location structure was significantly changed. Original montane spruce forests were preserved only in a thin belt along the upper forest boundary, on steep slopes and near the glacial cirques. The remains of original mixed and beech forests may be found mostly in the natural reserves (zone I) and partly in inaccessible locations of protective forests.

As to the forests vegetation zones, the largest are: FVZ 6 – spruce with beech (42.5%), FVZ 8 –

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spruce (20.7%) and FVZ 7 – beech with spruce (19.2%). Dominant are forest types of following groups (FTG): 6K – acid spruce with beech (18.8%) and 7K – acid beech with spruce (10.6%). Acid sites significantly predominate (acid and extreme ecological series) – 72% over fertile (fertile and humus-enriched ecological series) sites – 17%, and moist (moist ecological series, water-enriched, gleyic or peat) sites – 11% (Mikeska et al. 2007).

Forests of the Krkonoše Mountains are an important landscape component of the Czech Republic. They are object of a special interest in relation to the natural environment protection, stabilisation of natural processes and the overall landscape homeostasis. Moreover, they serve for several production and non-production functions. Attention paid to mountain forest ecosystems during the last two decades is undoubtedly rightful. Mountain forest ecosystems are generally very sensitive, and even in natural environmental conditions they are exposed to many stress factors. The most important stressors are impacts of extreme climate (low temperature, drought periods, intensive air flows), but also soil conditions may not be often favourable (mostly it is the case of relatively poorly developed soils and soils naturally considerably acid with low biological activity). For these reasons, dynamics of forest ecosystems is often a subject of interest of environmentalists and silviculturists. Attention is usually paid to natural or near-natural forests; however, these are often more or less afflicted with imission-ecological stress, and thus in different stage of forest development cycle or in different level of decline. Generally, a spatially limited community is observed; usually it is a research plot that sufficiently represents the community (mostly plant), not the whole forest ecosystem; the latter is composed of smaller or larger areas that represent different stages of the forest development. Yet, this is not the last problem. During the whole period of development of contemporary forest generation, significant changes of conditions under which these forests grew have been going on. To put it simple, let us mention only some of the most important ones:

(1) change of the air pollution load with an increase up to the early 1990s, and subsequent irregular decrease of this load and a change of proportional representation of individual pollutants;
(2) change of silvicultural technologies and preference of certain woody species;
(3) forest restoration at sites that had not been afforested for periods of variable length (Matějka, Vacek 2007).

Long-term dynamics of vegetation changes at similar sites and stand conditions has been studied by many authors. Classification and ordination methods at beech, mixed (spruce with beech, beech with spruce and spruce with fir and beech) and spruce forests were studied for instance by Sýkora (1971), Sofron (1981), Vacek and Lepš (1991, 1992, 1999), Ambros and Míchal (1992), Viewigh (1994), Elenberg (1996), Bohn et al. (2000), Pokorný (2002), Hédl (2004), Vacek and Matějka (2003), Šamonil and Vrška (2008), Podlaski (2008), who dealt with suitability of use of different input data for numerical analysis. In numerous cases, the impact of imission load on acceleration of vegetation changes was proven (Vacek, Lepš 1996; Moldan, Hak 2007; Vacek et al. 2007). Yet, long-term vegetation observations under natural conditions with almost minimal air-pollution load are rather few (Matuszkiewicz et al. 1960, 1967; Stöcker 1968; Mikyška 1972; Málek 1970, 1973; Pišta 1972, 1978; Moravec 1974; Vacek 1981; Průša 1985; Ujházy et al. 2005).

Evaluation of recorded changes in concrete site and stand conditions and their interpretation is considered as one of the most critical issue of phytocenological monitoring (Samek 1986). He underlines that the assessment of the rate of anthropogenic impact must necessarily stem from comparison and quantification of the observed impact. These conditions are often not fulfilled. Therefore, the above mentioned monitoring type should be set at sites of some other experimental measurements or autecological studies. According to Brang (2005), it is important for further implementation of these findings in forest ecosystem management. Our research of forest ecosystem on permanent research plots in the Krkonoše Mts. fulfilled this important condition.

The aim of this paper was to evaluate the state and development of phytocenoses in beech, mixed and spruce stands on permanent research plots in the Krkonoše Mts. in the years 1980–2005, i.e. during the air-pollution calamity and afterwards.

MATERIAL AND METHODS

Characteristics of permanent research plots

As in the research on state and development of soils, the state and development of phytocenoses in beech, mixed (beech with spruce to spruce to beech) and spruce stands was carried out on research plots 1–32 in the Krkonoše Mts.; their characteristics are given in our previous paper (Matějka et al. 2010).

Phytocenological relevés were recorded in the years 1980 (1976) to 2005 (with 5-year intervals: 1980, 1985, 1990, 1995, 2000 and 2005) by usual means, using the combined eleven-point Domin-Hadač scale for abundance and dominance. Phytocenological relevés were collected in database of the DBreleve software. It is a system developed by the IDS company for unified editing, storage and further processing of the records of species structure of communities (Matějka 2000). For calculations, the species representations were transformed: scale values were replaced by the values of average cover of individual scale levels and such values were multiplied by a constant (specific for the relevé and the etage), thus sum of representations of all species participating in the etage of the relevé should be equal to the total etage coverage.

To compute ordination (using the DCA method) and divisive classification (the TWINSPAN procedure; Hill 1979) the relevé data were exported. Ordination and classification results were again downloaded to the DBreleve programme. Both numerical methods were applied to process the data of herb (E1) and moss (E0) layer.

The evaluation of relevés was done based on the following methods:

– Evaluation of species diversity indices in the course of the period of observation: total species diversity (Shannon-Wiener's diversity index, H), species richness (S) and evenness (e).

– Classification of all phytocenological relevés using the TWINSPAN procedure.

– Agglomerative hierarchical classification of relevés, method of average linkage; Euclidean distance was used as a dissimilarity measure.

– Ordination of relevés using the DCA method using Canoco, version 4.5; data from all plots and all sampling periods were used together. Results were plotter within the PlotOA programme (Matějka 2009).

Extent of vegetation change throughout the period of monitoring (starting in the year 1980) was evaluated on the basis of the sum of variance of the first (one to four) DCA axes (the results of ordination from all plots were used) – using the formula

$$v_i = \sqrt{\sum_{j=1}^{i} \text{var}\,(DCA_{j,r})} \qquad (1)$$

where:
j – index of ordination axis,
r – index of year.

Random fluctuations were thus eliminated. Compare Matějka (2009), where $V_i = v_i^2$

Total difference (E_{r_1,r_2}) in species structure between two years (between a year and the original state in 1980, specially) was evaluated on the basis of the Euclidean distance between vectors of individual species representation in both phytocenological relevés compared. Maximal change in the vegetation structure during the whole observation period (1980–2005) was specified as $E_{max} = \max(E_{1980,r})$.

Total cover of woody plants was evaluated using the combination of total cover of tree and shrub layers. Both layers produce a shelter for herbal vegetation and during the regeneration of the declined cover, the plants gradually pass from shrub to tree layer. Canopy coverage (D) was expressed as follows:

$$D = 1 - [(1 - E2)\times(1 - E3)] \qquad (2)$$

where:
E3, E2 – the cover of tree and shrub layer.

RESULTS AND DISCUSSION

Numeric classification

Classification using the TWINSPAN procedure (Table 1) distinguished individual basic community classification classes. It is possible to describe them on the basis of their specific species composition.

The communities were divided as supramontane spruce forests (group *00; typical is occurrence of *Streptopus amplexifolius, Athyrium distentifolium, Sphagnum girgensohnii, Deschampsia cespitosa* and *Mylia taylorii*). Within this group, species composition on plots 13 and 14 are rather specific (group *0010 with *Adenostyles alliariae* and *Rhizomnium punctatum*); in the course of development, the canopy completely or partially declined, and specific was also the plant community on plot 23 (group *000 with *Carex limosa* as indicator species); all of them appear stable.

Among typical supramontane spruce stands belong communities of the classification group *0011 on plots 11, 12, 5, 4, 10, 2, and 21, with a stable canopy species composition. At the beginning of the 1980's, this group comprised also the plots 3, 25, 15, and 17; at these plots, however, the canopy sooner or later declined and as a result, the classification changed to montane spruce forest (*010). Opening of canopy probably resulted in a change of the temperature regime. A similar change was observed at plot 20, which may indicate its position at the verge between montane and supramontane spruce forests.

Typical montane spruce forests are gathered in the classification group *010 (or subgroup *0100),

Table 1. Results of the classification using the TWINSPAN procedure. At each classification group the indicator species and their representation according to "cut-levels" [0.00% (1)–3.12% (2)–6.25% (3)–12.50% (4)–25.00% (5)–50.00% (6)] are given. The last but one column contains labels of relevés belonging to respective classification group (No. of plot – one or more years [the last two digits of the year] of the relevé). The years following the stand decline are marked red. The relevés dated from 1980 or before are typed in bold. The last column provides the stand type, based on the apportionment of spruce (sp) and beech (be)

		*000 *Car lim* 1	*0000 *Bar gra* 1							**23–80**,85,90	
			*0001							23–95,00,05	
	*00 *Str amp* 1 *Ath dis* 1 *Sph gir* 1 *Des ces* 1 *Myl tay* 1			*00100 *Vio bif* 1	*001000 *Ace pse* 1					**14–76,80**,85	
					*001001					**13–76,80**,85	
			*0010 *Ade all* 1 *Rhi pun* 1		*001010	*0010100				14–90,05	
				*00101		*0010101 *Dry dil* 2				14–95,00	
					*001011 *Phe con* 1	*0010110				13–90,95	
						*0010111 *Bet pen* 1				13–00,05	
							*00110000 *Bar gra* 1			**11–76,80**,85	
						*0011000		*001100010 *Pel nee* 1		**12–76,80**,85	
					*001100 *Ath dis* 1		*00110001		*0011000110 *Phe con* 1	12–90,95,00,05	
								*001100011	*0011000111	11–95,00,05	
*0 *Ave fle* 2 *Tri eur* 1						*0011001 *Sph gir* 3	*00110010 *Luz luz* 1	*001100100		**05–80**,85	sp
								*001100101 *Vac myr* 2		05–90,95,00,05	
		*001					*00110011	*001100110		**03–80** **04–80**,85,90	
				*00110				*001100111 *Jun fil* 1		04–95,00,05	
	*01 *Vac myr* 5		*0011				*00110100 *Des ces* 1	*001101000 *Luz pil* 1		**10–80**,85	
								*001101001		10–90,95,00,05	
						*0011010		*001101010	*0011010100	**20–80** 24–90,95,00,05	
					*001101 *Oxa ace* 1 *Gen asc* 2		*00110101		*0011010101 *Pol com* 1	**25–80**,85,90	
								*001101011 *Ant odo* 1		**24–80**,85	
							*00110110	*001101100		21–90,95	
						*0011011 Pol ver 1		*001101101 *Ath dis* 1		21–00,05	
							*00110111 *Ant odo* 1			**21–80**,85	
				*00111 *Dry dil* 4	*001110					15–90 **17–80**,85	
					*001111 *Vac vit* 1					**15–76,80**,85	

Table 1 to be continued

					*010000 *Ade all* 1					15–95,00,05	
				*01000 *Poh nut* 1		*0100010 *Cam lat* 1				**22–80**,85	
					*010001		*01000110			22–00,05	
						*0100011	*01000111 *Sph squ* 1			22–90,95	
						*0100100	*01001000 *Myl tay* 1	*010010000 *Lyc ann* 1		**18–80**,85	
								*010010001		18–90,95	
							*01001001	*010010010 *Sca und* 1 *Epi ang* 1 *Sen her* 1		**16–80**,85,90,95	
		*010 *Ave fle* 4 *Tri eur* 1 *Epi ang* 1	*0100		*010010 *Dry dil* 1 *Oxa ace* 1			*010010011 *Oxa ace* 1 *Sph gir* 1	*0100100110 *Pol for* 2	**19–80**,85,90 20–85 25–95 **26–80**	sp
				*01001 *Ave fle* 5					*0100100111	20–90,95,00,05	
						*0100101 *Gal har* 1 *Gen asc* 1 *Epi ang* 1	*01001010	*010010100		16–00 25–00,05	
								*010010101 *Des ces* 1		18–00,05	
							*01001011 *Dic sco* 2	*010010110 *Epi ang* 1		17–90,95,00,05	
								*010010111		11–90	
					*010011 *Bet pen* 1 *Cal vul* 1	*0100110				26–85,90,95	
						*0100111 *Gal har* 1				26–00,05	
*0 *Ave fle* 2 *Tri eur* 1	*01 *Vac myr* 5		*0101 *Epi mon* 1 *Cal vil* 6 *Gen asc* 1	*01010	*010100					16–05 19–00,05	
					*010101 *Luz luz* 1					03–95,00,05	
				*01011 *Pla und* 1						03–85,90	
					*011000 *Ble spi* 1					**06–80**,85	
				*01100 *Cal vil* 5	*011001	*0110010				06–00 19–95	
						*0110011 *Hom alp* 1				06–90,95	
			*0110 Gen asc 1		*011010 Ave fle 1	*0110100 *Gym dry* 1				09–00,05	be-sp (sp)
						*0110101	*01101010			09–90,95	
		*011 *Fag syl* 1 *Dic het* 1 *Pol ver* 1 *Pre pur* 1		*01101			*01101011 *Cic alp* 1			**09–80**,85	
					*011011					08–95	
						*0111000				02–00,05 28–95	
					*011100 *Sor auc* 1	*0111001 *Luz luz* 1	*01110010 *Pic abi* 1	*011100100 *Tri eur* 1		27–90,95,00	
			*0111	*01110 *Mai bif* 1				*011100101		27–05 **28–80**,90	be-sp to be
							*01110011			**27–80**,85 28–85	
						*0111010				02–90,95	
					*011101	*0111011 *Ace pse* 1				**02–80**,85	

Table 1 to be continued

*0 Ave fle 2 Tri eur 1	*01 Vac myr 5	*011 Fag syl 1 Dic het 1 Pol ver 1 Pre pur 1	*0111	*01111 Ste nem 1 Pel nee 1	*011110	*0111100	01–00,05	be-sp to be
						*0111101 Bet pen 1	01–90,95	
					*011111 Ath fil 1		**01–80**,85	
*1 Gym dry 1 Dry fil 1 Ath fil 1	*10	*100	*1000 Par qua 1 Gen asc 1 Phe con 1 Ste nem 1 Rub ida 1 Cal vil 2	*10000 Ble spi 1			06–05	be-sp
				*10001	*100010		**07–80**,85	
					*100011 Ath fil 1	*1000110	07–90,95	
						*1000111 Asp odo 1	07–00,05	
			*1001	*10010 Ble spi 1			08–00,05	
				*10011	*100110 Vac myr 3		28–00,05	be to be(sp)
							29–90	
					*100111	*1001110	29–95,00,05	
						*1001111 Bra syl 1	31–05	
							32–05	
		*101 Myc mur 1 Gym dry 2	*1010				**29–80**,85	be(sp)
			*1011 Ble spi 1				**08–80**,85,90	be-sp
	*11 Mil eff 2	*110	*1100	*11000 Asp odo 1			**31–80**,85	be
				*11001	*110010 Dry fil 4		31–95	
					*110011 Asp odo 1		31–90,00	
							32–95	
			*1101 Lun red 1	*11010			32–90,00	
				*11011			**32–80**,85	
		*111 Act spi 1	*1110				30–95,00,05	
			*1111 Cir x i 1				**30–80**,85,90	

where the predominant species is *Avenella flexuosa*, and *Trientalis europaea* and *Epilobium angustifolium* occur. These communities were reported on plots 22, and 26 that were rather stable during the observation period, and on plots 6, 18, and 19, where the canopy decline occurred. This classification group includes also the communities developed after the canopy decline, with classification subgroups *0101 (characterised by dominant *Calamagrostis villosa* and further *Gentiana asclepiadea* and *Epilobium montanum*) and *0100101 (with appearance of the species *Galium saxatile*, *Gentiana asclepiadea* and *Epilobium angustifolium*).

Beech-spruce forests of the 5th to 7th vegetation zone belong into the classification group *011. They contain many indicators of spruce forests together with beech types. The structure of these communities (plots 1, 2 , 6, 9, 27) is rather stable in the course of time; exceptionally the communitiy may be shifted into the group *10 (plot 28), which may be interpreted as a change resulting in warming of the stand.

Communities of beech to spruce-beech stands at plots 7, 8, and 29 are similar to those of the previous group, however, the indicators of typical forest stand miss here. Stands correspond to the 6th to 7th vegetation zone and are classified in the group *10.

Typical beech stands on plots 30, 31, and 32 have communities of the classification group *11.

Ordination analysis

The interpretation of the first two ordination axes (Figs. 2 and 3) is relatively easy, compared to the third and four ordination axes (Figs. 4 and 5). High values along the first axis are observed in beech forest (plots 30, 31, 32); they usually show significant changes during the time, as well. Plots 7, 8, and 29 represent

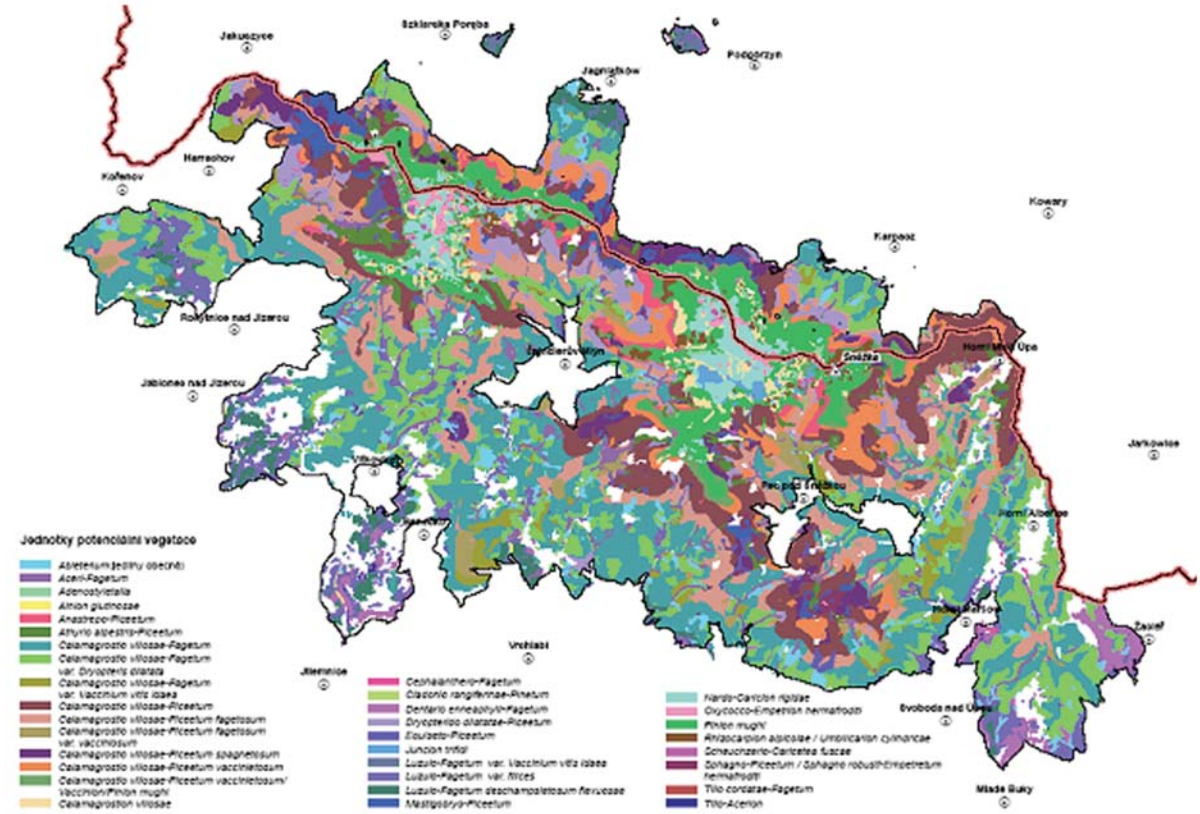

Fig. 1. Potential vegetation of the Giant Mountains (Vacek et al. 2006)

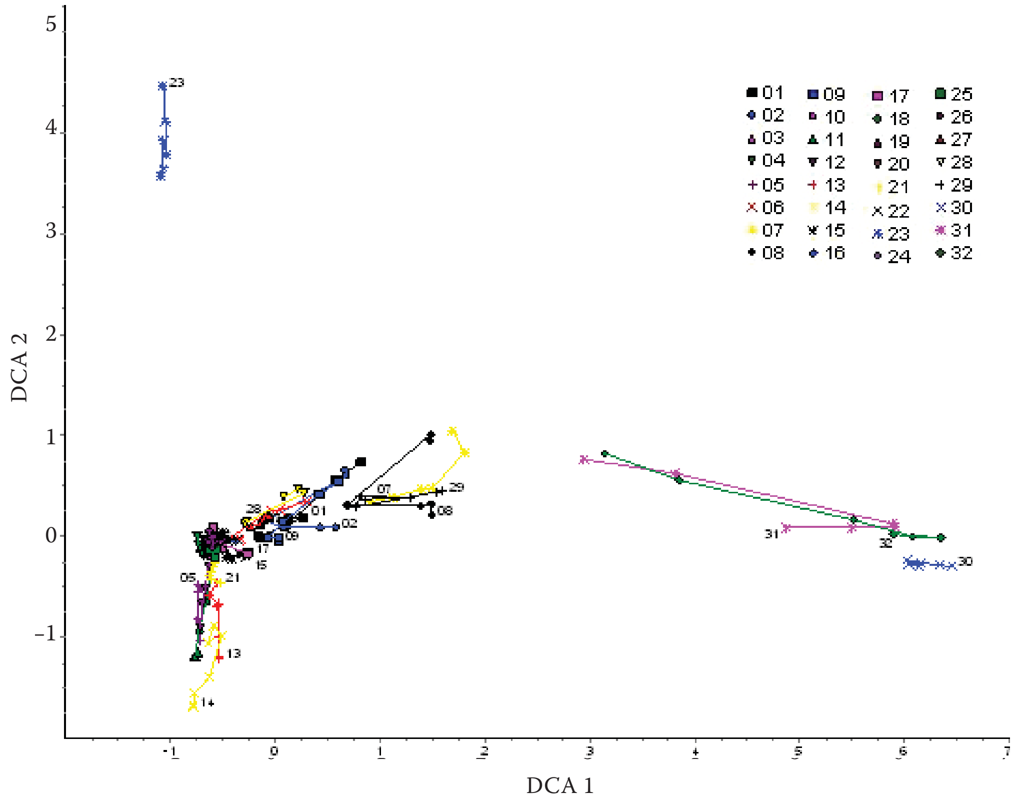

Fig. 2. Position of all relevés from PRP 1–32 in the DCA ordination space of the first two axes. Each series of relevés from one plot is connected with a trajectory with a plot number at its beginning (corresponding to the year 1980; at plots 11 to 15, to the year 1976)

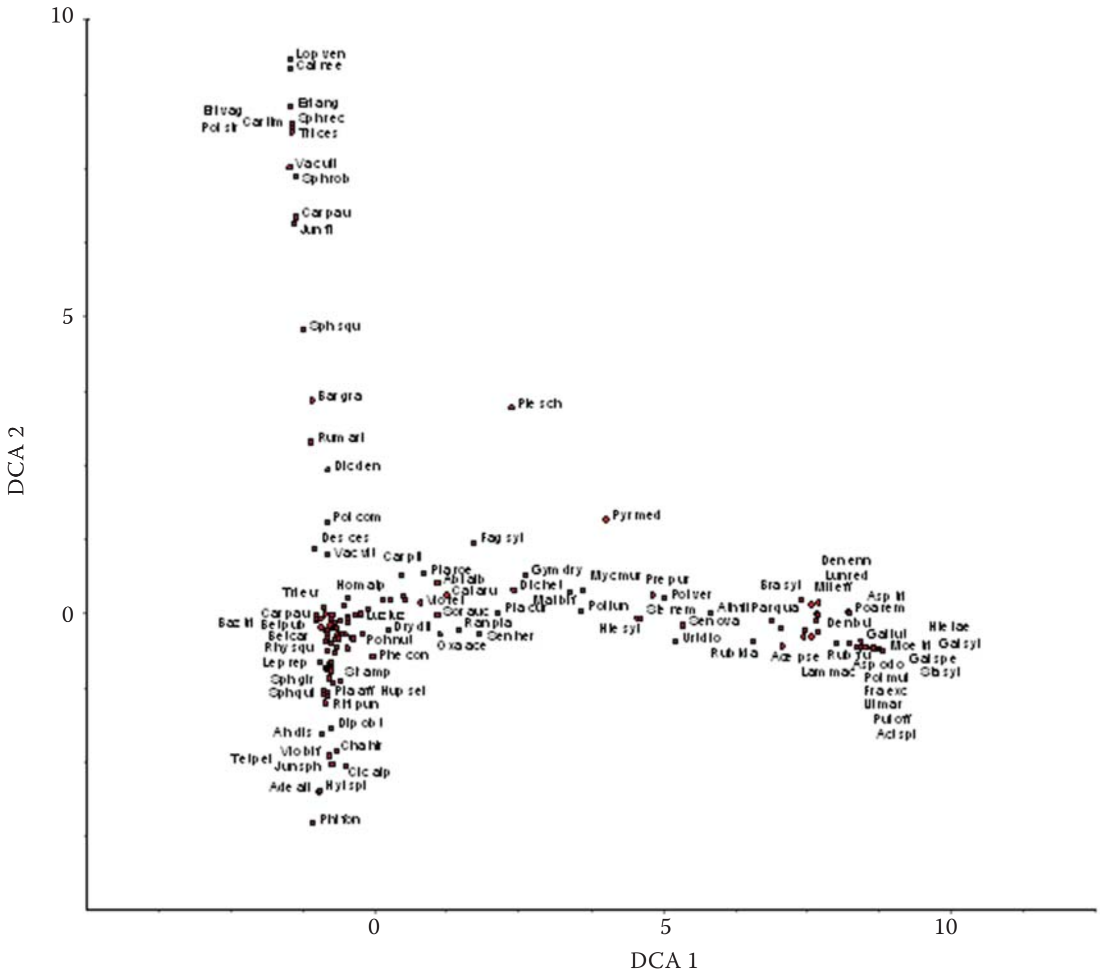

Fig. 3. Position of species in ordination space of the DCA 1 and DCA 2 axes

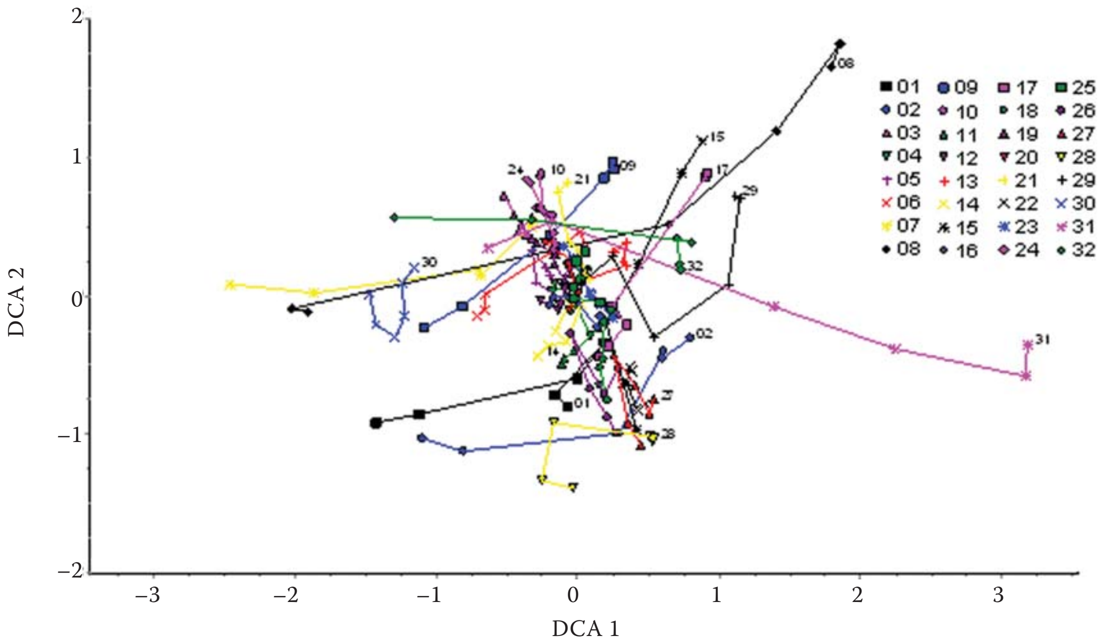

Fig. 4. Position of all phytocenological relevés from PRP 1–32 in the DCA ordination space of the 3rd and 4th axes. Each series of relevés from one plot is connected with a trajectory with a plot number at its beginning (corresponding to the year 1980; at plots 11 to 15, to the year 1976)

typical spruce-beech stands, followed, with the decreasing score, by stands of higher altitudes.

The second ordination axis discerns supramontane spruce communities with occurrence of subalpine tall-forb species; typical examples are plots 13 and 14, whereas the plot 23 lies at the opposite.

Gradual movement of the plots along the trajectories to the centre of ordination space is evident. It confirms reduction of forest community diversity in the Krkonoše Mts. area. There is, however, another distinguishable trend, characteristic for beech stands (plots 7, 8, 1, 2, 28, 6, 9); it results in a certain break of trajectory in the direction of increasing values of both the first and the second ordination axis.

Vegetation development on particular PRP

The development of various vegetation characteristics studied from 1980, on plots 11–15 from 1976, was presented in a graphic form; each plot was sorted in one of the basic classification groups based on the 1980 relevé.

Spruce stands – group *0000: PRP 23.

Spruce stands – group *0010: On both plots classified here (PRP 13 and 14), canopy decline was reported.

Spruce stands – group *0011: PRP 10, 21, 20, 24, 4, 12, 15, 5, and 11 (in respective order rises the extent of species composition change); next, this group includes PRP 3, 25 and 17, where canopy decline was reported. Except for PRP 17, these plots have autochthonous spruce vegetation. The change of floor layer vegetation is usually weak, medium or strong (even in the case of canopy stability).

Spruce stands – group *0100: this group comprises PRP 22 and 18 with vegetation classified as autochthonous, and PRP 16, 26 and 19 with allochthonous vegetation. The canopy decline was observed at all the plots, except for PRP 22.

Comparison of all spruce stands shows that the canopy decline is not a cause of the greatest changes in floor layers, if these changes are evaluated quantitatively using the change in cover of present species (e.g. Euclidean distance or score along the ordination axes). The changes may be noticed more in the vegetation classification, especially in the data such as presence – absence of species.

Spruce-beech stands – group *0110: PRP 9, 6.

Spruce-beech to beech stands – group *0111: PRP 2, 27, 1 and 28.

Spruce-beech stands – group *1000 (sp-be): PRP 7.

Beech stands with the admixture of spruce – group *1010: PRP 29.

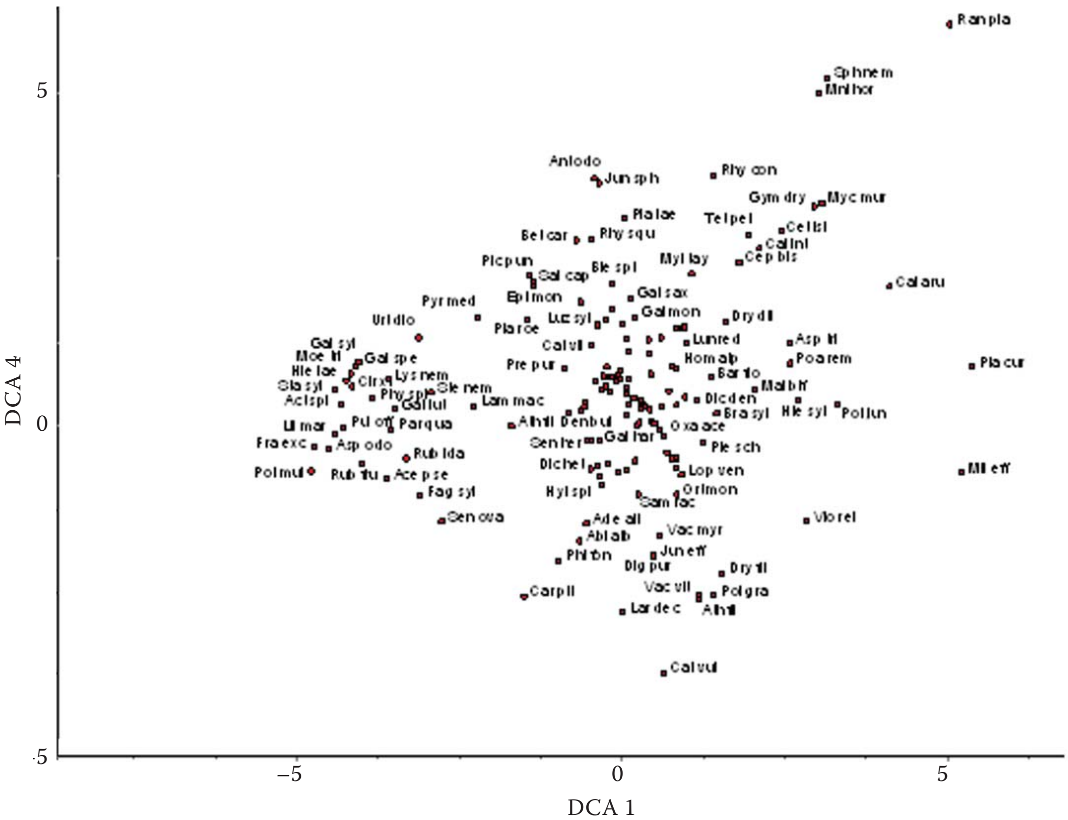

Fig. 5. Position of species in ordination space of the DCA 3 and DCA 4 axis

Table 2. Basic characteristics of plant community dynamics on studied plots

PRP	Stand type	Autochthonous vegetation	Canopy decline	TWINSPAN 1980	Basic classification group	Classification level change	v_1	v_2	v_3	v_4	E_{max}
23	sp	+		*00001	*0000	5	0.000	0.300	0.321	0.369	31.4
14	sp	+	+	*0010000	*0010	6	0.095	0.313	0.329	0.359	38.0
13	sp	+	+	*0010010	*0010	6	0.032	0.257	0.303	0.321	52.5
10	sp	+		*001101000	*0011	10	0.032	0.045	0.055	0.134	17.1
21	sp	+		*00110111	*0011	9	0.032	0.071	0.105	0.286	27.7
20	sp	+		*0011010100	*0011	3	0.000	0.055	0.100	0.210	30.7
24	sp	+		*001101011	*0011	10	0.000	0.000	0.084	0.219	34.5
4	sp	+		*0011001101	*0011	10	0.032	0.077	0.122	0.179	47.4
12	sp	+		*0011000100	*0011	10	0.045	0.239	0.257	0.283	51.9
15	sp	+		*0011111	*0011	3	0.084	0.130	0.268	0.802	60.5
5	sp	+		*001100100	*0011	10	0.000	0.207	0.232	0.265	68.3
11	sp	+		*001100001	*0011	3	0.063	0.395	0.420	0.442	76.1
3	sp	+	+	*0011001100	*0011	3	0.077	0.077	0.105	0.145	18.1
25	sp	+	+	*0011010101	*0011	3	0.032	0.045	0.077	0.155	37.4
17	sp		+	*0011101	*0011	3	0.141	0.167	0.365	0.660	53.1
22	sp	+		*0100010	*0100	8	0.084	0.089	0.100	0.164	35.7
18	sp	+	+	*010010000	*0100	8	0.032	0.045	0.055	0.241	23.1
16	sp		+	*0100100101	*0100	5	0.095	0.095	0.167	0.184	31.7
26	sp		+	*0100100110	*0100	7	0.000	0.055	0.130	0.265	38.1
19	sp		+	*0100100110	*0100	4	0.071	0.077	0.155	0.219	51.0
9	be-sp	+		*01101011	*0110	8	0.243	0.332	0.630	0.792	29.1
6	be-sp	+		*011000	*0110	2	0.261	0.307	0.449	0.508	33.5
2	be-sp	+		*0111011	*0111	7	0.297	0.387	0.837	0.901	29.1
27	be(sp)	+		*011100111	*0111	9	0.055	0.071	0.118	0.237	29.8
1	be-sp			*011111	*0111	7	0.321	0.415	0.740	0.764	34.6
28	be	+		*0111001011	*0111	2	0.241	0.283	0.446	0.480	35.1
7	be-sp	+		*100010	*1000	7	0.311	0.404	0.909	0.931	34.8
29	be(sp)	+		*1010	*1010	4	0.342	0.346	0.567	0.673	7.5
8	be-sp	+		*10111	*1011	2	0.290	0.438	1.706	1.875	70.7
31	be	+		*11000	*1100	3	1.107	1.142	1.889	1.932	45.7
32	be	+		*11011	*1101	3	1.203	1.245	1.472	1.479	29.0
30	be	+		*11111	*1111	5	0.152	0.152	0.190	0.259	30.3
AVG	sp						0.047	0.137	0.188	0.295	41.2
	be-+						0.402	0.460	0.829	0.903	34.1

AVG – average, sp – spruce; be-sp – beech-spruce; be(sp) – beech with admixed spruce; be – beech; The "basic classification group" was distinguished in 1980 using the TWINSPAN procedure. "Classification level change" determines the highest TWINSPAN classification level recorded after 1980. Variables v1 to v4 are calculated on the base of DCA ordination (see equation 1); E_{max} is the maximum Euclidean distance of a relevé with respect to the 1980 relevé

Spruce-beech stands – group *1011: PRP 8.

Beech stands – group *1100: PRP 31.

Beech stands – group *1101: PRP 32.

Beech stands – group *1111: PRP 30.

Plant communities in beech and mixed stands usually show medium to high change of the species composition, which is caused by higher species diversity in herb layer (Fig. 5).

Global trends in the plant community development

Species composition of vegetation on all 32 permanent research plots was significantly changing during the period 1980(1976)–2005, and some of the species completely disappeared (e.g. *Cicerbita alpina*, *Lamium maculatum*, *Phyteuma spicatum*, *Viola biflora*) or their apportionment decreased (e.g. *Blechnum spicant, Dentaria enneaphyllos*, *Homogyne alpina*). The number of species was greatly reduced especially in the moss layer.

To evaluate the trends in community development on studied research areas, the plots were divided to spruce, beech and beech-spruce stands (Table 2). The first group was then subdivided into the plots with canopy decline and the others. Canopy decline was reported when the overall canopy cover of woody plants during the observation reduced to 25% or less.

Average canopy cover of woody plants in beech and mixed stands decreased only insignificantly – by 8% in 25 years. A similar tendency was observed in spruce stands where the decline did not occur. Canopy decline was marked at phytocenological relevés since 1985 and the average canopy cover decreased until 2000. The canopy regeneration was observed in the last sampling year 2005 (Table 3).

Total herb layer coverage in beech and mixed forests changed insignificantly. In spruce stands, an increase in the total herb layer coverage was observed. At the beginning of the observation this cover was higher in communities that later went through the wooden canopy decline.

The change in the number of species richness in the Krkonoše Mountains was significant. In beech and mixed forests, an average decrease of species was 27% of those present in 1980. In non-declining

Table 3. Trends in the phytocenose features according to the dominant woody plants on PRP 1–32 in the years 1976–2005, with relation to the occurrence of canopy decline

Type	Canopy decline	Year	*N*	Canopy closure D (%)			Total cover of E1 (%)			Richness E1			Richness E0		
				MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
be	NO	1980	12	67	89	98	25	68	90	12	22.3	37	3	4.8	7
		1985	12	67	88	98	20	65	90	11	21.7	40	3	3.8	5
		1990	12	73	86	96	15	61	95	11	18.7	36	2	3.3	5
		1995	12	71	82	96	10	58	95	10	17.7	34	2	2.8	4
		2000	12	69	80	94	5	62	95	9	18.1	33	2	3.2	4
		2005	12	66	81	93	5	64	100	5	16.3	29	1	2.7	4
sp	NO	1976	3	53	60	65	70	75	80	10	12.7	14	10	14.3	21
		1980	11	42	60	75	55	78	100	12	17.2	24	8	11.6	20
		1985	11	40	56	75	60	82	100	11	16.8	23	7	10.0	17
		1990	11	40	55	80	65	86	100	9	14.9	20	3	6.9	11
		1995	11	35	54	80	70	89	100	8	14.1	20	3	5.7	10
		2000	11	40	54	75	75	91	100	10	15.9	22	3	6.4	9
		2005	11	40	57	75	80	93	100	10	15.7	23	2	5.5	9
sp	YES	1976	2	53	65	76	65	75	85	19	21.0	23	15	16.5	18
		1980	9	54	67	80	65	87	100	7	13.4	22	7	10.4	16
		1985	9	0	49	71	75	89	95	12	15.2	22	3	7.9	13
		1990	9	0	39	71	80	92	100	11	13.6	19	2	5.7	8
		1995	9	5	39	76	75	93	100	9	13.0	17	0	4.3	8
		2000	9	3	19	38	80	95	100	10	15.0	22	0	3.9	8
		2005	9	5	35	68	85	96	100	11	14.7	22	0	3.3	6

be – beech; sp – spruce; *N* – number of plots spruce forests, this change was observed more as a fluctuation, with the minimum around 1995. In declining spruce stands, the changes in total number of species were not observed in herb layer; it does not necessarily mean that the species composition did not change (Table 3). These findings are comparable with another results (Matějka 2007).

The most significant change was a reduced number of species in moss layer in all types of stands. In beech and mixed forests the average number of species dropped from 4.8 to 2.7 (44%), in non-declining spruce stands the number fell from 11.6 to 5.5 (53%), and in declining spruce stands it dropped from 10.4 to 3.3 (68%). Similarly, the reduction of total species diversity in these three groups was 36%, 31% and 43%, respectively. Lower percentage, compared to evaluation of the number of species, indicates that the reduction was recorded mainly at species with lower representation. Within the last group, the plots with no moss layer were observed (PRP 3 and 26) (Table 3).

CONCLUSION

The existing results of the phytocenoses study on 32 plots (beech, mixed and spruce stands) in the years 1980–2005 imply a relatively accelerated vegetation dynamics, mainly in the period of significant air-pollution impact of the range in the period from the 1970s to 1990s; and, on the contrary, important revitalisation processes after the year 2000. Great imission-ecological stress caused not only destruction or even dieback of wooden components of the ecosystems, but also significant changes in biodiversity of herbal and moss layer and the recess of lichens. Concerning the biodiversity, the most important change is a massive reduction of a number of species in moss layer (44 to 68%), at all types of stands (beech, mixed and spruce). Similarly, the overall species diversity at these three forest types decreased by 31% to 43%; the reduction concerned mainly the species with lower apportionment.

The greatest influence on differentiation of species composition was that of altitude and exposition of the plot. The influence of time on the decrease of species richness was also highly distinctive. The number of species that vanished was significantly higher than that of newly found species.

Some site changes were observed. This might be interpreted as indicators of shift of community to lower forest vegetation zones in the sense of global climate changes. A significant increase in the ratio of natural regeneration of beech was observed in the 6th and 7th forest altitudinal zone, too.

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