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Assessment of tending effect on stand structure and stability in mixed stands of spruce, fir and beech on research plot Hrable

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ABSTRACT: The paper is a contribution to the research on problems of thinnings in mixed (spruce-fir-beech) stands situated in the fifth altitudinal forest zone. One of the two investigated plots was tended by free crown thinning for a long time, while the other was left without planned silvicultural treatments as control and/or it was retained for self-thinning. Dynamic changes of stand structure and selected characteristics of biodiversity (tree species composition and height structure) were evaluated for a period of 30 years. The changes were compared with respect to differences between the plot with long-term silvicultural treatment and the control plot.

Keywords: thinnings; stand structure; static stability; mixed stands; spruce – fir – beech

Nowadays, the advantage of mixed stands is generally recognized in comparison to unmixed ones, especially in view of their stability and/or resistance to injurious factors. Accordingly, there are efforts for maximum conservation of mixed tree species composition, as well as of both the age and spatial diversity of stand structure. The above-mentioned stage can be achieved by management of forests in accordance with the principles of forest biodiversity conservation and/or their sustainable development.

Silviculture and/or management of mixed forests admittedly requires more demanding and complicated phytotechnical measures in comparison to management of unmixed stands. More consistent analysis of the published papers dealing with problems of mixed stands, especially the spruce-fir-beech mixture in Slovakia, showed that less attention was paid to silvicultural and/or silviculture-productional issues.

More attention and interest was paid to other issues, for example establishment of close-to-nature mixed stands of spruce, fir and beech (HÄBERLE 1997), production (ASSMANN 1961; ŠMELKO et al. 1992), static stability (KONÔPKA 1972), ecological stability (KANTOR, PAŘÍK 1998; ŠTEFANČÍK L. 1990), growth modelling and development of trees and stands (KAHN, PRETZSCH 1997; PRETZSCH 1992a,b), competition (BACHMANN 1997; PRETZSCH 1992a).

Considerably less published papers deal with studies of tending treatments in the growth stage of cleanings and thinnings. Also, the most complicated silvicultural and productional goals in mixed stands can be achieved only by their early and intensive tending. Above all, it is

true about management of the category of commercial forests with the first-rate wood-production function. At the same time, LEIBUNDGUT (1978) and SCHÜTZ (1994) in particular emphasized a mixed, single mixture and more complex structure of stands. Similarly, KORPEĽ (1997) accentuates a polyfunction feature of forest management.

Mixed spruce, fir and beech stands are under the European conditions an important forest type of mixed forest complex in higher situated regions in the Alps and the Carpathian Mountains. In spite of this fact the exact knowledge of silvicultural phytotechnics of their tending is rather rare (ASSMANN 1961, 1968; MOLOTKOV 1966; HOCKENJOS 1968; LEIBUNDGUT et al. 1971).

In Slovakia, the mentioned stands occurr on the area of more than 250,000 hectares mainly in the 4th and 5th altitudinal forest zone (HLADÍK 1996). Therefore the knowledge of their management and/or long-term effects on their structure, production and stability can be considered to be very valuable. We started the systematic research on these problems in 1967 by the method of establishment of permanent research plots (PRP). From 1967 to 1973 we established 7 series of PRP, i.e. totally 17 partial plots (PP). Of the mentioned number of PRP, two series (6 PP) were focused on research of cleanings and five series of PRP (11 PP) on research of thinnings. The first results of research were calculated and assessed in final reports, dissertation thesis and published papers as well (ŠTEFANČÍK L. 1977, 1984, 1990; PAUMER 1978; ŠTEFANČÍK I., ŠTEFANČÍK L. 1998; ŠTEFANČÍK I. 1999).

The aim of this work was to find and assess the changes in stand structure, stability and both the qualitative and quantitative production of mixed spruce, fir and

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beech stand at the growth stage of high forest on the PRP Hrable in a 30-year period of its tending.

MATERIAL AND METHODS

As an object of our research was chosen the mixed spruce, fir and beech stand at the growth stage of high forest on PRP Hrable. This PRP is located inside the zone of the Forest District Hrable, Branch Forest Enterprise Košice, and it was established in 1968 for research on problems of silviculture-production relations in mixed spruce, fir and beech stands. The series PRP Hrable consists of two partial plots (PP) – one with an area of 0.56 ha (designated as H), where the free crown thinning is applied (ŠTEFANČÍK L. 1984). The other plot is without treatment – control plot (designated as O) with the area of 0.35 ha. The plots are isolated from each other and from the other stand by 10 m wide tree belt. Before the research plots were established in the investigated stand, thinning treatments were carried out only rarely, in case they were realized their intensity was very low, focused on removal of thin and/or dying out individuals. The more detailed characteristic of the research plots is presented in Table 1.

On both plots the trees are numbered and measurement points at a breast height of 1.3 m are marked out where complex biometric measurements are carried out at 5-year intervals in accordance with standard methods which were developed for long-term research on silviculture-production issues of thinnings (ŠTEFANČÍK L. 1977). Within their framework, besides the quantitative parameters (breast height diameter, tree height, crown size at horizontal projection) the trees were also evaluated according to silvicultural and commercial classification with orientation to

Table 1. Basic characteristics of permanent research plot (PRP) Hrable

Characteristic	PRP Hrable
Establishment of PRP (year)	1968
Age of stand (years)	spruce 80, fir 82, beech 74
Geomorphologic unit	Volovské vrchy
Exposition	W
Altitude (m)	820–840
Inclination (degree)	25
Parent rock	phyllite and quartz-phyllitte slope deposits
Soil unit	Haplic Cambisol/Dystric Cambisol
Altitudinal forest zone	5th fir-beech
Ecological rank	B
Management complex	55
Management complex of forest types	511 fertile fir-beechwoods
Forest type group	*Abieto-Fagetum (AF)* n.st.
Forest type	5301 low-herbaceous fir beechwoods n. st.
Average annual temperature (°C)	6.0
Average annual precipitation sum (mm/year)	900

the trees of selective quality which are the main bearers of quality. Since establishment of PRP, seven biometric measurements have been carried out and simultaneously thinning treatments were always performed. From a rationalization point of view, the method of target trees (ŠTEFANČÍK L. 1984), which is focused on individual

Table 2. The model of crop trees in mixed spruce, fir and beech stand as a variant of the model for tree species and production target
Age of stand: 100 years, absolute site class (by HALAJ), spruce: 42–27, fir: 40–26, beech: 38–24

Characteristic	Tree species	Variant (percentage of beech crop trees)		
		1 (30%)	2 (40%)	3 (50%)
Number of trees per ha	coniferous trees	170–180	135–145	100–110
	beech	70–80	85–95	100–110
	total	240–260	220–240	200–220
Average spacing (m)	coniferous trees	6.0	6.5	7.0
	beech	8.0	7.3	6.8
	deciduous-coniferous	6.6	6.8	6.9
Minimal spacing (m)	coniferous trees	4.2	4.2	4.2
	beech	5.6	5.6	5.6
	deciduous-coniferous	5.0	5.0	5.0

Target diameter $d_{1.3}$ (cm) for dominant tree species

Altitudinal forest zone	Site	Target diameter $d_{1.3}$ (cm)		
		spruce	fir	beech
5th fir-beech	acid	41	36	29
	fertile	44	44	34
6th spruce-beech-fir	fertile	37	39	31

Note: The above-mentioned range of the number of trees is valid for square and triangular arrangement

tending of the trees of selective quality, was applied on the treated plot (H). From the model of tree species composition and production target according to ŠTEFANČÍK L. (1977, 1984, 1990) developed for mixed spruce, fir and beech stands, variant No. 2 was chosen for the PRP Hrable (Table 2).

Experimental material was processed by common biometrical and statistical methods according to presented standard methods for thinning research. Statistical significance of differences in arithmetical means of values was tested by Student's *t*-test.

In this paper we assessed the first measurement carried out at the time of establishment of PRP in 1969 (at stand age 74–82 years) and the last measurement in 1999 (at stand age 104–112 years) in order to compare dynamic changes of investigated parameters on the PRP Hrable for the period of 30 years. Outcomes of the first measurements were calculated already earlier (ŠTEFANČÍK L. 1977, 1981, 1988; ŠTEFANČÍK et al. 1982).

RESULTS AND DISCUSSION

TREE SPECIES COMPOSITION

Percentage proportions of trees according to the basal area (G) on the PRP Hrable are presented in Table 3. The values in the tables commented in the following text were rounded to whole percentage because of practical reasons. It can be seen that in the initial stage of our research the proportion of coniferous trees on treated plot H was 50%, while on control plot O only 27%. On plot H, fir dominated (41%) followed by beech (36%), contrary to the control plot where it was 60% for beech, and 24% for fir. An interesting high proportion of birch occurred on all plots due to the lack of silvicultural treatment of the stand during its younger growth stages. On plot H during 30 years the proportion of coniferous trees decreased to 46% and on control plot to 17%. According to the tree

species, there was a decrease in spruce proportion, moreover spruce was registered on control plots only rarely. This fact is in accordance with total decline of spruce in the Spiš region taking place since the late seventies. Effect of air pollutants was thought as a result of the above-mentioned fact (ŠTEFANČÍK L. et al. 1987). The fir proportion increased minimally on the treated plot, but if decreased by 8% on control plot. Beech increased in all plots over 30 years; by 17% on plot H, and 14% on control plot. It was again a consequence of environmental conditions which are more suitable for beech in comparison to fir and spruce. Similar results were published also by KONÔPKA et al. (1997) who investigated the damage to stands in this region. They found out health deterioration in coniferous trees from 1988 to 1995, and health improvement in beech. Our results also correspond to those published by KANTOR and PAŘÍK (1998), who determined a considerable decrease in fir proportion by assessment of 35-year changes of tree species composition in a self-thinned 65-year old mixed stand of spruce, fir, cedar, larch and beech. It can be concluded that the changes in tree species composition on the PRP Hrable were not marked because in older stands it is more difficult to regulate tree species composition by thinnings and/or the changes on control plots are less dynamic in advanced growth stages in comparison to younger stands (ŠTEFANČÍK L. 1977).

Comparison of tree species composition in the investigated period with developmental goals according to HANČINSKÝ (1972) showed that the treated plot only slightly differred from required composition (lower share of spruce to the detriment of beech) while this difference was more marked on control plot.

The above-mentioned development of tree species composition also corresponded with the process of self-thinning on control plot. During 30 years a decrease by 92% for spruce was observed, fir by 76%, beech by 47%, birch by 54% and sycamore maple by 36% (Table 4). As for a decrease in fir proportion (79% over 35 years), similar re-

Table 3. Tree species composition according to basal area

Stand	Tree species	Age (years)	Plot H		Plot O	
			(%)	(m²/ha)	(%)	(m²/ha)
Total	spruce	80	9.9	4.97	3.0	1.35
	fir	82	40.5	20.45	24.3	10.83
	beech	74	35.8	18.04	59.8	26.64
	birch	–	13.6	6.87	11.4	5.07
	other species	–	0.2	0.11	1.5	0.65
	total		100	50.44	100	44.54
Main	spruce	110	4.1	1.27	0.8	0.37
	fir	112	42.0	12.91	16.4	7.57
	beech	104	53.1	16.31	73.5	34.04
	birch	–	0.6	0.17	8.2	3.79
	sycamore maple	–	0.2	0.06	1.1	0.50
	total		100	30.72	100	46.27

Explanatory notes: H – plot with free crown thinning, O – plot without treatment (control)

Table 4. Relative frequency according to growth classes

Plot	Stand	Tree species	Age (years)	Growth class					Number of trees per 1 ha
				1	2	3	4	5	
H	total	spruce	80	22.0	29.6	15.4	25.3	7.7	91
		fir	82	10.4	36.1	17.3	27.9	8.3	434
		beech	74	9.7	24.0	27.0	35.3	4.0	682
		birch	–	62.7	33.3	2.0	2.0	–	102
		sycamore maple	–	–	50.0	50.0	–	–	4
	main	spruce	110	13.0	25.0	12.0	31.3	18.7	16
		fir	112	41.7	15.0	15.0	14.2	14.1	120
		beech	104	11.4	23.3	18.4	28.6	18.3	245
		birch	–	–	–	100	–	–	2
		sycamore maple	–	–	–	–	100	–	2
O	total	spruce	80	15.0	15.0	22.5	35.0	12.5	40
		fir	82	14.2	11.2	8.8	47.3	18.5	260
		beech	74	12.4	27.2	24.9	31.5	4.0	917
		birch	–	36.5	58.7	4.8	–	–	63
		other species	–	21.4	57.1	21.5	–	–	14
	main	spruce	110	100	–	–	–	–	3
		fir	112	41.2	17.5	4.8	17.5	19.0	63
		beech	104	15.3	26.7	25.5	26.1	6.4	483
		birch	–	20.7	58.6	20.7	–	–	29
		sycamore maple	–	–	–	66.7	33.3	–	9

sults were obtained by KANTOR and PAŘÍK (1998) in the above-mentioned mixed stand. Changes taking place in tree species composition and their decrease by self-thinning confirm the well-known overall decrease of fir in forest stands during the last decades (MÁLEK 1983) when its original proportion in Slovak forests decreased from former 14.1% to 4.5% at present (HLADÍK 1996; VLADOVIČ et al. 1998). Another reason could be a strong competition of beech against other tree species in the region of its growth optimum (fertile sites, altitude 400–700 m a.s.l.).

STAND STRUCTURE

Stand structure expressed by relative frequency according to the growth (tree) classes is presented in Table 4. It can be seen that in the initial stage of research there were differences between both plots in tree species composition of dominant and co-dominant trees – crown stand level (1st + 2nd growth class) and supressed stand level (3rd to 5th growth class). Birch dominated at a crown stand level (96%) followed by spruce (52%) on plot H. Fir and beech had a higher proportion at a suppressed stand level (54% and 66%). On control plot birch (95%) and other broadleaved trees (78%) were the most frequent at a crown level, followed by beech (40%), while the proportions of spruce and fir were 30% and 25%, respectively. After a 30-year period on treated plot fir achieved a crown level (57% proportion at this stand level), while spruce and beech had higher representation at a suppressed level 62% and 65%, respectively. On control plot spruce remained at a crown level (100%), followed by birch (79%)

and fir (59%) proportions at this level, while beech occurred more at a suppressed level (58%).

Stand structure (classification according to the growth classes) depends on site, tree species, age and tending measures (ŠEBÍK, POLÁK, 1990). On more fertile sites, the differentiation of trees according to tree classes occurs earlier and is more marked although without higher influence on the stands by silvicultural treatments. In the case of sun-loving tree species with increasing age the share of dominant trees increased on the contrary to suppressed individuals, the proportion of which decreased. For shade-loving tree species up to the age of 50–60 years (in relation to site conditions) the proportion of dominant trees decreased and the proportion of suppressed ones increased. Generally, it is stated that the intensity of shifts within the framework of relative height positions of trees decreases in relation to age, it means that a lower number of trees shifts into lower growth classes (ŠEBÍK, POLÁK 1990; ŠTEFANČÍK L. 1974). We suggest that management of mixed stands poses higher demands on silviculturists in comparison to tending of unmixed stands. Forest silviculturists have to know perfectly and take into account ecological requirements of stand tree species in accordance with site properties in order to fulfil the goals of forest practice.

DEVELOPMENT OF QUALITATIVE PRODUCTION BY THE METHOD OF CROP TREES

Table 5 presents the development of crop trees, the main bearers of both quantity and quality of stand. It can

Table 5. Development of crop trees

Plot	Age (years)	Tree species	Number of trees (per 1 ha)	Basal area (m²/ha)	Basal area (% from main stand)	Volume of timber to the top of 7 cm o.b. (m³/ha)	Volume of timber to the top of 7 cm o.b. (% from main stand)	Mean diameter $d_{1.3}$ (cm) (d_g)	Mean height (m) (h_g)
H	80	spruce	20	2.32	52.1	30.91	55.9	38.5	28.1
	82	fir	57	6.95	43.0	100.26	47.3	39.4	29.3
	74	beech	43	2.62	18.1	31.98	19.9	27.8	25.1
		total	120	11.89	33.0	163.15	37.2	–	–
	110	spruce	4	0.79	62.2	11.87	62.3	50.2	34.6
	112	fir	43	7.70	59.7	129.22	67.2	47.8	32.8
	104	beech	25	4.25	26.1	69.80	29.7	46.6	31.6
		total	72	12.74	41.5	210.89	46.9	–	–
O	80	spruce	6	0.55	40.3	6.89	46.5	34.0	26.6
	82	fir	29	3.90	36.0	57.76	40.0	41.3	30.4
	74	beech	89	5.52	20.7	72.58	22.9	28.0	27.0
		total	124	9.97	22.4	137.23	25.2	–	–
	110	spruce	3	0.37	100	5.82	100	39.8	33.4
	112	fir	11	2.99	39.5	48.29	42.9	58.8	35.4
	104	beech	46	5.98	17.6	101.84	19.1	40.7	32.9
		total	60	9.34	20.2	155.95	21.6	–	–

be seen that the number of crop trees is markedly lower in comparison to the model of tree species and production goal for variant 2 (Table 3) which was chosen at PRP establishment. Owing to the structure of the given stand it was necessary to take into account a certain modification of the model, especially with respect to the number of crop trees which already decreased by 30% in comparison to the minimal model level, i.e.154 individuals per hectare (ŠTEFANČÍK L. 1988). Although the required diameter of crop trees was already achieved, their number is still lower than the reduced and/or modified number of crop trees according to this model. It was also confirmed by a low proportion of crop tree volume in the growing stock (only 47%), although this fact is comprehensible because of the low number of crop trees. But on the other hand it can be seen that even though the tending of the stand started so late (growth stage of high forest) the results were always more favourable in comparison to plot without treatment. Of course both quantitative and qualitative losses could not be compensated because of neglected tending. This fact was confirmed by our finding from other mixed spruce, fir and beech PRP (Motyčky, Korytnica, Stará Píla). For example, on PRP Motyčky the proportion of crop tree volume in the growing stock 47% was achieved already at the stand age of approximately 60 years after four thinnings realized (ŠTEFANČÍK L. 1990). Likewise, on PRP Stará Píla crop tree volume was 36–39% of the growing stock on plots with whole-area tending, and 64–75% on plots with partial area tending at the age of 43 years (ŠTEFANČÍK I. 1999). For comparison, it was 40–57% at the stand age of 64 years on PRP Korytnica (ŠTEFANČÍK L. 1981).

On the other hand, it is necessary to suggest that also due to "production losses" of the stand, the cultivation of crop trees in stand is important from both static and ecological point of view. It was confirmed by research that the most favourable results were achieved in stands with long-term cultivation by the method of crop trees (KONÔPKA 1992). Growth parameters of the crop trees and their development are presented in Table 6. Almost all growth parameters which influence the static stability of stand are more favourable on treated plot in comparison to control one. Changes during the 30-year research were always significant on plot H unlike the control plot. Comparison of the growth parameters of crop trees with models of crop trees for coniferous trees according to KONÔPKA (1992) showed a favourable evaluation for the coefficient of slenderness, but unfavourable evaluation for the crown proportion in the total height of tree. It confirms the known fact that about the static stand stability it is decided at younger growth stages and/or it is not possible to influence it at older age (VICENA et al. 1979; ŠTEFANČÍK I. et al. 1999).

DEVELOPMENT OF QUANTITATIVE PRODUCTION

Tables 7–9 present the measured parameters of total stand and main stand at the first biometric measurement in 1969, as well as at the last one carried out in 1999. Likewise, Fig.1 and 2 show the polygons of distribution of absolute diameter frequency for total stand according to tree species in 1969 before the first thinning and/or for main stand in 1999, it means after the 7th thinning. At the same time a special attention was paid to development of total volume production.

Table 6. Growth parameters of crop trees

Plot	Tree species	Age (years)	Number (per 1 ha)	Diameter $d_{1,3}$ (cm)		Height (m)		Crown width (m)		Crown length (m)		Ratio of crown length to total height of tree (%)		Slenderness coefficient	
				x	s_x %	x	s_x %	x	s_x %	x	s_x %	x	s_x %	x	s_x %
H	spruce	80	20	38.4	14.7	27.3	8.6	5.7	17.5	8.4	21.1	30.6	18.0	0.72	12.8
	fir	82	57	39.0	13.1	28.0	8.3	6.0	10.9	7.7	36.1	27.0	30.7	0.74	9.5
	beech	74	43	27.6	15.6	25.2	8.0	6.3	16.4	7.7	33.7	30.5	28.7	0.92	13.9
O	spruce[+]	80	6	34.9	–	29.3	–	5.4	–	11.3	–	38.9	–	0.84	–
	fir	82	29	41.4	11.0	29.6	7.8	5.8	13.1	9.9	33.8	33.3	34.3	0.72	13.0
	beech	74	89	27.8	16.1	27.6	5.3	6.1	19.8	10.0	26.7	36.3	26.4	1.01	15.7
H	spruce[+]	110	4	52.9	7.8	32.3	8.5	8.8	6.8	11.5	17.4	35.4	9.0	0.61	0.8
	fir	112	43	47.5**	12.5	32.3**	5.0	7.9**	11.2	10.5**	17.4	32.4*	16.5	0.69*	9.9
	beech	104	25	46.0**	14.4	31.6**	4.4	10.3**	14.6	14.6**	14.9	46.1**	13.1	0.70**	14.4
O	spruce[+]	110	3	40.9	–	35.0	–	7.0	–	15.0	–	42.9	–	0.86	–
	fir	112	11	57.5**	9.2	34.3**	4.3	7.6**	10.6	10.3[N]	23.3	29.8[N]	22.3	0.60**	8.1
	beech	104	46	40.3**	16.4	32.6**	6.0	8.2**	19.9	13.0**	15.5	39.7[N]	12.1	0.83**	12.7

Explanatory notes: H – plot with free crown thinning, O – plot without treatment (control), x – arithmetical mean, s_x % – coefficient of variation, N – statistically insignificant difference ($P > 0.05$), * – statistically significant difference ($P < 0.05$), ** – statistically significant difference ($P < 0.01$)

Note: [+] – insufficient number of trees for statistical evaluation

The limited extent of this paper does not allow us to comment the intensity of all thinning treatments in greater detail, therefore we focused only on the first and the last (7th treatment). It can be seen that by the first thinning up to 26.1% of G (basal area) was removed on plot H, while by the 7th thinning only 1.2%. Since the given stand was neglected from the silvicultural point of view practically up to the growth stage of thin timber forest, relatively strong first treatment had to be realized. Intensity of the following treatments (according to G) ranged between 1–16%, 7% on average. After the 4th treatment the relative intensity of treatment decreased from 15.8% to the above-mentioned value 1.2% at the 7th treatment. On other plots (Motyčky, Korytnica) the intensity of the first treatment (thinning of living trees) ranged from 12.7 to 15.8% on plot H by expression according to G, while on control plot it increased by 9.9–16.5% on the PRP Motyčky (ŠTEFANČIK L. 1981). Our results also correspond to recommendations by MOLOTKOV (1966), who for spruce, fir and beech stands of the Carpathian region in Ukraine presents the treatment intensity of 15–30% of the growing stock and for later thinning treatments 10–20%.

During 30 years the number of trees decreased by 71% on the treated plot H and by 55% on control plot O in consequence of both self-thinning and abiotic injurious factors. Similarly, on plot H, G also decreased by 39%, while on control plot it increased by 4%. The volume of timber to the top of 7 cm o.b. decreased by 26% on plot H and increased by 33% on control plot O. Investigations into changes in the measured parameters according to tree species showed that on plot H by expression according to G, the highest decrease occurred for birch and spruce on contrary to beech, sycamore maple and fir where the least decrease was found. On control plot O, the values of G decreased mainly for spruce, fir and birch, but increased for beech and sycamore maple.

Study of thinning problems, especially in mixed stands, has always been very interesting for forest managers. Moreover, the issue of total volume production (TVP) evoked an active discussion. Therefore, we also deal with it in this paper at least briefly. However, we present only the most necessary values (Table 10) on volume production development in timber to the top of 7 cm o.b. as a total during 30 years on investigated partial plots of the PRP Hrable. It can be seen that development of the investigated parameters of volume of timber to the top of 7 cm o.b. and/or TVP was more favourable on plot H, that means in the stand tended by free crown thinning in comparison to plot O (without treatment). On plot H during 30 years TVP of the stand as a total was increasing by index 2.06, while on plot O by index 1.62. Similar relations were also found for the main tree species such as beech, fir and spruce. The above-mentioned statement also applies to total current annual increment of these tree species. This fact is properly ex-

Table 7. Development of the mean diameter and mean height

| Plot	Age (years)	Tree species	Total stand – mean		Main stand – mean	
			diameter $d_{1.3}$ (cm) (d_g)	height (m) (h_g)	diameter $d_{1.3}$ (cm) (d_g)	height (m) (h_g)
H	80	spruce	26.4	23.2	29.2	24.6
	82	fir	24.5	23.4	25.2	23.8
	74	beech	18.5	21.8	18.9	22.4
		birch	29.2	26.2	28.7	25.9
		sycamore maple	19.3	22.2	19.3	22.2
	110	spruce	33.6	32.3	31.9	31.9
	112	fir	36.9	29.1	37.0	29.1
	104	beech	29.1	26.6	29.0	26.6
		birch	33.3	28.2	33.3	28.2
		sycamore maple	20.1	21.7	20.1	21.7
O	80	spruce	20.7	19.5	20.7	19.5
	82	fir	22.9	21.8	22.9	21.8
	74	beech	19.3	23.5	19.3	23.5
		birch	32.1	28.1	32.1	28.1
		sycamore maple	20.6	24.2	20.6	24.2
	110	spruce	39.8	33.4	39.8	33.4
	112	fir	38.3	30.2	39.2	30.5
	104	beech	29.6	29.5	29.8	29.6
		birch	40.8	32.9	40.8	32.9
		sycamore maple	26.7	28.3	26.7	28.3
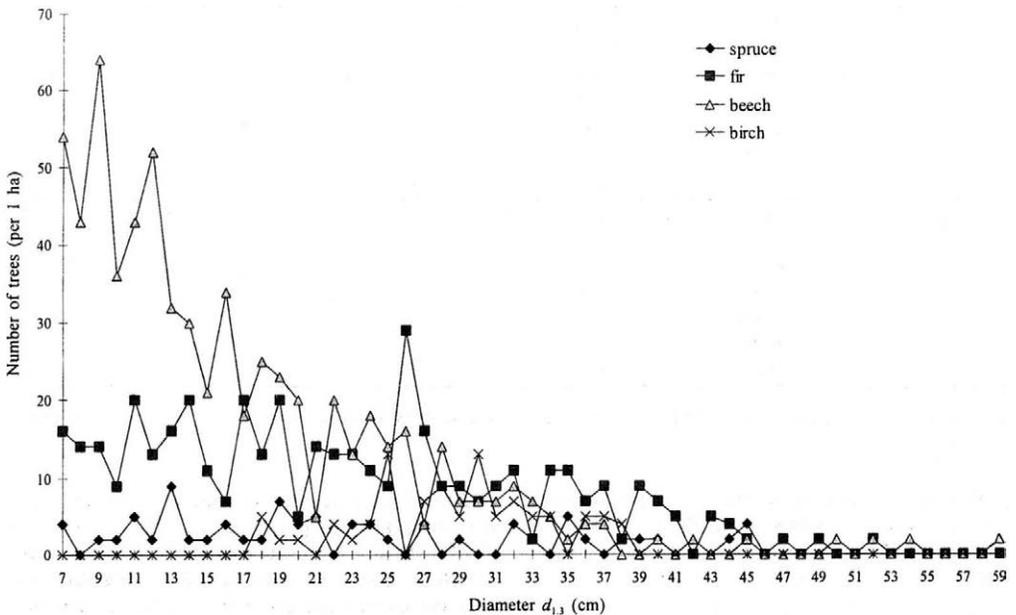
Fig. 1. Polygons of distribution of the absolute number of trees according to diameter classes at the initial stage (before the first treatment in 1969) on the permanent research plot (PRP) Hrable, plot H in 1969

Table 8. Measured parameters of stand and their decrease in 1969

Plot	Measured parameter	Age (years)	Tree species	Total stand (abs/ha)	Decrease (secondary stand)					Main stand (abs/ha)
					thinning of living trees (%)	dead trees (%)	other* decrease (%)	treatment intensity (abs/ha)	(% total)	
H	N	80	spruce	91	23.1	–	4.4	25	27.5	66
		82	fir	434	22.1	–	3.0	109	25.1	325
		74	beech	682	18.0	–	5.3	159	23.3	523
			birch	102	87.3	–	–	89	87.3	13
			sycamore maple	4	–	–	–	–	–	4
			total	1,313	25.1	–	4.0	382	29.1	931
	G (m²)	80	spruce	4.97	9.9	–	0.5	0.52	10.4	4.45
		82	fir	20.45	18.8	–	2.1	4.28	20.9	16.17
		74	beech	18.04	15.4	–	4.3	3.56	19.7	14.48
			birch	6.87	87.7	–	–	6.03	87.7	0.84
			sycamore maple	0.11	–	–	–	–	–	0.11
			total	50.44	26.1	–	2.4	14.39	28.5	36.05
	V_{7b} (m³)	80	spruce	59.94	7.5	–	0.2	4.61	7.7	55.33
		82	fir	265.50	18.2	–	1.9	53.37	20.1	212.13
		74	beech	201.54	15.7	–	4.6	40.78	20.3	160.76
			birch	75.49	87.6	–	–	66.11	87.6	9.38
			sycamore maple	1.28	–	–	–	–	–	1.28
			total	603.75	24.9	–	2.4	164.87	27.3	438.88
O	N	80	spruce	40	–	–	–	–	–	40
		82	fir	260	–	–	–	–	–	260
		74	beech	917	–	–	–	–	–	917
			birch	63	–	–	–	–	–	63
			sycamore maple	11	–	–	–	–	–	11
			aspen	3	–	–	–	–	–	3
			total	1,294	–	–	–	–	–	1,294
	G (m²)	80	spruce	1.35	–	–	–	–	–	1.35
		82	fir	10.83	–	–	–	–	–	10.83
		74	beech	26.63	–	–	–	–	–	26.63
			birch	5.07	–	–	–	–	–	5.07
			sycamore maple	0.37	–	–	–	–	–	0.37
			aspen	0.29	–	–	–	–	–	0.29
			total	44.54	–	–	–	–	–	44.54
	V_{7b} (m³)	80	spruce	14.81	–	–	·	·	·	14.81
		82	fir	144.53	–	–	–	–	–	144.53
		74	beech	316.26	–	–	–	–	–	316.26
			birch	59.70	–	–	–	–	–	59.70
			sycamore maple	4.33	–	–	–	–	–	4.33
			aspen	4.10	–	–	–	–	–	4.10
			total	543.73	–	–	–	–	–	543.73

Explanatory notes: N – number of trees per 1 ha, G – basal area, V_{7b} – volume of timber to the top of 7 cm o.b. per 1 ha, * – stem break or windthrow

pressed by percentage increment of TVP which was on plot H as a total 1.71% (for beech 1.95%, fir 1.29%, spruce 1.30%) and 1.28% on control plot O (1.50%, 0.70%, 1.01%), respectively.

SILVICULTURAL ANALYSIS OF THINNINGS

Table 11 presents a silvicultural analysis of the free crown thinning at the first and the last treatment on the PRP Hrable. The results show that according to G, the most intensive thinning was carried out at a crown level (54.8%), followed by relative maturity selection (16.6%) when birch trees were removed, and the third place was taken by negative stem selection (11.6%). These values definitely confirm that till establishment of the research plot, the mentioned stand was neglected from a silvicultural point of view. It is also demonstrated by the total

Table 9. Measured parameters of stand and their decrease in 1999

Plot	Measured parameter	Age (years)	Tree species	Total stand (abs/ha)	thinning of living trees (%)	dead trees (%)	other* decrease (%)	treatment intensity (abs/ha)	treatment intensity (%) total	Main stand (abs/ha)
					Decrease (secondary stand)					
H	N	110	spruce	20	–	10.0	10.0	4	20.0	16
		112	fir	126	–	3.2	1.6	6	4.8	120
		104	beech	254	2.0	–	1.6	9	3.5	245
			birch	2	–	–	–	–	–	2
			sycamore maple	2	–	–	–	–	–	2
			total	404	1.2	1.5	2.0	19	4.7	385
	G (m²)	110	spruce	1.78	–	16.8	11.9	0.51	28.7	1.27
		112	fir	13.51	–	2.0	2.4	0.61	4.5	12.90
		104	beech	16.88	2.4	–	1.0	0.57	3.4	16.31
			birch	0.18	–	–	–	–	–	0.18
			sycamore maple	0.06	–	–	–	–	–	0.06
			total	32.41	1.2	1.8	2.2	1.69	5.2	30.72
	V_{7b} (m³)	110	spruce	26.92	–	16.9	12.3	7.87	29.2	19.05
		112	fir	201.02	–	1.9	2.5	8.84	4.4	192.18
		104	beech	243.05	2.3	–	0.9	7.85	3.2	235.20
			birch	2.53	–	–	–	–	–	2.53
			sycamore maple	0.68	–	–	–	–	–	0.68
			total	474.20	1.2	1.8	2.2	24.56	5.2	449.64
O	N	110	spruce	3	–	–	–	–	–	3
		112	fir	66	–	4.5	–	3	4.5	63
		104	beech	498	–	1.8	1.2	15	3.0	483
			birch	29	–	–	–	–	–	29
			sycamore maple	9	–	–	–	–	–	9
			total	605	–	2.0	1.0	18	3.0	587
	G (m²)	110	spruce	0.38	–	–	–	–	–	0.38
		112	fir	7.59	–	0.2	–	0.02	0.2	7.57
		104	beech	34.24	–	0.4	0.2	0.21	0.6	34.03
			birch	3.79	–	–	–	–	–	3.79
			sycamore maple	0.50	–	–	–	–	–	0.50
			total	46.50	–	0.3	0.2	0.23	0.5	46.27
	V_{7b} (m³)	110	spruce	5.82	–	–	–	–	–	5.82
		112	fir	112.75	–	0.1	–	0.06	0.1	112.69
		104	beech	535.11	–	0.2	0.1	1.84	0.3	533.27
			birch	64.48	–	–	–	–	–	64.48
			sycamore maple	7.33	–	–	–	–	–	7.33
			total	725.49	–	0.2	0.1	1.90	0.3	723.59

For explanation see Table 8

treatment intensity (28.6%) which is almost twice higher in comparison to other treatments on this plot or those on other PRP in mixed spruce, fir and beech stands (ŠTE-FANČÍK L. 1981). On the contrary, by the last treatment the highest share was found for the category of other decrease (break of stems), which confirms our results with respect to the static stability of stand and/or to the unsuitable crown length to total tree height ratio. Totally, the intensity of the 7th thinning did not exceed 3.5%.

CONCLUSION

Evaluation of 30-year changes in the stand structure and measured parameters of more than 100-year old mixed spruce, fir and beech stand, located at the 5th altitudinal forest zone, on a fertile site, brought about the following results:

– In the initial stage, the proportion of coniferous trees was 50% on treated plot (H) and 27% on control plot

Table 10. Development of volume production of timber to the top of 7 cm o.b. per hectare for 30 years

Plot	Tree species	Age (measurement) years	Main stand (m³/ha)	Total decrease		Total volume production		Total current annual increment		
				(m³/ha)	(% of TVP)	(m³/ha)	(index)	(m³/ha)	(% of TVP)	(index)
H	beech	74	160.76				1.00			
		104	235.20	153.23	39.45	388.43	2.42	7.589	1.954	1.304
	fir	82	212.13				1.00			
		112	192.18	153.29	44.37	345.47	1.47	4.445	1.287	1.836
	spruce	80	55.33				1.00			
		110	19.04	71.50	78.97	90.54	1.64	1.174	1.297	1.287
	other deciduous trees	(1)	10.68				1.00			
		(7)	3.22	75.13	95.89	78.36	7.34	2.256	2.879	2.541
	total	(1)	438.88				1.00			
		(7)	449.64	453.15	50.19	902.79	2.06	15.464	1.713	1.372
O	beech	74	316.26				1.00			
		104	533.27	41.06	7.15	574.33	1.82	8.602	1.498	1.000
	fir	82	144.53				1.00			
		112	112.69	70.36	38.44	183.04	1.27	1.284	0.701	1.000
	spruce	80	14.81				1.00			
		110	5.82	15.42	72.60	21.24	1.43	0.214	1.008	1.000
	other deciduous trees	(1)	68.13				1.00			
		(7)	71.81	31.39	30.42	103.20	1.51	1.169	1.133	1.000
	total	(1)	543.73				1.00			
		(7)	723.58	158.23	17.94	881.81	1.62	11.269	1.278	1.000

Explanatory notes: H – plot with free crown thinning; O – control plot (without planned treatment); TVP – total volume production; (1) – stage of stand at the first measurement in 1969; (7) – stage of stand at the seventh measurement in 1999

(O). On plot H fir showed the highest proportion (41%), followed by beech (36%), contrary to control plot, where the respective proportions were beech 60% and fir 24%. A high proportion of birch on both plots was due to lack of silvicultural treatments in the previous period. After 30 years the proportion of coniferous trees decreased to 46% (plot H) and to 17% (control plot). According to tree species, a decrease of spruce proportion was found, moreover on the control plot it occurred only rarely. The proportion of fir increased minimally on treated plot, but decreased by 8% on control plot. Beech increased in all plots over 30 years; by 17% on plot H, and 14% on control plot.
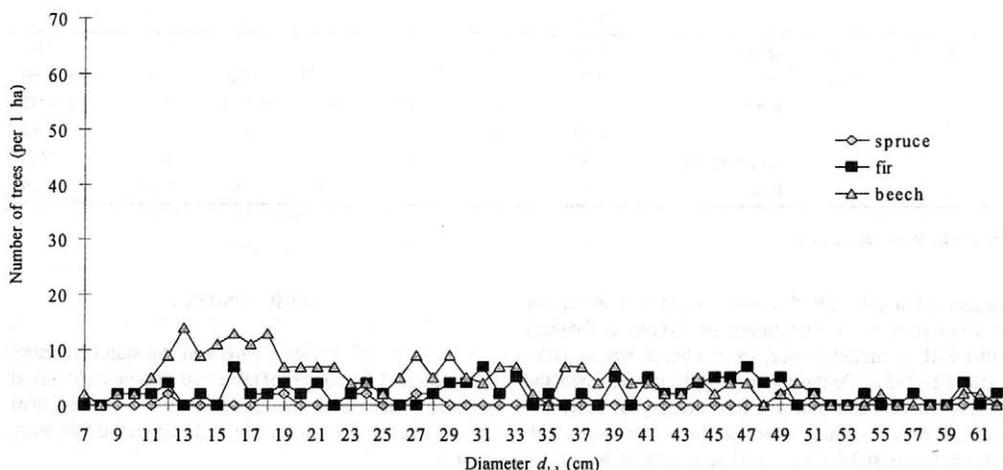

Fig. 2. Polygons of distribution of the absolute number of trees according to diameter classes after 30-year tending (after the 7th treatment in 1999) on the permanent research plot (PRP) Hrable, plot H in 1999

Table 11. Silvicultural analysis of the free crown thinning (felling of living trees) on plot H

Measured parameter	Order of treatment	Tree species	Selection					Other* decrease (%)	Thinning	
			positive		negative		maturity		per 1 ha abs. = 100%	treatment intensity (%)
			at crown level (%)	at suppressed level (%)	stem (%)	sanitary (%)				
N	1	spruce	16.0	28.0	28.0	12.0	–	16.0	25	27.5
		fir	41.3	18.3	24.8	4.6	–	11.0	109	25.1
		beech	25.8	23.3	28.3	–	–	22.6	159	23.3
		birch	51.7	2.2	5.6	–	40.5	–	89	87.3
		total	35.6	17.3	22.0	2.1	9.4	13.6	382	29.2
	7	spruce	–	–	–	–	–	100	2	10.0
		fir	–	–	–	–	–	100	2	1.6
		beech	33.3	22.2	–	–	–	44.5	9	3.5
		total	23.1	15.4	–	–	–	61.5	13	3.3
G (m^2)	1	spruce	25.6	26.0	29.8	14.1	–	4.5	0.52	10.4
		fir	64.0	8.5	12.2	5.1	–	10.2	4.28	20.9
		beech	45.9	10.6	21.6	–	–	21.9	3.56	19.8
		birch	56.2	0.8	3.4	–	39.6	–	6.03	87.7
		total	54.8	6.4	11.6	2.0	16.6	8.6	14.39	28.6
	7	spruce	–	–	–	–	–	100	0.21	11.9
		fir	–	–	–	–	–	100	0.33	2.4
		beech	61.7	8.0	–	–	–	30.3	0.58	3.4
		total	31.9	4.1	–	–	–	64.0	1.12	3.5
V_{7b} (m^3)	1	spruce	30.1	24.1	29.6	14.0	–	2.2	4.61	7.7
		fir	68.6	6.8	9.8	5.2	–	9.6	53.37	20.1
		beech	49.0	7.1	21.3	–	–	22.6	40.78	20.2
		birch	56.9	0.6	2.8	–	39.7	–	66.11	87.6
		total	58.0	4.9	10.4	2.1	15.9	8.7	164.87	27.4
	7	spruce	–	–	–	–	–	100	3.31	12.3
		fir	–	–	–	–	–	100	5.08	2.5
		beech	66.5	5.7	–	–	–	27.8	7.85	3.2
		total	32.2	2.7	–	–	–	65.1	16.24	3.4

For explanation see Table 8

– In the process of self-thinning in 30 years, a decrease of spruce by 92%, fir 76%, beech 47%, birch 54% and sycamore maple 36% was observed.

– In the initial stage birch dominated at a crown stand level (96%) followed by spruce (52%) on plot H. Fir and beech had higher proportions at a suppressed stand level (54% and 66%). On control plot at a crown level, birch (95%) and other broadleaved trees (78%) were most frequent, followed by beech (40%), while spruce and fir accounted for 30% and 25%, respectively. After 30 years, fir achieved the crown level on treated plot (57% proportion at this stand level), while spruce and beech occurred to a larger extent at a suppressed level (62% and 65%). On control plot spruce remained at a crown level (100%) followed by birch (79%) and fir (59%) at this level, while beech occurred to a larger extent at a suppressed level (58%).

– The proportion of crop trees amounted to 47% of the growing stock.

– Almost all growth parameters which influence the static stability of stand were more favourable on treated plot in comparison to control one. Comparison of growth parameters of the crop trees with models of crop trees for coniferous trees according to KONÔPKA (1992) showed favourable evaluation for the coefficient of slenderness, but unfavourable evaluation for the crown length to total tree height ratio.

– During 30 years the number of trees decreased by 71% on treated plot H and by 55% on control plot O in consequence of self-thinning and abiotic injurious factors. Likewise, on plot H, G also decreased by 39%, while on control plot it increased by 4%. The volume of timber to the top of 7 cm o.b. decreased by 26% on plot H, and increased by 33% on control plot O. Investigations into changes in the measured parameters according to tree species showed that on plot H by expression according to G, the highest decrease occurred for birch and spruce contrary to beech, sycamore maple and fir where the

least decrease was found. On control plot O, the values of G decreased mainly for spruce, fir and birch, but increased for beech and sycamore maple.
- As for the volume production of timber to the top of 7 cm o.b. as a total and of the tree species and/or total volume production, we found better results on plot H in comparison to plot O. On plot H during 30 years, TVP of stand as a total increased by index 2.06, while on plot O only by index 1.62. Similar relations were also found for total current annual volume increment of stands as a total and for the tree species. An advantage of tended stands (plot H) to untended one (plot O) is confirmed by index 37.2%, for beech it was 30.4%, for fir 83.6% and for spruce 28.7%.
- Silvicultural analysis of thinnings showed that according to G the most intensive thinning was carried out at a crown stand level (54.8%), followed by relative maturity selection (16.6%) when birch trees were removed, and the third place was taken by negative stem selection (11.6%).

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Zhodnotenie vplyvu výchovy na porastovú štruktúru a stabilitu zmiešaného smrekovo--jedľovo-bukového porastu na výskumnej ploche Hrable

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ABSTRAKT: Práca je príspevkom k výskumu problematiky prebierok v zmiešaných smrekovo-jedľovo-bukových poras-
toch 5. lesného vegetačného stupňa. Z dvoch sledovaných plôch sa jedna dlhodobo vychovávala úrovňovou voľnou prebier-
kou, kým druhá plocha zostala bez úmyselného zásahu ako kontrolná, resp. ponechala sa na samovývoj. Vyhodnotili sa
dynamické zmeny porastovej štruktúry a vybraných znakov biodiverzity (drevinové zloženie a výšková štruktúra) za ob-
dobie 30 rokov. Zistené zmeny sa porovnali aj z hľadiska rozdielov medzi dlhodobo vychovávanou plochou a kontrolnou
plochou.

Kľúčové slová: prebierky; porastová štruktúra; statická stabilita; zmiešané porasty; smrek – jedľa – buk

Cieľom práce bolo zistiť a zhodnotiť zmeny v porasto-
vej štruktúre, stabilite a kvalitatívnej i kvantitatívnej pro-
dukcii zmiešaného smrekovo-jedľovo-bukového porastu
v rastovej fáze kmeňoviny na výskumnej ploche Hrable
za 30-ročné obdobie jeho výchovy.

Objektom výskumu bol zmiešaný smrekovo-jedľovo-
bukový porast v rastovej fáze kmeňoviny na trvalej vý-
skumnej ploche (TVP) Hrable. TVP, ktorá sa nachádza
v obvode Lesnej správy Hrable, odštepný lesný závod
Košice, bola založená v roku 1968 na výskum problemati-
ky pestovno-produkčných vzťahov v zmiešaných smre-
kovo-jedľovo-bukových porastoch. Sériu TVP Hrable tvo-
ria dve čiastkové plochy (ČP) – jedna má výmeru 0,56 ha
(označenie H), kde sa aplikuje úrovňová voľná prebierka
(ŠTEFANČÍK L. 1984). Druhá ČP je bez zásahu – kontrolná
(označená O) s výmerou 0,35 ha. Plochy sú medzi sebou
i od ostatného porastu oddelené 10 m širokými pásmi stro-
movia, tzv. izolačným pásom. Pred založením výskumných
plôch sa v sledovanom poraste len zriedkavo vykonávali
prebierkové zásahy, aj to slabé, zamerané na odstraňova-
nie tenkých, resp. hynúcich jedincov.

Na obidvoch plochách sú stromy očíslované s označe-
ním meriska hrúbky vo výške 1,3 m, kde sa vykonávajú
kompletné biometrické merania v päťročných intervaloch
v súlade so štandardnými metodikami, ktoré sú vypraco-
vané pre dlhodobý výskum pestovno-produkčných otá-
zok prebierok (ŠTEFANČÍK L. 1977). V rámci nich sa okrem
kvantitatívnych znakov (hrúbka $d_{1,3}$, výška stromu, roz-
mery koruny pri horizontálnej projekcii) hodnotili stromy
aj podľa pestovnej a hospodárskej klasifikácie s orientá-
ciou na pestovanie stromov výberovej kvality, ktoré sú

jej hlavným nositeľom. Od založenia plochy sa tu vyko-
nalo sedem biometrických meraní a súčasne s meraniami
sa vždy vykonal aj prebierkový zásah. Z hľadiska racio-
nalizácie sa na zasahovanej ploche (H) aplikovala metóda
cieľových stromov (ŠTEFANČÍK L. 1984), ktorá sa zame-
riava na individuálnu výchovu spomínaných stromov
výberovej kvality. Z modelu drevinového a produkčného
cieľa ŠTEFANČÍKA L. (1977, 1984, 1990) pre zmiešané smre-
kovo-jedľovo-bukové porasty sa pre TVP Hrable vybral
variant č. 2 (tab. 2).

V príspevku sme vyhodnotili 1. meranie vykonané pri
založení plochy v roku 1969 (vo veku porastu 74–82 ro-
kov) a posledné meranie v roku 1999 (pri veku 104–112 ro-
kov), aby sme porovnali dynamické zmeny sledovaných
znakov na TVP za obdobie 30 rokov. Výsledky z prvých
meraní sa spracovali už skôr (ŠTEFANČÍK L. 1977, 1981,
1982, 1988).

Vyhodnotenie 30-ročných zmien v porastovej štruktúre
a taxačných parametroch vyše 100-ročného zmiešaného
smrekovo-jedľovo-bukového porastu v 5. lesnom vege-
tačnom stupni na živnom stanovišti prinieslo nasledujú-
ce výsledky:

– Pri východiskovom stave bol podiel ihličnanov na vy-
chovávanej ploche (H) 50 % a na kontrolnej ploche (O)
27 %. Na ploche H bola najviac zastúpená jedľa (41 %)
a potom buk (36 %), kým na kontrolnej ploche to bolo
opačne – buk 60 % a jedľa 24 %. Vysoký podiel brezy na
oboch plochách je výsledkom pestovného zanedbania
porastu v predošlom období. Za 30 rokov došlo
k zníženiu podielu ihličnanov na 46 % (plocha H), resp.
na 17 % (kontrolná plocha). Z jednotlivých drevín sa

znížilo zastúpenie smreka, pričom na kontrolnej ploche je už len ojedinelý. Podiel jedle sa na vychovávanej ploche zvýšil minimálne, ale na kontrolnej ploche sa znížil o 8 %. Buk na oboch plochách zvýšil svoj podiel – na ploche H o 17 % a na kontrolnej ploche o 14 % za 30 rokov.

– V procese samoprerieďovania na kontrolnej ploche sme za 30 rokov zaznamenali pri smreku úbytok 92 %, pri jedli 76 %, pri buku 47 %, pri breze 54 % a pri javore horskom 36 %.

– Pri východiskovom stave na ploche H dominovala v porastovej úrovni breza (96 %), potom smrek (52 %). Jedľa a buk mali väčšie zastúpenie v podúrovni (54 % a 66 %). Na kontrolnej ploche bola v úrovni najpočetnejšia breza (95 %) a ostatné listnáče (78 %), potom buk (40 %), kým smrek a jedľa 30 %, resp. 25 %. Po 30-ročnom období sa na zasahovanej ploche dostala do úrovne jedľa (zastúpenie 57 % v úrovni), kým smrek a buk mali vyššie zastúpenie v podúrovni – 62 a 65 %. Na kontrolnej ploche ostali v úrovni smrek (100 %), breza (79 %) a jedľa so zastúpením 59 %, kým buk bol viac zastúpený v podúrovni (58 %).

– Cieľové stromy mali podiel 47 % na zásobe porastu.

– Takmer všetky rastové parametre, ktoré ovplyvňujú statickú stabilitu porastu, boli priaznivejšie na zasahovanej ploche v porovnaní s kontrolnou. Porovnaním rastových parametrov cieľových stromov s modelmi cieľových stromov pre ihličnaté dreviny podľa KONÔPKU (1992) sme zistili priaznivé hodnotenie pre štíhlostný koeficient, ale nepriaznivé hodnotenie pre podiel koruny z celkovej výšky stromu.

– Za 30 rokov poklesol počet stromov na ploche H o 71 % a na ploche O v dôsledku samoprerieďovania a abiotických škodlivých činiteľov o 55 %. Podobne došlo na ploche H aj k poklesu kruhovej základne o 39 %, kým na kontrolnej ploche sa zvýšila, a to o 4 %. Objem hrubiny poklesol o 26 % na ploche H, na ploche O sa zvýšil o 33 %. Pri sledovaní zmien uvedených taxačných veličín podľa jednotlivých drevín sme zistili, že na ploche H sa pri vyjadrení podľa kruhovej základne najviac znížili hodnoty pre brezu a smrek a naopak najmenej pre buk, javor horský a jedľu. Na ploche O (kontrolnej) to bolo najviac pre smrek, jedľu a brezu, pričom pre buk a javor horský došlo k zvýšeniu.

– Z hľadiska vývoja produkcie objemu hrubiny porastov ako celku aj drevín, resp. celkovej objemovej produkcie sme zistili pozitívnejšie výsledky na ploche H ako na ploche O. Za 30 rokov tu rástla COP porastu ako celku indexom 2,06, kým na ploche O len indexom 1,62. Podobne je tomu aj pri reláciách celkového bežného ročného objemového prírastku porastov ako celku aj drevín. Prednosť vychovávaného porastu (H) pred nevychovávaným (O) dokumentuje príslušný index, a to hodnotou 37,2 %, pri buku je to 30,4 %, pri jedli 83,6 % a pri smreku 28,7 %.

– Pestovná analýza prebierok ukázala, že najviac sa zasahovalo v úrovni porastu (54,8 % podľa kruhovej základne), ďalej nasleduje relatívne zrelostný výber (16.6 %), ktorým sa odstránili jedince brezy, a na treťom mieste bol negatívny tvarový výber (11,6 %).

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The Razula virgin forest after 23 years (1972–1995)

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ABSTRACT: Repeated measurements of mensurational, typological and stand characteristics were made in the Razula National Nature Reserve in 1995, which followed up the initial studies from 1972. The methodology of the measurements was identical and changes were assessed which occurred in the area under study in the given period of time. Soils exhibited an increased degree of sorption saturation, other characteristics exhibited only a very slight change. The whole area of the reserve showed conspicuous quantitative changes in the herb layer (a severe reduction of the cover). In contrast, the qualitative traits exhibited only very slight changes with the communities maintaining the species composition very similar to that observed in 1972. The reason can be seen in the tree layer where the growing space was intensively filled with European beech by developing tree classes III and IV. The old generation of silver fir reached its final stage of disintegration with younger trees occurring only sporadically and the population can be considered critically endangered.

Keywords: dynamics; monitoring; virgin forest

In 1995, the Razula National Nature Reserve was subjected to the repeated assessment of mensurational, typological and stand characteristics in the entire area of the virgin forest. The works were made within a long-term project *Research into Developmental Dynamics of the Virgin Forest Reserves in the Czech Republic*, conducted by a team of experts from the CR Agency for Nature and Landscape Protection – Detached Workplace in Brno (AOPK). The work links up with detailed studies made by Ing. Eduard Průša, CSc., and Ing. Jaroslav Holuša in 1972, and strives after a characteristic of developmental changes in the territory under study and after a deduction of the general developmental regularities in order to provide a qualified basis for the management practice in the given area.

Both field and office works were implemented by a team that included the following experts: Mgr. Dušan Adam, Ing. David Horal, Ing. Libor Hort, Ing. Bohumil Jagoš, Daniela Plisková, Petra Odehnalová, Ing. Pavel Unar, Dr. Ing. Tomáš Vrška. The field research was assisted by Radka Křížová, Yvona Petříčková, Ing. Pavel Popelář, p.g. Jan Petřvalský and Petr Grendziok from the Administration of The Beskydy Protected Landscape Area and the assistance was greatly appreciated by the authors. A special acknowledgement is forwarded to Dr. Ing. Jan Štykar from the Institute of Forest Botany, Dendrology and Typology at the Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry in Brno for his assistance at the processing of data from phytosociological relevés, and to Ing. Eduard Průša, CSc., for his valu-able professional advice and instigations without which the work could have never come into existence.

HISTORY

As everywhere in Walachia, the Javorník forests went through an eventful development. The original virgin forests became a subject to the Walachian colonization spreading along the mountain ridges from Hungary towards the end of the 15th century. This was when the intact forests started to be stumped and 'wildlands', i.e. meadows to keep the Walachian sheep and goats first appeared. At the same time, the pressure of the local population onto the forests from valleys into the mountains increased. Sheep-breeding was very popular. At the beginning of the 19th century, the farmers used to have 30–60 head of sheep that were jointly kept out at grass on chalets, mountain pastures, and mainly in the grazing forests. Also, the forests of landowners were burdened with the right of pasture up to 1850. Since 1843 when the pressure onto the forests culminated, the fragmentary character of the forests and the number of enclaves even at higher altitudes became apparent. Extensive afforestation, particularly that of desolated pastures, was started in 1875 in a project of afforestation led by wood-reeve Bernard and subsidized by the Provincial Council. The large-scale afforestation project was supported by the law on the afforestation of the Vsetínská Horní Bečva River area that was passed in 1896. The result was magnificent; forests in the cadastral area of Velké Karlovice and Malé Karlo-

vice grew from 3,690 ha in 1834 to the present 6,307 hectares, which is by 2,617 hectares (71%) more (PRŮŠA, HOLUŠA 1976).

The forest composition was intentionally directed from the beech-fir mixtures to the Norway spruce management. The Velké Karlovice estate fasse of the Josephine cadaster mentions 60% fir, 30% beech and 10% Norway spruce in 1787. Stable cadaster valuation elaborates of 1839 report 65% fir, 10% beech, and 25% Norway spruce. According to the 1822 enumeration survey, the commercial forests had the species percentage of 65% (fir), 30% (beech), 5% (Norway spruce) and the species composition in the grazing forests was 25% (fir), 20% (beech), 55% (Norway spruce). The forest management plan of 1935 already included 78% of Norway spruce with fir and beech reduced to 14% and 8%, respectively. Creaming was the main method of management until 1908, the year when the railway from Vsetín to Velké Karlovice was accomplished. This year saw the introduction of Norway spruce clear-cutting system with slash being burned, stumps grubbed, and clearcuts let for alternate forest and farm crops. After the potato harvest the Norway spruce was planted in the second year together with the sown oats, perennial rye and caraway. The last alternate forest and farm crops were here in 1930 (PRŮŠA, HOLUŠA 1976).

The continual mixed deep forests had a lot of game. The Vsetín estate transact of 1700 mentions a game keeper's obligation to deliver every year a wolf, a fox, 2 martens, 8 hares, 6 hazel hens, 30 fieldfares, 10 partridges and 100 small birds. There were several wolves shot here every year during nearly the entire 18th century. At the beginning of the 19th century, wolf, lynx and bear still occurred often on the Hungarian (Slovak) border. Red deer and wild boar were to be found as early as in the 18th century but only as alternate game species to disturb grazing of farm animals. It might be called surprising that the virgin forest could survive under these circumstances. Secondary crops were regenerated by clear felling and by alternate forest and farm crops; and there was also the pressure of the adjacent enclaves. The data about the virgin forest originate from the forest management plan of 1924 (Léskové forest district, Stand 20a): the Stand is described as follows: fir 5, beech 5; well developed, sparsely stocked stand with abundant beech undergrowth, sporadically treated after the "Dunkelschlag" shelterwood felling method. FMP Directive: gradual opening up of the whole area. Table 1 indicates that the Stand was still managed ("Dunkelschlag") in the period between 1924–1933 and the fallen wood extracted (breakages and windthrows) – altogether 2,048 m³. The forest management plan worked out by Ing. Čeněk Fránek (Léskové forest district, Stand 20a, area 23.52 ha) in 1935 mentions the age of 171 years and the following species composition: fir 48%, beech 42%, Norway spruce 10%. Stand description: Overmature large-diameter stand with abundant undergrowth, left as a reserve. Proposed measures: Regarding the fact that the Stand is left to become a reserve with no management at all, the Stand is excluded from the regular management. Consequently, all mensurational data are irrelevant. Fell-

Table 1. Stand 20a – felling records

Year	Cut in m³	Felling method
1924	308.93	Dunkelschlag and breakages
1925	414.17	Dunkelschlag and breakages
1926	556.29	Dunkelschlag
	10.40	Breakages
1927	316.09	Breakages and windthrows
1928	53.19	Breakages
1929	84.15	Breakages
1930	44.38	Dunkelschlag
	17.50	Breakages
1931	85.43	Breakages and windthrows
1932	151.16	Breakages and windthrows
1933	8.42	Breakages and windthrows
Total	2,047.61	

ing (including incidental fellings) is excluded. The document provides an evidence that since 1935 the stand was declared a complete (strict) reserve by the forest management plan, in which felling and even fallen wood extraction were not permitted (PRŮŠA, HOLUŠA 1976).

The reserve was officially declared by the Ministry of National Education and its Decree No. 143547/33-V of 31 December 1933. Once again confirmed on the area of 23.52 hectares was the reserve by Decree No. 111318/49 of the Ministry of Education, Science and Arts passed on 8 December 1949, and its additional registration in Law Gazette was made through Order No. 14.200/88 of the CSR Ministry of Culture, 29 November 1988. According to Decree No. 395/1992 Gaz. of 11 June 1992, the territory was classified in the category of national nature reserves with the officially confirmed acreage of 23.52 hectares.

METHOD

The revision was based on detailed maps and calculations illustrating the virgin forest's condition in 1972 (PRŮŠA, HOLUŠA 1976; PRŮŠA 1985) and made use of the methodology of field studies modified by Ing. Průša and the method of valuating the logged data (VRŠKA 1997). The tree species layer was revised and into the existing map were added all trees that achieved the breast height diameter of 20 cm in the period under study. The mapping also included the newly fallen trees. All trees of d.b.h. over 20 cm were callipered and their characteristics recorded (dead standing tree, stub, and the like). The fallen trees were classified into three stages of disintegration. Some 230 trees were measured for the construction of height flow sheets in order to calculate volumes. The mensurational calculations made use of volume tables issued by Lesprojekt (1952).

The volume calculation in 1972 made use of tariffs introduced by Dr. Řehák for the Mionší virgin forest since there were no fitted height curves (PRŮŠA, HOLUŠA 1976). The comparison of these investigations can not therefore be considered fully representative. Undergrowths with trees below 20 cm d.b.h. were mapped.

Table 2. Changes in the chemistry of soils in the period 1972–1995

PTP No.	4						Parallel PTP					
Horizon	A0	O	Ah	Ah	A/B	A/(Bv)	A0	O	Ah	Ah	A/B	A/(Bv)
Horizon thickness (cm)	0–3	0–3	3–8	3–8	8–30	8–30	0–2	0–2	2–15	2–15	15–40	15–40
Year	1972	1995	1972	1995	1972	1995	1972	1995	1972	1995	1972	1995
pH – H_2O	–	–	4.42	4.7	4.30	5.1	–	–	4.29	4.2	4.5	4.52
pH – KCl	–	–	3.86	3.7	3.45	3.6	–	–	3.52	3.2	3.5	3.50
Cox (%)	–	31.23	5.52	3.56	0.69	1.44	–	45.60	4.50	4.76	1.08	1.56
Nt (%)	–	0.82	0.59	0.32	0.13	0.15	–	1.08	0.49	0.37	0.22	0.15
C : N	–	38.1	9.4	11.1	5.2	9.6	–	42.2	9.2	12.9	5.0	10.4
Al + H (me/100 g)	–	0.9	–	3.4	–	4.2	–	3.2	–	6.5	–	7.1
CEC (me/100 g)	–	27.2	–	13.0	–	10.3	–	19.9	–	11.8	–	10.5
S = CEC – (Al + H)	–	26.3	19.4	9.6	7.1	6.1	–	16.7	6.8	5.3	2.7	3.4
BS = V (%)	–	96.6	59.9	73.5	33.0	59.6	–	84.1	23.1	44.5	13.8	32.1

Notes: Cox – percentage of oxidizable carbon; Nt – total nitrogen content; Al+H – exchange aluminium and hydrogen; CEC– cation exchange capacity; S – instantaneous content of exchangeable bases (Ca, Mg, K, Na, Fe, Mn); BS – degree of sorption complex saturation; me – milliequivalent

Samples were taken from surface humus horizons from 4 soil pits in permanent typological plots (PTP) (3 PTPs in the virgin forest and 1 PTP on a parallel plot in the cultural stand with dominating Norway spruce) and subjected to chemical, biochemical and microbiological analyses in order to assess soil changes (chemical analysis). The biochemical and microbiological analyses were not usually made in the past and are considered a comparison material for further repeated investigations. All soil analyses were made in the accredited laboratories of AOPK CR – Detached Workplace Brno. The terminology and marking of soil horizons and soil subtypes were reworked to the soil classification system currently in force, used by the Institute of Forest Management (MACKŮ, VOKOUN 1993). The results of the soil analyses made in 1972 were borrowed from PRŮŠA and HOLUŠA (1976). As the material is rather extensive, the paper mentions only some of pedological data.

Phytosociological relevés were repeated in 16 PTPs on circular plots of 25 m in diameter (ca. 490 m²) that link up with the phytosociological relevés from 1972 (PRŮŠA,

HOLUŠA 1976). The names of plants were terminologically unified (DOSTÁL 1989). At making the phytosociological relevés the layering scale according to Zlatník (RANDUŠ-KA et al. 1986) was used to classify the tree species synusia, and the Braun-Blanquet combined scale of abundance and dominance, modified and refined by Zlatník (RANDUŠKA et al. 1986) for the herb synusia. For the evaluation of the phytocoenological relevés the authors adopted the ecological groups of plant species (EGS) currently used by Lesprojekt (PLÍVA, PRŮŠA 1969). The evaluation of the phytosociological relevés made use of the TYP programme, developed at the Institute of Forest Botany, Dendrology and Typology, Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry in Brno.

14 directional relevés were made for repeated photographing, and their place and direction were plotted in the detailed tree map.

The original maps were digitalized in the geographical information system (GIS) TOPOL by using a special software made by Mgr. Dušan Adam for mapping virgin for-

Table 3. Changes in the chemistry of soils in the period 1972–1995

PTP No.	6						11					
Horizon	A0	O	Ah	Al	A/B	Al/(Bv)	A0	O	Ah	Al	A/B	Al/(Bv)
Horizon thickness (cm)	0–2.5	0–3	2.5–20	3–20	20–55	20–55	0–3	0–4	3–15	4–15	15–50	15–50
Year	1972	1995	1972	1995	1972	1995	1972	1995	1972	1995	1972	1995
pH – H_2O	–	4.4	4.6	4.6	4.5	4.6	–	4.3	4.87	4.6	4.69	4.6
pH – KCl	–	3.7	3.9	3.6	3.9	3.6	–	3.8	4.08	3.6	3.84	3.7
Cox (%)	–	19.52	3.12	18.95	1.68	1.23	–	28.94	4.50	8.10	1.26	2.04
Nt (%)	–	0.67	0.41	0.25	0.25	0.18	–	0.76	0.48	0.32	0.25	0.21
C : N	–	29.1	7.6	75.8	6.6	6.8	–	38.1	9.3	25.3	5.1	9.7
Al + H (me/100 g)	–	2.8	–	6.2	–	6.5	–	2.2	–	4.9	–	5.6
CEC (me/100 g)	–	18.5	–	10.1	–	9.9	–	15.9	–	8.5	–	8.8
S = CEC – (Al + H)	–	15.7	9.7	3.9	5.2	3.4	–	13.7	11.6	3.6	3.5	3.2
BS = V (%)	–	84.8	45.3	38.8	26.0	34.7	–	86.3	48.5	42.3	18.1	36.4

ests. Other analyses were made by means of digital maps and connected databases with using common softwares such as FOXPRO, MS Excel, MS Word.

NATURAL CONDITIONS

Localization and broader territorial context

The Razula National Nature Reserve can be found about 1.5 km to South-East of Léskové in the Vsetín district, in the territory of the Beskydy Protected Landscape Area, amidst the forest stands administered by the state enterprise Lesy České republiky, s. p. (Forests of the Czech Republic). In organizational terms, it belongs to the forest district of Velké Karlovice, Stand No. 112 A. According to the digital map the total aligned area amounts to 22.88 hectares.

The entire territory is situated in the forest area 41 – The Hostýn-Vsetín Upland and The Javorníky Mts. (PLÍ-VA, ŽLÁBEK 1986) and its biogeographical regionalization is as follows: sub-province Carpathian, biogeographical region 3.9 – Vsetín (CULEK et al. 1995).

Geomorphological situation

The Razula National Nature Reserve is to be found at altitudes ranging between 660–812 m. The territory is formed by two pronounced ridges with steep slopes exposed mainly to the North, North-West and North-East. The ridges are divided by a brook incision that joins a brook at the northern edge, which forms the northern frontier of the whole territory. Numerous windthrow areas, particularly at steep places, contribute to the considerably broken micro-relief.

Geological situation

Prevailing are claystones of Zlín layers (the flysch zone of the West Carpathians), grey colour, medium fertility, shelly exfoliating, easily weathering. Less represented are glauconitic sandstones of greenish-grey colour and fine to medium texture. They form difficult-to-weather ridges (PRŮŠA, HOLUŠA 1976).

Climatic conditions

Average monthly rainfalls (mm) in 1901–1950, Station Velké Karlovice-Javorníky, 952 m (KOLEKTIV 1961):

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
72	71	81	79	80	108	121	113	81	85	88	78

Year	IV–IX	X–III
1,057	582	475

Average monthly rainfalls (mm) in 1901–1950, Station Velké Karlovice – Podťaté, 631 m (KOLEKTIV 1961):

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
75	73	76	73	83	118	132	115	83	88	87	80

Year	IV–IX	X–III
1,083	604	479

Average monthly air temperatures (°C) in 1901–1950, Station Nový Hrozenkov, 460 m (KOLEKTIV 1961):

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
–3.6	–2.3	2.2	7.1	13.0	15.5	17.2	16.3	12.8	8.1	3.0	–0.9

Year	IV–IX
7.4	13.6

The territory belongs in the cold zone – CH6 (QUITT 1974).

TYPOLOGICAL SITUATION AND ITS CHANGES

Rich fir-beech stand with woodruff – 5B1
(14.96 ha, 65.3%)

The forest type of rich fir-beech stand with woodruff takes up approximately two thirds of the reserve and houses permanent typological plots (PTP) 1, 2, 3, 6, 7, 8, 9, 10.

Soil conditions are described on the example of PTP 6:
O – 0–3 cm – loose leaves and other types of organic litterfall at different stages of decomposition,
Al – 3–20 cm – dark grey-brown, sandy-loam soil, crumbly, loose, fresh,
Al/(Bv) – 20–55 cm – grey-brownish, sandy loam, slightly compressed, fresh, weakly skeletal,
Bv – 55–90 cm – light brown, loamy-sand soil, slightly compressed, fresh, medium-skeletal,
Cd – 90–130 cm – grey, loamy soil, compact, fresh, heavily skeletal with prevailing weathered slate.

The soil subtype is Mesotrophic Cambisol, the soil type sandy-loam, the humus subform mull moder. The active soil reaction is entirely without any change and remains medium acid with the potential soil exchange capacity slightly decreased (from 3.9 to 3.6) in all horizons under study, yet remaining very acid. The content of oxidizable carbon is markedly increased in the Al horizon and decreased in the Al/(Bv) horizon. The upper soil layer can be considered strongly humous and the transition horizon Al/(Bv) humous. The total nitrogen content dropped in the both horizons under study and is classified as high (originally very high) in the Al horizon and medium (originally high) in the Al/(Bv) horizon. In spite of the both-sided fluctuations the immediate content of the exchangeable bases remains very low with the soils exhibiting a slightly unsaturated sorption.

Results of the phytocoenological investigations are illustrated in Fig. 1 and Tables 4 and 5. Permanent typological plots 1, 2, 3, 6, 7, 8 and 9 exhibited a pronounced reduction of herb layer cover due to the filling of the growing space with European beech in tree classes III and IV. The fall of several individuals of European beech resulted in a moderate opening of PTP 10 (at the stage of culminating optimum), which was also reflected in the increased cover of the herb layer from 45% to 60%. All permanent typological plots had the representation of the ecological groups of species (EGS) shifted towards the higher proportion of EGS 5/6 – fresh, fertile sites/nitrophilous sites, the shift having been attributed to the very even (and least changed) cover by *Athyrium filix-femina* which results in its relatively increased representation as compared with other species. On the other hand, the shrinking representation of EGS 10 (fresh, medium fertile sites) on

Table 4. Phytocoenological table – Summary

Number of permanent typological plot (PTP No.)		1	1	2	2	3	3	6	6	7	7	8	8	9	9	10	10	4	4	5	5	16	16	11	11	12	12	13	13	14	14	15	15
Number of phytocoenological relevé		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Forest type		5B1																5B6						5D6				5J3		5L1		5F1	
Cover of tree species synusia (%)		.	95	.	95	.	75	.	80	.	95	.	90	.	95	.	80	.	95	.	95	.	80	.	85	.	90	.	80	.	85	.	85
I.	Abies alba	.	.	.	5	.	.	.	.	10	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Picea abies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	35	.	.	.	5
II.	Abies alba	40	.	.	.	.	.	20	5	50	5	50	5	.	.	.	.	.	.	.	.	.	.	50	15	.	.	30	5	20	5	20	.
	Fagus sylvatica	.	.	.	20	.	10	40	20	.	5	20	5	.	15	80	75	40	50	20	70	.	.	.	.	5	30	20	40	.	5	50	40
	Picea abies	20	15	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	90	65	.	.	.	.	.	.	.	.	.	.
III.	Abies alba	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	1
	Acer pseudoplatanus	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Fagus sylvatica	.	30	.	20	.	20	.	5	.	10	.	.	.	75	.	5	.	20	70	30	20	5	.	40	.	70	.	20	.	20	.	15
	Picea abies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
IV.	Abies alba	.	.	.	5	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.
	Fagus sylvatica	70	50	50	60	30	50	20	50	90	75	40	80	90	5	.	10	80	30	10	10	.	5	90	30	50	15	10	30	50	50	30	40
	Picea abies	.	.	.	.	.	.	.	.·	.	.	.	.	.	.	30	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
V–1a.	Abies alba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	.	.	.	.	.	.	.	–	.	–
	Acer pseudoplatanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	.	.	–	.	.
	Fagus sylvatica	.	–	.	3	.	3	.	10	.	3	.	3	.	–	5	+	.	.	.	+	.	–	.	.	.	.	30	1	.	1	.	1
	Picea abies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.
	Sambucus racemosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	+	.	.	.	+
	Sorbus aucuparia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	.	.	.	.	.
V–1b.	Abies alba	.	–	.	–	.	+	.	+	.	+	.	.	.	+	.	+	.	+	.	+	.	+	.	–	.	–	.	.	.	–	.	–
	Acer pseudoplatanus	.	.	.	.	.	.	.	–	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	–	.	.	.	.	.	.	.	.
	Fagus sylvatica	.	.	.	–	.	+	.	.	.	+	.	–	.	.	.	+	.	+	.	+	.	+	.	–	.	.	.	.	.	–	.	+
	Picea abies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Sambucus nigra	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	Sorbus aucuparia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	.	.	.	–	.	.	.	.	.	.	.	.	.	.
V–2.	Abies alba	.	+	.	3	.	+	.	+	.	+	.	+	.	+	.	+	.	+	.	+	.	.	.	+	.	+	.	+	.	+	.	+
	Acer pseudoplatanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	–	.	.
	Fagus sylvatica	.	–	.	–	.	–	.	.	.	+	.	+	.	+	.	+	.	+	.	–	.	+	.	+	.	+	+	.	.	–	.	.
	Picea abies	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	–	.	.	.	–	.	.

Table 4 to be continued

Number of permanent typological plot (PTP No.)	1	1	2	2	3	3	6	6	7	7	8	8	9	9	10	10	4	4	5	5	16	16	11	11	12	12	13	13	14	14	15	15
Number of phytocoenological relevé	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Forest type	5B1																5B6						5D6				5J3		5L1		5F1	
Cover of non-woody undergrowth synusia (%)	60	20	70	10	50	30	80	25	30	5	80	5	30	5	45	60	30	2	40	5	70	10	60	45	90	10	70	40	90	25	70	30
Actaea spicata	.	.	.	−	.	−	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.
Ajuga reptans	−	.	.	−	.	.	−	+	+	+	.	.	+	.	.	−	.	.	.	.	.	.	.	.	.	.	.	.	.	+	−	.
Aruncus vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.
Asarum europaeum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Athyrium filix-femina	2	−2	.	1	2	+2	1	−2	1	1	2	1	1	1	1	−2	+	−	+	+	1	.	3	+2	3	−2	2	−2	+	1	2	−2
Cardamine amara	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Carex sylvatica	.	.	+	+	.	+	+	+	+	+	.	.	.	−	+	.	.	−	+	+	+	+	+	−	.	.	.	.	.	.	2	.
Circea intermedia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	+	.
Corydalis sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.	.	.	.	.
Dentaria bulbifera	.	.	.	.	.	.	1	+	1	1	1	−	.	+	.	−	.	+	1	+	1	−	+	.	.	.	.	.	.	+	1	+
Dentaria enneaphyllos	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.
Dentaria glandulosa	1	−	1	+	1	−	1	+	2	.	2	+	2	1	1	+	+	−	1	−	.	+	1	1	1	1	+	+	.	+	+	+
Dryopteris carthusiana	+	+	.	−	+	−	+	+	1	+	1	−	.	−	+	+	−	.	.	.	+	+	.	+	.	−	.	.	1	+	.	−
Dryopteris filix-mas	.	−	.	−	.	+	.	+	.	−	+	−	+	−	.	1	.	.	.	.	.	.	1	1	2	+	2	+	+	+	1	−
Epilobium montanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.
Galeobdolon montanum	.	+	.	.	.	+	1	−	.	.	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	1	1	2	1	+	1
Galium odoratum	1	.	2	+	2	1	2	−2	2	−	2	+	2	+	1	1	+	.	1	−	1	+	1	.	1	+	1	1	+	+	1	+
Galium rotundifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	−	.	.	.	.	.	.	.	.	.	.
Geranium robertianum	.	.	1	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	+	.	1	+	1	1	.	+
Gymnocarpium dryopteris	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Chaerophyllum hirsutum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
Chrysosplenium alternifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.	.	.
Impatiens noli-tangere	−	+	3	.	2	1	4	+	.	+	4	.	.	.	.	+	.	.	.	.	.	.	.	.	.	−	.	−	1	+	+	−
Luzula sylvatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	−	.	.	.	.	.	+	.	.	.
Lysimachia nemorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.
Mercurialis perennis	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	−2	.	.	.	.	.	.	.	+

Species																																
Mycelis muralis	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Myosotis sylvatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.
Neottia nidus-avis	.	.	.	−	.	.	.	.	.	.	.	.	.	−	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oxalis acetosella	3	+	2	+	2	+	2	+	2	+	2	−	2	+	3	+	+	−	2	.	2	+	2	1	2	+	1	+	1	1	2	+
Paris quadrifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	+	+	−	.
Petasites albus	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	2	.	3	−	2	−2	4	1	1	1
Polygonatum verticillatum	.	.	.	+	.	.	.	.	.	+	−	.	−	.	.	.	−	.	.	.	.	1	.	.	.	.	−	.	.	−	.	+
Polypodium vulgare	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.	.	.
Polystichum aculeatum	.	−	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	1	+	.	.	.	.
Prenanthes purpurea	+	−	.	−	.	.	+	−	+	−	.	.	−	+	.	.	.	.	1	−	−	−	.	.	.	−	+	+	.	−	.	1
Pulmonaria obscura	.	.	.	.	.	−	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	−	.	.
Ranunculus lanuginosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	−	.
Rubus fruticosus agg.	−	.	.	.	.	.	.	−	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	−	.	.	.	.	.
Rubus idaeus	.	.	+	.	.	−	.	.	1	.	.	+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	+	.	.	.	.	.
Sanicula europaea	+	.	.	.	.	.	.	+	.	−	.	.	−	.	.	.	.	.	1	.	+	1	.	2	+	.	+	.	.	.	1	−
Senecio ovatus	.	.	.	−	.	.	.	−	.	+	.	+	+	−	.	+2	.	−	.	.	1	−2	.	+	.	−	.	+	+	+	+	.
Stachys sylvatica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	+
Stellaria nemorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	+	.	.	2	.	.
Thalictrum aquilegiifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	+
Tithymalus amygdaloides	.	.	.	.	.	−	.	−	.	.	.	.	.	+	.	.	.	−	.	−	.	.	.	.	.	.	.	.	.	.	−	.
Veronica montana	.	+	.	+	.	.	+	+	.	.	.	.	+	+	−	.	.	.	.	.	+	.	.	.	+	.	.	+	.	+	.	.
Viola reichenbachiana	.	.	.	.	.	.	+	.	−	+	.	.	+	+	−	.	.	.	−	1	−	.	.	.	.	.	.	−	.	.	.	−

1) Phytocoenological relevés on the individual permanent typological plots (PTP) marked with "Record No. 1" were made in July 1972 (PRŮŠA, HOLUŠA 1976)

2) Phytocoenological relevés on the individual PTP marked with "Record No. 2" were made 11. 7. 1995

3) The relevés of 1972 did not use the finer scale of abundance and dominance

Fig. 1. Changes of phytocoenoses – 5B1 – rich fir-beech stand with woodruff

Legend (from the figure):
- 17/13 – subalpine sites (17)
- 13/6 – moist, fertile sites (13)
- 12 – moist, medium fertile sites
- 12/11 – alternating moist sites (11)
- 12/10
- 10/17
- 10 – fresh, medium fertile sites
- 10/5
- 6 – nitrophilous sites
- 6/5
- 5/13
- 5 – fresh, fertile sites
- 5/6
- 4 – slightly moist, fertile sites

the whole area of the forest type results from a marked withdrawal of *Oxalis acetosella*. The permanent typological plots 2, 3, 6 and 8 exhibit a severe shrinkage of the species *Impatiens noli-tangere* and these PTPs which were classified as the light stages of the phytocoenoses in the given forest type show at the present time the same parameters of the herb layer as the other PTPs under the fully enclosed canopy of the tree layer. Although the quantitative changes are conspicuous, there are no important qualitative changes in the plots under study (with the exception of PTP 2), which can be documented by relatively high indexes of similarity (Table 5).

Rich fir-beech stand with maple – 5B6
(4.74 ha, 20.7%)

The rich fir-beech stand with maple is situated in the western part of the reserve on the northern steep slope and includes PTP 4 and PTP 5. Soil conditions were measured on PTP 4 and on a parallel plot (PTP 16) of the identical forest type in the commercial stand adjacent to the western border of the reserve.

The description of the PTP 4 soil pit is as follows:

0 – 0–3 cm – leaf litterfall at different stages of decomposition with mull beneath,

Ah – 3–8 cm – dark brown, sandy-loam, crumbly soil, loose, freshly moist, slightly skeletal,

A/(Bv) – 8–30 cm – light brown, sandy-loam, crumbly soil, loose, fresh, medium skeletal,

(Bv)/Cd – 30–120 cm – light brown, sandy-loam, compressed, heavily skeletal soil.

The soil subtype is Mesotrophic Cambisol, the soil type sandy-loam, the humus form mull. The active soil reaction showed a slight increase in both horizons under study

and can be classified as medium acid (originally strongly acid). The potential exchangeable soil reaction recorded changes in both directions, which were however ranging in an interval of up to two tenths of pH value and this is why the reaction still remains strongly acid. Horizon Ah remains strongly humous despite a slight decrease in the values of oxidizable carbon. Horizon A/(Bv) with the increased Cox content can be classified as humous (originally weakly humous). Total N content dropped in horizon Ah from 0.59% to 0.32% being still classified as very high. The change in horizon A/(Bv) is minimum and the Nt content medium. The immediate content of basic cations in the forest soils decreased in comparison with 1972 and is still classified as very low. The degree of soil sorption complex saturation is higher in both cases under study, the soil in horizon Ah still being highly saturated and the soil in horizon A/(Bv) being now saturated (slightly unsaturated in 1992).

The soil pit at the parallel PTP 16 can be described as follows:

0 – 0–2 cm – needle and leaf litterfall under gradual decomposition,

Ah – 2–15 cm – grey-brownish, sandy-loam, crumbly soil, loose, fresh, weakly skeletal,

A/(Bv) – 15–40 cm – ochre-brownish, sandy-loam, lumpy soil, slightly compressed, fresh, heavily skeletal,

Bv – 40–80 cm – light brown, loamy-sand, prismatic soil, compressed, fresh, heavily skeletal,

(Bv)/Cd – 80–100 cm – ochre, loamy, loose soil, fresh, heavily skeletal.

The soil subtype is Mesotrophic Cambisol, the soil type sandy-loam, the humus type mull moder. The active soil reaction is unchanged in both horizons under study and can be classified as strongly acid (horizon Ah) up to medium acid (horizon A/(Bv)). The potential exchange-

Table 5. Indices of similarity of the phytocoenoses

PTP No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Jaccard index	42.9	23.5	40	30	42.9	65	58.8	61.5	50	42.1	41.2	42.1	53.3	50	44	45.5
Sörensen index	60	38.1	57.1	46.2	60	78.8	74.1	76.2	66.7	59.3	58.3	59.3	69.6	66.7	61.1	62.5

able soil reaction recorded a drop only in horizon Ah (from 3.52 to 3.2) and remained unchanged in horizon A/(Bv); it is classified as strongly acid in both cases. The Cox content was increased only in horizon A/(Bv) which means that the horizon can now be classified as humous with horizon Ah remaining very strongly humous. The two repeatedly classified horizons recorded a decreased Nt content which is, however, still considered very high in horizon Ah and dropped from the category of the high Nt content into the category of the medium Nt content in the case of horizon A/(Bv). The immediate content of exchangeable basic cations remains very low, the degree of the soil sorption complex saturation improved in both horizons under study (its value having been approximately doubled) and the soils are now slightly unsaturated (originally highly unsaturated).

The changes of the phytocoenoses are presented in Tables 4 and 5 and in Fig. 2. PTP 4 and PTP 5 exhibit a conspicuous cover reduction (from 30% to 2%, and from 40% to 5%, respectively) with the herb synusia being restricted to the occurrence of several dispersed individuals of some plant species. Despite the strong reduction of the cover, the species diversity exhibits just a partial restriction with only a few new species. Although the indices of similarity are slightly below-average (from the viewpoint of the reserve as a whole), there are no special fluctuations in their values (Table 5). Rather pronounced is the disappearance of a formerly dominant species *Dentaria enneaphyllos* from EGS 6/5 – (nitrophilous sites/ fresh, fertile sites), and a nearly complete disappearance of the species *Oxalis acetosella* from EGS 10 – fresh, medium fertile sites, which is also reflected in the changed

Table 6. The summary of tree species by tree numbers, stand basal area and timber volume on the whole area

Razula	1972 1995	Live trees			Dead trees				Total	Live (%)	Dead (%)
		intact trees	fractures	total live	standing	stubs	fallen	total dead			
Norway spruce	number			323	5	4	6	15	338	13.3	3.1
	number	358		358	11	8	49	68	426	12.0	6.1
	m^2			79.826	2.191	1.956	2.310	6.457	86.283	11.2	3.2
	m^2	89.772		89.772	2.867	3.189	20.146	26.202	115.974	13.1	5.7
	m^3			1,405.21	43.38	36.20	39.28	118.86	1,524.07	11.3	3.4
	m^3	1,431.69		1,431.69	45.59	6.43	237.02	289.04	1,720.73	10.5	6.5
Fir	number			580	171	122	21	314	894	23.8	65.0
	number	268	5	273	94	214	421	729	1,002	9.2	65.3
	m^2			263.883	64.076	59.321	9.259	132.656	396.539	37.0	66.6
	m^2	140.217	2.812	143.029	42.112	98.668	180.647	321.427	464.456	20.9	70.0
	m^3			4,562.19	1,088.73	1,032.96	159.96	2,281.65	6,843.84	36.6	64.5
	m^3	2,878.71	24.83	2,903.54	855.43	313.78	1,905.65	3,074.86	5,978.40	21.2	69.3
European beech	number			1,533	14	126	14	154	1,687	62.9	31.9
	number	2,324	11	2,335	11	77	231	319	2,654	78.5	28.6
	m^2			369.434	3.740	51.119	5.114	59.973	429.407	51.8	30.1
	m^2	447.237	4.194	451.431	1.288	35.295	75.137	111.720	563.151	65.9	24.3
	m^3			6,509.67	67.35	971.81	96.65	1,135.81	7,645.48	52.2	32.1
	m^3	9,311.25	38.17	9,349.42	23.01	107.84	940.68	1,071.53	10,420.95	68.3	24.2
Other	number			0				0	0	0.0	0.0
	number	8		8				0	8	0.3	0.0
	m^2			0.00				0.00	0.00	0.0	0.0
	m^2	0.423		0.423				0.00	0.423	0.1	0.0
	m^3			0.00				0.00	0.00	0.0	0.0
	m^3	5.86		5.86				0.00	5.86	0.0	0.0
Total	number			2,436	190	252	41	483	2,919	100.0	100.0
	number	2,958	16	2,974	116	299	701	1,116	4,090	100.0	100.0
	m^2			713.143	70.007	112.396	16.683	199.086	912.229	100.0	100.0
	m^2	677.649	7.006	684.655	46.267	137.152	275.930	459.349	1,144.004	100.0	100.0
	m^3			12,477.07	1,199.46	2,040.97	295.89	3,536.32	16,013.39	100.0	100.0
	m^3	13,627.51	63.00	13,690.51	924.03	428.05	3,083.35	4,435.43	18,125.94	100.0	100.0

Other: sycamore maple, European ash, European hornbeam

relative representation of the individual ecological groups of species. The share of EGS 5 – (fresh, fertile sites) increased to the account of the above mentioned ecological groups of species thanks to the participation of *Dentaria bulbifera* in spite of the fact that its cover value is expressed with the "+" mark.

The changes that occurred on the parallel plot (PTP 16) cannot be objectively compared since the original PTP was not precisely localized and its new alignment against the original plot was made with the accuracy of tens of meters. Nevertheless, a certain degradation of sites and changed light conditions are expressed by the participation of *Senecio ovatus* from EGS 10/5 (fresh, medium fertile sites/fresh, fertile sites), which is a dominant species of the herb synusia on the parallel PTP.

Enriched fir-beech stand with butterbur – 5D6
(1.62 ha, 7.1%)

The site of the enriched fir-beech stand with butterbur can be found as small spots on the eastern and northern slopes at the places of under-slope deluvia. The vegetation is characterized by phytocoenological relevés made on PTP 11 and PTP 12, and by a soil pit made on PTP 11:
O – 0–4 cm – organic material in different stages of decomposition (fallen leaves and needles),

Al – 4–15 cm – grey-brownish, loamy-sand, crumbly soil, fresh, weakly skeletal,

Al/(Bv) – 15–50 cm – brown, sandy-loam, lumpy soil, slightly compressed, fresh, weakly skeletal,

Bv(g) – 50–95 cm – light grey-brownish, sandy-loam, coarse lumpy soil, compressed, moist, medium skeletal,

(B)/Cd – 95–140 cm – grey-brownish, solid soil, moist, heavily skeletal, severely weathered slate.

The soil subtype is Mesotrophic Gleyed Cambisol, the soil type sandy-loam, the humus subform mull moder. The active soil reaction decreased by only a minimum and remains medium acid. The potential exchangeable soil reaction dropped from 4.08 to 3.6 in the case of horizon Al, with a minimum decrease in the case of horizon Al/(Bv). The soil reaction can still be classified as strongly acid. In spite of the increased Cox content in the two repeatedly measured horizons, the horizon Al remains in the group of strongly humous soils and horizon Al/(Bv) in the group of humous soils. The both horizons (Al and Al/(Bv)) recorded a slight decrease of Nt content. Nevertheless, in both cases the soils remain in their original group – horizon Al in the group of soils with the very high content of nitrogen, horizon Al/(Bv) in the group of soils with the high content of nitrogen. The immediate content of exchangeable basic cations dropped with the values indicating a very low content already in 1972. The degree of

17/13 – subalpine sites (17)
12/11 – moist, medium fertile (12)/alternating moist sites (11)
10/17
10 – fresh, medium fertile sites
10/5
6 – nitrophilous sites
6/5
5/13 – moist, fertile sites (13)
5 – fresh, fertile sites
5/6
4 – slightly moist, fertile sites
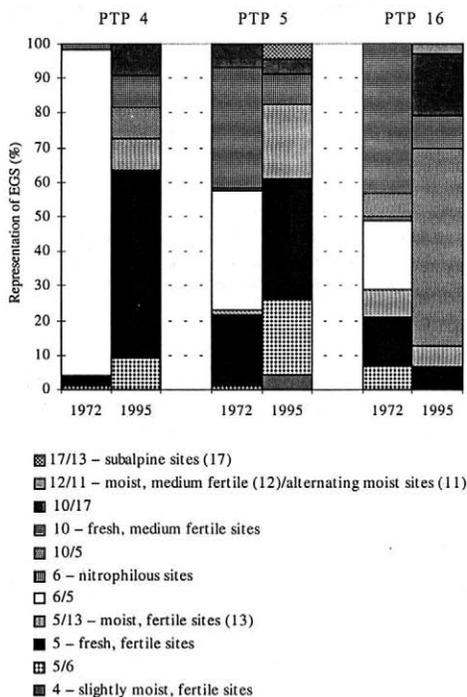
Fig. 2. Changes of phytocoenoses – 5B6 – rich fir-beech stand with maple

5/6
5/13
6 – nitrophilous sites
10 – fresh, medium fertile sites
12/10
13/6
14 – wet sites, flowing water
17 – subalpine sites

5 – fresh, fertile sites
6/5
10/5
10/17
12 – moist, medium fertile sites
13 – moist, fertile sites
17/13
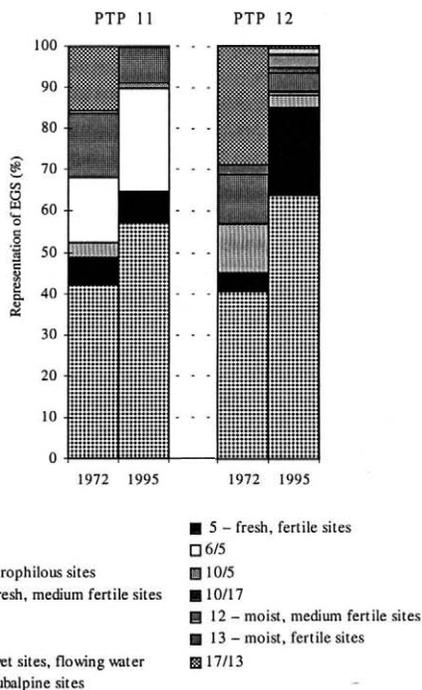
Fig. 3. Changes of phytocoenoses – 5D6 – enriched fir-beech stand with butterbur
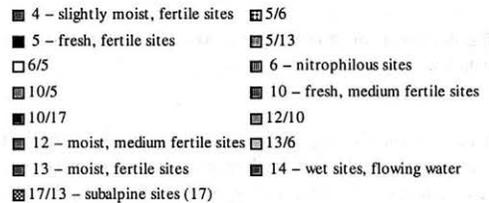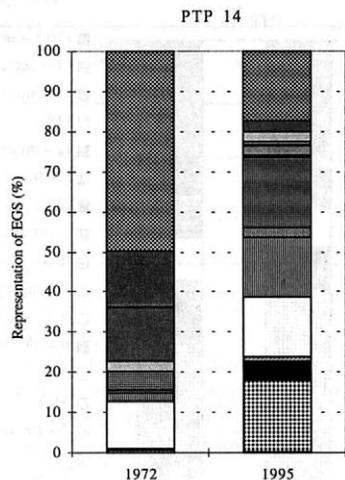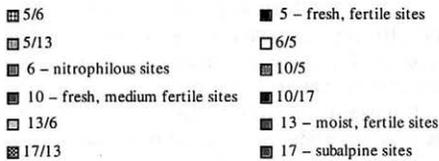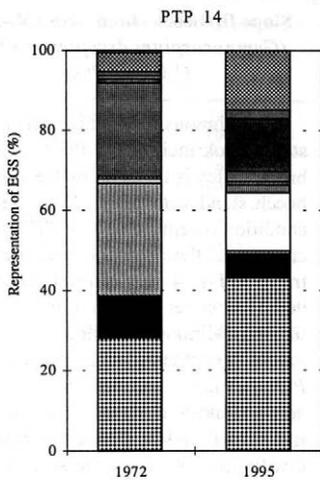
Fig. 4. Changes of phytocoenoses – 5F1 – slope fir-beech stand with oak-fern (*Gymnocarpium dryopteris*)

Fig. 5. Changes of phytocoenoses – 5L1 – mountain stream ash-alder stand

sorption saturation did not change in horizon Al and the soil remains slightly unsaturated; the degree of sorption saturation in horizon Al/(Bv) was doubled with the soil being now also slightly unsaturated (highly unsaturated in 1972).

The changes in the phytocoenoses are illustrated in Fig. 3 and Tables 4 and 5. PTP 12 exhibited a conspicuous reduction of herb layer cover (from 90% to 10%) due to the very dynamic development of the central storey of

beech (tree layer III). The same trend – although at the lower measure of intensity – was observed in PTP 11. The two permanent typological plots show a withdrawal of the originally dominant species *Oxalis acetosella* from EGS 10 (fresh, medium fertile sites), *Petasites albus* from EGS 17/13 (subalpine/moist, fertile sites), and *Sanicula europaea* from EGS 5/13 (fresh, fertile/moist, fertile sites). In contrast, the species *Athyrium filix-femina* from EGS 5/6 (fresh, fertile/nitrophilous sites) kept its original repre-

Table 7. Live trees by species and diameter classes on the whole area (standing intact trees + fractures)

Razula	1972 1995	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total live
Norway			48	95	38	20	22	25	38	23	7	4	1	1	1		323
spruce			41	91	60	45	19	20	35	29	17	1	2				358
Fir			5	19	28	54	83	123	115	77	45	16	8	2	2	3	580
			7	9	7	19	29	45	54	39	38	10	8	4	3	1	273
European		1	92	190	311	327	236	186	115	56	11	7	1		1		1,533
beech		1	720	414	218	278	268	210	158	71	21	15	5				2,335
Other																	
			5	2	1												8
Total			145	304	377	401	341	334	268	156	63	27	10	3	4	3	2,436
		1	773	516	286	342	316	275	247	139	76	26	15	4	3	1	2,974

Look out: The sums of individual trees by the individual diameter classes do not correspond to the total number of individuals in the column Total live. The reason is that the trees with twin or triple stems were not included

Other: sycamore maple, European ash, European hornbeam
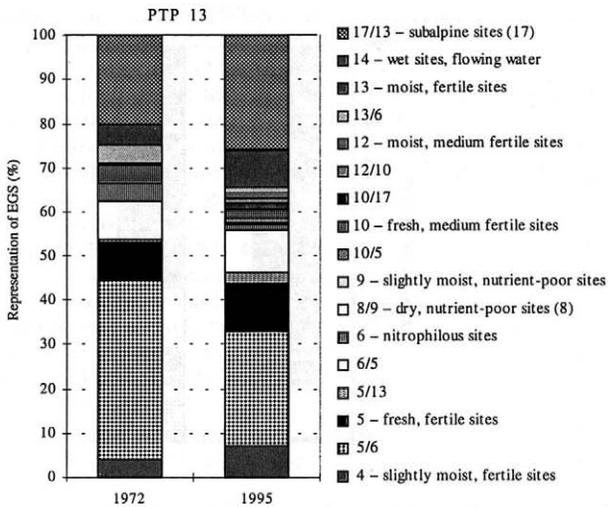
Fig. 6. Changes of phytocoenoses – 5J3– talus elm-maple stand with fern

Legend for chart:
- 17/13 – subalpine sites (17)
- 14 – wet sites, flowing water
- 13 – moist, fertile sites
- 13/6
- 12 – moist, medium fertile sites
- 12/10
- 10/17
- 10 – fresh, medium fertile sites
- 10/5
- 9 – slightly moist, nutrient-poor sites
- 8/9 – dry, nutrient-poor sites (8)
- 6 – nitrophilous sites
- 6/5
- 5/13
- 5 – fresh, fertile sites
- 5/6
- 4 – slightly moist, fertile sites

Slope fir-beech stand with oak-fern (*Gymnocarpium dryopteris*) – 5F1
(1.0 ha, 5.7%)

A continuous belt along narrow and steep brook incisions at the floor of the brook valley is taken up by the slope fir-beech stand with ferns. The vegetation condition is represented by PTP 15. The changes of the phytocoenoses are illustrated in Fig. 4 and Tables 4 and 5. The herb layer cover dropped from 70% down to 30%. Minimum changes of absolute values were recorded in plant species *Petasites albus* and *Athyrium filix-femina*. In contrast, the greatest cover reduction was found in *Carex sylvatica* and *Oxalis acetosella*. A conspicuous decrease in the relative representation of the ecological groups of species is obvious in EGS 10 (fresh, medium fertile sites) thanks to the heavy loss of *Oxalis acetosella*. A significantly increased representation is exhibited by ecological groups of species closely related to the nitrophilous communities – particularly EGS 5/6 (fresh, fertile sites/nitrophilous sites) – with the increase in the relative representation from 28.2% to 42.8% thanks to the permanent cover by *Athyrium filix-femina*, and EGS 6/5 (nitrophilous/fresh, fertile sites), represented by *Galeobdolon montanum*. In spite of the above mentioned changes, the indices of qualitative similarity do not exceed the average of the whole area under study.

sentation and the ecological groups of species remained dominant on both PTPs with an even higher relative representation (56.9% and 63.6%, resp.). PTP 11 exhibited a stronger relative representation of EGS 6/5 (nitrophilous/fresh, fertile sites) thanks to a considerably permanent presence of *Mercurialis perennis*. From the viewpoint of the reserve under assessment, the indices of similarity of the phytocoenoses represent an average (Table 4).

Other – sycamore maple, European ash, European hornbeam; BK – European beech; SM – Norway spruce; JD – fir

Fig. 7. Representation of live trees in per cent on the whole area

Table 8. The representation of live trees by species in per cent on the whole area

Tree species Acreage 22.88 ha		Norway spruce	Fir	European beech	Other	Total
Representation by	1972	13.3	23.8	62.9		100
tree numbers	1995	12.0	9.2	78.5	0.3	100
Representation by	1972	11.2	37.0	51.8		100
stand basal area	1995	13.1	20.9	65.9	0.1	100
Representation by	1972	11.3	36.6	52.1		100
timber volume	1995	10.5	21.2	68.3	0.0	100

Wet fir-beech stand – 5V0
(0.04 ha, 0.2%)

The wet fir-beech stand can be found only on a small plot in the NW part of the reserve, in a depression (a small furrow) with the spring area whose modest flowing opening affects the surrounding soils and results in their gleyzation.

Mountain stream ash-alder stand – 5L1
(0.20 ha, 0.9%)

This forest type takes up several dispersed plots of the stream alluvium in the northern and eastern parts of the reserve. The young Fluvisols exhibit a high content of humus and a good reserve of nutrients.

The vegetation is characterized on PTP 14. The herb layer evolution is documented in Fig. 5 and Tables 4 and 5. This permanent typological plot exhibits a pronounced reduction of the herb layer cover from 90% down to 25% due to a massive withdrawal of *Petasites albus* from EGS 17/13 (subalpine/moist, fertile sites). A considerable withdrawal was further observed in *Stellaria nemorum* from EGS 13 (moist, fertile sites), and *Chaerophyllum hirsutum* from EGS 14 (wet sites with flowing water). On the other hand, a slight increase was recorded in the relative representation of EGS 6 (nitrophilous sites) with *Geranium robertianum* as the main species, although its absolute cover in 1995 was identical with that recorded in 1972. Another moderate increase in the relative representation was found out in a related EGS – 5/6 (fresh, fertile/nitrophilous sites). However, the general reduction of the cover was evenly distributed within the entire range of the species, which can be documented by the above-average values of the qualitative indices of similarity for the phytocoenoses across the whole reserve (Table 5).

Talus elm-maple stand with fern – 5J3
(0.02 ha, 0.1%)

The talus elm-maple stand with fern occurs only on a single small plot in the stream incision at the northern edge of the reserve. It is a torn-off part of the slope in the stream gully. The soils are denudated and there was another land slip in the course of the period under study. The soil subtype is Mesotrophic Cambisol, severely disturbed, with the occurrence of buried horizons.

It is this small plot that bears PTP 13. The herb layer changes are illustrated in Fig. 6 and Tables 4 and 5. The herb layer cover in this PTP was reduced from 70% to 40% due to the gradual filling of the growing space with a new generation of beech in the lower tree layers (III and IV). The plant species of spring aspect, especially the dominant *Petasites albus* (EGS 17/13 – subalpine/moist, fertile sites) maintained their representation also in the absolute values because the full foliage of the tree layer at the end of May does not overlap with their main growing period. In contrast, other plant species that are bound to the half-shaded sites recorded a general reduction of the cover without any larger fluctuations in the individual ecological groups of species. The sole exception is a more pronounced reduction in the representation of EGS 5/6 (fresh, fertile/nitrophilous sites) which resulted from the conspicuous withdrawal of the *Dryopteris filix-mas* population.

The general response of the community is a direct consequence of the increased shading of the tree layer and does not suggest any other causes. The qualitative similarity of the communities is rather high (Table 5), the quantitative similarity – in contrast – is low.

MENSURATIONAL CHARACTERISTICS AND THEIR CHANGES

Area under study

Tree layer changes occurring in the reserve area under study in 1972–1995 are illustrated in Tables 6–9 and in Figs. 7 and 11–14. In this period of time, the total numbers of live and dead trees increased from 2,436 to 2,974 and

Table 9. Razula – the whole area – per-hectare indices

		Live trees	Dead trees	Total
Tree number per	1972	105	21	126
hectare	1995	130	49	179
Stand basal area	1972	30.739	8.581	39.320
per hectare (m²)	1995	29.924	20.076	50.000
Timber volume	1972	537.80	152.41	690.21
per hectare (m³)	1995	598.36	193.86	792.22

Note: The indices of 1972 are related to the area of 23.20 ha (PRŮŠA, HOLUŠA 1976)
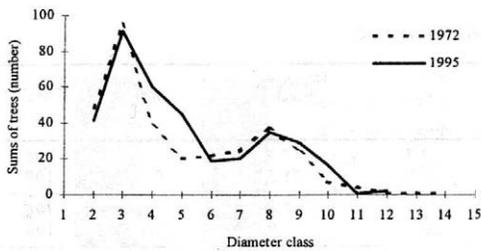
Fig. 8. The sums of live trees in the diameter classes – Norway spruce
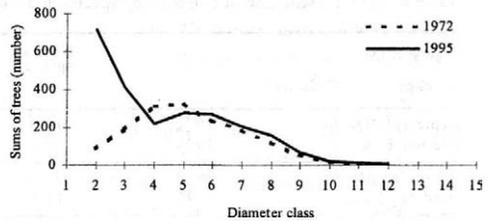
Fig. 10. The sums of live trees in the diameter classes – European beech
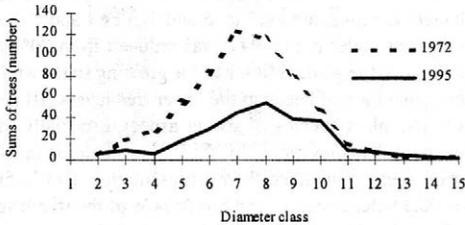
Fig. 9. The sums of live trees in the diameter classes – fir
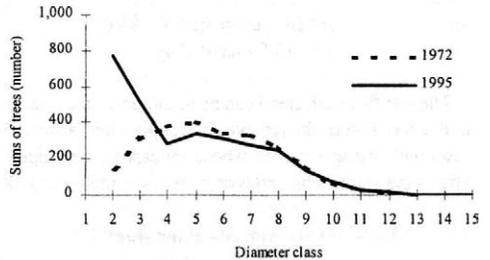
Fig. 11. The sums of live trees in the diameter classes – total

from 483 to 1,116, respectively. This means that in 1995, the dead trees amounted to 37.5% of the live trees and to 27.3% of the total number of trees. The basal area of live trees dropped from 713.1 m² down to 684.7 m², and at the same time, the timber volume of live trees increased from 12,477.1 m³ to 13,690.5 m³. The discrepancy resulted from the inaccurate measurement of breast height diameter in the sizeable firs in 1972 when the d.b.h. value of numerous individuals was higher than that measured in 1995, another reason being the use of the volume tariffs set up for the Mionší virgin forest (ŘEHÁK 1963) where the fir trees reach greater heights and thus show greater timber volume per unit basal area. At the same time, the new beech generation at the stage of maturation exhibited a growing timber volume, which was reflected in an accelerated increase of the timber volume in comparison with the growth of the basal area.

The conspicuous increase in the basal area and timber volume of dead trees is primarily determined by the decaying old generation of firs when the decline of an old

tree at the breast height diameter = 110 cm results in dead timber increased by 0.95 m² for the basal area and by ca. 20 m³ for the volume. A considerable percentage of firs were dead standing trees in 1972, of which the majority became lying dead trees in 1995. And because the rot often occurs at the height of 2–3 m, there is a number of stubs left within the space, whose volume is very low as compared with their basal area.

Average hectare values presented in Table 9 provide a good illustration of the increasing live and dead dendromass in the whole area under study, i.e. an ever more perfect filling of the growing space with the respective species or with individual trees. The diagramme of live trees in diameter classes (Fig. 11) exhibits a more favourable curve, particularly in its initial phase. Diameter Class 2 showed a rapid increase of tree number from the original 145 up to 773, which is a good evidence of the beginning whole-area regeneration of beech that occurred some 30–35 years ago.
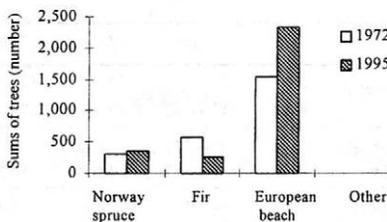
Other – sycamore maple, European ash, European hornbeam

Fig. 12. Changes of sums of live trees
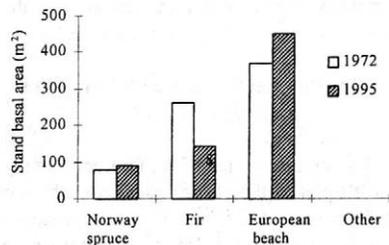
Other – sycamore maple, European ash, European hornbeam

Fig. 13. Changes of stand basal area of live trees
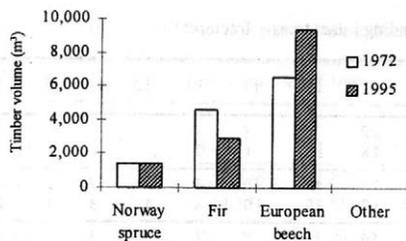
Other – sycamore maple, European ash, European hornbeam

Fig. 14. Changes of stem volume of live trees

The "virgin forest"

The "virgin forest" is a prevailing portion of the area under study (20.67 ha) that was not systematically subjected to regeneration under shelterwood. Changes in the tree layer are illustrated in Tables 9–13. Regarding the fact that the "virgin forest" takes up about 90% of the studied area, the developmental trend is identical to that of the

whole area under study with only the shrinkage of fir being pointed out, whose occurrence is minimal after shelterwood felling (the remaining 10% of the area).

Shelterwood felling

Tree layer changes are presented in Tables 14–17. The eastern part of the reserve (area under study – 2.21 ha) that was regenerated under shelterwood experienced an insignificant change. The total number of live trees dropped from 533 to 477 with the simultaneous increase in the basal area from 71.6 m² to 78.3 m², and in the timber volume from 1,111.2 m³ to 1,450.5 m³. The developmental trend signals a culminating optimum stage with the beginning transition to the stage of disintegration. In this section of its developmental cycle the beech forms the stands of simple spatial structure with co-dominant trees of the main level (tree class II) and individual intermediate trees (tree class III). Beech is a conspicuously dominant species (89% of live trees) and larger fluctuations in the values of all mensurational indices must be expected during the transition to the stage of disintegration with regard to the much simpler stand structure.

Table 10. The summary of tree species by tree numbers, stand basal area and timber volume – "virgin forest"

Razula	1972 1995	Live trees			Dead trees				Total	Live (%)	Dead (%)
		intact trees	fractures	total live	standing	stubs	fallen	total dead			
Norway spruce	number			271	3	4	6	13	284	14.2	2.9
	number	310		310	11	8	44	63	373	12.4	6.2
	m²			71.804	1.484	1.956	2.310	5.750	77.554	11.2	3.0
	m²	82.013		82.013	2.867	3.189	19.251	25.307	107.320	13.5	5.7
	m³			1,274.73	29.07	36.20	39.28	104.55	1,379.28	11.2	3.0
	m³	1,314.19		1,314.19	45.59	6.43	229.24	281.26	1,595.45	10.7	6.5
Fir	number			563	163	118	21	302	865	29.6	66.2
	number	264	5	269	92	210	405	707	976	10.8	69.0
	m²			261.046	62.614	57.309	9.259	129.182	390.228	40.7	66.7
	m²	139.101	2.812	141.913	41.759	97.631	177.843	317.233	459.146	23.4	71.2
	m³			4,519.78	1,065.79	997.64	159.96	2,223.39	6,743.17	39.8	64.6
	m³	2,857.02	24.83	2,881.85	849.34	310.37	1,880.04	3,039.75	5,921.60	23.5	70.4
European beech	number			1,069	10	118	13	141	1,210	56.2	30.9
	number	1,901	9	1,910	6	69	179	254	2,164	76.5	24.8
	m²			308.658	3.441	50.161	5.043	58.645	367.303	48.1	30.3
	m²	377.930	4.092	382.022	0.974	33.756	68.162	102.892	484.914	63.0	23.1
	m³			5,571.33	63.35	957.30	95.74	1,116.39	6,687.72	49.0	32.4
	m³	8,000.58	37.50	8,038.08	18.54	103.77	876.84	999.15	9,037.23	65.7	23.1
Other	number							0		0.0	0.0
	number	8		8				0	8	0.3	0.0
	m²							0.000		0.0	0.0
	m²	0.423		0.423				0.000	0.423	0.1	0.0
	m³							0.00		0.0	0.0
	m³	5.86		5.86				0.00	5.86	0.0	0.0
Total	number			1,903	176	240	40	456	2,359	100.0	100.0
	number	2,483	14	2,497	109	287	628	1,024	3,521	100.0	100.0
	m²			641.508	67.539	109.426	16.612	193.577	835.085	100.0	100.0
	m²	599.467	6.904	606.371	45.600	134.576	265.256	445.432	1,051.803	100.0	100.0
	m³			11,365.84	1,158.21	1,991.14	294.98	3,444.33	14,810.17	100.0	100.0
	m³	12,177.65	62.33	12,239.98	913.47	420.57	2,986.12	4,320.16	16,560.14	100.0	100.0

Other: sycamore maple, European ash, European hornbeam

Table 11. Live trees by species and diameter classes – "virgin forest" (standing intact trees + fractures)

Razula	1972 / 1995	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total live
Norway spruce	1972		35	72	30	17	22	24	37	22	7	4	1					271
	1995		32	78	48	37	18	18	33	28	16	1	2					310
Fir	1972		2	17	22	52	81	122	114	77	45	16	8	2	2	3		563
	1995		6	9	7	18	29	44	53	39	38	10	8	4	3	1		269
European beech	1972		38	76	149	227	212	179	112	56	11	7	1		1			1,069
	1995	1	678	340	100	146	216	195	156	70	21	15	5					1,910
Other	1972																	0
	1995		5	2	1													8
Total	1972		75	165	201	296	315	325	263	155	63	27	10	2	3	3		1,903
	1995	1	721	429	156	201	263	257	242	137	75	26	15	4	3	1		2,497

Look out: The sums of individual trees by the individual diameter classes do not correspond to the total number of individuals in the column Total live. The reason is that the trees with twin or triple stems were not included
Other: sycamore maple, European ash, European hornbeam

The amount of dead timber begins to slightly increase (from 27 to 92 individuals, i.e. from 5.5 m² to 13.9 m² and from 92.0 m³ to 115.3 m³), which is in good harmony with the anticipated development.

European beech (*Fagus sylvatica*)

Beech unambiguously confirmed its pronounced onset and became the main tree species in the reserve with the absolute dominance of all indices of which most marked is an increase in the number of live trees within the whole area under study from the initial 1,533–2,335 individuals (Fig. 12, Table 6). A lesser increase was recorded in the basal area (from 369.4 m² to 451.4 m²) and in the timber volume (from 6,509.7 m³ to 9,349.42 m³). This is given by the onset of the new generation with a great number of trees which do not yet reach larger volume dimensions. The representation of live trees in the diameter classes follows from Fig. 10. Most conspicuous is the increase in Diameter Classes 2 and 3, which is given by the above mentioned growing new generation of measurable dimensions. In comparison with 1972, the curve shape got closer to the ideal curve of the natural forest. Beech is represented in all tree classes and gradually takes over the entire growing space of the area under study.

In terms of the dead timber, a great shift occurred between the snags and the dead lying trees. The old trees which were at the beginning of their disintegration stage in 1972 are now lying at the stage of progressive decomposition. This is why their whole tabular timber volume cannot be included in the lying dead timber (as it was in 1972), but only its part (the so far not decomposed stems). This also explains the slight shrinkage of the European beech dead timber in the area under study from 1,135.8 m³ in 1972 down to 1,071.5 m³ in 1995 (Table 6).

Silver fir (*Abies alba*)

In contrast to beech, fir entirely withdrew from the tree layer of the area under study, its representation dropping for the live trees and increasing for the dead trees in all indices (Table 6, Figs. 12–14). Conspicuous is the shrinkage of the live trees from the original 580 down to 273 individuals, which is a decrease from 23.8% down to 9.2% in terms of the percentual representation of tree species in the whole area under study. The timber volume of the live trees dropped from 4,562.2 m³ to 2,903.5 m³; on the other hand, the timber volume of the dead trees increased from 2,281.7 m³ to 3,074.9 m³. Fir has a share of 69.3% in the total amount of the dead timber in the area under study. It is not only the oldest and most sizeable individuals which are dying, but also the individuals from the lower diameter classes (Fig. 9).

As compared with 1972, the curve of live trees in the respective diameter classes shows a much flatter course. Alarming is the loss of the live trees in Diameter Classes 2–7. Fir has in fact no younger generation today and is steadily deprived of the space suitable for its regeneration and invigoration due to the "invasive" behaviour of beech. The nearly regularly appearing annual regener-

Table 12. Razula – the representation of live trees by species in per cent "virgin forest"

Tree species Acreage 20.69 ha		Norway spruce	Fir	European beech	Other	Total
Representation by tree numbers	1972	14.2	29.6	56.2		100
	1995	12.4	10.8	76.5	0.3	100
Representation by stand basal area	1972	11.2	40.7	48.1		100
	1995	13.5	23.4	63.0	0.1	100
Representation by timber volume	1972	11.2	39.8	49		100
	1995	10.7	23.5	65.8	0.0	100

Table 13. Razula – "virgin forest" – per-hectare indices

		Live trees	Dead trees	Total
Tree number	1972	91	22	113
per hectare	1995	121	50	171
Stand basal area	1972	30.548	9.218	39.766
per hectare (m²)	1995	29.335	21.550	50.885
Timber volume	1972	541.24	164.02	705.26
per hectare (m³)	1995	592.16	209.01	801.17

Note: The indices of 1972 are related to the area of 21.00 ha (PRŮŠA, HOLUŠA 1976)

ation is subjected to intensive browsing by game, which results in its long-term poor existence and gradual decline. In addition, the surviving individuals of smaller diameters are being damaged by bark stripping with their prospects of survival and fructification steadily shrinking.

Norway spruce (*Picea abies*)

The Norway spruce population exhibited the most stable behaviour of all represented species in the period under study with only a slight increase of live and dead trees (from 323 to 358, and from 15 to 68 individuals, respectively) and a similar development in the basal area and timber volume (Table 6). However, the percentual representation of live spruce trees dropped from 13.3% down to 12.0% (Fig. 7) due to a generally higher number of the live trees in the studied area. The curve of live trees in diameter classes has two conspicuous peaks, similarly

like in 1972; its fall in Diameter Classes 4–6 is slower and there is also a clear trend to its gradual levelling, which is another evidence to the gradually stabilizing Norway spruce population slowly approaching the natural distribution of tree numbers in the respective diameter classes. The number of individuals in lower diameter classes (up to 30 cm breast height diameter) still remains a problem – see Chapter *Development of natural regeneration*. The number of live individuals in these sizes has not changed since 1972 and is markedly lower than the corresponding curve of the natural forest.

Other tree species

Tree species not mentioned so far and represented in the area under study (Table 6) form a small group not significant in terms of the studied indices. Their important contribution is that of the carriers of biological diversity. They include sycamore maple (*Acer pseudoplatanus*) – 6 individuals, European ash (*Fraxinus excelsior*) – 1 individual, and European hornbeam (*Carpinus betulus*) – 1 individual. Particularly the occurrence of the last mentioned species on the SE edge of the area under study (near the entrance into the reserve along the foot-path from the SE direction) is a curiosity on the sites of the 5th forest altitudinal vegetation zone. Sycamore maple does not yet appear in the advance regeneration due to the low number of individuals. Nevertheless, should the present individuals keep their position in the stand, there is no doubt they will make use of their growth potential to spread their population in the future.

Table 14. The summary of tree species by tree numbers, stand basal area and timber volume – "shelterwood felling"

Razula	1972 1995	Live trees			Dead trees				Total	Live (%)	Dead (%)
		intact trees	fractures	total live	standing	stubs	fallen	total dead			
Norway spruce	number			52	2			2	54	9.8	7.4
	number	48		48			5	5	53	10.1	5.4
	m²			8.022	0.707			0.707	8.729	11.2	12.8
	m²	7.760		7.760			0.896	0.896	8.656	9.9	6.4
	m³			130.48	14.31			14.31	144.79	11.7	15.6
	m³	117.50		117.50			7.77	7.77	125.27	8.1	6.7
Fir	number			17	8	4		12	29	3.2	44.4
	number	4		4	2	4	16	22	26	0.8	23.9
	m²			2.837	1.462	2.012		3.474	6.311	4.0	63.1
	m²	1.115		1.115	0.353	1.037	2.804	4.194	5.309	1.4	30.1
	m³			42.41	22.94	35.32		58.26	100.67	3.8	63.3
	m³	21.69		21.69	6.09	3.41	25.62	35.12	56.81	1.5	30.5
European beech	number			464	4	8	1	13	477	87.1	48.1
	number	423	2	425	5	8	52	65	490	89.1	70.7
	m²			60.776	0.299	0.958	0.071	1.328	62.104	84.8	24.1
	m²	69.307	0.102	69.409	0.314	1.539	6.975	8.828	78.237	88.7	63.4
	m³			938.34	4.00	14.51	0.91	19.42	957.76	84.4	21.1
	m³	1,310.67	0.67	1,311.34	4.47	4.07	63.84	72.38	1,383.72	90.4	62.8
Total	number			533	14	12	1	27	560	100.0	100.0
	number	475	2	477	7	12	73	92	569	100.0	100.0
	m²			71.635	2.468	2.970	0.071	5.509	77.144	100.0	100.0
	m²	78.182	0.102	78.284	0.667	2.576	10.675	13.918	92.202	100.0	100.0
	m³			1,111.23	41.25	49.83	0.91	91.99	1,203.22	100.0	100.0
	m³	1,449.86	0.67	1,450.53	10.56	7.48	97.23	115.27	1,565.80	100.0	100.0

Table 15. Live trees by species and diameter classes – "shelterwood felling" (standing intact trees + fractures)

Razula	1972 / 1995	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total live
Norway	1972	13	23	8	3			1	1	1				1	1		52
spruce	1995	9	13	12	8	1	2	2	1	1							48
Fir	1972	3	2	6	2	2	1	1									17
	1995	1					1	1									4
European	1972	54	114	162	100	24	7	3									464
beech	1995	42	74	118	132	52	15	2	1								425
Total	1972	70	139	176	105	26	9	5	1	0	0	0	1	1	0		533
	1995	0	52	87	130	141	53	18	5	2	1	0	0	0	0	0	477

Look out: The sums of individual trees by the individual diameter classes do not correspond to the total number of individuals in the column Total live. The reason is that the trees with twin or triple stems were not included

DEVELOPMENT OF STAND STRUCTURE AND TEXTURE

Development of natural regeneration

The development of natural regeneration in 1972–1995 is documented in two enclosed colour maps. The situation in 1972 is characterized by a nearly whole-area continuous layer of regeneration at the height interval ranging between 2 and 6 metres. The regeneration could only be distinguished as thin and dense. An exception was 4 plots of total acreage amounting to about 9% of the area under study that formed a higher layer of the regeneration at the height interval ranging between 8 and 13 metres. The eastern part of the studied area, which is not of the virgin forest origin but was regenerated under shelterwood showed the regeneration only at the edges with the virgin forest portion. Here, the continual canopy of beech did not allow its natural regeneration.

The status of natural regeneration in 1995 confirms the dynamic development of the whole reserve as affected by the disintegrating main level of the upper canopy of firs whose falling down markedly differentiated the regenerated groups. The original continual layer of beech regeneration at the height interval from 2 to 6 metres was differentiated, and it was possible to capture it at intervals of 5–10 m and 10–16 m, exceptionally also at the interval of 15+ m. The eastern part of the area under study showed a thinner regeneration of beech due to the opening up (breaking) of the beech storey that could be divided into two height intervals: 1–6 metres and 5–10 metres. The regeneration developed on 95% of the area under study.

In terms of the species, the advance regeneration is uniform and formed by European beech. Only in the NE and NW parts, there are individual Norway spruce trees maturing to the measured dimensions, their numbers and degree of coverage being too low to allow their plotting in the map. As to the increment, Norway spruce can hardly compete with European beech. The individual spruce trees appear in the regeneration in the vicinity of groups of old spruces where beech is not represented, or they grow in the mixture with beech at places where a falling tree completely destroyed the neighbouring competition of young beeches.

Regarding the very low number of sycamore maples, there are no aggressively growing groups of the advance regeneration of the species, the fact which makes the entire reserve acquire the character which is optically different from that of other reserves at comparable sites (not only in the Beskids) where the sycamore maple makes itself particularly useful at the regeneration of a more complex stand structure after long-term anthropogenic impacts on the development of the given area.

Stand structure

The reserve's stand structure is illustrated in Fig. 16. In 1972, fir still formed a distinguishable storey (main level – tree layer II) in the mixture with beech. The generation of the oldest and most sizeable firs formed the dominant lev-

Table 16. The representation of live trees by species in per cent – "shelterwood felling"

Tree species Acreage 2.21 ha		Norway spruce	Fir	European beech	Total
Representation by tree numbers	1972	9.8	3.2	87.0	100
	1995	10.1	0.8	89.1	100
Representation by stand basal area	1972	11.2	4.0	84.8	100
	1995	9.9	1.4	88.7	100
Representation by timber volume	1972	11.8	3.8	84.4	100
	1995	8.1	1.5	90.4	100

Table 17. Razula – "shelterwood felling" – per-hectare indices

		Live trees	Dead trees	Total
Tree number per hectare	1972	242	12	254
	1995	216	42	258
Stand basal area per hectare (m²)	1972	32.564	2.505	35.069
	1995	35.423	6.298	41.721
Timber volume per hectare (m³)	1972	505.00	41.82	546.82
	1995	656.35	52.16	708.51

Note: The indices of 1972 are related to the area of 2.20 ha (PRŮŠA, HOLUŠA 1976)
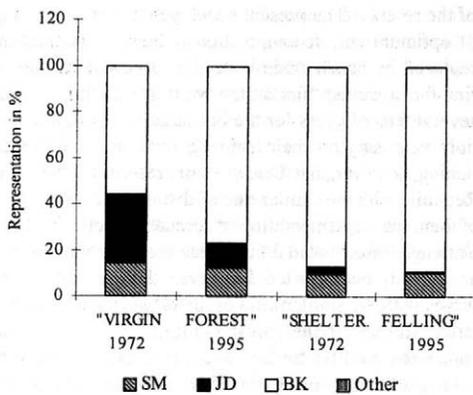
Other – sycamore maple, European ash, European hornbeam
BK – European beech; JD – fir; SM – Norway spruce

Fig. 15. The representation of tree species by sums of live trees in "virgin forest" and "shelterwood felling"

el (tree layer I). With regard to favourable light conditions the beech went through the whole-area regeneration too and formed a layer that was slightly differentiated in terms of height (tree layer IV). Fir regeneration was recorded no more.

Along with the disintegration of the older generation of fir the main level gradually opened up and light found its way to the regenerating beech (the right half of the transect from 1995) which gradually reached maturity being differentiated by falling old firs. The regeneration plots included in the height interval of 8–13 metres in 1972 were all included in the height interval 15+ m in 1995 with a good deal of them reaching the height over 20 m today (the left half of the transect from 1995). The advance growths form a large (5.31 ha) and important storey of intermediate trees (tree layer III). The plots with the beech advance regeneration, which suffered heavier damage by the falling firs or did not have light enough and partly stagnated in their development, form a today's subdominant level (tree layer IV), classified into two height intervals: 5–10 m and 10–16 m. The advance growths newly appeared in 1972–1995 form the height interval of 1–6 m and they came into existence in the structurally simplest part – in the stand regenerated under shelterwood, which is at its peak optimum at present, gradually slightly opening up by declining and falling individual bulky beeches.

Stand texture

The period of 1972–1995 can be classified as a gradual refinement of the stand texture. In 1972, the eastern part of the studied area – regenerated under shelterwood in the past – was at its optimum (maturity). The majority of the remaining stands were either at their optimum (maturity) or at the stage of disintegration (regeneration phase). The terminal phase of the optimum stage (maturity) was distinguishable at some places in sections with a more diverse structure and the participation of younger firs.

However, the acreage of this phase did not exceed 20% of the total area under study.

The area at the stage of disintegration gradually increases, the regeneration phase (in the period of 1972–1995) results in a greater differentiation of the stand texture since some irregularly spread parts still remain at their optimum (maturity), a part being formed by the stage of disintegration, the regeneration phase, and a part can be classified as the stage of growth completion, the phase of decline. This is typically developed i.e. in the NW part of the area under study where the beech advance growths gradually achieve the measured dimension of $d_{1.3} = 20$ cm thus forming a new main storey while the original main storey consists of only individually standing fragments of firs or individually occurring sizeable beeches.

DISCUSSION

The orientation of windthrows in the reserve was assessed in 1972 with the result indicating that the majority of the fallen stems (windthrows) of all important tree species (beech, fir, spruce) lie in the NE, E, and SE directions. The situation was reasoned in such a way that with regard to the steep gradient the trees fall down the slope,
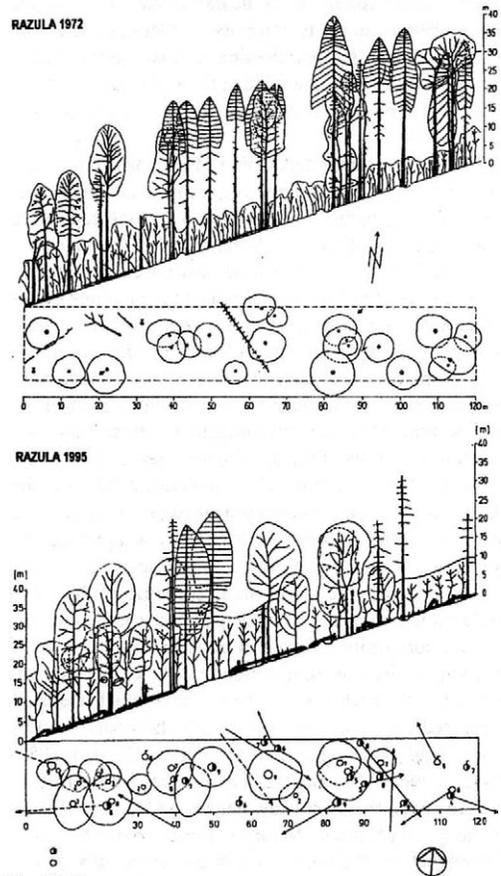
Fig. 16. Transect

this being added the fact that their crowns in the down-slope direction were better developed due to the greater space for the crown formation, and thus also had greater weight which helped to direct the fall of the tree (PRŮŠA, HOLUŠA 1976). At the same time, there were strong winds causing windbreaks and windfalls coming most often from the west. The trend is apparently no longer justifiable at the time of the repeated study since the tree falls are recorded to be directed to all cardinal points without any clear pattern even on the steepest slopes. The impact of the strong winds causing windbreaks and windfalls doubtlessly increased (to the detriment of the growth capacity) with their blowing not only in one direction any longer. However, there are no exact data available such as meteorological measurements made in the locality, which would confirm the hypothesis.

Unlike in the year 1972, there are all three stages of wood decomposition occurring now in the reserve (hard, touch and disintegrating wood). The former absence of all three stages was explained by the fact that the fallen timber used to be hauled out of the reserve until 1935. The period of dead wood decomposition varies a lot and depends on the tree species, on the position of the dead tree (or its parts) in the growing space of the virgin forest (fully on the ground, parts on the ground, standing), on microclimatic conditions in the immediate vicinity of the tree (substrate humidity, intensity of solar radiation), etc. In about 65 years, when the timber is left on the spot to decompose, all trees that died at the end of the period of died timber haulage would however be entirely decomposed.

The comparison of the number of trees and timber volumes between the so called "virgin forest"and the part of the forest regenerated by shelterwood felling suggests a lower capacity of the pure beech stands to make use of the stand's growing space (and thus the site potential). On the sites of rich fir-beech stands the mixtures of fir-beech-interspersed tree species reach the higher stem volume at the lower number of trees (in the part of the virgin forest). Application possibilities of the above mentioned mixture are sufficiently known and the by man impacted natural forest returning to its most advanced condition in terms of the development serves as a model example. This should be taken into consideration at the decision-making on silvicultural measures in commercial stands on comparable sites, especially at applying the principles of nature-oriented forest management.

Very questionable is the future response of the stand under study to structural changes and changes in the species composition recorded in about the last twenty-five years. The issue of the evolution cycle of the natural forest on fir-beech sites is one of those which are most discussed and assessed, particularly the issue of alternating evolution cycles of fir and beech (MÍCHAL 1983, 1992; KORPEĽ 1989) and the issue of the management of disturbed protected areas by man (SCHERZINGER 1996). In the Razula National Nature Reserve, no standard evolution cycle of the natural forest can apparently be expected in the coming century due to the disturbance rate of the reserve. The present beech generation at the stage of optimum and decomposition is being spontaneously replaced by beech again instead of a new generation of firs, the so called "firs on the waiting list" that can wait several tens of years for the optimization of light conditions necessary for their further growth. It is worth mentioning, however, that there are more reserves in the Czech Republic with the similar rate of disturbance and in some of them the implementation of rescue projects (fir underplanting, differentiated felling measures promoting fir, etc.) has already been started. However, there are only 2 reserves with the similar kind of disturbance where the detailed studies of the forest community evolution are conducted with no further direct influence of the man. A long-term monitoring of such an evolution can provide interesting results about the secondary succession of the forest communities and cast an entirely different light on our ideas about the behaviour of the forest tree species in the disturbed environment. The present trend of beech advance growth differentiation might for example rise the interest in the future since the theory suggests its coming back to the simple spatial construction. These results can then be used for differentiated management of disturbed forest reserves, particularly for making a fundamental decision whether the natural development of the reserve should be intervened or not. This is why we assume that there should be no active felling measures adopted in the case of the National Nature Reserve of Razula.

The problem of alternating tree species in the natural evolution cycle of the studied area or – in other words – the fluctuation of silver fir in the last centuries is similar to that described in the historical study of the Mionší National Nature Reserve (VRŠKA et al. 2000). Identical is also the problem of the growth of the natural regeneration of tree species in regions with the unnatural (increased) stock of hoofed game. The absence of predators or their marginal influence (due to anthropogenic impacts) and the contemporary standard of game management combine into a strong secondary anthropic pressure on the protected areas. The idea about fir being regenerated in the reserve is a mere illusion without protecting the advance growths by which we try to eliminate the impact. The mentioned secondary anthropic pressure can be eliminated by fencing the regeneration clusters, by the protection of individual trees at the stage of pole timber, and the measures should be applied consistently enough (naturally without any selective measures in the groups of firs, etc.). The possibility that fir can ever be regenerated is shrinking with the decline of the original fir generation. Yet, there are still some 25% of the reserve at the minimum where the conditions for the fir regeneration and its growth are good. The fact is that the fructification of the remaining fir specimens is highly variable and thus the potential for its natural regeneration is not that much promising. Beech grows well in spite of the strong game pressure because the spontaneous regeneration of beech on the sites of rich fir-beech stands is most massive of the whole scale of sites on which beech can be considered a properly fitting species.

The future participation of spruce and other interspersed species (especially sycamore maple) should be left to its own spontaneous development in the reserve since the existence of the mentioned species is not jeopardized in this country. The intensity of the future employment of sycamore maple in the area under study is important for the assessment of the species aggressiveness against beech on the described sites (and also for the comparison with other sites). It is exactly the comparison of sycamore maple participation, especially at the stage of maturation on the sites of fir-beech stands, with other sites (at regarding the differentiated growth conditions) in the similarly disturbed reserves that could be one of the auxiliary indices to classify the degree of disturbance (impact) of the reserve by the man. The suggestions were observed and recorded in the case of reserves in the Bohemian-Moravian Uplands (VRŠKA et al. 1999).

GENERAL EVALUATION

Soils as the most stable component of the ecosystem are medium to strongly acid in the area under study with active acidity remaining more or less at the same level or slightly increased. The average content of oxidizable carbon showed a slight increase, the soils are strongly humous to humous with a small increase in the Cox content having no particular influence on the classification. The total carbon content decreased in all cases, yet the soils still maintain its very high content which can be classified in sporadic cases only as high to medium. The immediate content of exchangeable basic cations was very low already in 1972 and dropped further; all PTPs on which soil analyses were made exhibited a very low content. The degree of soil sorption complex saturation increased in some horizons, the general classification of the soils being slightly unsaturated in terms of sorption.

Conspicuous quantitative changes in the whole area of the reserve occurred in the herb layer (synusia of the non-woody stand). Due to the development of the tree layer, particularly due to the more complex stand structure of tree classes III and IV, the soil surface is under a greater shade, the fact that was reacted upon by a heavy shrinkage in the herb layer number of species. Qualitative changes were not pronounced and the species composition did not change very much, but the reduced cover (quantitative index) was recorded in nearly all species. Fern species won a greater representation (*Athyrium filix-femina*); however, the increase is relative since the absolute values indicated that the share of the mentioned species remained practically same, only the relative representation of *Athyrium filix-femina* was significantly increased due to the heavy reduction of the cover rate in other species of the herbal synusia.

The number of live and dead trees was increased. European beech became an entirely dominant species of the tree layer. The species is going to determine the structure and texture of the whole reserve for several coming decennia. On the fertile sites, beech was capable of growth and created a new structure on the whole area despite the severe pressure of particularly red deer since its natural regeneration achieved a quantitative maximum on these sites. Norway spruce maintains its representation which is slightly over 10% in all studied indices (number of trees, basal area and timber volume). Due to the decline of the older generation there is a great reduction in the representation of silver fir in all indices, its present population amounting to 273 live trees with only 23 individuals representing diamater classes 1–4. Silver fir has now become a critically endangered tree species in the reserve and a range of measures to rescue the species was proposed within the new programme of management which takes into account also the hitherto development of the reserve and its mission.

The percentage of dead timber increased in the whole area. The formerly obvious influence of man – dead timber haulage from the reserve, which ceased before World War II – was entirely eliminated.

The natural regeneration exhibited a very dynamic development in the period under study. Now, the individual groups are differentiated to a much finer scale in terms of their height. At the same time, the groups become more diverse across the whole area, which makes the stand texture finer, too. The whole stand is heading towards a formation much more complex in terms of its structure and texture (a question still remains for how long). The mutual ratio of surfaces at the stage of maturation, optimum and decomposition gets gradually balanced.

CONCLUSIONS FOR THE FUTURE DEVELOPMENT OF THE AREA

With regard to
– the suggested course of the now spontaneous evolution processes in the reserve,
– the imperfection of the existing knowledge on the return of the by man influenced communities back to the evolution trajectory of the natural forest and related shortcomings at looking after forest reserves,
– the fact that there is a minimum of forest stands in the Czech Republic which are left to the spontaneous development (a great majority of the national nature reserves are still subjected to active forestry management);
these measures are proposed to be taken:
– The evolution of the forest community in the reserve should not be disturbed by tree felling.
– The fir regeneration, particularly on the plots which are at the stage of decomposition or at the stage of optimum, should be fenced against browsing in the form of small seclusion fences protecting the individual seedlings and the groups of seedlings.
– In contrast, any protection of the regenerated fir is excessive at the stage of maturation with regard to the expected long-term shade (up to the stage of decomposition, e.g. 200 years).
– The fir individuals approaching maturation should be individually protected against barking by commonly used methods (mechanical barriers, repellents).

– No selective measures are to be made in the regenerated fir in clusters.

– Seeds from fertile fir trees should be collected and introduced into stands adjacent to the reserve by sowing in seeding nurseries and by subsequent underplanting.

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Pralesovitý porost Razula po 23 letech (1972–1995)

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ABSTRAKT: V roce 1995 bylo provedeno opakované šetření dendrometrických, typologických a porostních charakteristik v Národní přírodní rezervaci Razula. Práce navazují na původní šetření z roku 1972, byly provedeny stejnou metodikou a následně byly vyhodnoceny změny, ke kterým ve sledovaném území došlo. U půd došlo ke zvýšení stupně sorpční nasycenosti, ostatní charakteristiky se změnily jen mírně. Na celé ploše rezervace došlo k výrazným kvantitativním změnám (silný pokles pokryvnosti) v bylinném patře, naopak po stránce kvalitativních znaků jsou změny velmi mírné, společenstva mají velmi podobné druhové spektrum jako v roce 1972. Příčinou jsou změny v dřevinném patře, kdy došlo k intenzivnímu vyplnění růstového prostoru bukem lesním rozvojem stromové třídy III a IV. Stará generace jedle bělokoré se definitivně rozpadá, mladší stromy se vyskytují pouze jednotlivě a populaci lze označit za kriticky ohroženou.

Klíčová slova: dynamika; monitoring; prales

Půdy jako nejstabilnější složka ekosystému jsou na sledovaném území středně až silně kyselé, hodnota aktivní kyselosti zůstala na víceméně stejné úrovni, případně mírně stoupla. V průměru se mírně zvýšil obsah oxidovatelného uhlíku, půdy jsou silně humózní až humózní a malé zvýšení obsahu Cox nemá z celkového hlediska vliv na změnu klasifikace. Obsah celkového dusíku ve všech případech poklesl, půdy si i nadále zachovávají jeho velmi vysoký obsah, v ojedinělých případech však již obsah

můžeme hodnotit pouze jako vysoký až střední. Okamžitý obsah výměnných bazických kationtů byl již v roce 1972 velmi nízký, dále poklesl a všechny TTP, na kterých byly prováděny půdní rozbory, mají obsah velmi nízký. Stupeň nasycení sorpčního komplexu půd u některých horizontů stoupl, celkově jsou půdy sorpčně mírně nenasycené.

V bylinném patře (synuzii nedřevnatého porostu) došlo k výrazným kvantitativním změnám na celé ploše rezervace. Vlivem rozvoje dřevinného patra – zejména tvor-

bou složitější porostní struktury ve stromové třídě III a IV – došlo k silnějšímu zastínění půdního povrchu, na což reagovalo bylinné patro silným početním úbytkem. Kvalitativní změny nebyly výrazné, garnitura druhů se příliš nezměnila, avšak pokles pokryvnosti (kvantitativní ukazatel) byl zaznamenán takřka u všech druhů. Významnější zastoupení získaly kapraďorosty (*Athyrium filix-femina*). Jedná se však o nárůst relativního zastoupení, neboť v absolutních hodnotách zůstala účast uvedeného druhu prakticky stejná, ale vzhledem k silnému poklesu hodnot pokryvnosti u ostatních druhů synuzie bylin stouplo významně relativní zastoupení druhu *Athyrium filix-femina*.

Zvýšil se počet živých i odumřelých stromů. Zcela dominantním druhem v dřevinném patře se stal buk lesní. Tato dřevina bude několik příštích desetiletí určovat strukturu i texturu celé rezervace. Na bohatých stanovištích dokázal buk odrůstat a vytvářet celoplošně novou strukturu i přes silný tlak zejména jelení zvěře, neboť na těchto stanovištích je jeho přirozená obnova na kvantitativním maximu. Smrk ztepilý si udržel své zastoupení mírně přes 10 % ve všech sledovaných ukazatelích (podle počtu stromů, výčetní základny i objemu kmenů). Vlivem odumírání starší generace došlo k velkému propadu v zastoupení jedle bělokoré ve všech ukazatelích. Současná populace čítá 273 živých stromů, přičemž v 1.–4. tloušťkové třídě je zastoupeno pouze 23 jedinců. Jedle bělokorá je nyní v rezervaci kriticky ohroženou dřevinou a v rámci navrženého managementu, který zohledňuje i dosavadní vývoj rezervace a její poslání, je navržena série opatření pro záchranu této dřeviny.

Na celé ploše stoupl podíl odumřelého dřeva. Zcela je eliminován dříve patrný vliv člověka – vyvážení odumřelého dřeva z rezervace, který skončil před druhou světovou válkou.

Přirozené zmlazení se ve sledovaném období rozvíjelo velmi dynamicky. Došlo k jemnější výškové diferenciaci jednotlivých skupin. Současně se skupiny více rozčlenily i po ploše, takže textura porostu je jemnější. Celý porost směřuje ke strukturálně i texturně složitějšímu útvaru (otázkou zůstává, na jak dlouho). Dochází k postupnému vyrovnání vzájemného poměru ploch stadia dorůstání, optima a rozpadu.

Na základě výsledků historického průzkumu, výsledků opakovaných šetření a s ohledem na:
– naznačený průběh nyní již spontánních vývojových procesů v rezervaci,
– nedokonalost existujících poznatků o návratu člověkem ovlivněných společenstev na vývojovou trajektorii přírodního lesa a z toho plynoucích nedostatků při péči o lesní rezervace,
– skutečnost, že lesních porostů ponechaných samovolnému vývoji je v ČR minimum (i většina národních přírodních rezervací je předmětem aktivních lesnických zásahů)
je navrženo:
– nezasahovat do vývoje lesního společenstva v rezervaci těžbou stromů,
– zmlazení jedle, zejména na plochách ve stadiu rozpadu a stadiu optima, plotit proti okusu formou malých oplocenek chránících jednotlivé semenáče i hloučky semenáčů,
– naopak ve stadiu dorůstání je ochrana zmlazené jedle nadbytečná vzhledem k předpokladu dlouhotrvajícího zástinu (až do stadia rozpadu např. 200 let),
– odrůstající jedince jedle chránit individuálně proti loupání běžně užívanými prostředky (mechanické zábrany, repelentní přípravky),
– neprovádět ani u zmlazené jedle selektivní zásahy v hloučcích,
– sbírat osivo z plodících jedlí a formou síjí v semeništích a následnou podsadbou ji vnášet do porostů přiléhajících k rezervaci.

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T-disease – a little investigated phenomenon of the beech (*Fagus sylvatica* L.) necrotic damage

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ABSTRACT: The paper deals with the T-disease as a hidden little known phenomenon of necrotic disease of beech in a pole-stage stand. By means of analysis of trunk cross-sections taken in necrotized places the outbreak of T-disease was dated and the time data on its oldest relic traces were obtained. Out of this, incidence frequency of the T-disease was evaluated retrospectively from 1999 to 1967 in relation to the stand thinning. A sporadic incidence frequency was found before the first thinning, in the period of 1967–1983, when it did not exceed 1%. Only in one case the frequency exceeded 1% (1.89% in 1975). The years after the first thinning are characterized by periods of a strong increase (1984, 1988 and 1993) and gradual decrease in the T-disease frequency. One of the possible causes of increase in T-disease frequency is cambial damage caused by local wounding of beech bark remaining in the thinned stand. Another cause of the T-disease frequency increase may also be changes in the stand microclimate after the thinning and fungal pathogenes activating.

Keywords: *Fagus sylvatica* L.; necrotic disease; T-disease; stand thinning

External manifestations of the tracheomycosis-type necrotic damage to beeches are bark necroses on trunks and branches which are visible by the naked eye. There also exists, however, a hidden form of necrotic damage which arises in a living tree, is visible only on cross-sections of the trunks or branches in the necrotic places and is T-shaped. BUTIN (1995) characterized the T-shaped scars in wood as rests of old cambial damage. The author consequently considers them to be defects indicating possible old wounding of beech bark. Different terms for this damage can be found in the literature: T-disease, T shaped defects, T-Flecken, T-Fleckigkeit, T-Krebs, T-Krankheit, T-Überwallung, T-vada, maladie du T, etc. (PERRIN 1981; BUTIN 1995; KLEIN 1997; DENGLER 1997; JANČAŘÍK et al. 2000). The different names reflect the lack of knowledge of damage causes. Some authors tend to support the opinion that the T-disease is caused by abiotic factors whereas others believe T-disease to have biological causes. The T-disease manifestations in beech can be caused, besides the abiotic factors, by fungal pathogens, mainly by fungi of the *Nectria* (Fr.) Fr. genus. Different names have, however, one common feature – they all reflect the mostly T-shaped relic trace well visible on the trunk cross-sections. This relic trace can be dated according to the annual rings (BUTIN 1995). So the year of origin of this damage can be established. This fact was used in this paper, the aim of which is:

a) to date the beginning of T-disease and the obtain time data on its oldest relic trace,

b) to evaluate T-disease frequency retrospectively from the year 1999,

c) to evaluate the data on T-disease frequency in relation to thinnings having been carried out in the beech pole-stage stand on the permanent study plot (PSP) Štagiar-Zábučie.

MATERIAL AND METHODS

The analysed material was represented by rings from trunk cross-sections led through the middles of randomly selected necroses and cross-sections made immediately under the necrosis. They were obtained from 75 cut trees (one ring from each tree) at the time of the fourth thinning (November 1999) in the beech pole-stage stand on the permanent study plot (PSP) Štagiar-Zábučie. This PSP is situated in the Kremnické vrchy hills, on a west-exposed slope, at an altitude of 590 m above sea level. In 1999 the stand was 53 years old, stocking 0.7–0.8, horizontal crown closure. The PSP consists of 4 partial plots (PP) designated as I, II, III and IV. In each PP different variants of crown thinning are studied (ŠTEFANČÍK 1984). The PSP is described in details by CICÁK and MIHÁL (2000).

The cross-section rings were dried at a room temperature. After drying, the cutting surface led through the necrotic wounding was faceted. On the rings prepared in this way each relic trace of the T-disease was evaluated and according to the annual rings the year of its origin was established (Fig. 1). Using the number of traces that
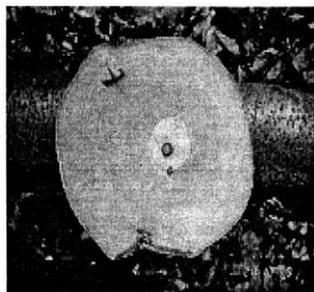

Fig. 1. Relic traces of T-disease on a stem cross-section

originated in individual years, retrospectively from 1999 to 1967, we calculated incidence frequency (expressed in per cent). The number of relic traces of the T-disease was higher (108) than the total number of analysed cross-section rings. Among the 75 cross-section rings, only one trace was found in 49 rings, two traces in 22 rings, three traces in three rings, and four traces were recorded in one ring. From the chosen samples of cross-section rings we took inoculation material for laboratory cultivation. Thus we confirmed the presence of the fungal parasite. Using the methods *in vivo* and *in vitro* we confirmed the occurrence of the parasite *Nectria coccinea* (Pers.) Fr. on the PSP Štagiar-Zábučie (CICÁK, MIHÁL 2000).

RESULTS AND DISCUSSION

Frequency values of T-disease relic traces in the years 1967–1999 are given in Fig. 2. These data can be classified into three partial periods. In the first partial period (1967–1983), the null values of frequency predominate. The low frequency values not exceeding 1% occur only sporadically. Only in one case did the frequency reach the value exceeding 1% (1.89% in 1975). The oldest relic trace of the T-disease recorded on the PSP Štagiar-Zábučie was dated to 1967. This statement is very close to the first known data on a strong increase in the bark necrosis incidence in

the pole-stage beech stands in Slovakia. In 1960 the bark necroses were observed in the pole-stage beech stands in the Koňuš and Kalša localities in East Slovakia and in 1962 in the Jalná locality in Central Slovakia (ŠTEFANČÍK 1974).

In the second partial period (1984–1999), higher values of frequency were recorded. The periodicity of a strong increase (in 1984, 1988 and 1993) and gradual decrease in the T-disease frequency was characteristic of this period. The lowest frequency values are close to those recorded in the first partial period. The first strong increase in the T-disease frequency reaching even 14.45% was recorded in 1984. This year was the year of the *first thinning* on the PSP Štagiar-Zábučie, which was carried out during the *growing season (June)*. The two next thinnings, *in March 1989* and *April 1994* repeatedly provoked an increase in the T-disease frequency. In contrast with the first thinning in 1984, in the latter two cases the established year of the T-disease frequency increase was not identical in any case with the year of carrying out the thinning. In both these cases a high frequency was recorded already one year before the thinning (1988 and 1993). The discordance between the T-disease frequency increase and stand thinning in 1989 and 1994 (when compared with 1984) seems to be caused just by the time of carrying out the thinning. This consideration is based on an assumption that the T-shaped scars in the wood represent rests of healed old cambial damage showing possible places of old bark wounding (BUTIN 1995). For this reason the increase in the frequency of T-disease relic traces coincides with the year of thinning carried out in the growing season, in June 1984. On the contrary, thinnings in 1989 and 1994 were carried out before the beginning of the growing season. This excludes time coincidence of the increase in cambial damage with the year of thinning.

A strong increase in the T-disease frequency after the first thinning in 1984 also confirms an increase in health (sanitary) selection in the next thinnings. In the first thinning (1984) the health selection intensity ranged from 1.5 to 5.5% on all four PP, but in the third thinning (1994), several times higher values (11.1–20.7%) were recorded (ŠTEFANČÍK I., ŠTEFANČÍK L. 1999).
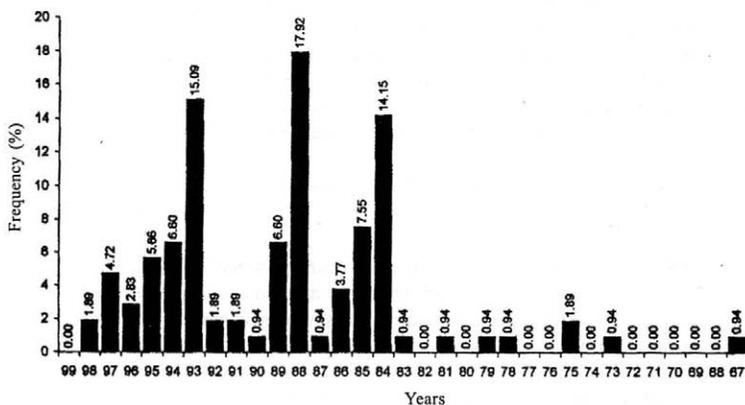

Fig. 2. Frequency values of T-disease relic traces in the years 1967–1999

As mentioned above, one of the possible causes of increase in the T-disease frequency is cambial damage arising on the wounded bark of trees remaining in a stand after each thinning. ŠTEFANČÍK (1978) found that the number of damaged trees per 100 trees cut during the thinning ranged from 6 to 71. This author explains the large differences in the number of damaged trees as a result of many causes, such as the thinning timing, thinning technology, workers carrying out the thinning. We presuppose the striking increase in the T-disease frequency to result not only from the mechanical wounding of remaining trees. Another cause may be the changes in the stand microclimate after thinning which may activate fungal parasites, in the case of PSP Štagiar-Zábučie the fungi of the *Nectria* genus. The years after a steep increase in the T-disease are characterized by a slow gradual decrease of frequency (Fig. 2). This may be caused by gradual microclimate stabilization made possible by expansion of beeches into the spaces vacated after thinning.

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T-choroba – málo preskúmaný fenomén nekrotického poškodenia buka (*Fagus sylvatica* L.)

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ABSTRAKT: V príspevku sa venujeme problematike T-choroby ako skrytému a málo známemu fenoménu nekrotického poškodenia buka v poraste bukovej žrďoviny. Analýzou kotúčov z priečnych rezov kmeňov v mieste nekróz sme datovali vznik T-choroby a získali časový údaj o jej najstaršej reliktnej stope. Okrem toho sme vyhodnotili frekvenciu T-choroby spätne od roku 1999 až do roku 1967 vo vzťahu k prebierkovým zásahom. Zistili sme sporadický výskyt nízkych hodnôt frekvencie pred prvým prebierkovým zásahom, ktoré od roku 1967 až po rok 1983 nedosahovali ani 1 %. Len v jednom prípade frekvencia dosiahla vyššiu hodnotu ako 1 % (1,89 % v roku 1975). Pre roky po prvom prebierkovom zásahu je charakteristická periodicita prudkého nárastu (rok 1984, 1988 a 1993) a postupného poklesu hodnôt frekvencie T-choroby. Jednou z možných príčin nárastu frekvencie T-choroby mohli byť kambiálne poškodenia, ktoré vznikajú na miestach poranenia bukovej kôry kmeňov stromov zostávajúceho porastu po každej prebierke. Ďalšou príčinou nárastu frekvencie mohla byť aj aktivizácia hubových patogénov vyvolaná zmenou mikroklímy v poraste po prebierke.

Kľúčové slová: *Fagus sylvatica* L.; nekrotické ochorenie; T-choroba; prebierkový porast

Vonkajším prejavom nekrotického poškodenia buka tracheomykózneho typu sú nekrózy kôry na kmeňoch a na konároch, ktoré sú viditeľné i voľným okom. Existuje však aj skrytá forma nekrotického poškodenia, ktorá vzniká v stojacom strome a je viditeľná na priereze sekcie kmeňa alebo konára v mieste nekrózy a má tvar písmena T (obr. 1).

Reliktná stopa tvaru písmena T sa dá odčítať na ročných prírastkoch dreva, čo umožňuje určiť rok vzniku poškodenia. Túto skutočnosť sme využili v tejto práci, v ktorej sme si dali za cieľ:
a) datovať vznik T-choroby a získať časový údaj o jej najstaršej reliktnej stope,

b) vyhodnotiť frekvenciu T-choroby spätne od roku 1999,

c) údaje o frekvencii T-choroby vyhodnotiť vo vzťahu k prebierkovým zásahom, ktoré sa doteraz urobili v poraste bukovej žrďoviny na trvalej výskumnej ploche (TVP) Štagiar-Zábučie.

Analytický materiál tvorili kotúče z priečnych rezov kmeňov vedených stredom náhodne vybratých nekróz a rezov tesne pod nekrózou. Získali sme ich zo 75 spílených stromov (z každého stromu jeden kotúč) v čase štvrtého prebierkového zásahu (november 1999) v poraste bukovej žrďoviny na trvalej výskumnej ploche (TVP) Štagiar-Zábučie. Podrobná charakteristika TVP je popísaná v práci CICÁK, MIHÁL (2000).

Kotúče priečnych rezov kmeňov sme sušili pri laboratórnej teplote. Po vysušení sme reznú plochu vedenú stredom nekrotickej rany vybrúsili. Na takto upravených kotúčoch sme vyhodnotili každú reliktnú stopu T-choroby a podľa letokruhov zistili rok jej vzniku. Z údajov o počte stôp prislúchajúcich jednotlivým rokom (spätne od roku 1999 až po najstaršiu reliktnú stopu) sme vypočítali percento frekvencie.

Výsledky frekvencie reliktných stôp T-choroby za časový úsek od roku 1967 až po rok 1999 uvádzame na obr. 2. Získané údaje o frekvencii môžeme rozdeliť do dvoch dielčich časových úsekov.

V prvom dielčom časovom úseku (od r. 1967 do r. 1983) majú prevahu nulové hodnoty frekvencie. Sporadicky sa vyskytujú nízke hodnoty frekvencie, ktoré nedosahujú ani 1 %. Len v jednom prípade frekvencia dosiahla vyššiu hodnotu ako 1 % (1,89 % – rok 1975). Najstaršia reliktná stopa T-choroby, ktorú sme zistili, je datovaná do roku 1967.

V druhom dielčom časovom úseku (od r. 1984 do r. 1999) sa vyskytujú výrazne vyššie hodnoty frekvencie. Pre tento časový úsek je charakteristická periodicita prudkého nárastu (rok 1984, 1988 a 1993) a postupného poklesu hodnôt frekvencie T-choroby.

Prvý výrazný nárast frekvencie až na hodnotu 14,15 % sme zistili v roku 1984. Ide súčasne o rok *prvého prebierkového zásahu* na TVP Štagiar-Zábučie, ktorý sa uskutočnil *vo vegetačnom období (jún)*. Ďalšie dva zásahy, *v marci 1989* a *v apríli 1994*, opakovane vyvolali zvýšenie hodnôt frekvencie T-choroby. Zistený rok zvýšenia frekvencie T-choroby však nebol ani v jednom prípade zhodný s rokom uskutočnenia prebierkového zásahu, tak ako to bolo pri prvom prebierkovom zásahu v roku 1984. V obidvoch prípadoch sme vysoké hodnoty frekvencie zaznamenali rok pred prebierkovými zásahmi (1988 a 1993). Za príčinu nezhody zisteného zvýšenia frekvencie T-choroby pri prebierkovom zásahu v roku 1984 v porovnaní s prebierkovými zásahmi v rokoch 1989 a 1994 môžeme pokladať práve dobu uskutočnenia prebierkového zásahu. Vychádzame pritom z úvahy, že jazvy v dreve v tvare písmena T sú zvyšky starých zavalených kambiálnych poškodení, ktoré ukazujú na možné bývalé miesta poranenia bukovej kôry. Preto je zvýšenie frekvencie reliktných stôp T-choroby časovo zhodné s rokom prebierkového zásahu, ktorý sa uskutočnil vo vegetačnej dobe (jún 1984). Naopak, prebierkové zásahy v rokoch 1989 a 1994 sa uskutočnili pred nástupom vegetačnej doby, čo vylučuje možnosť výskytu zvýšenej frekvencie kambiálneho poškodenia, ktoré by bolo časovo zhodné s rokom zásahu.

Predpokladáme, že výrazný nárast frekvencie T-choroby nie je spôsobený len mechanickým poškodením ostávajúcich stromov. Ďalšou príčinou môžu byť aj zmeny v mikroklíme porastu po prebierke, ktoré môžu vplývať na aktivizáciu hubových parazitov, v prípade TVP Štagiar-Zábučie na huby rodu *Nectria* (Fr.) Fr. Pre roky po prudkom náraste frekvencie T-choroby je charakteristický pozvoľný pokles frekvencie (obr. 2). Toto môže byť spôsobené procesom ustaľovania mikroklímy vďaka expanzii buka do uvoľnených priestorov porastu po prebierkach.

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Epidemiology of occupational accidents of Finnish forestry workers

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ABSTRACT: The aim of this study was to analyze the occupational accidents of Finnish forestry workers. The subjects of this analysis were 228 loggers. They reported 44 accidents during the past 12 months. The main causes of the accidents were losing of one's balance, a small flying object, and the chain saw. The most typical work phase was delimbing and felling. The lower limbs and back were affected most often. The mechanization of logging operations and the increased use of personal protectors have reduced the accident frequency of the loggers by 54%.

Keywords: near-accidents; part of body; type of accident; personal protectors; questionnaire

Forest work is one of the most hazardous jobs. The fatality rate of forest workers was 49 times higher than that of all workers in Australia (DRISCOLL et al. 1995). In the United States, the fatality rate of forestry and logging workers was 22 times higher than that of the overall employed population (TOSCANO, WINDAU 1994). In New Zealand, the average fatality rate in forest work was 11.5 times higher than in the overall workforce (CRYER, FLEMING 1987). "Logging camps and contractors" were the most dangerous industry based on the occupational fatality rates of the United States (LEIGH 1995).

The felling of trees and the rolling of logs were the most typical causes of fatal accidents among forest workers. Motor vehicles, machines, and especially tractors, caused many deaths (DRISCOLL et al. 1995; MARSHALL et al. 1994; SALISBURY et al. 1991). Chainsaws were the main cause of injuries for loggers (GASKIN et al. 1988; HOLMAN et al. 1987; MARSHALL et al. 1994).

Hands, legs, feet, and arms were the commonest parts of the body injured in loggers (CROWE 1986; GASKIN et al. 1988; KAWACHI et al. 1995; HELMKAMP, DERK 1999). In fatal accidents, multiple injuries, internal injuries, and head injuries were the most typical (DRISCOLL et al. 1995; HOLMAN et al. 1987). The aim of this study was to analyze the occupational accidents of forestry workers in Finland.

MATERIALS AND METHODS

As part of a broader Nordic study investigating accident prevention, a postal questionnaire was sent to 450 Finnish loggers in the spring 1986. Despite two reminders, only 228 questionnaires (51%) were returned. If those who had retired from logging work were screened away from the original sample, the response rate would have risen to 70% (KLEN 1997).

The occupational accidents of the subjects were checked for the last 7–9 years from the company's records. In the questionnaire, the subjects reported their compensation claims from accidents during the past 12 months, and also the hazards during the past 12 months which would have injured them if they had not used personal protectors. The concordance of self-reported accidents with company-recorded accidents was excellent (KLEN, OJANEN 1998).

RESULTS

The company accident records included 35 accidents to the loggers participating in this study. 27 loggers were involved in one accident, whereas four were involved in two accidents during the follow-up period.

The subjects had reported 44 accidents at work during the past 12 months. 33 loggers had been involved in one accident, four in two accidents, and one in three accidents. Four out of five forest workers had avoided occupational accidents during the past year. The accident frequency (accidents per 1,000 work years) of the subjects was 192.98.

The loggers encountered altogether 221 near-accidents during the past 12 months. This means an average of 0.97 near-accidents per forest worker. The near-accidents accumulated strongly, because the mean of near-accidents was 2.46 for those 90 loggers who reported near-accidents. The maximum number of near-accidents was 20 per year. The loggers reported also 88 hazardous situations where personal protectors had prevented an accident.

Table 1 shows that the causes of accidents, near-accidents and hazardous situations were very different. The main causes of accidents were losing of one's balance, a

Table 1. Source of accidents, hazardous situations and near-accidents among Finnish forestry workers (in %)

Source	Accidents (n = 38)	Near accidents (n = 220)	Hazards (n = 88)
Unexpected falling of a trapped tree	8	21	8
Hand tools	0	6	6
Chain saw	13	38	16
A large falling object, e.g. butt end of a tree	8	9	15
A small bounding object, e.g. rebounding sapling	16	10	31
Losing of one's balance	39	8	14
Overexertion	13	7	7
Other	3	1	3
Total	100	100	100
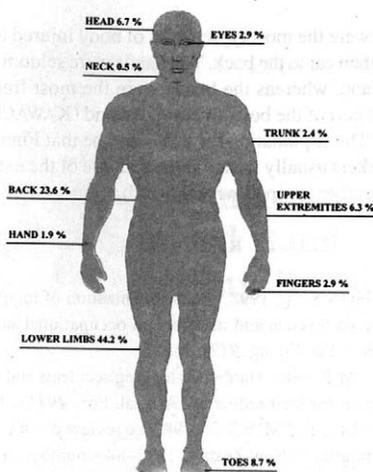
Fig. 1. Injured parts of the body of Finnish forestry workers

small bounding object, chain saw, and overexertion. Chain saw, unexpected falling of a trapped tree, and a small bounding object caused most of near-accidents. The main causes of the hazardous situations were a small bounding object, chain saw, and a large falling object.

In the accident situation, only 5% of the loggers followed safety rules. 74% of the forest workers did not follow the safety rules during the accident situation, and 21% could not say. In the near-accident situations 10% of the loggers followed safety rules. 56% of the subjects did not follow the rules, and 34% could not say.

Thirty-eight per cent of the loggers said that they changed their working habits after a near-accident. 19% of the subjects did not change their behavior. Almost half of the loggers (48%) reported having broken the safety rules at least once a week.

Eighty-nine per cent of the loggers said that the use of personal protectors had increased the feeling of safety in their job. 5% of the subjects reported no effect, and the remaining 5% could not say. 45% of the subjects assessed that their working habits became less careful when using personal protectors, 41% said more relaxed, and 14% said faster.

Twelve per cent of the loggers agreed with the statement that accident risks and hazards are part of the logger's work. 11% disagreed and 77% could not say.

The most typical work phase at the moment of the accident was delimbing (43%). Felling (31%) came second. 21% of the accidents occurred during piling up.

The lower limbs were most often affected (Fig. 1). Next came the back. Then came the toes and the head.

DISCUSSION

In this study the accident frequency was 192.98. According to the official statistics on forest accidents forest workers had 2,547 occupational accidents in 1986 (Ministry of Social Affairs and Health 1997). The number of forest workers was 30,000; thus the accident frequency was 84.90. The higher accident frequency in this study can be partly explained by the subjects reporting even accidents

that did not cause sick leave, whereas the official statistics included only accidents causing at least three days of sick leave. On the other hand, it is possible that the loggers did not report all their accidents to the insurance company because of difficulties in reporting.

This study shows that forestry work is a hazardous and strenuous activity. Accidents and near-accidents are still a part of forest work. The accident frequency of forestry workers however fell from 53.7 accidents per million work hours in 1986 to 22.6 in 1994, i.e. by 54% (Ministry of Social Affairs and Health 1997). Along the same line, the accident frequency of forest workers in the United States fell by 40% from 1972 to 1988 (RUMMER 1995). In Sweden, the accident frequency of chainsaw operators fell by 48% and that of logging machine operators by as much as 70% between 1970 and 1990 (AXELSSON 1998). Obviously the mechanization of logging operations and the increased use of personal protectors explained most of this positive trend.

The results show that the causes of accidents, near-accidents and hazardous situations differed greatly. The main cause of accidents was losing of one's balance, whereas the main cause of near-accidents was the chain saw, and a small bounding object was the main cause of hazardous situations. These results did not confirm the previous view that searching for near-accidents gives information about the hazards of actual accidents (LAITINEN 1984).

Falls due to losing of one's balance were the main cause of accidents in Finland. This is in line with Australian observations (CROWE 1986). In Alaska, the majority of the nonfatal logging injuries were caused by being struck by an object, followed next by falls. The most common objects striking the workers were trees and logs (HUSBERG et al. 1998). Falls were hazardous in the forest when one worked with the rotating blade of the chain saw. Chain saws were also a significant source of accidents, as reported in previous studies (GASKIN et al. 1988; HOLMAN et al. 1987; MARSHALL et al. 1994).

Feet were the most typical part of body injured in forest work; then came the back. The hands were seldom injured in Finland, whereas the hands were the most frequently injured part of the body in New Zealand (KAWACHI et al. 1995). The explanation for this could be that Finnish forest workers usually wear gloves because of the extremely cold weather (even down to –30°C).

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Epidemiologie pracovních úrazů finských lesních dělníků

ABSTRAKT: Cílem studie byla analýza pracovních úrazů finských lesních dělníků. Objektem analýzy se stalo 228 dřevorubců, kteří oznámili během uplynulých 12 měsíců 44 úrazů. Hlavními příčinami těchto úrazů byla ztráta vlastní rovnováhy, drobný letící předmět a řetězová pila. Typickou pracovní operací bylo odvětvování a kácení. Nejčastěji byly postiženy dolní končetiny a záda. Mechanizací těžebních operací a zvýšeným používáním osobních ochranných pomůcek se frekvence úrazů dřevorubců snížila o 54 %.

Klíčová slova: provozní nehody; část těla; typ úrazu; osobní ochranné pomůcky; dotazník

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