Development of the spruce natural regeneration on mountain sites in the Šumava Mts.

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ABSTRACT: The aim of this study was the evaluation of the spruce natural regeneration growth and development in Modrava and Plechý areas, which represent the first and late bark beetle attack areas. Study was done on 13 permanent research plots, partly with vital tree layer and canopy cover and partly characteristic by open or none canopy, due to bark beetle attack. Actually amount of this regeneration is sufficient (average over 12,000 pcs/ha in the living stands and almost half of this amount in the declined stands) on the both types of plots. Faster growth is usually on the declined plots, with saplings larger amount and height increments, in the higher height classes. Particular interest was aimed to the microhabitat conditions, especially herbal cover influence. There were statistically important differences in the amounts and height growth of the first height class on the different microhabitats. As the most sufficient for the seedlings occurrence appeared to be the dead wood and the least suitable were fern and grasses. For the height growth the least suitable was vital tree foot with litter cover. The results indicate, that declined stands, without vital mature trees and without seed source, will likely develop into more or less even-aged forest.

Keywords: Bohemian Forest Mts. National Park; mountain spruce forests; forest decline; spruce natural regeneration; management of protected areas

National Park (NP) Šumava Mts. (Bohemian Forest Mts.) together with the Bavarian National Park on the border with Germany and with buffering zone has been declared as Protected Landscape Area (90,000 ha). It represents the largest protected area in the Europe, with forest coverage 66% (Chábera et al. 1987). Majority of the forest stands is over 120 years old presently (Zatloukal 1998), as a consequence of bark-beetle calamities in 1860's–70's (Jelínek 1988) and consequent forest management. Also other anthropogenic factors influenced this area. Acid rains with high immission loads in the 80's of the 20th century affected soil conditions of mountain ecosystems and forest stability decreased due to nutrients looses (Pasuthová, Lomský 1998). Forests influenced and changed by anthropogenic factors are more susceptible to insect attacks, e.g. bark beetle attack. About 4,000–5,000 ha of declined spruce forests was a consequence of these conditions and bark beetle calamity since 1995 (Vinš et al. 1999).

Natural regeneration is one of the basic factors for management and future development of mountain forests in protected areas (Tesař, Tesařová 1996), including such as those declined during bark beetle calamity in the NP Šumava Mts. There are some special problems with natural regeneration in the mountain zones: higher influence of climatic and microclimatic factors and in consequence longer periods between seed years – usually 8–14 years (Šerá et al. 2000), lower germination, slower growth of the seedlings. Higher seedlings mortality is caused by drought, frost, movement of snow cover during the spring, ground vegetation competition, or game damages (Vacek, Podrázský 2003).

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In the cases of plots with low potential of natural regeneration, the management measures could be taken to prevent ecological and environmental damages – replanting pioneer or missing climax species to improve unfavorable microclimatic conditions, changing the dead wood amount left on the site, acceleration of succession (Podrázský et al. 1999).

The aim of the article was to evaluate potential of natural regeneration on the vital and declined plots in the most affected area by bark beetle calamity. It is also an attempt to find microhabitat characteristics important for the natural regeneration occurrence and growth.

METHODS

Study area

Permanent research plots (PRP) were located in the Forest Districts Modrava and in the Forest District Plechý area, in the I. and II. zone of the NP Šumava Mts. (Podrázský 1997). Modrava area represents one of the first parts affected by bark beetle outbreak in 1990s, Plechý area has been affected just in the last years.

The altitude of the plots varied between 1,120 to 1,370 m. The climate is cool and wet with mean annual precipitation 900–1,380 mm, mean annual temperature 3.5–5°C, and mean length of annual vegetation period is 60–100 days. The bedrock is biotitic granite partly combined with gneiss, soils are mainly podzolic soils of ranker or humic type. Plot differences due to the slope gradients, exposition and water regime are described in Tables 1 and 2. The tree layer is dominated by Norway spruce (*Picea abies* L.), with some (up to 600 pcs/ha) admixture of rowan (*Sorbus aucuparia* L.) or pubescent birch (*Betula pubescens* Ehrh.) (up to 130 pcs/ha) in the waterlogged and more open stands.

Plots are distributed basically in 4 localities and include two types of plots:

First type, "vital stands", are partly endangered stands with vital mature tree layer, so far with relatively scarce bark beetle sanitation: Plots Mo 1, 4, close to Modrava (49°N, 13°30´E), on the slope under the Studená Mt., and plots Pl 18–20 on the Plechý Mt. (48°05´N, 13°50´E) and plots Tr 1–3 close to this locality, in the saddle between Plechý Mt. and Trojmezná Mt.

Second type are "declined stands", plots with declined mature trees since 1996–1998: Plots Py 1, 2 in Pytlácký roh locality in the Modrava area, and plots Lu 1–3 on the slope of Velká Mokrůvka Mt. at the end of the Luzen valley, also close to Modrava. These are located in the area of former large scale bark beetle calamity in the 1870-ies, so stands were previously relatively even-aged, probably not with fully autochthonous ecotypes. Thick grass cover and abundant log breakage are typical on this plot.

Herbal cover on the particular plots depends mainly on the canopy and humidity of the site (Table 2). Main species are: *Vaccinium myrtillus, Calamagrostis villosa, Avenella flexuosa, Anthyrium distentifolium.* Lower abundance species are: *Trientalis europea, Homogyne alpina, Oxalis acetosella, Lycopodium annotinum, Maianthemum bifolium*, and on the declined plots *Chamaerion angustifo-*

Table 1. Site characteristics of the particular plots

Plot	Stand	Forest type	Altitude (m)	Exposition	Age/Stand characteristics
Mo 1	68B4	8N3	1,140	E, slope 60°	age 134, vital, occasionally bark beetle sanitation
Mo 4	68B	8R1	1,120	flat	age 120, vital, occasionally bark beetle sanitation
Pl 18	4A1/6	7N3	1,250	SE, slope 25°	age 190, vital, occasionally bark beetle sanitation
Pl 19	5A	8Y2	1,300	SE, slope 40°	age 150, vital, occasionally bark beetle sanitation
Pl 20	5A	8Y2	1,370	flat top	age 150, vital mature trees, occasionally bark beetle sanitation
Tr 1	47A	8Y2	1,300	NW, slope 5°	age 180, vital mature trees
Tr 2	47A	8Y2	1,300	NW, slope 5°	age 180, vital mature trees
Tr 3	47A	8Y2	1,300	NW, slope 5°	age 180, vital mature trees
Lu 1	55B4	8K3	1,220	W, slope 20°	age 150, since 1996 declination, no vital mature trees
Lu 2	55B4	8Y0	1,260	W, slope 30°	age 164, since 1996 declination, a few vital mature trees
Lu 3	55C3	8Y0	1,300	W, slope 45°	age 164, since 1996 declination, no vital mature trees
Py 1	76C8	8S1	1,230	N, slope 25°	age 149, since 1996 declination, no vital mature trees
Py 2	80A3	8S1	1,260	N, slope 30°	age 149, since 1996 declination, no vital mature trees

Table 2. Herbal cover site characteristics

Plot	Canopy (%)	Site	Moss cover (%)	Herbal cover (%)	Dead wood (m^3/ha)	Dominant herbs
Mo 1	45	skeletal	100	60	35	*Vaccinium*
Mo 4	45	wet	70	95	112	*Vaccinium/Calamagrostis*
Pl 18	40		20	85	62	*Dryopteris/ Vaccinium*
Pl 19	45	skeletal	45	95	186	*Vaccinium*
Pl 20	45		30	95	207	*Avenella, Dryopteris*
Tr 1	45		75	95	165	*Avenella, Dryopteris*
Tr 2	40		70	95	23	*Luzulla, Dryopteris*
Tr 3	55		75	85	71	*Avenella, Dryopteris*
Lu 1	0	wet/partly peat	30	95	–	*Calamagrostis*
Lu 2	3	skeletal	70	95	–	*Calamagrostis*
Lu 3	0	skeletal	70	95	–	*Calamagrostis*
Py 1	0		5–10	95	–	*Calamagrostis*
Py 2	0		20	80	–	*Calamagrostis*

Canopy – canopy covers of mature trees layer

lium. In the highest elevations, the main species are *Polytrichum formosum, Dicranum scoparium, Sphagnum* sp.

Grass cover, especially of *Calamagrostis villosa*, largely prevails on the plots with declined mature trees (Lu 1–3, Py 1, 2) or on the plots with open canopy. High herbal cover can be also on the plots with intact canopy, but there is typical another species – *Vaccinium myrtillus* (situation on the plots Mo 1 and Pl 19). Usually there is typical mixture of grasses (*Luzulla, Avenella, Calamagrostis*) fern, *Vaccinium* on the sites surrounding stumps or mature trees, and few dicotyledonous plats and litter cover on the main part of plots (Tr 1–3, Pl 18, 20, Mo 4).

The 13 permanent research plots were established in the representative parts of the selected stands. The area of each of research plot is 50 × 50 m and they are used for complex forest ecosystem study, including the natural regeneration dynamics. Its first evaluation was done in 1997 (Podrázský 1997), last one in 2005. For detail natural regeneration evaluation purpose, transects of 5 × 50 m were established through these plots.

Basic characteristics of regeneration were determined: spatial structure, i.e. its location on transects, increments for the last 3 years, height structure – saplings were divided into height categories sorted by 10 cm (with the accuracy of 0.5 cm), and the average height of regeneration on the plot was counted as a height of saplings to 5 m (that year seedlings were excluded). Also there were recorded health state (yellowing) and damages (by deer browsing e.g.). On the research plots with relatively intact mature tree layer, microhabitat pattern was characterized by vegetation and decaying wood cover (estimated to the 10% ground cover) on the plot and by immediate surroundings of each particular seedling: stumps, tree foot, logs, vegetation cover. Rare ground cover, not typical, or mixture of a few different types, was described as "other" category. Declined stands were excluded from the microhabitat evaluation, because of almost 100% grass cover and high grass invasion – which led to the relatively too low stability of microhabitat pattern in previous years and no real differences in the conditions within the plot nowadays.

Microhabitat influence to the seedlings and saplings growth was estimated like relative proportion of natural regeneration amount on the specific microhabitat to total amount of regeneration (tree foot microhabitat was associated with "other" category for increment calculation). Relative influence of specific microhabitat to natural regeneration was calculated like relative occurrence of natural regeneration on the specific microhabitat, to the relative proportion of microhabitat on transect. Expected occurrence of regeneration with neutral effect of this microhabitat should have values about one, microhabitat with negative influence should have values below one and values over one shows how many times is amount of saplings on the specific microhabitat higher, than is expected from the relative area of this microhabitat on the plot.

Dead wood on the stand was also described just on the plots with vital mature trees, on the snags with more than 10 cm diameter, including visibly determined stumps. Relative "wood cover" of the stand was estimated like average log length and its width.

Spatial structure (horizontal distribution of regenerated trees) was analyzed in relation to the tree species composition and substrate on a soil cover with the use of the Ripley's K-function (calculated by original software developed by D. Zahradník).

Ripley's K-function:

$$K(r) = \sum_{0<|x_i - x_j| \leq r} \frac{1}{\lambda^2 s(\|x_i - x_j\|)}$$

where: r – the sociability,

λ – the mean number of trees per unit area (stand density),

$s(r) = \dfrac{ab - r(2a + 2b - r)}{\pi}$ – the edge correction factor,

a, b – dimensions of the rectangle (sample plot),

$\|x_i - x_j\|$ – distance between i-th and j-th tree.

Foliar samples were collected to assess nutrient state in the end of October. Needles were collected from adventitious last year shots from the 4th whirl on the sunny part of crown. Samples were collected from 30 individuals per plot. Chemical analyses were conducted at the Tomáš laboratory, a. s., in Research Station Opočno by flame photometry.

Statistical analyses for the differences in seedlings numbers and their height increments on the particular plots and microhabitats were performed by one way ANOVA (S PLUS version 6).

RESULTS

Amount of natural regeneration

Average numbers of natural regeneration on the particular plots are presented in Table 3, and show relatively great variability within plots. Range is relatively wide and covers 1,300 to 31,000 pcs/ha. There is statistically significant difference between plots with vital mature tree layer – 12,080 pcs/ha (± 9,409) and declined stands with low canopy and none parent trees 5,929 pcs/ha (± 6,706). The highest proportion of natural regeneration is in the seedling phase (to 80%) especially on the vital plots with mature trees as a seed source.

Spatial structure

Two typical samples of Ripley's K-function for spatial structure characterizations are presented in Fig. 1. Thin irregular line shows K-function for real trees on the stand. Central of the three curves demonstrate K-function for random spatial pattern and both lateral curves demonstrate 95% confidence interval for random spatial pattern. In our case K-function for real situation run over this interval, which indicate strong aggregation of natural regeneration, in whole spatial scale (given by the size of

Table 3. Spruce natural regeneration height distribution

Plot		Mo 1	Mo 4	Pl 18	Pl 19	Pl 20	Tr 1	Tr 2	Tr 3	Lu 1	Lu 2	Lu 3	Py 1	Py 2
Average height (cm)		44	33.09	5.9	4.3	29.1	13.02	9.6	20	65.5	35.7	30.5	37.2	99
Amount of regeneration in the particular height classes (pcs/ha)	≤ 10 cm	2,400	5,520	15,680	28,400	4,160	2,280	2,200	2,240	40	120	1,400	120	0
	≤ 30 cm	6,800	8,680	17,120	30,000	9,480	3,760	3,320	2,560	1,040	2,040	11,133	480	80
	≤ 30 cm %	59.2	65.4	92.8	96.8	80.1	94.9	95.4	81.0	19.1	56.0	57.6	37.5	3.1
	40+	4,000	3,240	960	960	1,800	120	40	600	3,560	960	4,733	520	2,120
	150+	360	360	40	120	520	80	40	360	120	0	0	40	560
	Total < 500	11,480	13,280	18,440	31,000	11,840	3,960	3,480	3,160	5,440	3,640	19,333	1,280	2,600
	Significant difference	abc	abc	a	a	a	bc	bc	bc	abc	abc	abc	bc	bc

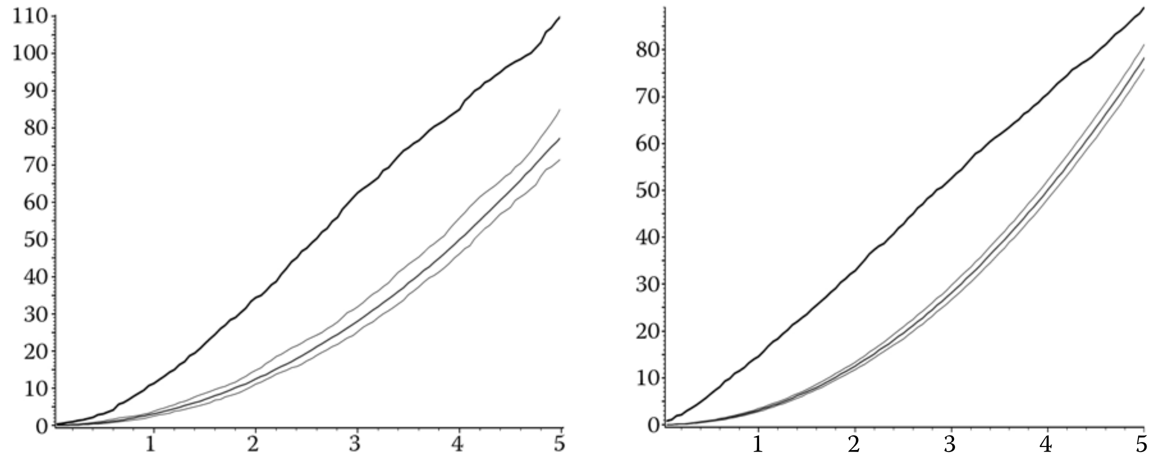

Fig. 1. Spatial structure of the spruce natural regeneration by Ripley's *K*-function. Plot Lu 3 (left) – declined forest, plot Pl 20 (right) – intact forest

transects). There are no real differences between vital and declined stands.

Height structure

Height structure (Table 3) depends not only on the growth conditions and increment, but also on the age structure. Age composition of spruce regeneration depends on the type of the plot – with vital or declined parent trees. On the plots with seed source, there is very high number of seedlings (Fig. 2), and the height distribution of regeneration makes exponential curve with many young seedlings and lower number of older saplings. Distribution of regeneration on the plots with declined mature trees (and none or strictly reduced source of seeds) is more Gaussian, with low number of seedlings and higher of saplings. For the average height of saplings on the plot, there are again great differences: on the plots with declined mature trees layer is average height about 64.9 (± 37.9) cm and on the vital 19.8 (± 14.3) cm. For the older regeneration, with low competition of high grass herbal cover, there are average of saplings (over 1 m), 460 (± 416) per ha on the vital plots and 669 (± 761) per ha on the declined plots. Differences are probably given by the canopy (different intensity of radiation) and number of the youngest regeneration.

Seedling growth

For the saplings growth, there are significant differences between plots with declined and vital mature trees layer (Table 4). For the last 3 height increments of saplings (seedlings excluded), the average on the declined plots is almost twice higher, than on the vital plots. The results could be influenced by different proportion of regeneration in the particular

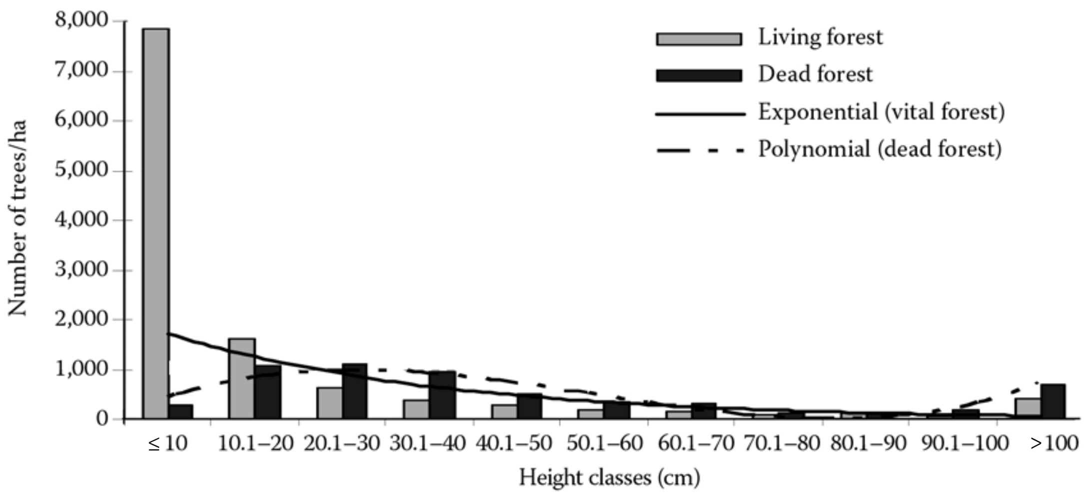

Fig. 2. Norway spruce regeneration height distribution, comparison of vital and declined stands

Table 4. Average annual height increments for natural regeneration on the different plots

Increment	Increment 2002	St. dev.	Increment 2003	St. dev.	Increment 2004	St. dev.	Average increment	St. dev.
Mo 1	1.72	0.81	1.78	0.91	1.22	0.86	1.57	0.31
Mo 4	2.23	1.30	2.70	1.57	2.13	1.54	2.35	0.30
Pl 18	3.54	3.60	2.98	1.59	4.10	3.09	3.54	0.56
Pl 19	1.92	1.07	1.61	0.97	1.56	1.09	1.70	0.20
Pl 20	2.50	1.19	2.70	1.51	2.55	1.79	2.58	0.10
Tr 1	2.62	1.13	2.89	1.31	2.90	1.54	2.80	0.16
Tr 2	2.35	0.85	1.97	0.95	1.70	1.01	2.01	0.33
Tr 3	1.83	1.19	1.60	0.72	1.84	0.94	1.76	0.14
Lu 1	3.96	2.68	5.50	3.39	6.02	3.19	5.16	1.07
Lu 2	2.59	2.82	4.50	3.18	6.53	3.22	4.54	1.97
Lu 3	3.56	2.60	4.63	2.42	6.77	3.59	4.99	1.63
Py 1	5.32	2.59	8.14	3.99	9.18	4.74	7.55	2.00
Py 2	4.40	2.14	5.24	2.52	7.02	4.53	5.55	1.34
Declined plots	3.97	2.57	5.60	3.10	7.10	3.85	5.56	1.60
Vital plots	2.34	1.39	2.28	1.19	2.25	1.48	2.29	0.26

age categories, but the effect of higher radiation is evident.

Microhabitat influence

The occurrence of seedlings depends strongly on microhabitat conditions. There are no saplings found in the *Dryopteris dilalata* cover, irrespective of its occurrence in the plots on the Plechý and Trojmezná locality. The results show relative proportion of natural regeneration in the specific microhabitat on the particular plots (first six columns of Table 5). There is also rate of really found and expected (from the ground cover proportion) amount of seedlings and saplings in the particular microhabitat (last 5 columns Table 5). Significantly lower proportion of seedlings was found in the stands of fern, grass, and bilberry, on the opposite, decaying wood was the most favorable microhabitat.

Average annual height increment during last 3 years (Table 6) is only slightly related to the ground microhabitat type. Significant differences was only in the last year, as a relative better microhabitat for spruce saplings growth appeared dead wood, tree foot, and category "other" including thin herbal cover or mixture of litter and moss cover. So the main part of favorable microhabitats is (slightly) uplifted in comparison with surrounding terrain. Less suitable is microhabitats of moss, litter and bilberry.

Nutrient and health state

There are only small differences in nutrient content in foliar samples (Table 7) between vital and declined

Table 5. Microhabitat importance for the spruce natural regeneration occurrence

M. type	Proportional amount of regeneration on the microhabitat (%)						Relative proportion, real to expected				
	moss	bilberry	grass	wood	other	tree foot	moss	bilberry	grass	wood	other
Mo 1	39.70	9.80	0	37.6	25.4	13.5	0.40	0.10	0	5.64	5.08
Mo 4	0.30	9.00	0	55.3	32.4	12.4	0	0.18	0	38.40	1.12
Pl 18	54.50	12.00	1.10	4.0	28.1	4.2	2.73	0.80	0.16	1.15	0.37
Pl 19	23.00	0	0	73.4	3.5	0.7	0.51	0	0	10.95	1.75
Pl 20	5.40	6.00	2.50	75.0	11.2	10.1	0.18	0.17	0.05	10.06	2.24
Tr 1	0	0	1.00	88.5	10.4	9.4	0	0	0.02	33.20	0.35
Tr 2	0	18.70	2.70	25.3	53.3	50.7	0	2.67	0.04	9.25	3.55
Tr 3	0	1.90	1.50	42.9	53.7	41.1	0	0.38	0.02	8.09	3.58

Other include litter microhabitats or thin herbal cover

Table 6. Average annual height increments of the natural regeneration in the different microhabitat

Year	2002		2003		2004	
Height increment	increment (cm)	st. dev.	increment (cm)	st. dev.	increment (cm)	st. dev.
Bilberry	2.45	1.38	2.34	1.59	1.96 c	1.43
Bilberry on the wood	2.33	1.27	2.62	1.42	2.33 b	1.59
Litter	1.54	1.01	1.87	1.27	1.72 c	1.17
Log	2.28	1.10	2.44	1.38	2.15 b	1.56
Moss	2.00	1.17	2.12	1.37	1.38 c	0.92
Tree foot	2.33	1.20	2.29	1.34	2.69 b	5.77
Grass	2.37	1.05	2.26	1.69	15.95 a	22.73
Other	2.84	4.77	2.21	1.07	3.62 b	10.05

Table 7. Nutrient state of spruce natural regeneration on the vital and declined plots

Nutrient	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Vital stands	1.42 (± 0.108)	0.15 (± 0.019)	0.63 (± 0.076)	0.13 (± 0.023)	0.07 (± 0.009)	0.15 (± 0.032)
Declined stands	1.56 (± 0.065)	0.19 (± 0.026)	0.54 (± 0.081)	0.23 (± 0.075)	0.07 (± 0.011)	0.14 (± 0.024)
Defficience limit	1.2	0.15	0.35	0.15	0.07	0.122

stands. Amount of nitrogen, phosphorus and calcium is higher in declined stands, due to nutrients leaching from the decaying wood. Temporary immission load is probably relatively low, as reflects the sulphur content in the last year foliar samples.

Health state of spruce saplings is good in both types of stands, on the vital stands no color change (yellowing) is observed, on the declined stands little bit more – up to 10% of saplings. Grouse damage was reported mainly on the spruce regeneration on the declined stands. Deer and elk browsing damage were low on the spruce and abundant on the broadleaves, e.g. 70% for the rowan tree.

DISCUSSION

Amount of natural regeneration

Amount of spruce natural regeneration in the mountain spruce forests of similar conditions like in the Šumava Mts. was already previously evaluated (Jonášová, Prach 2004; Šerá et al. 2000; Zatloukal 2000; Hunziker, Brang 2005; Saniga, Szanyi 1996). There are not detailed long term studies of regeneration demands to the microhabitat conditions yet.

Amount of natural regeneration on the selected plots was affected by crop year in 2002–2003 and 2003–2004, so number of seedlings was relatively high in the vital stands. Average numbers of regeneration on vital plots correspond with previous results from the similar areas of the Šumava Mts. (Zatloukal 2000), although the number was twice lower in our case on the plots declined before 1998, than according to this author. It could be result of competition with grass cover and declining last paternal trees during the time and so very low occurrence of the new seedlings on such type of plots.

Spatial structure

High sociability of regeneration indicates the concentration of individuals on microhabitats with favorable conditions. This trend is typical for natural regeneration in mountain forest (Vacek et al. 1995). No real differences between vital and declined stands indicate strong changes of microhabitats on the declined plots in the past or strong influence of the conditions under surface.

Height structure

For the plots with natural height distribution is typical highest number of the young seedlings or saplings and relatively very strong influence of the selection factors as are light conditions, intraspecific competition, competition with herbal layer (Jonášová, Prach 2004; Šerá et al. 2000) which lead to the high mortality till the age of 4–5 years (Zatloukal 2000). This was typical pattern for the main part of selected vital plots, with exception of Trojmezná locality, probably due to missing crop year and thus low number of seedlings there. Age structure is also connected with proportion of regeneration in the particular height classes. Previous results from the Šumava Mts. for the total proportion of seedlings are 42.4–76.3% (Zatloukal 2000), which is comparable to average 60% and maximum 95% on our plots. Proportion of regeneration older than 10 years could be 10–15% on the Šumava Mts. declined plots (Jonášová 2001), and in our case this proportion was similar. For the secure regeneration in the close to nature mountain forest in the stage of declination, there should be 320–3,100 trees over 1.3 m height (Korpeľ 1993). This could be a problem on the plots with declined tree layer in our case, because of low actual proportion of higher trees, due to fast declination and probably high grass competition for further seedlings.

Seedling growth

Growth of saplings in the plots with declined mature tree layer was two times faster, than on the vital plots, apparently due to better light conditions. Similar experience were also reported by Hunziker and Brang (2005), Jonášová (2001), Jonášová and Prach (2004), Diaci (2002), Zatloukal (2000). Low increments, about 1–2 cm/year for the 1st class off regeneration under canopy and about 3 cm on the sites without canopy cover, in similar condition, were also reported (Hunziker, Brang 2005). The height increment of saplings was related to microhabitat and was relatively low due to high altitude and harsh climatic factors.

Microhabitat influence

Species composition of ground vegetation and its type has a strong influence on initial seedling density as well as mortality during the first age stage. Influence of microhabitat conditions – growth substrate, canopy and herbal vegetation is widely discussed problem (Rumpf, Pampe 2003; Šerá et al. 2000; Jonášová, Prach 2004; Hunziker, Brang 2005), although not all authors have the same experiences. Some appreciate the litter as a favorable substrate for germination of seeds (Šerá et al. 2000; Hunziker, Brang 2005), although there is slightly higher mortality than in the bilberry cover (60:40%) (Šerá et al. 2000). A little different experiences were also (Jonášová, Prach 2004), who noticed the fastest decreasing of seedling numbers in the spruce litter. Litter was intermediate microhabitat in relation to particular plots in our case. Probably litter influence to the seedling mortality depends on the climatic factors, e.g. humidity or high temperatures. Bilberry cover have also ambiguous results, it could protect seedlings in the winter, but usually is also reported like microhabitat with a low germination rate in comparison with other one (Šerá et al. 2000; Rumpf, Pampe 2003). Last favorable conditions are on microhabitat with high grasses, as a *Calamagrostis villosa* and *Avenella flexuosa,* or *Deschampsia flexuosa* (Šerá et al. 2000; Rumpf, Pampe 2003). It corresponds with our results and the lowest proportion of grasses microhabitat in regeneration occurrence (Table 5). In our plots the microhabitat and herbal vegetation appeared as a statistically significant factor for the seedlings occurrence and probably less important for the seedlings growth.

Dead and decaying wood appeared as a favorable microhabitat for seedlings occurrence in our plots and it is in the mountain conditions often considered as the most favorable microsite (Hunziker, Brang 2005; Jonášová, Prach 2004; Svoboda 2005).

Not only abiotic characteristics like humidity and slightly uplift terrain are connected with this substrate – also lower herbal competition and special ectomycorrhizal types present on the decaying wood can improve seedlings germination and further growth (Uhliarová et al. 1999). On the declined plots majority of the dead standing logs are already broken and on the ground. Changes were very rapid in last years, depends on the weather, and ground cover evaluation could not be correct. On this type of plots seedlings or saplings were not found on the logs. Logs without bark have the very dry and hard surface unfavorable for seedling occurrence on the declined plots.

Nutrient and health state

Nutrient state of the spruce natural regeneration is in accordance to relatively poor nutrient soil status on granite rock. Critical could be phosphorus and magnesium content, which is just on the limit and deficiency is already reported from the other parts of the Šumava Mts. (Podrázský, Vacek 2004). But this is not limiting factor for the saplings in the 1st height class now.

CONCLUSION

Amount of seedlings and saplings strongly varies, even between very similar plots. Basic difference between stand with vital and declined mature tree layer is in the amount of seedlings and natural regeneration in the first age class, due to seed source on the vital stands.

Accordingly, there are differences in the natural regeneration age and height structure between the vital and declined stands. Space structure of natural regeneration is similar on the vital and declined stands, trees growth in clusters, which comport with altitude and character of mountain spruce forests. Microhabitat conditions and growth substrate have significant influence to the amount and growth of natural regeneration, especially microhabitat with dead wood. There are great differences in the exploitation of this woody microhabitat on the plots with and without canopy cover. Temporary state of natural regeneration on the declined stands is strongly dependent on the missing seeds source and unfavorable grass cover and could lead in the future to the unstable even-aged forest.

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Vývoj přirozené smrkové obnovy v horských oblastech Šumavy

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ABSTRAKT: Příspěvek se vztahuje k tématu přirozené obnovy smrku v oblasti NP Šumava a jejímu hodnocení na lokalitách s vitálním a odumřelým dospělým porostem v oblasti Modravy, Luzného a Plechého. Podrobněji byl hodnocen počet jedinců v jednotlivých výškových třídách, charakter zmlazení vzhledem k jeho sociabilitě a vliv mikrostanoviště (mrtvé dřevo, porost bylinné vegetace). Základní rozdíl mezi stanovištěm s vitálním a odumřelým porostem je v počtech zmlazení (průměr 12 tisíc) v živém porostu a poloviční v odumřelém porostu, ve výškovém rozdělení obnovy a výrazněji chybějícím množství nejmladších semenáčků na odumřelých plochách. Naopak růst zmlazení je na odumřelých plochách díky dostatečnému osvětlení rychlejší. Vzhledem k mikrostanovištním podmínkám má na výskyt zmlazení pozitivní vliv mrtvé dřevo, relativně negativní vliv má porost kapradí a trav. Vzhledem k přírůstům může negativně působit i silné zastínění na mikrostanovišti u kořenových náběhů.

Klíčová slova: NP Šumava; horské smrkové lesy; odumírání lesa; přirozená obnova smrku; management chráněných území

Téma přirozené obnovy smrku v oblasti NP Šumava, zejména v oblastech postižených kůrovcovou kalamitou a z těchto důvodů s odumřelým dospělým porostem, je stále ještě široce diskutováno. I tento příspěvek se vztahuje k uvedenému tématu a k hodnocení stavu přirozené obnovy smrku na lokalitách v oblasti Modravy, Luzného a Plechého. Hodnocení bylo prováděno na 13 trvalých zkusných plochách (tab. 1 a 2) na čtyřech základních lokalitách dvou typů. Do prvního typu – vitálních porostů s jen mírným ovlivněním kůrovcem – patří lokalita Modravy (Mo 1, 4), a vrcholové části Plechého a sousedícího sedla Trojmezné (Pl 18–20, Tr 1–3). Druhý typ – s odumřelými porosty – je zastoupen lokalitou Pytláckého rohu (Py 1, 2) a Velké Mořůvky (Lu 1–3). U ploch s odumřelým porostem (před rokem 1989) je charakteristický hustý travní pokryv tvořený zejména *Calamagrostis* a časté zlomy souší v poslední době, takže většina (2/3) mrtvého dřeva je již na povrchu půdy a má stejnorodý charakter. U ploch s živým (i když místy asanací již ovlivněným) mateřským porostem je bylinný pokryv podstatně variabilnější a zahrnuje borůvčí, mech, opad a porosty kapradin, ležící mrtvé dřevo je v různém stadiu rozkladu.

Na všech pokusných plochách (0,25 ha) byly pro podrobnější hodnocení obnovy vytyčeny dva transekty 5 × 25 m, na kterých byla zaznamenávána charakteristika povrchu a přirozené obnovy. V rámci celého souboru ploch pak byly porovnávány celkové počty zmlazení v jednotlivých výškových třídách (po 10 cm), relativní podíl zmlazení na jednotlivých typech mikrostanoviště a průměrné přírůsty na jeho jednotlivých typech. Dále byl hodnocen i stav výživy pomocí směsných listových vzorků odebraných na podzim r. 2004.

Počty zmlazení v jednotlivých výškových třídách byly poměrně dosti variabilní (tab. 3, obr. 2) a pohybovaly se od 1 200 do 30 000 ks/ha s výrazněji nižšími (polovičními) počty na plochách s odumřelým mateřským porostem, kde s výjimkou jedné plochy nepřesahovaly výrazněji 5 000 ks/ha. Na plochách s živým mateřským porostem převažovala nejmladší obnova (vzhledem k semennému roku 2003 a 2004 ve sledované oblasti) a největší počet zmlazení byl ve výškové třídě do 30 cm (okolo 80 % proti 50 % v odumřelých porostech).

Průměrná výška zmlazení byla vyšší na plochách s odumřelým porostem stejně jako přírůsty (tab. 4), kde byly rozdíly v přírůstu pro výškovou třídu do 30 cm dokonce dvojnásobné.

Vliv mikrostanoviště na výskyt obnovy se projevil statisticky významně; jako nejméně vhodný se jevil porost kapradí, trav a borůvčí. Nejvhodnější (tab. 5) bylo především tlející dřevo v živém porostu. V odumřelém porostu obnova na kládách zaznamenána nebyla. Zatímco v živém porostu jsou klády často pokryté bylinnou vegetací nebo mechem, snadněji se rozkládají a jsou dostatečně vlhké, u odumřelých porostů dochází často k usychání nastojato a na povrch půdy se dostávají odkorněné, na povrchu vyschlé klády, na kterých se semenáčky zatím nemají šanci uchytit.

Vliv mikrostanoviště na přírůsty (tab. 6) byl méně výrazný, i když mrtvé dřevo nebo kořenové náběhy (zejména souší) mají podmínky pro růst semenáčků poměrně výhodné. Jako nejméně vhodný se jevil porost mechu, těsné sousedství klády, která stanoviště mohla stínit, a volný opad, kde pravděpodobně hrají roli nepříznivé vlhkostní poměry.

Prostorová struktura zmlazení je podle předpokladu ve shlucích (obr. 1) a na obou typech stanovišť – v živém i odumřelém porostu – velmi podobná.

Hodnocení stavu výživy (tab. 7) ukázalo relativně malé kolísání obsahů základních živin mezi jednotlivými plochami a lokalitami. Rozdíl mezi živým a odumřelým porostem (po 8–10 letech) se projevil významněji jen u draslíku (vyšší v živých porostech) a vápníku (vyšší v odumřelých porostech) a statisticky méně významný byl rozdíl v obsahu N (mírně vyšší v odumřelých porostech). Problémem do budoucna mohou být hraniční hodnoty v obsahu fosforu a hořčíku, i když se zatím nejedná o limitující faktor.

Rozdíly mezi plochami s živým a odumřelým mateřským porostem spočívají zejména v odlišném výškovém (a do budoucna věkovém) rozdělení přirozené obnovy a ve využití mrtvého dřeva jako růstového substrátu.

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