JOURNAL OF FOREST SCIENCE, *54*, 2008 (12): 545–553

A change in structural diversity and regeneration processes of the spruce virgin forest in Nefcerka NNR (TANAP) in relation to altitude

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ABSTRACT: This report assesses the structural diversity of the spruce virgin forest in Nefcerka NNR in the Tatra National Park (TANAP). The structure of the virgin forest is evaluated by the indices proposed by Clark & Evans, Füldner and Jaehne & Dohrenbusch. Concerning the spatial distribution of trees (Clark & Evans index), a statistically significant difference was confirmed between the growth stage and the optimum and the breakdown stages. The influence of altitude on the tendency of concentration of virgin forest trees was also confirmed. In the case of complex diversity evaluation by the Jaehne & Dohrenbusch index (1997), a statistically significantly different diversity of the spruce virgin forest between the growth stage and the other stages was found. The analysis of the regeneration processes revealed their good dynamics even at an altitude above 1,400 m, and with the ascending altitude (above 1,300 m) the dead wood and knolls of wind-thrown roots have the greater importance as seedbeds.

Keywords: spruce virgin forest; structural diversity; regeneration processes

The majority of stands in the 7th forest vegetation level should fulfil difficult ecological functions, the soil protection and hydrological ones in particular. A significant part of spruce stands in this forest vegetation level preserves the character of the natural forest.

Long-term monitoring of natural forests of this forest vegetation level has revealed so far remarkable differences in the process of developmental stages, in the dynamics of forming the stand structure depending on altitude (Korpeľ 1989, 1995). The author found out that the permanently open crown canopy of the spruce virgin forest is typical of altitudes above 1,400 m (NNR Chopok, Kosodrevina, Babia hora). The change in the structure of spruce natural forests is significantly modified by climatic conditions. The quantification of diversity through mathematic formulas allows us to evaluate this problem objectively and to understand better the relations of a given forest ecosystem. A remarkable part of their diversity is the structural diversity, which, according to some authors, is defined as the composition of biotic and abiotic components in forest ecosystems (Lexer et al. 2000), specific arrangement of the components in the system (Gadow 1999) or as their positioning and mutual connections (Heupler 1982 in Lübbers 1999). According to Zenner (1999), the structure can be characterized horizontally, i.e. the spatial distribution of trees, and vertically in their height differentiation. Lübbers (1999) adds to these attributes the amount and the form of dead wood. The horizontal distribution of trees in the space is factually described by Clark & Evans index (1954).

Concerning a different point of view there are some indices that describe diameter, height or volume differentiation (Füldner 1995) or complex indices describing more components of the structural diversity (Pretzsch 1996, 1998; Jaehne, Dohrenbusch

Supported by the Slovak Research and Development Agency of the Ministry of Education of the Slovak Republic, Project No. 0082-06.

1997; Zenner 1999; Lähde et al. 1999). By their help it is possible to add other hierarchical levels of the stand diversity.

Selected indices for the description of structural diversity were used in the research of the spruce natural forest in Babia hora NNR (Vorčák et al. 2006). In the altitudinal range of 1,260–1,460 m, on the series of 57 circular sample plots of 5 ares each, its structural diversity and regeneration processes were studied. Concerning the spatial distribution of the trees in the virgin forest, no tendency of their clustering in connection with altitude was found in the zones below 1,460 m. The influence of altitude was confirmed in the zone above 1,461 m where the groups of "family spruces" are typical. Diameter differentiation was statistically significantly higher in the growth stage. Evaluation of this attribute in terms of altitude detected significant differentiation at an altitude below 1,260 m in the growth stage. According to the Füldner index, it was found out that the virgin forest has a generally medium differentiated diameter structure. According to the Jaehne and Dohrenbusch index (1997), the differentiation of the virgin forest decreases with the ascending altitude up to 1,460 m, where the compact forest ends. The average value for the entire reserve (B = 7.5) posted this spruce virgin forest to the height differentiated stands with uneven structure. The highest value was found out in the growth stage (11.5) and in the breakdown stage (11.8) at an altitude below 1,260 m. The structure of the virgin forest is very heterogeneous in this altitudinal zone.

The number of the individuals from natural regeneration (individuals of the height below 130 cm) is declining in all stages of the virgin forest with the increasing altitude. This is caused by worse ecological conditions and lower fructification of the trees. Evaluation of the seedbed revealed that 46.2% of the naturally regenerated individuals were growing on the soil, 52.4% on dead wood and 1.4% on windthrown roots. Regarding the developmental stages of the virgin forest, 46% of the individuals were found in growth stage, 23% in optimum stage and 31% in breakdown stage. According to Korpeľ (1989), Vorčák (2005), Saniga (2002, 2007), the portion of individuals from natural regeneration on dead wood is increasing with the ascending altitude, the most of them being in the initial phase of the growth stage.

Conditions of spruce natural forests in NNR in Slovakia are highly variable. The phenomenon mentioned influences their different structures.

The objective of this report is to describe the structural diversity and dynamics of regeneration processes of the spruce natural forest in Nefcerka NNR in Tatra National Park on the basis of 27 research plots of 5 ares in size that were established in various stages of the natural forest developmental cycle (3) and at various altitudes (3 levels).

MATERIAL AND METHODS

The Nefcerka Valley (Nefcerská dolina) is located at 49°10' of north latitude and 19°59' of east longitude, between the Kriváň massif and the Hrubô ridge on a rocky slope of south-west aspect. The bedrock is built of granite rocky mantle rock. Present soil types are: humus brown forest soil with gley at the bottom, humus iron podzol and ranker (Korpeľ 1989). These soils are clay at the top, sand-clay in lower parts, highly gravelled, well-aerated and they leak water very well. They are acid or very acid, with great stocks of humus and with the lack of easily accessible nutrients. The average annual temperature reaches about 2–2.5°C and the average annual precipitation is 1,200–1,300 mm.

In the Nefcerka Valley, 27 circular sample plots were established and stabilized in three altitudinal categories (up to 1,300, 1,300–1,400, above 1,400 m a.s.l.). In each category, there were 9 plots, 3 in each developmental stage of the natural forest (growth stage, optimum stage and breakdown stage). Each plot has a constant surface of 500 m^2, which fully complies with statistical principles of sampling optimization (Šmelko 1968, 2000; Meyer et al. 2001). It is used in a standard way for research of mountain forests (Merganič et al. 2003; Vorčák 2005). On a sample plot, we recorded the individuals of diameter $d_{1.3}$ above 2 cm. For each individual, the following set of basic attributes was found out, which is necessary for the complete description of the stand structure:

- type of tree.
- diameter $d_{1.3}$ (cm, to the nearest 1 mm),
- height (m, to the nearest 0.5 m),
- height to crown base (m, to the nearest 0.5 m),
- parameters of crown projection – four dimensions in two perpendicular directions (m, to the nearest 0.1 m),
- tree location – azimuth (in grades) and distance (m, to the nearest 0.1 m) from the centre of the plot.

In this measurement, Field-Map technology was used.

To characterize the structural diversity of stands on individual sample plots, we used, apart from the quantification of basic dendrometric attributes, the following structural indices: Clark and Evans index (1954) or so-called aggregation index, Füldner

Table 1. Average values of Clark & Evans, Füldner and Jaehne & Dohrenbusch indices per altitudinal category and developmental stages

Altitudinal category	Developmental stage	Füldner index	Clark & Evans index		Jaehne & Dohrenbusch index
			value	*T* statistics	
Up to 1,300 m a.s.l.	growth stage	0.390 ± 0.052	1.032 ± 0.033	0.09–0.92	5.89 ± 0.43
	optimum stage	0.307 ± 0.046	1.125 ± 0.035	0.81–1.90	3.23 ± 0.19
	breakdown stage	0.258 ± 0.055	1.107 ± 0.084	0.01–1.71	5.29 ± 0.24
1,300–1,400 m a.s.l.	growth stage	0.444 ± 0.040	0.927 ± 0.060	0.21–1.87	6.20 ± 0.33
	optimum stage	0.276 ± 0.037	1.006 ± 0.062	0.30–1.19	3.87 ± 0.63
	breakdown stage	0.412 ± 0.054	0.939 ± 0.091	0.19–1.27	5.46 ± 1.20
Above 1,400 m a.s.l.	growth stage	0.475 ± 0.053	0.732 ± 0.103	1.93–3.39	7.07 ± 0.56
	optimum stage	0.371 ± 0.041	1.079 ± 0.130	0.35–2.39	4.43 ± 0.61
	breakdown stage	0.379 ± 0.021	1.040 ± 0.065	0.04–1.06	4.99 ± 0.34

index (1995), so-called index of diameter differentiation and Jaehne and Dohrenbusch index (1997), so-called complex stand diversity index. Their description can be found in the paper by Vorčák et al. (2006). The individual indices were assessed by means of two-factor analysis of variance, where the two factors were represented by developmental stage and by altitude. Then Tukey's test followed. It helps us to find out pairs of individual factors which were significantly different.

Regeneration processes were assessed on each sample plot on 10 small circular sample plots of 10 m^2 (100 m^2). The first one was in the centre of the sample plot and the others were established in a systematic way in the regular distance around the centre of the sample plot. The evaluated individuals were classified according to the stand type, height category (up to 20, 21–50, 51–80, 81–130 and above 131 cm) and the seedbed where they grew (soil, wind-thrown roots and dead wood).

RESULTS

Structural diversity

The evaluation of the horizontal diversity by Clark & Evans index in relation with the altitude and developmental stage of the virgin forest is shown in Table 1 and in Fig. 1.

Based on an analysis of the plots of the spruce virgin forest representing the growth stage we can state that the spruce, as a basic tree species, has a tendency of clustering with the increasing altitude (Fig. 1). At an altitude of 1,300 m, the index was 1.032 ± 0.033, which documents a random distribution of trees on the plot. The value decreased with the ascending altitude and in the height category above 1,400 m, the index was 0.732 ± 0.103 (Table 1).

There is a remarkable difference in the values of Clark & Evans index between the plots representing the optimum and the breakdown stages. The analysis

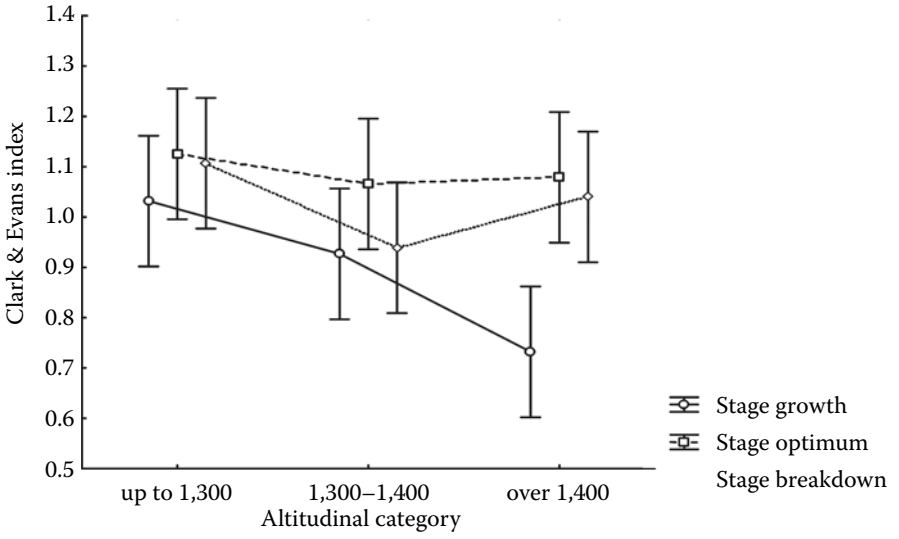

Fig. 1. The results of Clark & Evans index in individual altitudinal categories and developmental stages of the virgin forest Nefcerka

of the plots which characterize the optimum stage in relation to the ascending altitude does not confirm its effect. By this attribute of its structure, the virgin forest behaves in a similar way. The index confirmed a random distribution of trees in this stage (Fig. 1, Table 1).

The structure of the spruce virgin forest on the plots representing the breakdown stage has similar values of the index like in the optimum stage. A slight difference was observed just at altitudes of 1,300–1,400 m (Fig. 1). The testing of the values of *R* index confirmed a statistically highly significant difference between the growth stage and the other stages of the spruce natural forest in the whole height profile of the virgin forest. The testing of the influence of the altitude revealed its great influence in the growth stage. In the optimum and breakdown stages a statistically significant difference in the index was confirmed in the spruce virgin forest in the altitudinal range of 1,300–1,400 m.

The analysis of the structure of the spruce virgin forest in Nefcerka NNR assessed according to the Clark & Evans index confirmed that trees, regardless of the altitude, had a random spatial distribution. In the case of developmental stage, the effect of altitude was confirmed in the growth stage, where trees had a tendency of moderate clustering with the ascending altitude.

Diameter structure of the virgin forest is another indicator of its structural diversity. In this case, we analyzed it by means of the Füldner index TM (Fig. 2, Table 1).

Evaluation of the average value of this indicator confirmed that the greatest diameter differentiation can be found in the spruce forest in the growth stage, which is understandable. On the other hand, the evaluation in relation to altitude confirmed the effect of climate changes. The value of the Füldner index rises with the ascending altitude and at an altitude above 1,400 m it reaches 0.475 ± 0.05, which represents the medium level of differentiation (Table 1, Fig. 2). In the case of the developmental stage, this value was lower in the optimum stage. Its minimum was reached at an altitude above 1,400 m: 0.371 ± 0.04. A stochastic character of this index could also be observed in the breakdown stage, where at altitudes of 1,300–1,400 m it reached the value 0.412 ± 0.05 with the following fall to 0.379 ± 0.021 (Table 1, Fig. 2). The testing of the two factors (stage, altitude) confirmed that the growth stage, as in the case of trees, has an influence on the greater diameter differentiation of the virgin forest trees. This differentiation increases with the ascending altitude.

Information about the complete stand diversity was assessed by the B Jaehne and Dohrenbusch index (1997). Data can be found in Table 1 and in Fig. 1. If we consider this attribute from the aspect of the developmental stage of the virgin forest, we can state that the highest values were found out in the growth stage and according to the scale outlined by the authors it is evaluated as a stand with uneven structure. The testing of this value confirmed that it is higher, which is statistically very important, in comparison with the average values found out in the optimum and the breakdown stages. In spite of the fact that this value, in the growth stage of this spruce virgin forest, increases with the ascending altitude, its influence was not confirmed in testing (Table 1). An analysis of the general structural diversity by means of the Jaehne and Dohrenbusch index (1997) confirmed that the structural diversity of the spruce virgin forest in Nefcerka NNR was significantly influenced by its developmental stage and partly also by the altitude. It is the texture of

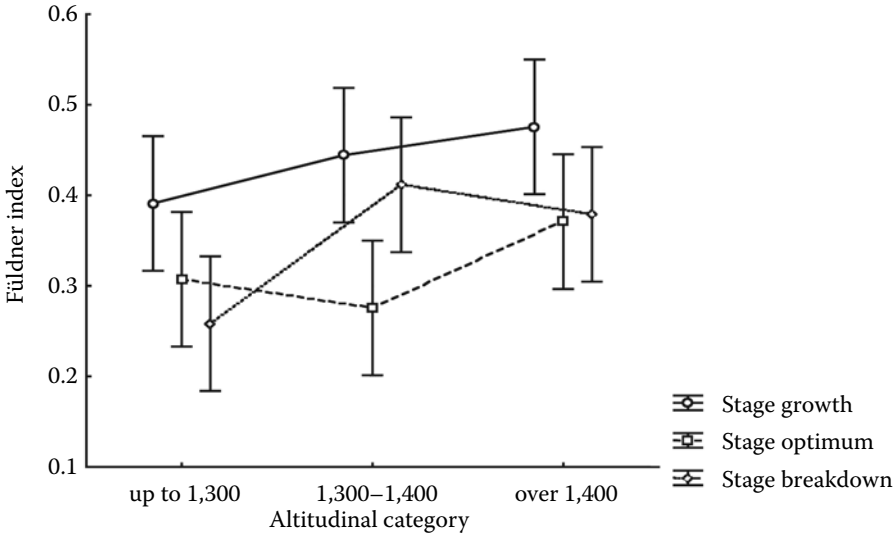

Fig. 2. The values of Füldner index in individual altitudinal categories and developmental stages of the virgin forest Nefcerka

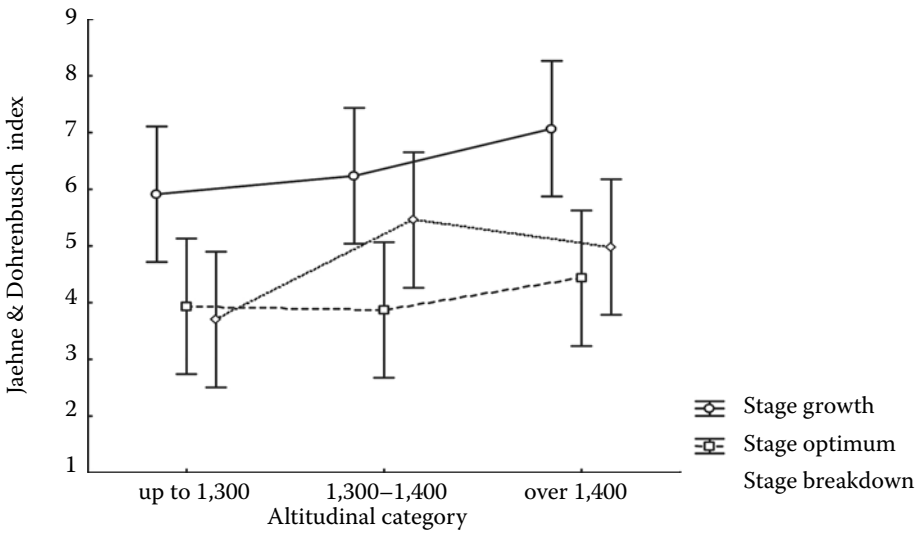

Fig. 3. The values of the complex Jaehne & Dohrenbusch index in individual altitudinal categories and developmental stages of the virgin forest Nefcerka

the virgin forest that decides on the degree of its diversity, and namely the percentage of the overall area share of this stage as well as the area alternation with other stages.

Regeneration processes

Information concerning the regeneration processes in relation to the altitude is shown in Tables 2 to 4. Based on the evaluation of the natural regeneration of spruce from the sample plots at altitudes up to 1,300 m we can state that its dynamics is good in each developmental stage. Apart from the spruce as the basic tree species of the virgin forest, we were surprised by the great number of rowan-trees practically in all developmental stages. Its relative proportion ranged between 34.0% in the growth stage up to 53.2% in the optimum stage. In absolute figures, in the breakdown stage there were 10,599 individuals/ha. The spruce with its number ranging from 5,534 ind/ha in the optimum stage to 12,000 ind/ha in the breakdown stage forms the base for the generation succession of this virgin forest. From the aspect of the height shifts, the most favourable conditions for the spruce are in the growth and breakdown stages (Table 2).

The structure of the natural regeneration of the virgin forest at altitudes of 1,300–1,400 m has better indicators (Table 3). The highest number of individuals was found out in the breakdown stage, where we recorded 22,067 ind/ha of spruce with its greatest numbers in the height level up to 20 cm. These values represent a nearly double increase in comparison with the virgin forest up to an altitude of 1,300 m. We were surprised by the number of spruce individuals in the optimum stage – 13,133 ind/ha, which was higher than at altitudes up to 1,300 m. On the other hand, we have to say that its height shift to higher classes is greatly inhibited by the unfavourable ecological conditions which are not suitable

Table 2. Tree species structure of natural regeneration (trees/ha) in the altitudinal category up to 1,300 m a.s.l. and developmental stages

Stage	Tree species	Height class (cm)					Total	
		up to 20	21–50	51–80	81–130	above 130	*N*	(%)
Growth stage	spruce	4,767	633	233	367	333	6,333	66.0
	rowan	2,267	700	267	33	–	3,267	34.0
	total	7,034	1,333	500	400	333	9,600	100.0
Optimum stage	spruce	5,067	267	100	100	–	5,534	46.8
	rowan	3,033	1,833	900	500	33	6,299	53.2
	total	8,100	2,100	1,000	600	33	11,833	100.0
Breakdown stage	spruce	9,633	1,734	200	300	133	12,000	53.1
	rowan	2,900	3,066	2,566	1,567	500	10,599	46.9
	total	12,533	4,800	2,766	1,867	633	22,599	100.0

Table 3. Tree species structure of natural regeneration (trees/ha) in the altitudinal category 1,300–1,400 m a.s.l. and developmental stages

Stage	Tree species	Height class (cm)					Total	
		up to 20	21–50	51–80	81–130	above 130	*N*	(%)
Growth stage	spruce	5,633	400	166	367	233	6,799	63.2
	rowan	2,733	1,000	100	33	100	3,966	36.8
	total	8,366	1,400	266	400	333	10,765	100.0
Optimum stage	spruce	12,333	400	166	167	67	13,133	62.6
	rowan	5,333	1,867	600	33	–	7,833	37.4
	total	17,666	2,267	766	200	67	20,966	100.0
Breakdown stage	spruce	17,833	3,000	567	367	300	22,067	70.9
	rowan	1,533	2,133	2,967	1,933	500	9,066	29.1
	total	19,366	5,133	3,543	2,300	800	31,133	100.0

for its growth. The values of spruce individuals in the growth stage are similar to those at altitudes up to 1,300 m and the dynamics of its shifts to higher height classes is at a similar level.

The structure of the natural regeneration of the virgin forest at altitudes above 1,400 m is characterized by optimistic results (Table 4). The spruce in the breakdown stage with its number 7,399 ind/ha creates good conditions in the long-term developmental cycle (300 years) for generation succession in spite of the fact that its shift to higher height classes is inhibited by the plant competition. On the other hand, we have to state that the high numbers of rowan individuals – 19,567 ind/ha, with the good dynamics of height growth improve, from the long-term aspect, ecological conditions for the growth of spruce. The data confirm that the spruce in the optimum stage has better ecological conditions for its height growth, as the virgin forest at this altitude also has open canopy or canopy with gaps in this stage. Such a long-term state creates a better ecological profile for the height growth of spruce. The growth stage with its differentiated structure disturbs regeneration processes from the aspect of the survival and growth of spruce seedlings.

An analysis of the influence of the seedbed on the number of spruce and rowan individuals is recorded in Table 5. The analysis of this factor in the spruce virgin forest at altitudes up to 1,300 m confirmed that soil was the prevailing seedbed. In relation to the developmental stage of the virgin forest, we found from 5,600 ind/ha (growth stage) to 18,467 ind/ha (breakdown stage) of spruce and rowan individuals on the soil, which accounted for 58.3% to 81.7%. Lying dead wood with stumps as a seedbed forms from 9.3% in the breakdown stage up to 19.1% in the growth stage of the total number of individuals of natural regeneration.

The natural regeneration structure of the studied spruce virgin forest Nefcerka at altitudes of

Table 4. Tree species structure of natural regeneration (trees/ha) in the altitudinal category above 1,400 m a.s.l. and developmental stages

Stage	Tree species	Height class (cm)					Total	
		up to 20	21–50	51–80	81–130	above 130	*N*	(%)
Growth stage	spruce	167	233	167	134	333	1,035	14.5
	rowan	1,300	1,300	2,133	1,167	200	6,100	85.5
	total	1,467	1,533	2,300	1,301	533	7,134	100.0
Optimum stage	spruce	8,034	300	33	200	–	8,567	44.8
	rowan	6,033	3,367	833	333	–	10,566	55.2
	total	14,067	3,667	866	533	–	19,133	100.0
Breakdown stage	spruce	6,133	866	333	67	–	7,399	27.4
	rowan	4,600	8,467	5,067	1,200	233	19,567	72.6
	total	10,733	9,333	5,400	1,267	233	26,966	100.0

Table 5. Tree species structure of natural regeneration (trees/ha) per altitudinal category, developmental stage and seedbed type

Altitude category	Seed bed type	Growth stage				Optimum stage				Breakdown stage			
		spruce	rowan	total		spruce	rowan	total		spruce	rowan	total	
				N	(%)			*N*	(%)			*N*	(%)
Up to 1,300 m a.s.l.	soil	2,500	3,100	5,600	58.3	3,333	6,033	9,366	79.2	8,234	10,233	18,467	81.7
	windthrow	2,033	133	2,166	22.6	933	266	1,199	10.1	1,800	233	2,033	9.0
	dead wood	1,800	33	1,833	19.1	1,267	–	1,267	10.7	1,966	133	2,099	9.3
1,300–1,400 m a.s.l.	soil	1,600	3,367	4,967	46.1	4,833	6,167	11,000	52.5	8,134	6,633	14,767	47.4
	windthrow	1,667	600	2,267	21.1	4,265	1,500	5,765	27.5	5,033	1,867	6,900	22.2
	dead wood	3,533	–	3,533	32.8	4,033	166	4,199	20.0	8,900	566	9,466	30.4
Above 1,400 m a.s.l.	soil	234	3,833	4,067	57.0	2,466	8,934	11,400	59.6	1,167	15,933	17,100	63.4
	windthrow	634	1,666	2,300	32.2	4,300	1,067	5,367	28.0	2,066	2,767	4,833	17.9
	dead wood	167	600	767	10.8	1,800	567	2,367	12.4	4,165	866	5,031	18.7

1,301–1,400 m is different. The relative proportion of individuals on the soil was from 46.1% in the growth stage up to 52.5% in the optimum stage (Table 5). In all developmental stages at this altitude, the relative number of individuals on the wind-thrown roots increased as well as the number of individuals of both trees species on lying dead wood or stumps.

If we evaluate the number of spruces as the main component of the virgin forest structure at the upper line of its distribution at an altitude above 1,400 m, we can state that 56.3% of the spruce individuals (4,165 ind/ha) can be found on dead wood in the breakdown stage. On the soil, it is only 1,167 ind/ha (15.8%). Elevated places of wind-thrown roots participate in the regeneration in this stage by 27.9% (2,066 ind/ha). By an analysis of the seedbed in the optimum stage having the characteristics of open canopy it was found out that from the total number of spruce individuals – 8,566 ind/ha, only 1,800 ind/ha grew on dead wood. Most of the individuals – 4,300 ind/ha (50.2%) was found on wind-thrown roots. A similar situation can be observed in the growth stage although the value of these data is not so important, as only 1,035 ind/ha of spruce was found in this stage. The reason is a substantially lower proportion of dead wood in this stage – 2.3% of the surface of 15 ares, as well as a dense canopy which leaks less warmth necessary to start the processes of seedling germination. In the breakdown stage, the proportion of dead wood is 7.5%. With much better thermal conditions, it creates better circumstances for the spruce seedling germination.

We learnt from the analysis of regeneration processes that at an altitude above 1,300 m, dead wood contributes to the preservation of the spruce natural forest by 40.3% up to 56.3% in the breakdown stage.

DISCUSSION AND CONCLUSION

The bedrock of the spruce natural forest in Nefcerka NNR in TANAP is built of a crystalline complex. Its structure is determined to a great extent by the soil type – ranker soil, which contributes to the diversity of this virgin forest from the aspect of irregular nutrient supply. In comparison with the structural diversity of the virgin forest Babia hora (Vorčák et al. 2006) determined by Jaehne and Dohrenbusch index (1997), the structural diversity of the spruce virgin forest in Nefcerka NNR is slightly lower, in the growth stage even remarkably lower. The reason is better soil (flysch) in the Babia hora NNR, higher number of individuals per unit area with greater height differentiation having nearly a character of unnatural forest structure (Saniga 2007). In the complex mathematic formula of Jaehne and Dohrenbusch index (1997), great support is given to the vertical structure index. In the formula, 3 thickest and 3 thinnest trees are involved, which logically gives lower values of this complex index with the lower number of trees in Nefcerka NNR. The information given by the index concerned is more important for the virgin forests in lower forest vegetation levels, where the diameter and height differentiation is greater and tree species structure is richer. Structural diversity qualified by the three indices confirmed the highest structural diversity in the growth stage and its increase with the ascending altitude.

Regeneration processes, by their dynamics and seedbed influence on the number of spruce individuals, confirmed the existing findings obtained in the research on the developmental cycle of the spruce virgin forest Babia hora (Holeksa 1998; Vorčák

et al. 2006). The higher the altitude, the greater the importance of dead wood as a seedbed. At altitudes above 1,400 m, we found out the number of spruce individuals in the breakdown stage 4,165 ind/ha, which represents 56.3% of the total number of natural regeneration individuals. This number is lower than in the case of NNR Babia hora. However, it confirms the rising importance of dead wood for the preservation of generation succession of the spruce virgin forest. On the other hand, we have to underline a far greater importance of wind-thrown roots as a seedbed. The number of individuals on this germination medium – 2,066 ind/ha (27.9%) in the breakdown stage depends on the ranker soil of this virgin forest. The soil on the root clusters remains longer and thus creates a suitable seedbed for the spruce regeneration.

The research of the spruce natural forest NNR Nefcerka confirmed that, with the ascending altitude, the structural diversity increases most in the growth stage. Regeneration processes are continuous and the importance of dead wood and wind-thrown roots as seedbeds grows.

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Received for publication March 12, 2008
Accepted after corrections July 11, 2008

Zmena štrukturálnej diverzity a regeneračné procesy smrekového pralesa v NPR Nefcerka (TANAP) v závislosti od nadmorskej výšky

ABSTRAKT: Príspevok hodnotí štrukturálnu diverzitu smrekového pralesa v NPR Nefcerka v Tatranskom národnom parku (TANAP) v závislosti od vývojových štádií a nadmorskej výšky. Štruktúra pralesa sa hodnotí pomocou indexu

Clark & Evans, Füldnera a indexu Jaehne & Dohrenbusch. V prípade rozmiestnenia stromov (index Clark & Evans) sa potvrdil štatisticky významný rozdiel v štádiu dorastania voči štádiu optima a rozpadu. Potvrdil sa tiež vplyv nadmorskej výšky na tendenciu koncentrácie stromov pralesa. V prípade hodnotenia komplexnej diverzity podľa indexu Jaehne & Dohrenbusch (1997) sa potvrdila štatisticky významne rozdielna diverzita smrekového pralesa v štádiu dorastania voči ostatným vývojovým štádiám. Rozbor regeneračných procesov potvrdil, že tieto prebiehajú v dobrej dynamike aj v nadmorskej výške nad 1 400 m, pričom so stúpajúcou nadmorskou výškou (nad 1 300 m) nadobúda väčší význam klíčne lôžko moderové drevo a kopčeky po koreňových baloch vyvrátených stromov.

Kľúčové slová: smrekový prales; štrukturálna diverzita; regeneračné procesy

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