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Yellowing of Norway spruce stands in the Silesian Beskids – damage extent and dynamics

V. Šrámek, M. Vejpustková, R. Novotný, K. Hellebrandová

Forestry and Game Management Research Institute, Strnady, Czech Republic

ABSTRACT: In recent years, the Czech part of the Silesian Beskids has been affected by strong yellowing of Norway spruce stands and gradual decline of individual trees. Similar damage has also been observed in the neighbouring parts of Poland and Slovakia. The article presents the results of an investigation in the Forest District Jablunkov – part Nýdek. To evaluate the situation, monitoring plots were established and a regional survey was carried out together with tree-ring analysis. The results show a mosaic distribution of damage in the region studied, independent of the altitude and forest type. Defoliation was lower in 20–40 years old stands. Even these young classes, however, show yellowing symptoms. The decline of stands started to be visible at the end of the 1990s; significant loss of vitality was observed in the most affected stands in 2003, after an extremely hot and dry vegetation period. Actual development of meteorological conditions plays an important role in the stand damage. Lastly, possible causes of damage and further development are discussed.

Keywords: Norway spruce; forest decline; needle yellowing; Silesian Beskids

A part of the Silesian Beskids has been affected by significant yellowing of Norway spruce (*Picea abies* [L.] Karst.) stands in recent years, resulting in gradual drying-off and decay of individual trees. This damage has been observed not only in the Czech Republic – similar symptoms were recorded also in Poland, Beskid Śląski, and Beskid Żiwiecki (Wilczyński, Feliksik 2005), and in Slovakia, in the region of the Kysucké and Oravské Beskydy (Kmeť, Kulla 2001). In the Czech Republic, mainly the stands in the Forest District (FD) Jablunkov are significantly affected. The damage corresponds to the symptoms observed since 1999 in the western part of the Krušné hory Mts. (Lomský, Šrámek 2004), where the regeneration process was successfully initiated by the application of chemical amelioration (Lomský et al. 2006; Šrámek et al. 2006). Here also the primary symptoms of yellowing are connected with the critically low content of magnesium in spruce needles and in the upper mineral horizons of soil. In many aspects, however, the damage observed in Jablunkov FD is different from the already "known" damage in the Hercynian Mountains. The stands of lower vegetation zones are affected there (the core of the localities damaged is in zone 4–5(6) of the forest altitude zoning) and in suitable typology series (B, S). The neighbouring beech stands in the same localities do not show any symptoms of disturbed vitality. Biotic agents also play a role in the complex of harmful factors, mainly pathogenic fungi – *Armillaria* spp. and *Heterobasidion annosum* (Naukowe, D. 2004) and bark beetles. In the present article the summary of the knowledge acquired on spatial distribution, dynamics, and long-term development of the forest decline is presented, as was investigated in the region of Jablunkov – Nýdek during 2006–2007.

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MATERIAL AND METHODS

The study was focused on the Forest District Jablunkov, forest part Nýdek, where the decline of spruce stands was the most significant. Assessment of the health state was done within the 2-year research project. Three different methods were used to get an as realistic as possible view on the stand state in such a short time period.

Assessment of the health state on monitoring plots

In April 2006, four plots were established in the region studied, and they are presented in Table 1. In total, 25 trees were numbered on each plot to assess defoliation. The assessment was done during spring and autumn: on April 26–27, 2006, October 26, 2006 and May 2, 2007. Defoliation was established by the method used within the ICP Forests (UNECE 2006) international monitoring programme, in 5% steps. The results were evaluated as the relative number of trees in individual defoliation classes.

Regional survey of the spruce health state

The assessment of the spruce health state was done from the end of April to mid-July of 2006. The health state of the individual stands with prevailing spruce was assessed visually in the most damaged part of the Forest District Jablunkov – Nýdek. The survey was carried out in each forest stand in the District Nýdek. Average defoliation was assessed, as well as the relative number of trees showing symptoms of yellowing. The average discoloration of these trees in 5% steps was evaluated as the percentage of trees showing a sign of yellowing (discoloration) or as the percentage of yellowing trees weighted by the proportion of discoloured needles on a single tree (combined discoloration). The mortality was recorded in three steps, 0 – null occurrence of dead trees, 1 – individual dead trees, 2 – groups or mosaic of dead trees. The results were marked on maps of damage. The maps were produced with the help of ArcView software. Based on this data as well as on forest management data, the evaluation of damage was related to forest type groups and forest age. Stand age was characterized by the age class, i.e. in ten-year intervals in which individual stand groups are distributed. Statistical evaluation was done using QC Expert and Statistica programmes, differences between groups were tested by Scheffe's method.

Tree-ring analysis

In April 2006, three spruce stands were selected to analyze radial growth. The stands were selected in localities where the health state was assessed, in order to characterize different levels of spruce damage (Table 1). In each stand, 20 co-dominant trees, representing a medium stem diameter, were selected. Two cores for the diameter growth analyses were taken at breast height (1.3 m) from each sample tree. Tree-ring widths were measured to the nearest 0.01 mm using the Kutschenreiter digital positiometer. Each tree-ring series was visually cross-dated, checked, corrected for missing and false rings, and statistically verified using the program COFECHA (Holmes 1983). Then the average ring-width series were calculated for each stand. The average ring-width series were compared; similarity was quantified by the sign test (Schweingruber 1989). The test is a measure of the year-to-year agreement between the interval trends of two tree-ring series, usually expressed as the percentage of cases of agreement.

In all stands and for each tree, negative years were identified, defined as extremely narrow rings, showing growth reduction over 40%, compared to the average ring width in four previous years (Schweingruber et al. 1990). A negative pointer year was defined as an event year identified for at least 20% of the trees in the stand.

Ring-width series were standardized to eliminate the age trend. The resulting index series were aggregated by calculating mean values into the stand chronologies. The average, as calculated from the set of curves standardized for one stand, gave the standard tree-ring chronology.

Table 1. Monitoring plots in FD Jablunkov – Nýdek

Forest stand	Latitude	Longitude	Altitude	Intensity of damage	Dendrochronological analysis
117B5	49°36'50"	18°48'51"	630	heavy damage	yes
115F7	49°37'28"	18°48'11"	690	intermediate damage	no
104B5	49°40'54"	18°49'30"	590	weak damage	yes
103A8	49°40'50"	18°45'27"	558	intermediate damage	yes

To express incremental losses of spruce in recent years, the following method was used: the average values of ring width in the control stand were used as a standard, and the average increment values of the damaged stand were related to them. The difference between the obtained value and 100% expresses the incremental loss.

RESULTS

Assessment of the health state on monitoring plots

The results of defoliation assessment in the four spruce stands are shown in Fig. 1. It confirms that the development is unsatisfactory. The average defoliation of the most damaged stand 117B5 was around 50%, which means significant damage with usually a low chance of regeneration. Even in the "control" stand 104B5 with relatively low damage, the average defoliation was 27–31%, which more or less corresponds to the average defoliation of spruce stands in the CR (in 2006 it was 29.7%). However, healthy trees with defoliation from 0 to 10% are missing. Compared results of individual assessments show certain dynamics of damage development in different stands even in a short period. The summer period of 2006 was very warm and dry in July and wet and cold in August. Practically all the stands evaluated show a worsening of the state. It was most significant in the stand 117B5, where vast tree decay was also recorded. In contrast, the warm winter period of 2006/2007 resulted in certain regeneration in the strongly damaged stand 117B5 and in the less damaged stand 104B5. Also in the two remaining stands, where the average defoliation increased, the proportion of trees with low defoliation, in class 10–25%, was higher in spring compared to the autumn results.

Regional assessment of the spruce health state

Several different types of maps were prepared based on the data acquired. Fig. 2 shows defolia-

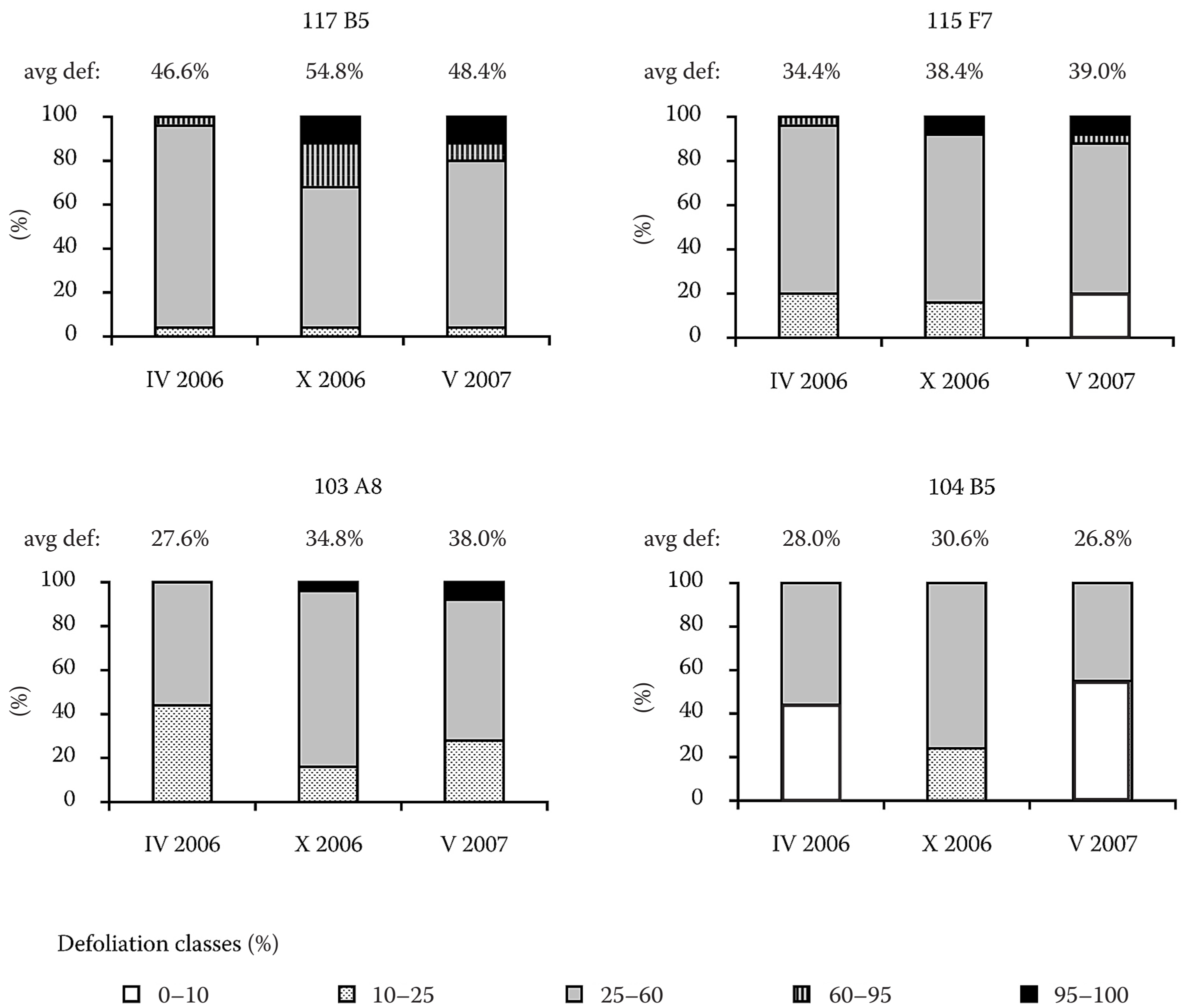

Fig. 1. The relative number of trees in defoliation classes on monitoring plots in FD Jablunkov – Nýdek
(avg def = mean defoliation in individual assessments)

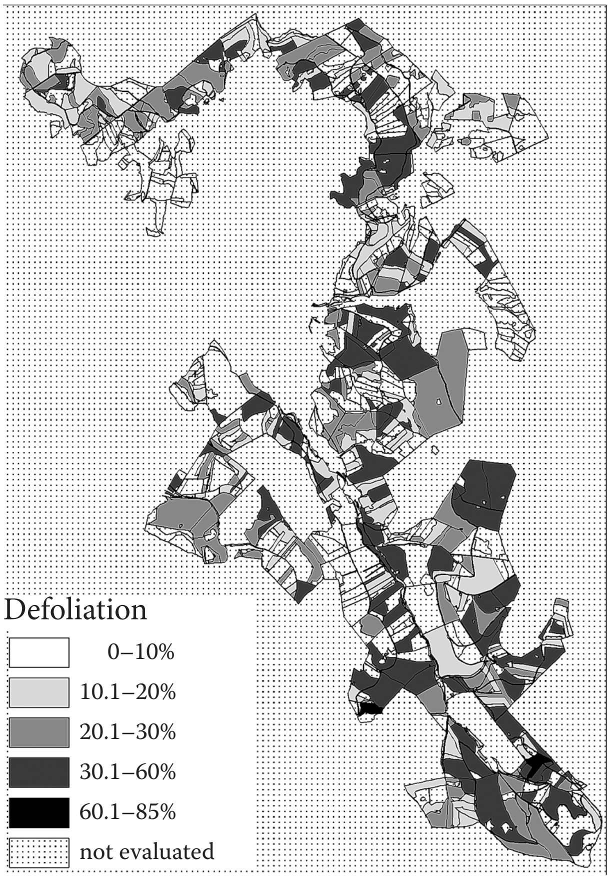

Fig. 2. Defoliation of Norway spruce stands in FD Jablunkov – Nýdek

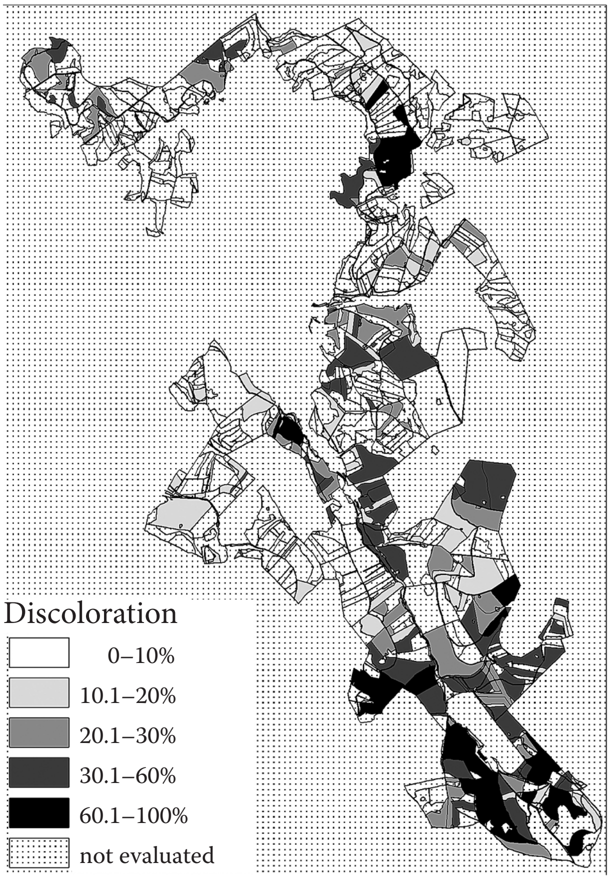

Fig. 3. Discoloration of Norway spruce stands in FD Jablunkov – Nýdek

tion classes of the spruce stands. The map shows that healthy stands, with defoliation under 10%, are distributed in a mosaic within the whole region. In most cases they are the youngest age class, with some of them showing slight symptoms of yellowing. With respect to the stand stability, the

Table 2. Differences in defoliation and discoloration between individual age classes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		F	F	F	F	F	F/C	F/C	F	F	F/C	F/C	F	F/C
2	F		F		F	F	F	F/C	F		F	F/C	F/C	C
3	F	F			F		F				F/C	F		C
4	F				F		F				F/C	F		C
5	F	F	F	F										C
6	F	F												C
7	F/C	F	F	F										C
8	F/C	F/C												
9	F	F												C
10	F													C
11	F/C	F	F/C	F/C										
12	F/C	F/C	F	F										C
13	F	F/C												
14	F/C	C	C	C	C	C	C		C	C		C		

F – significant difference ($\alpha < 0.05$) in defoliation, C – significant difference ($\alpha < 0.05$) in discoloration

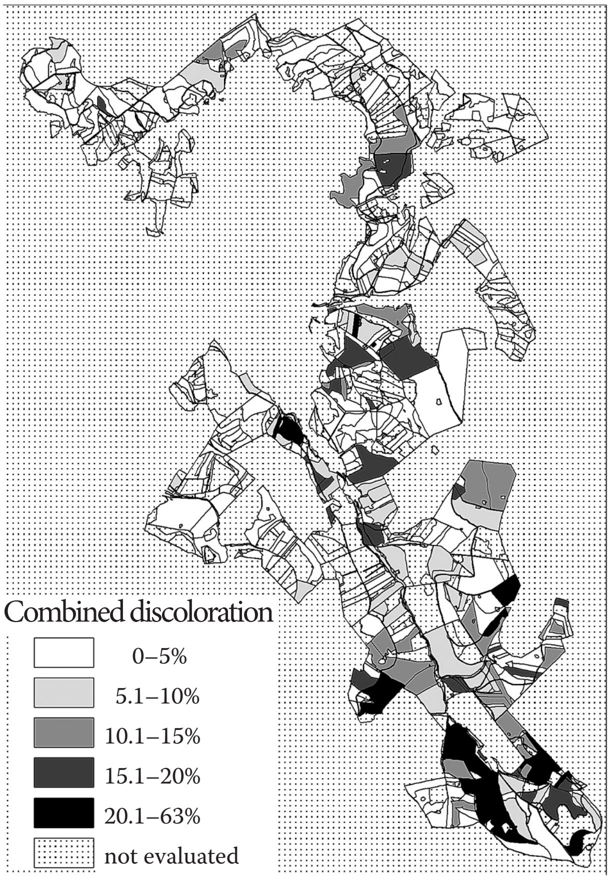

Fig. 4. Combined discoloration of Norway spruce stands in FD Jablunkov – Nýdek

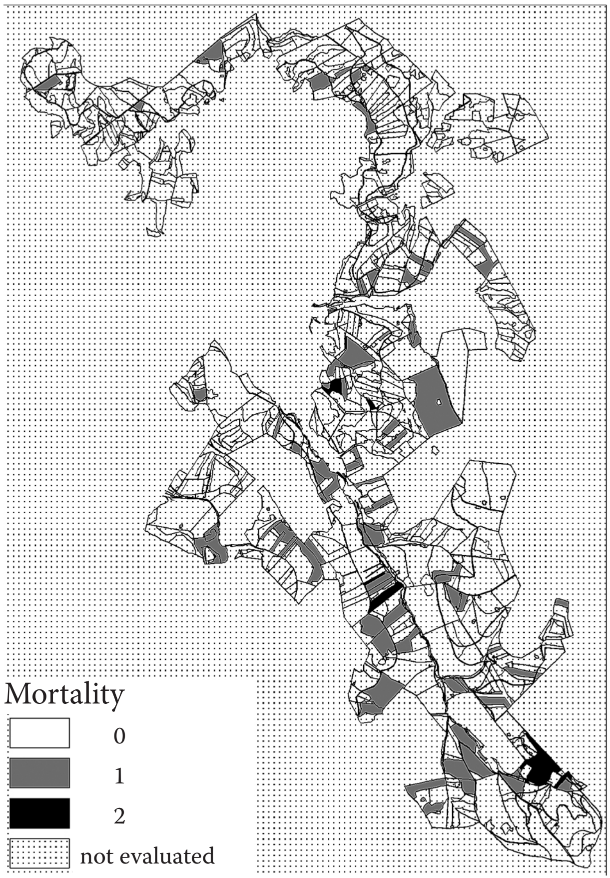

Fig. 5. Mortality of Norway spruce stands at FD Jablunkov – Nýdek

representation of moderate (31–60%) and strong (> 60%) class defoliation is of importance. Stands with moderate defoliation are distributed practically throughout the whole region of the Nýdek District, while strong defoliation connected with total stand disturbance was recorded only in a few localities in the southern part of the region – in the valley of the Hluchová River.

The map of discoloration (Fig. 3) shows the percentage of yellowing trees in the stand. It is evident that the southern part of the region studied is significantly more damaged than the rest. It is even clearer in Fig. 4, showing combined information on the extent and intensity of discoloration in individual stands. Fig. 5 represents mortality in individual stands. In some cases mortality was recorded even in stands with low average defoliation, which confirms the activity of biological harmful agents. In contrast, e.g. in the most damaged stand 117B5 no mortality was recorded because the most damaged and dead trees were removed before the assessment.

The results of the statistical evaluation show that the degree of damage is not connected with the forest type. Defoliation sets for individual forest types (groups of forest types) do not show any important deviations either in medium values or in extent. This is confirmed to a certain extent also by the fact that damage is not related to the altitude. However, a relation between defoliation and the age of the stand was found (Table 2). The loss of assimilation tissues was significantly lower in the first and second age class, compared to the others. Classes three and four were of much lower defoliation than classes 5, 7, 11 and 12. Discoloration (yellowing), however, does not show the same pattern as defoliation. Young age classes are mostly involved in the same way as mature stands. Age classes 11 and 14 only exhibit significantly higher discoloration than other stands.

Tree-ring analysis

Comparing the average ring-width series of damaged stand 117B5 and control stand 104B5 shows very synchronous curves – the age trend is the same (i.e. a natural gradual decrease in increments with the age of the stand), and also inter-annual fluctuations of ring widths. The high similarity of the curves is confirmed by the value of the sign test $G = 80\%$.

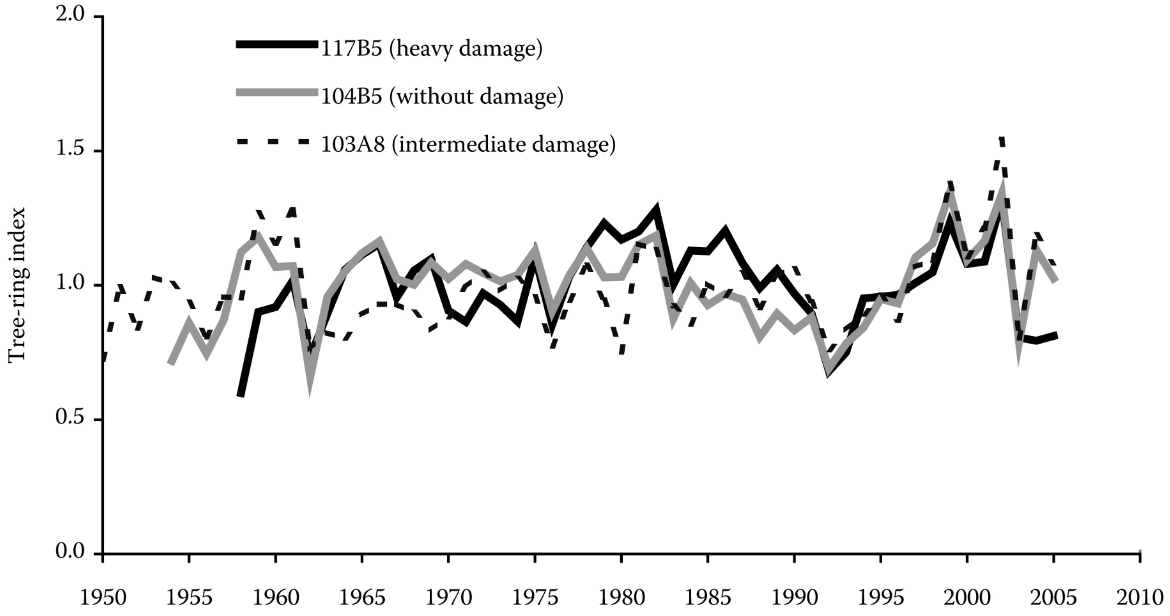

Fig. 6. Tree-ring indices of differently damaged Norway spruce stands

The tree-ring series of the third stand studied, 103A8, which is much older, shows lower similarity of inter-annual growth variation than those of 104B5 (G = 72%) and 117B5 (G = 65%).

In Fig. 6 there are standardized tree-ring chronologies of individual stands. The impact of different age and site conditions on growth was filtered out by the process of standardization. The results show that in 1977–1991 the radial increment in 117B5 was higher than in the control stand 104B5, while later, until 1996, the growth was approximately the same in both stands. Since 1997 the increments of damaged stand 117B5 are lower than the growth of control stand. The growth development of the third stand analyzed, 103A8, during the last 15 years was the same as the growth of control stand 104B5. A significant decrease in ring widths of all three stands was observed in 2003, when a negative pointer year was identified. (Other negative pointers were recorded in 1962 and 1992.) However, in 2004 and 2005 abnormal development was recorded in the strongly damaged stand 117B5. Meanwhile in other stands, after growth decline in 2003, a significant increase in increment was recorded in 2004, in the stand 117B5

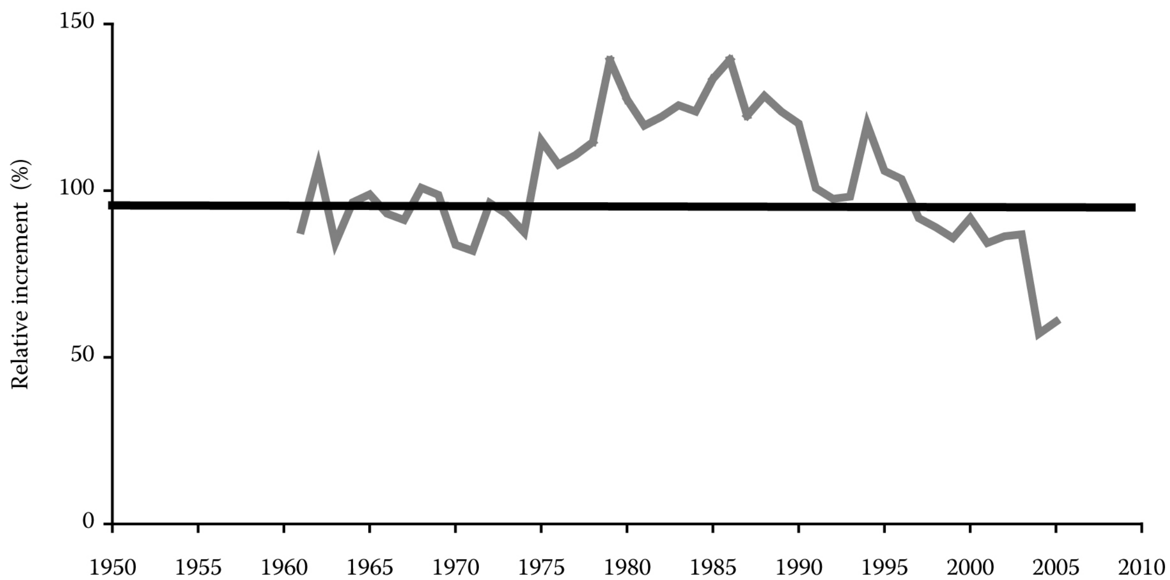

Fig. 7. Relative increment of heavily damaged forest stand 117B5 expressed as the percentage of increment of control stand 104B5

growth was further declining. The loss of the radial increment in 117B5 was 43% in 2004 and 40% in 2005. No such a strong decrease in increment values in the stand 117B5, compared to the control stand, was recorded in previous years (Fig. 7).

DISCUSSION

Defoliation found on the monitoring plots and in the regional survey is comparatively high and on a part of the plots it documents a significant disturbance of the health state. Similar values of defoliation, up to 50%, were observed in the Beskids region at the end of the 1980s (Štefančík, Cicák 1994). At that time it was on the top ridge part of the Moravian-Silesian Beskids, while the more protected part of the Silesian Beskids was much less damaged. Today, the Silesian Beskids are much more affected. Repeated assessments in the spring and autumn periods of 2006–2007 show that actual state of the stands is significantly influenced by meteorological factors. The most damaged stands, however, can hardly be regenerated.

The mosaic distribution of damage does not have a visible gradient and is not connected either with typology characteristics or with altitude. This corresponds to the results published by Modrzyński (2002) for the region of the High Beskids and the Tatras. Defoliation did not show a significant relation to stand age, altitude or exposition there. In the region of Horní Orava Šmelko (1999) found increased defoliation by about 5% per 100 m of the altitude. Such a relatively small shift in a comparatively homogenous region need not be observable. The maps of defoliation (Fig. 2) and mortality (Fig. 5) show that this is so in spite of the fact that the health state of spruce is significantly disturbed; only few stand groups show higher mortality or defoliation over 60%, where the chance of regeneration is small. The evaluation of mortality should be done very carefully, as in some stands thinning was done recently (removal of dry trees). The maps of discoloration (Figs. 3 and 4) show that the yellowing of stands was observed mostly in the southern part of the region studied, in the valley of the Hluchová River. In this part, the stands with the highest defoliation were also recorded.

The tree-ring analysis confirms that current damage in the terms of increment decrease started to be detectable only at the end of the nineties, with a decrease in the relative increment of the most damaged stands. This corresponds to the paper of Wilczyński and Feliksik (2005) documenting the increased growth of spruce stands in the Polish Beskids in the first half of the nineties. The fact that the critical state of the most damaged stands was started by the extreme meteorological conditions of the dry and hot year 2003 is of importance.

The situation in the Beskids corresponds to the situation in the Krušné hory Mts. to a certain extent. From the seventies to the nineties of the last century, attention was paid there mainly to the eastern part with significant decline that was caused by acute air pollution damage. At the end of the nineties attention was focused on the western part, where the yellowing of spruce stands, connected with long-term deposition load, was observed. In the Silesian region this shift started in the Moravian-Silesian Beskids and went on towards the lower Silesian Beskids. However, similarities between the two regions are limited, as the situation in the Beskids is probably more complicated (Šrámek et al. 2007). Significant magnesium, calcium and phosphorus deficiency in forest soil and spruce needles was also observed there (Bytnerowicz et al. 1999; Zwoliński 2003), and the current state of the soils on these sites is an important predisposing factor (Kulhavý, Klimo 1998). In contrast to the western Krušné hory Mts., the stands studied are situated at significantly lower altitudes where spruce is influenced by many other stress factors, such as biological harmful agents and meteorological factors. Expected climate change can play an important role in the future development of spruce in the Silesian Beskids. The changes can mean better growth conditions at higher altitudes (Ďurský et al. 2006); however, for spruce in vegetation zone 4–6 they imply an increased risk, mainly with respect to water balance (Minďáš, Škvarenina 2003).

CONCLUSION

The results of the evaluation of the health state in the Forest District Jablunkov in the Silesian Beskids show the mosaic distribution of damage. The damage was, however, most severe in the southern part of the region – in the Hluchová River valley. In spite of serious damage, only a few groups are in the state when regeneration is hardly probable. Damage is not correlated with typology criteria and altitude. The dynamics of the damage depends significantly on the development of meteorological conditions. The tree-ring analysis confirms that today the growth reduction can be observed since the end of the 1990s and the most damaged trees suffered a significant loss of vitality in 2003, in the vegetation period of extremely hot and dry weather.

Today's state is most probably the result of many stress factors – historically heavy pollution load, today's state of soil and stand nutrition, meteorological factors and biotic harmful agents. The situation needs a complex increase in the stability of forest stands in relation to different types of stress.

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Žloutnutí smrkových porostů v oblasti Slezských Beskyd – rozsah a dynamika poškození

ABSTRAKT: Část Slezských Beskyd je v posledních letech postižena výrazným žloutnutím smrkových porostů, které vede až k postupnému usychání a odumírání jednotlivých stromů. Poškození je pozorováno také v přilehlých částech Polska a Slovenska.Příspěvek uvádí výsledky šetření zdravotního stavu na části lesní správy Jablunkov – revír Nýdek. Pro hodnocení byly použity monitorační plochy, plošné šetření a dendrochronologická analýza. Výsledky ukazují, že poškození je rozloženo poměrně mozaikovitě, v rámci sledované oblasti není závislé ani na nadmořské výšce, ani na typologických kategoriích. Defoliace je nižší u porostů do 20–40 let, žloutnutím jsou však postiženy i tyto mladší věkové třídy. Chřadnutí se na růstu porostů začalo projevovat koncem devadesátých let, u nejsilněji poškozených porostů došlo k výrazné ztrátě vitality v roce 2003, kdy bylo extrémně suché a teplé vegetační období.

Na průběhu poškození se výrazně projevuje aktuální průběh meteorologických podmínek. V závěru se diskutuje o pravděpodobných příčinách poškození a možnostech budoucího vývoje.

Klíčová slova: smrk ztepilý; chřadnutí lesa; žloutnutí; Slezské Beskydy

Corresponding author:

Ing. Vít Šrámek, Ph.D., Výzkumný ústav lesního hospodářství a myslivosti, v.v.i, Strnady 136, 252 02 Jíloviště, Česká republika
tel.: + 420 257 892 232, fax: + 420 257 921 444, e-mail: sramek@vulhm.cz