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Structure, production and regeneration processes in the primeval oak forest in the National Nature Reserve Boky

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Abstract
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The National Nature Reserve Boky near Budča (district Zvolen) is an extraordinarily precious and important object of studies, equally from the viewpoint of natural sciences as well as for nature protection. The aim of this study was to examine the structure, production and regeneration abilities of the primeval mixed deciduous forest at the site in 2004 and to compare the actual values with the corresponding values obtained in 1994. We focussed our investigation on the forest type Corneto-Quercetum. In the examined biocoenosis, *Quercus pubescens* is not present, it is substituted by its ecological equivalent *Quercus cerris*, growing here at the northen boundary of its distribution range. We measured selected dendrometrical biometrical variables on the trees (thicker than 2 cm) on three permanent research plots established in the Reserve. The evaluation revealed that there is a rather high variability in the total number of trees and timber volume, (in 1994 the number of trees in separate stages ranged between 747 and 924, and in 2004 between 614 and 1,000 per ha). *Quercus petraea* was the most abundant species in all permanent research plots (PRP). In case of large timber (stemwood), the share of winter oak ranged between 4%–71% and between 35%–65% in 1994 and in 2004, respectively and the share of *Quercus cerris* between 16% and 27% and between 13% and 24%. The diameter interval was found the widest for the advanced phase of disintegration stage turning into the initial phase of ingrowth stage on PRP 3. The smallest variation interval was obtained for PRP 1 – the optimum stage. According to the volume of large timber, the average standing volume ranged between 340–470 m^3 and between 322–330 m^3 per ha in 1994 and in 2004, respectively. Tree regeneration processes running in this primeval forest are different, on the background of differences in their ecological tolerance to light corresponding to the individual developmental stages. The best conditions for growth of *Quercus cerris* and *Quercus petraea* seedlings were observed till the end of the optimum stage.

Key words
NNR Boky, *Quercus cerris*, primeval forest, structure, production, regeneration

Introduction

The importance of research into primeval forests has increased dramatically over the last 20–30 years, both in Europe and in the world-wide context – thanks to establishment of a separate scientific working group within the International Union of Forestry Research Organisation (IUFRO). This group has been settled in Munich (Germany), and it coordinates the study and research on primeval forests (Bublinec and Pichler et al., 2001).

The development of natural mixed oak forests is ruled by very complex developmental processes, depending on different ecological demands of the woody plants, their different growth potential and physical age. More fertile is the site, more conspicuous are differences in stand structure in individual stages of forest development. Over the whole developmental cycle, both the spatial and vertical structure of natural mixed oak forests at sites with middle-rated production are much more differentiated in comparison with natural forests in higher situated forest vegetation tiers. Prevalent is two-layered vertical structure, evident already in the advanced optimum stage and maintaining over the whole decomposition stage and over the first half of the ingrowth stage (Vyskot et al., 1981; Korpeľ, 1989; Korpeľ and Saniga, 1995).

The Slovak forest communities in the 2-nd and 3-rd forest vegetation tiers have been exposed to a considerable human-induced influence, consequently, the original state of these stands has been disturbed to a considerable extent. On the other hand, in Central Slovakia have been preserved remnants of the original primeval ecosystems in four important nature reserves: Boky, Kašivárová, Lesná and Sitno. In Eastwestern Slovakia, the close-to primeval status has been preserved in the NNR Kokošovská dubina and NNR Bujanov (Korpeľ, 1989,1995). In the European context, important remnants of primeval forests with pedunculate oak and sessile oak are mainly in Romania (Smejkal et al., 1995), some also in Poland (Jaworski et al., 2005).

The preserved remnants of primeval oak forests with sessile oak distinctly show that the better are site conditions, the more intensive is natural tree elimination, and vice versa (Korpeľ, 1989). This trend has also been confirmed in oak primeval forests in Romania (Smejkal et al., 1995). For the forest unit Lipova (Neudorf) it was found that the concerned primeval mixed oak forest has just reached its optimum stage with prevailing two-layered vertical structure, the upper layer consisting of sessile oak and Turkey oak, the lower created by linden, Norway maple, hedge maple, hornbeam and elm. The research on productivity of these primeval forests revealed that the maximum age of sessile oak was 350 years. Turkey oak in these forest ecosystems can reach 220–230 years. These findings about the age are in accordance with the data obtained in the primeval mixed oak forests in the NPR Boky in Slovakia. The vertical structure of the primeval forest in the optimum stage is mostly distinct differentiated. This corresponds to the extreme site conditions unfavourable for creation of a connected horizontal canopy. On the other hand, namely these conditions promote natural regeneration over the whole developmental cycle of the primeval forest (Korpeľ, 1995; Korpeľ and Saniga, 1995).

In terms of productivity, the concerned primeval mixed oak forests in Romania are better, mainly based on higher annual precipitation totals and thanks to better physical properties of their soils (Smejkal et al., 1995).

The aim of this work was to analyse selected variables concerning structure, production and regeneration processes in the natural mixed oak forest in the NNR Boky over the recent 10 years.

Methods

The National Nature Reserve (NNR) Boky is situated on a steep slope at the southern border of the Kremnické vrchy Mts., between the villages Budča and Hronská Breznica, district Zvolen. The altitude ranges from 280 to 589 m asl, the mean annual temperature is 6.2–8.0 °C, vegetation period comprises 154–164 days. The mean annual precipitation total ranges from 700 to 820 mm, the number of days with snow cover is 55–80 a year (Bublinec and Pichler, et al. 2001). According to the valid FMP – forest management plan (2003–2012), the area of the NNR Boky is 165.69 ha. At present is the territory of the NNR Boky protected according to the highest protection degree 5, specified by the Act No. 543/2002 Z. z. on Nature and Landscape Protection (Burkovský and Rybár, 2004). The reserve is situated just at the boundary of the distribution area of the Turkey oak (*Quercus cerris*). The occurrence of Turkey oak at different localities and with different admixtures of other woody plants allows us to study its ecology and increment trends. The obtained knowledge can subsequently be applied in Turkey oak forests in Southern Slovakia (Magic, 1968). The forest stands in the protected territory belong to the oak (1.), beech-oak (2.) and oak-beech (3.) vegetation tiers comprising four forest type groups (ftg) with five forest types (ft). The most frequent (53%) is the ftg Fageto-Quercetum. The proportion of Corneto-Quercetum is 32% of the area. In the valleys are present Tilieto-Aceretum 13%. Very low (2%) is presence of Querceto-Fageto-tiliosum (Hančinský, 1972).

The dynamics of changes in the primeval forest structure within its developmental cycle was studied using the methods by Korpeľ, 1989. Apart from the values measured in 2004 (Halamová, 2005), we used the values collected by the department staff in 1994 (Pindiaková, 1995).

The research ran on a series of three permanent research plots (PRP) established in 1974 by the staff of the Department of silviculture. The PRP area is 0.50 ha, and they are situated at the same altitude and have the same exposure with the aim to reflect the biggest differences in the stand structure and growing stock within the group Corneto-Quercetum (CoQ) .

PRP 1 was established in the territory part with unilayered vertical structure and rather low number of trees characterizing the initial phase of the optimum stage. PRP 2 was established in the part with distinct altitudinal differentiation and with considerably higher number of trees in the upper and middle layer compared to the low layer. The development stage in this part is characteristic for the advanced phase of ingrowth stage. PRP 3 was established in the part with lower tree number in the upper layer with ununiforms gaps in the canopy and, on the other hand, higher total number of registered trees and higher volume of dead trees. The development phase in this part is at the boundary between the decomposition stage and the beginning of the ingrowth stage.

On each research plot we established a transect 10 m in width. The aim was to provide a detailed analysis of stand structure and exploitation of the growth space by crowns of the individual woody plants.

Over the whole plot we recorded the following variables concerning the trees:

- o Tree diameter $d_{1,3}$ with an accuracy of 1 mm (trees with diameter bigger than 2 cm)
- o Tree class (relative height status).

Biometric variables measured at the transects:

- o Spacing vectors for trees with diameter $d_{1,3}$ bigger than 2 cm x, y
- o Tree height with an accuracy of 0.5 m
- o Crown height with an accuracy of 0.5 m
- o Crown projection x_1–x_4 with an accuracy of 0.1 m.

We provided with the measured height values (at least 3 values for each diameter class) for construction of height curves, separately for each plot and woody plant (oak, Turkey oak, other broadleaved species). The smoothed values of height and diameter $d_{1,3}$ were compared with the values in Schwappach´s tables to obtain the volume of large timber of the living trees corresponding to the separate woody plants.

The crown volume for the woody plants (Turkey oak, oak, other broadleaved species) on the transects was calculated using the formula: $Ck = \pi/8 \cdot b2 \cdot l$ (Jurča, 1968), where b = crown width in m, l = crown length in m.

Providing with the data on the horizontal projection and the mean upper height values, we calculated the growth space of the primeval forest. The summary value of crown volumes over the transect divided by the volume of its growth space and multiplied by 100 gives the value expressing exploitation of the growth space by tree crowns from the viewpoint of production.

The inventory of the natural regeneration was performed on the individual transects according to the woody plant and tree height: (lower than 20 cm, from 21 to 50 cm, from 51 to 80 cm, from 81 to 130 cm and higher than 131 cm up to the diameter of $d_{1,3}$ 2 cm).

Results

Tree numbers, diameter and volumetric structure of the primeval forest

The number of all registrated trees ($d_{1,3}$ bigger than 2 cm) (Table 1) on PRP 1 decreased from 747 ex ha^{-1} in 1994 to 700 ex ha^{-1} in 2004, which represents a decrease by 6.3%. The low number of trees also detects that the stand is at the beginning of its optimum stage. The measurements carried out in 2004 also revealed certain changes in proportion of individual woody plants. The current share of sessile oak is 65.1%, Turkey oak 19.4%, the other woody plants participate with 15.4%. From the results it is evident that there is an increasse in proportion of other broadleaved species by almost 10% over the recent 10 years. The total number of trees on PRP 2, in advanced ingrowth stage, decreased by autoreduction from 882 ha^{-1} in 1994 to 614 ha^{-1} in 2004 (Table 2). Concerned are primarily tree classes 16–36 cm. The observations carried out in 2004 also resulted in detection of somewhat changed stand species composition. The sessile oak participated by 47.6%, Turkey oak by 23.8%, the share of the other broadleaved species was 28.6%. Also on this plot was detected and increase in proportion of the other broadleaved species – by 7%. The highest number of trees was found on the plot PRP 3 at the boundary between the advanced decomposition stage and the beginning of ingrowth stage (Table 3). The number of trees has increased over the recent 10 years from 924 per ha^{-1} in 1994 to 1,000 per ha^{-1} in 2004, i.e. by 8.2%. This increase is most evident in the first diameter class (by 86 ex ha^{-1}). Also on this plot, there was an increase in proportion of the other woody plants by 13.5%. The highest contribution to the stand differentiation has sessile oak. In lower diameter classes is this woody plant more abundant than Turkey oak which confirms its higher tolerance to the shading by the upper tree layer.

The smallest differences in the species composition after 10 years were found in oak and Turkey oak, the biggest in the other woody plants. The sessile oak was the most abundant wood species over the whole developmental cycle, with the number of trees considerably fluctuating during the ingrowth stage (PR2). The distribution of trees according to the individual woody plants and the changes from 1994 to 2004 are expressed using diameter frequency polygons (Figs 1–3). The frequency polygon describing the optimum stage (PRP 1) in 1994 had two peaks. Neither the today state of this part can be fitted with a curve with one single peak (Fig. 1). Also the frequency polygon describing the stage of ingrowth (PRP 2) had in 1994 two distinct peaks, and the measurements performed in 2004 confirmed that the two peaks have been maintained (Fig. 2). The frequency polygon representing the advanced phase of decomposition stage (PRP 3) shows mostly decreasing trend, indicating structure similar to selection forest (Fig. 3). The trend found in 2004 was very similar.

The evaluation of large timber volume revealed that the difference between years 1994 and 2004 was the smallest on the plot in the optimum stage (PRP 1). The volume decreased from the initial value of 340.4 m^3 ha^{-1} to the current 330.3 m^3 ha^{-1} what means that here is the growing stock the most consolidated. The highest proportion of the growing stock volume was in 1994 represented by the diameter classes III (24–36 cm) – 44% and IV – 35.3% from the total. Similar tendency was observed in 2004 (Table 1).

Table 1. Number of trees, basal area and volume according to tree species and diameter class on PRP 1 (permanent research plot) in 1994 and 2004 (converted per 1 ha)

Tree species Diameter class (cm)		*Quercus petraea*			*Quercus cerris*			Other species			Total		
		Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)
						1994							
I.	AV	204	1.85	10.03	31	0.38	2.02	41	0.18	0.50	276	2.40	12.55
8.1–16.0	%	38.38	9.91	5.13	17.98	2.73	1.40	100.00	100.00	100.00	37.01	7.35	3.69
II.	AV	124	3.98	32.46	31	1.04	8.02	–	–	–	155	5.02	40.48
16.1–24.0	%	23.25	21.31	16.59	17.98	7.50	5.56	–	–	–	20.73	15.34	11.89
III.	AV	169	8.40	108.60	61	4.27	41.09	–	–	–	230	12.67	149.69
24.1–36.0	%	31.73	44.95	55.51	34.83	30.82	28.48	–	–	–	30.71	38.73	43.97
IV.	AV	35	4.45	44.56	45	6.68	75.63	–	–	–	80	11.13	120.19
36.1–52.0	%	6.64	23.83	22.77	25.84	48.20	52.41	–	–	–	10.76	34.03	35.30
V.	AV	–	–	–	6	1.49	17.54	–	–	–	6	1.49	17.74
52.1–72.0	%	–	–	–	3.37	10.75	12.15	–	–	–	0.79	4.55	5.15
Total	AV	532	18.68	195.65	174	13.86	144.29	41	0.18	0.50	747	32.72	340.44
	%	71.13	57.10	57.47	23.36	42.37	42.38	5.51	0.53	0.15	100.00	100.00	100.00
						2004							
I.	AV	156	1.64	8.45	22	0.16	–	106	0.38	0.78,	284	2.17	9.23
8.1–16.0	%	34.21	7.08	4.11	16.18	1.39	–	98.15	89.15	75.19	40.57	6.26	2.79
II.	AV	98	3.07	22.87	24	0.80	7.43	2	0.05	0.26	124	3.91	30.55
16.1–24.0	%	21.49	13.23	11.12	17.65	7.16	6.01	1.85	10.85	24.81	17.71	11.26	9.25
III.	AV	152	10.78	92.91	50	3.61	38.51	–	–	–	202	14.40	131.42
24.1-–36.0	%	33.34	46.48	45.18	36.76	32.49	31.16	–	–	–	28.86	41.43	39.79
IV.	AV	46	6.65	69.71	34	4.89	56.83	–	–	–	80	11.54	126.54
36.1–52.0	%	10.09	28.67	33.90	25.00	43.95	45.99	–	–	–	11.43	33.21	38.32
V.	AV	4	1.06	11.71	6	1.67	20.80	–	–	–	10	2.73	32.51
52.1–72.0	%	0.88	4.56	5.69	4.41	15.00	16.83	–	–	–	1.43	7.84	9.84
Total	AV	456	23.21	205.64	136	11.12	123.57	108	0.42	1.03	700	34.75	330.25
	%	65.14	66.78	62.27	19.43	31.99	37.42	15.43	1.22	0.31	100.00	100.00	100.00

AV – absolute value

Table 2. Number of trees, basal area and volume according to tree species and diameter class on PRP 2 (permanent research plot) in 1994 and 2004 (converted per 1 ha)

Tree species Diameter class (cm)		*Quercus petraea*			*Quercus cerris*			Other species			Total		
		Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)
1994													
I.	AV	308	2.09	8.57	72	0.41	1.72	190	0.83	2.66	570	3.33	12.95
8.1–16.0	%	67.84	13.57	5.38	30.51	1.59	0.56	98.96	94.29	89.70	64.63	7.93	2.76
II.	AV	64	1.86	14.78	6	0.15	1.18	2	0.05	0.31	72	2.06	16.26
16.1–24.0	%	14.10	12.05	9.29	2.54	0.58	0.38	1.04	5.71	10.30	8.16	4.91	3.46
III.	AV	30	1.88	18.47	18	1.52	16.06	–	–	–	48	3.40	34.53
24.1–36.0	%	6.61	12.19	11.61	7.63	5.94	5.22	–	–	–	5.44	8.12	7.35
IV.	AV	38	5.57	65.27	120	18.10	216.98	–	–	–	158	23.68	282.25
36.1–52.0	%	8.37	36.12	41.02	50.85	70.60	70.57	–	–	–	17.91	56.44	60.11
V.	AV	14	4.02	52.03	20	5.46	71.56	–	–	–	34	9.48	123.58
52.1–72.0	%	3.08	26.07	32.70	8.47	21.29	23.27	–	–	–	3.86	22.60	26.32
Total	AV	454	15.43	159.11	236	25.64	307.49	192	0.88	2.97	882	41.95	469.57
	%	51.47	36.79	33.89	26.76	61.12	65.48	21.77	2.09	0.63	100.00	100.00	100.00
2004													
I.	AV	194	2.26	7.94	46	0.35	1.78	166	0.91	5.23	406	3.51	14.95
8.1–16.0	%	66.44	17.86	6.08	31.51	2.21	0.97	94.32	77.68	72.76	66.12	11.89	4.65
II.	AV	32	1.08	8.64	2	0.08	0.61	10	0.26	1.96	44	1.42	11.21
16.1–24.0	%	10.96	8.58	6.61	1.37	0.51	0.33	5.68	22.32	27.24	7.17	4.82	3.49
III.	AV	22	1.38	13.59	10	0.82	8.64	–	–	–	32	2.20	22.23
24.1–36.0	%	7.53	10.90	10.41	6.85	5.24	4.70	–	–	–	5.21	7.46	6.91
IV.	AV	34	5.23	62.02	82	12.84	156.52	–	–	–	116	18.07	218.54
36.1–52.0	%	11.64	41.34	47.49	56.16	81.74	85.18	–	–	–	18.89	61.21	67.97
V.	AV	10	2.70	38.40	6	1.62	16.20	–	–	–	16	4.31	54.60
52.1–72.0	%	3.42	21.33	29.40	4.11	10.30	8.81	–	–	–	2.61	14.61	16.98
Total	AV	292	12.64	130.60	146	15.71	183.74	176	1.17	7.19	614	29.52	321.53
	%	47.56	42.82	40.62	23.78	53.23	57.15	28.66	39.47	22.37	100.00	100.00	100.00

AV – absolute value

Table 3. Number of trees, basal area and volume according to tree species and diameter class on PRP 3 (permanent research plot) in 1994 and 2004 (converted per 1 ha)

Tree species		*Quercus petraea*			*Quercus cerris*			Other species			Total		
Diameter class (cm)		Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)	Number of trees	Basal area (m^2)	Volume (m^3)
1994													
I.	AV	212	1.80	9.74	56	0.54	3.26	326	1.94	7.41	594	4.28	20.41
8.1–16.0	%	50.48	10.24	5.09	38.35	5.07	2.38	91.06	62.67	49.51	64.28	13.66	5.95
II.	AV	106	3.20	28.31	32	1.06	9.88	26	0.73	4.55	164	4.98	42.74
16.1–24.0	%	25.24	18.17	14.77	21.92	9.92	7.24	7.26	24.46	30.41	17.75	15.88	12.46
III.	AV	50	3.31	36.24	18	1.14	12.58	6	0.43	3.01	74	4.88	51.83
24.1–36.0	%	11.90	18.84	18.92	12.33	10.65	9.22	1.68	13.86	20.08	8.01	15.56	15.11
IV.	AV	38	5.69	70.65	26	4.30	57.96	–	–	–	64	9.99	128.62
36.1–52.0	%	9.05	32.36	36.88	17.81	40.21	42.47	–	–	–	6.93	31.84	37.49
V.	AV	14	3.59	46.63	14	3.65	52.81	–	–	–	28	7.24	99.43
52.1–72.0	%	3.33	20.39	24.34	9.59	34.15	38.69	–	–	–	3.03	23.06	28.99
Total	AV	420	17.59	191.57	146	10.68	136.48	358	3.10	14.97	924	31.38	343.03
	%	45.45	56.07	55.84	15.80	34.05	39.79	38.75	9.88	4.37	100.00	100.00	100.00
2004													
I.	AV	166	1.59	10.54	42	0.41	2.43	472	2.82	11.78	680	4.82	24.76
8.1–16.0	%	47.16	9.98	6.02	33.34	1.26	1.98	90.42	60.67	43.34	68.00	15.91	7.62
II.	AV	80	2.51	22.05	22	0.83	7.69	38	1.17	9.35	140	4.52	39.08
16.1–24.0	%	22.73	15.74	12.58	17.46	8.57	6.26	7.28	25.28	34.38	14.00	14.91	12.02
III.	AV	58	3.59	37.94	30	2.02	22.30	12	0.65	6.06	100	6.26	66.29
24.1–36.0	%	16.48	22.52	21.65	23.81	20.74	18.17	2.30	14.05	22.27	10.00	20.65	20.39
IV.	AV	34	4.93	61.05	24	4.07	42.96	–	–	–	58	9.00	104.00
36.1–52.0	%	9.66	30.83	35.41	19.05	41.85	35.01	–	–	–	5.80	29.69	31.99
V.	AV	14	3.32	43.67	8	2.39	47.34	–	–	–	22	5.71	91.01
52.1–72.0	%	3.98	20.82	24.92	6.35	24.59	38.58	–	–	–	2.20	18.84	27.99
Total	AV	352	15.93	175.25	126	9.72	122.72	522	4.65	27.19	1000	30.30	325.14
	%	35.20	52.59	53.90	12.60	32.07	37.74	52.20	15.34	8.36	100.00	100.00	100.00

AV – absolute value

The biggest change in large timber volume over 10 years was found for the phase of advanced ingrowth (PRP 2). The value 469.6 m^3 ha^{-1} found in 1994 dropped to 321.5 m^3 ha^{-1} in 2004. The measurements carried out in 1994 confirmed that the major part of volume stock in the ingrowth stage is in the diameter class IV (36–52 cm), representing 60% from the total volume, and the classes IV and V (36–72 cm) representing altogether 86.3%. This tendency has been preserved until 2004. The biggest proportion of Turkey oak was found both in 1994 and 2004 exactly on this plot. In 1994 it represented 65.5%, in 2004 it was 57.2%. Bigger volumetric share of this woody plant in the stage of ingrowth confirms the higher growth rate of this species and earlier possibilities to utilize the growth space in the concerned primeval forest for the production (Table 2). The shares

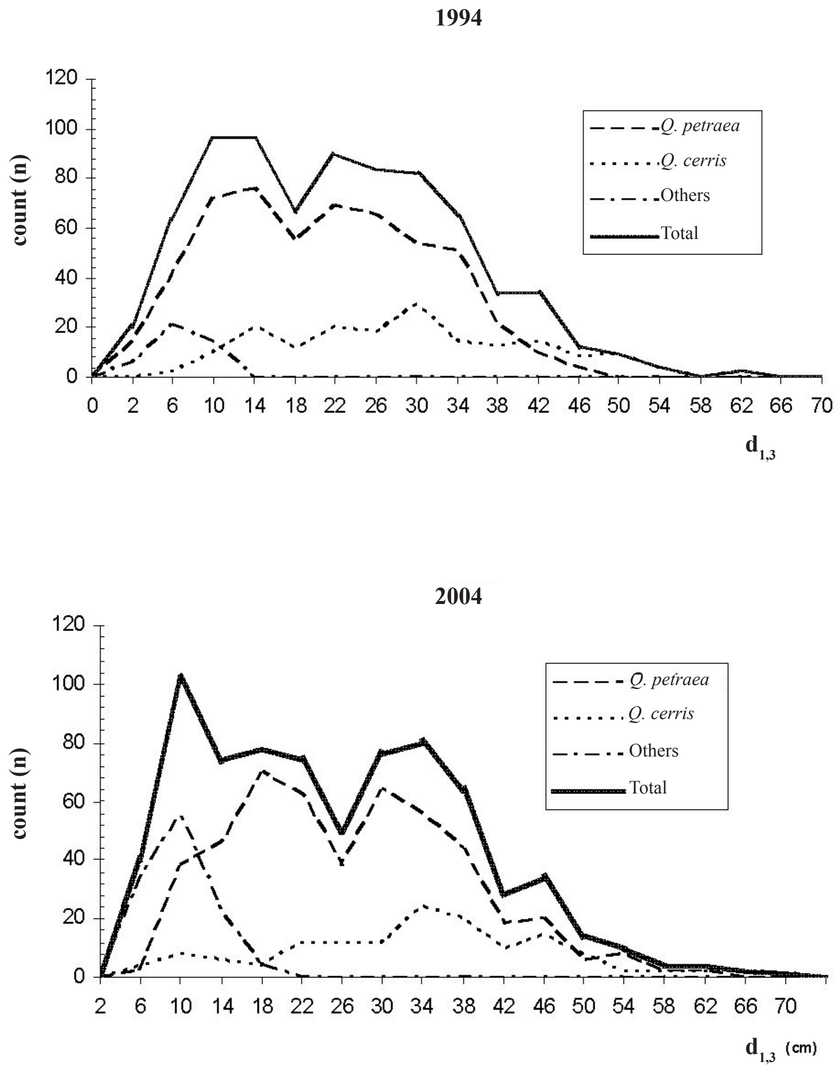


Fig. 1. Distribution of individual tree species on PRP 1 according to tree diameter (years 1994 and 2004)

of the other broadleaved species were negligible. For the decomposition stage (PRP 3) was found a decrease in large timber volume from 343.0 m^3 ha^{-1} in 1994 to 325.1 m^3 ha^{-1} in 2004 (Table 3). In both years were the biggest volumetric proportions provided by trees belonging to the diameter classes IV and V. The difference between the share of large timber volume of sessile oak and Turkey oak between the years 1994 and 2004 is the smallest over the whole developmental cycle. This plot has the biggest proportion of the other accompanying broadleaved species (common maple, wild service tree, hornbeam, wild cherry) participating in the lower, seldom also medium stand (Table 3).

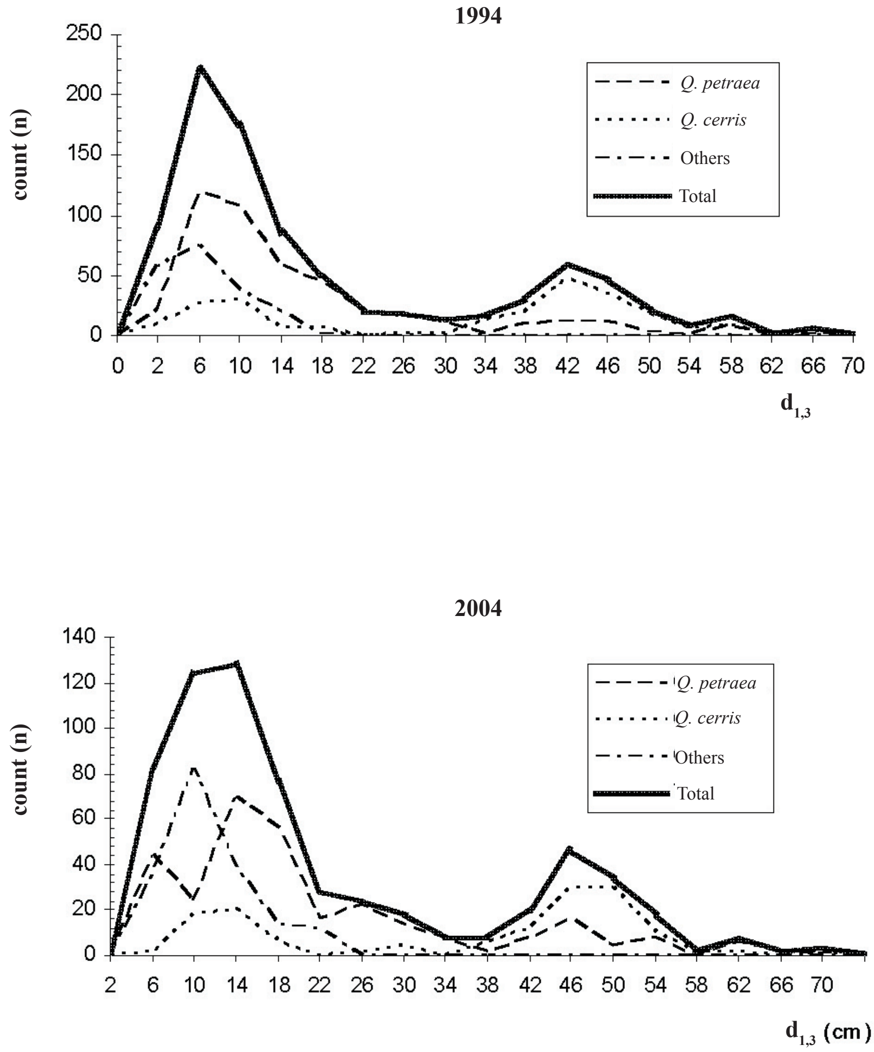
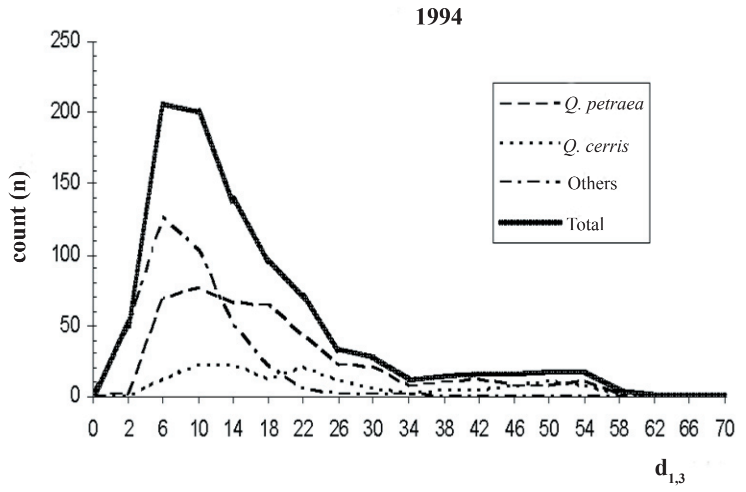


Fig. 2. Distribution of individual tree species on PRP 2 according to tree diameter (years 1994 and 2004)



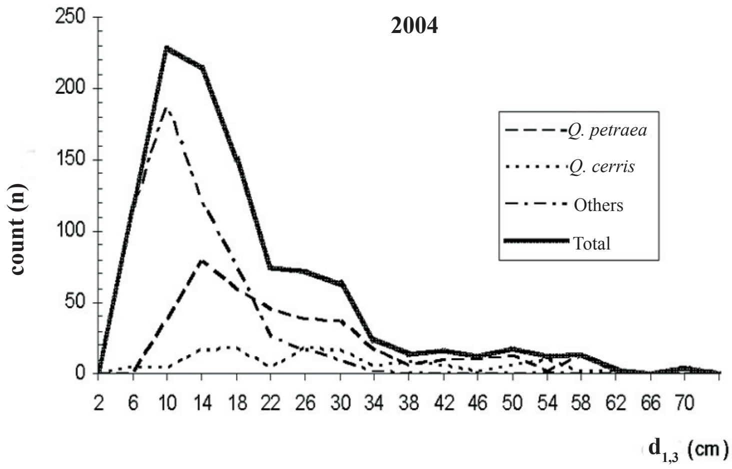


Fig. 3. Distribution of individual tree species on PRP 3 according to tree diameter (years 1994 and 2004)

Areal and spatial structure

The areal and spatial structure of the primeval forest in the individual stages of its development is visualised by means of stand profiles (Fig. 4) and Table 4.

PRP 1 shows an irregular pattern of single vigorous oak trees and clumps of ingrowing exemplars. Poor compactness of the upper crown layer, primarily in the central part of the plot, together with high light transparence of the crowns provide favourable conditions for continual viability of dwarfed forms of heliotrophic woody plants – sessile oak and Turkey oak. The stand structure is two-layered over major part of the plot area (Transect 1). The structure of the stand in advanced phase of ingrowth stage (PRP 2) is two-layered. The upper layer mostly consists of Turkey oak exemplars with vigorous, well developed crowns. The distribution of trees in the upper layer is more uniform compared to the plot on PRP 1, on the other hand, the spacing between the trees is rather big. For this reason, the compactness of the crown layer is low, and consequently, there is sufficient supply of sunlight for the ingrowing trees, mainly the sessile oak – dominant tree species in the second layer. More distinct vertical differentiation can be found in the upper part of the plot where the stand is locally vertically connected

(Transect 2). The stand on PRP 3 is in advanced phase of decomposition stage turning into the ingrowth stage. The stand structure is similar to the structure of selection forest. Over the whole plot can be found dying oak trees, either individually or in clumps. The upper stand layer consists of a few oak and Turkey oak trees

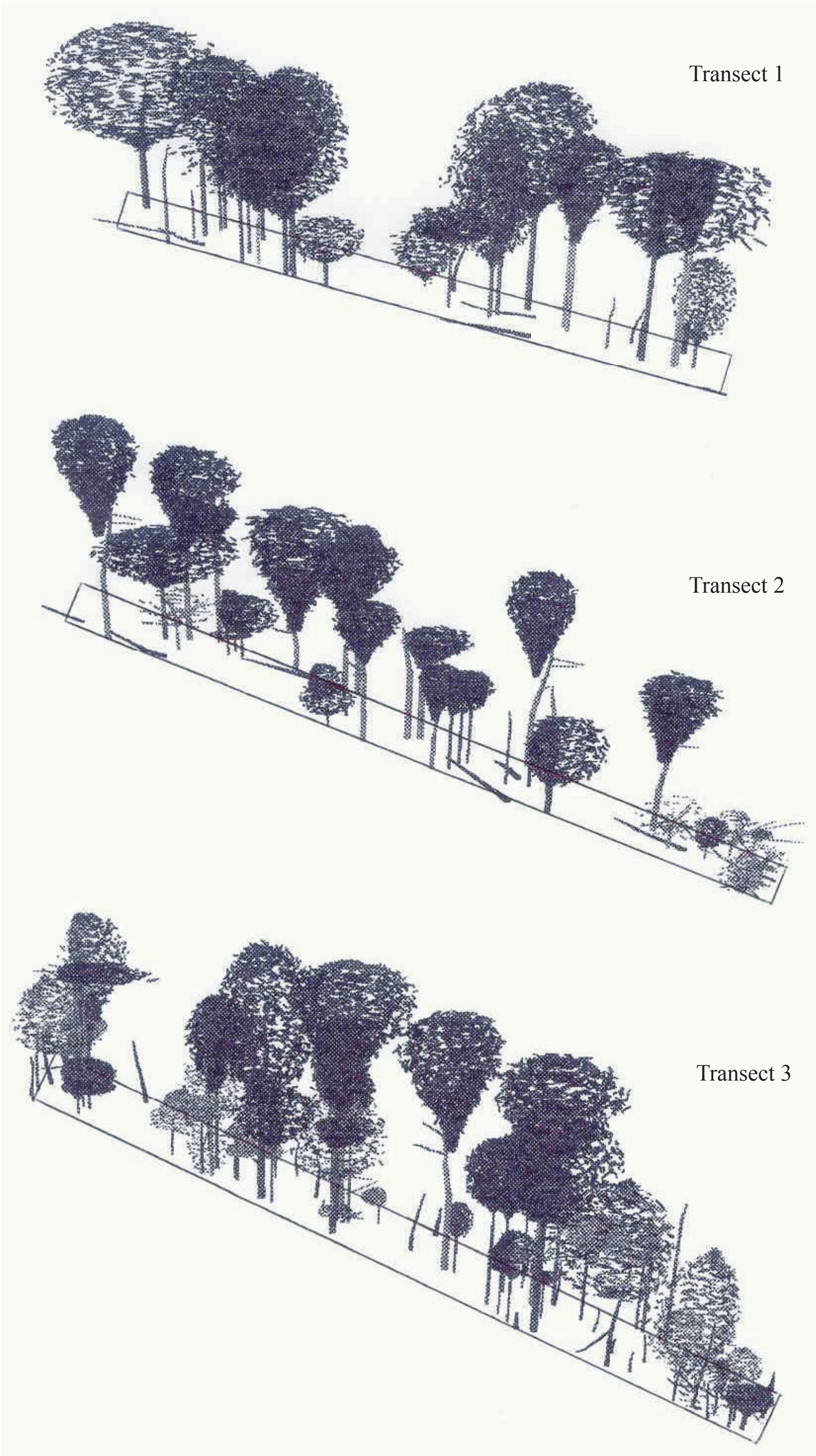


Fig. 4. Stand profiles characterizing stand structures on particular transects of PRP with its proportions: Transect 1 optimum stage (10 x 50 m), Transect 2 advanced phase of ingrowth stage (10 x 70 m) and Transect 3 at the boundary between the decomposition stage and the beginning of the ingrowth stage (10 x 70 m)

rendering the space either to the following generation or to the exemplars belonging to the lower stand layers. The result is a distinct vertical differentiation of the stand structutre on the plot (Transect 3).

The growth space (Table 4) on PRP 1, in the optimum stage, has a value of 10.350 m^3 from which the tree crowns used 53.2% and 44.5%, in 1994 and 2004, respectively. The space utilisation on this plot is the best within the whole developmental cycle. The crown volume of sessile oak and crown volume of Turkey oak make together 5,509 m^3. There are no other broadleaved species in this transect. The stand in ingrowth stage (PRP 2) has a growth space 16,590 m^3 in size, from which 56.7% and 24.3% were exploitated in 1994 and 2004, respectively. The total volume of tree crowns on this plot in 1994 was 9,406 m^3, in 2004 it was reduced to 4,026 m^3, because the preceding generation of sessile oak and Turkey oak had already been extinct. The highest tree number and the highest differentiated structure is on the plot PRP 3 (decomposition stage). On this plot was recorded the highest volume of tree crowns: 13,143 m^3 in 1994, dropped to 5,759 m^3 in 2004. This drop is a result of dying of vigorous exemplars of the receding generation of the primeval forest.

Regeneration processes

The dynamics of regeneration processes over the recent 10 years is summarised in Table 5. The analysis of the species composition manifests a distinct differentiation. It is necessary to note that the sessile oak and Turkey oak are in Tables summarised as a single species. The reason was in difficult distinction between these two woody plants in the first two years of their development when the number of both is the highest. Consequently, the two woody plants were not distinguished either in other height classes. The two oak species are dominant on PRP 1, representing the optimum stage, in spite of the fact that from the value of 7,600 ex ha^{-1} in 1994 there was a decrease to 2,680 ex ha^{-1} in 2004. The shifting to higher categories is significantly reduced. While the seedlings lower than 20 cm show signs of viability and physiological vitality, their shift into higher height categories is connected with a considerable mortality (Table 5). This is also true for other semi-heliophilous woody plants: ash, hornbeam and wild service tree. Sporadically occurring beach and maple have considerably lower autoreduction.

The advanced ingrowth stage is characterised with similar signs in the dynamics of tree shifts and mortality. Also in this phase, oaks have a considerable proportion in hight categories below 50 cm, from this number only a very small part is shifted to higher height classes.

There is only a sporadic natural regeneration of woody plants on the plot PRP 3, characterising the boundary between the final decomposition stage and the beginning of the following ingrowth stage. The mast years in oak show certain regular trends, the seedlings are capable to survive and to a certain extent, further grow, but only a very small number of trees can reach higher height categories. The cause is in unfavourable ecological conditions at the site. The same holds for almost all the other woody plants. This analysis allow us to conclude that there exist some regularities in regeneration processes of woody plants in the studied primeval forest, and that the most favourable conditions for development of large seedlings of the dominant species are towards the end of the optimum stage.

Table 4. Productive utilization of growing space with crowns according to tree species on transects of permanent research plots (PRP) in 1994 and 2004

Year		1994				2004			
Tree species		*Q. petraea*	*Q. cerris*	Others	Total	*Q. petraea*	*Q. cerris*	Others	Total
PRP 1	Crown volume (m^3)	1,019.5	4,489.7	–	5,509.2	648.6	3,956.7	–	4,605.3
	Proportion of the total space %	9.9	43.4	–	53.2	6.3	38.2	–	44.5
PRP 2	Crown volume (m^3)	6,253.2	2,950.3	202.1	9,405.6	3,180.0	647.6	198.7	4,026.3
	Proportion of the total space %	37.7	17.8	1.2	56.7	19.2	3.9	1.2	24.3
PRP 3	Crown volume (m^3)	4,180.6	4,524.2	4, 438.1	13,142.9	2,512.7	1,157.0	2,089.5	5,759.3
	Proportion of the total space %	26.6	28.5	27.9	82.7	15.8	7.3	13.2	36.2

Table 5. Structure of natural regeneration according to tree species on permanent research plots (PRP) in 1994 and 2004 (count per 1 ha)

Height category	*Q. petraea +cerris*	*Fagus sylvatica*	*Acer campestre*	*Fraxinus excelsior*	*Carpinus betulus*	*Sorbus torminalis*	*Pirus communis*	Total	Total %
				PRP 1	1994				
< 20 cm	4,980	–	260	40	40	320	40	5,680	58.32
21–50	2,380	20	560	60	200	260	60	3, 540	36.34
51–80	180	–	40	20	–	–	–	240	2.46
81–130	40	20	80	–	–	–	–	140	1.44
130+	20	–	120	–	–	–	–	140	1.44
Total	7,600	40	1,060	120	240	580	100	9, 740	100
Total %	78.02	0.41	10.89	1.23	2.47	5.95	1.03	100	100
				PRP 1	2004				
< 20 cm	1,200	20	60	–	–	60	–	1,340	37.33
21–50	1,300	–	80	60	–	–	–	1,440	40.11
51–80	100	20	60	–	10	–	40	230	6.41
81–130	20	60	100	–	–	–	20	200	5.57
130+	60	20	300	–	–	–	–	380	10.58
Total	2,680	120	600	60	10	60	60	3,590	100
Total %	74.66	3.34	16.71	1.67	0.28	1.67	1.67	100	100
				PRP 2	1994				
< 20 cm	2,357	–	100	14	14	14	–	2,499	44.75
21–50	1,514	–	657	14	–	57	–	2,242	40.14
51–80	386	–	171	15	–	29	–	601	10.76
81–130	14	–	129	–	–	–	–	143	2.56
130+	15	14	57	–	–	–	14	100	1.79
Total	4,286	14	1,114	43	14	100	14	5,585	100
Total %	76.74	0.25	19.95	0.77	0.25	1.79	0.25	100	100
				PRP 2	2004				
< 20 cm	2,186	–	71	–	–	–	–	2,257	66.72
21–50	500	–	–	14	14	28	14	570	16.85
51–80	86	14	171	–	–	–	14	285	8.42
81–130	14	–	186	–	–	–	14	214	6.33
130+	–	–	57	–	–	–	–	57	1.68
Total	2,786	14	485	14	14	28	42	3,383	100
Total %	82.36	0.41	14.35	0.41	0.41	0.82	1.24	100	100
				PRP 3	1994				
< 20 cm	1,586	29	914	57	243	14	–	2,843	71.59
21–50	271	–	500	100	43	–	114	1,028	25.89
51–80	–	–	14	–	–	–	14	28	0.71
81–130	–	–	43	–	–	–	–	43	1.08
130+	–	–	29	–	–	–	–	29	0.73
Total	1,857	29	1,500	157	286	14	128	3,971	100
Total %	46.77	0.73	37.78	3.95	7.2	0.35	3.22	100	100

Table 5. Continued

Height category	*Q. petraea +cerris*	*Fagus sylvatica*	*Acer campestr*	*Fraxinus excelsior*	*Carpinus betulus*	*Sorbus torminalis*	*Pir communis*	Total	Total %
				PRP 3	2004				
< 20 cm	2,431	–	28	–	14	–	–	2,473	80.53
21–50	86	–	372	–	42	–	–	500	16.28
51–80	42	–	28	–	–	–	–	70	2.28
81–130	–	–	28	–	–	–	–	28	0.91
130+	–	–	–	–	–	–	–	–	–
Total	2,559	–	456	–	56	–	–	3,071	100
Total %	83.33	–	14.85	–	1.82	–	–	100	100

Discussion and conclusions

At the very beginning we need to note that the results of a 10-year study into the structure and regeneration processes in a primeval forest can only represent a really small piece of knowledge connected with the problem. We can, however, conclude about some tendencies concerning the growth of the woody plants in question. The rate of lowering the proportion of Turkey oak is higher – thanks to shorter rotation age of this species in comparison with the sessile oak. This fact was also confirmed by Korpeľ (1989,1995) and Smejkal et al., (1995).

The values of amounts and trends of large timber volume in this primeval forest correspond to the values obtained by Korpeľ (1995) and Smejkal et al., (1995). As for the growth space exploitated by tree crowns, the smallest changes were observed on PRP 1 (optimum stage) where is the proportion of the utilised space 44.5%. The largest crown volume is on PRP 3 – representing the beginning of ingrowth stage. As for PRP 1 and PRP 2, the utilisation of growth space on the two plots was getting more and more similar towards the end to the 10-year study period, because the stand on PRP 2 is at advanced ingrowth stage characterised by conspicuous autoreduction of trees in the lower stand layer. The values of crown volume decreased on PRP 2 and PRP 3, the last in the advanced decomposition stage by more than half of the area. The indicators of this sign of primeval forest structure were not included into the study of the above mentioned authors.

Regeneration processes of woody plants building up the studied primeval forest are very different, because of the different ecological tolerance to light in the individual stages of development. Based on the analysis of the results we can conclude that the regeneration processes in the dominant species of the primeval forest indicate some regularities (mast years in oak occur at least each 5–7 years), and that the most favourable conditions for growth of seedlings of sessile oak and Turkey oak are towards the end of the optimum stage.

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Štruktúra, produkčné pomery a regeneračné procesy dubového prírodného lesa v NPR Boky

Súhrn

Práca sa zameriava na štúdium štruktúry, produkčných a regeneračných schopností prírodného zmiešaného listnatého lesa za 10-ročné obdobie (roky 1994–2004). Výskum sa sústredil na lesný typ Corneto-Quercetum. V porastoch tohto spoločenstva sa *Quercus pubescens* nevyskytuje a ekologicky ho nahrádza *Quercus cerris*, ktorý je tu na severnej hranici svojho rozšírenia. Všetky merania dendrometrických veličín a biometrických znakov stromov (od hrúbky 20 mm) a jedincov prirodzenej obnovy boli uskutočnené na troch trvalých výskumných plochách. Bola zistená pomerne veľká variabilita celkového počtu stromov a stromov hrubiny v závislosti od vývojových fáz. V roku 1994 sa počet stromov pohyboval od 747 ks ha^{-1} do 924 ks ha^{-1}. Merania v roku 2004 potvrdili ešte vyššiu variabilitu 614–1000 ks ha^{-1}. Rôznenie celkového počtu stromov v rámci vývojového cyklu je 38,6 %. Dub zimný má na všetkých TVP najväčšie zastúpenie. Podiel duba zimného kolísal v roku 1994 podľa počtu hrubiny medzi 45 % až 71 % a v roku 2004 medzi 35 % až 65 %. Podiel duba cerového sa v roku 1994 pohyboval od 16 % do 27 % a v roku 2004 od 13 % do 24 %. Hrúbkové rozpätie je najväčšie v pokročilej fáze štádia rozpadu s prechodom do počiatočnej fázy štádia dorastania na TVP 3. Najmenšie variačné rozpätie je v štádiu optima na TVP 1. Na všetkých tranzektoch sa zaznamenal pokles objemu korún ako aj využitia rastového priestoru. Priemerná zásoba varírovala v roku 1994 podľa objemu hrubiny v závislosti od vývojových fáz medzi 340 m^3 ha^{-1} až 470 m^3 ha^{-1} a v roku 2004 medzi 322 m^3 ha^{-1} až 330 m^3 ha^{-1}. Podiely drevín na kruhovej základni sa za 10-ročné obdobie na jednotlivých plochách výrazne nezmenili.

Regeneračné procesy drevín vytvárujúcich tento prales sú z pohľadu ich ekologickej tolerancie na svetlo v jeho jednotlivých vývojových štádiach rozdielne. Na základe analýzy výsledkov možno konštatovať, že regeneračné procesy základných drevín prírodného lesa vykazujú známky pravidelnosti (bohatšia semenná úroda dubov sa dostavuje aspoň raz za 5–7 rokov), pričom najvhodnejšie podmienky pre odrastanie semenáčikov duba zimného a duba cera sú v záverečnej fáze štádia optima.