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SUCCESSION OF HERBACEOUS AND TREE SPECIES COMPONENT OF PHYTOCOENOSES AFTER THE FIRE IN THE NATIONAL PARK SLOVENSKÝ RAJ

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Monitoring of the status of forest stands after the fire (2000), which damaged approximately 64 ha of the forest in the National park Slovenský raj, is presented in the paper. Monitoring of the forest health status was executed at two levels. Observation of dying process of the forest in units of forest spatial arrangement was the first level. The observation of health conditions of individual trees on 52 permanent monitoring plots, by means of defoliation values and other characteristics (fungal and insect attack) was carried out on the second level. Monitoring of the succession of woody (shrubby) and herbaceous component of phytocoenoses was aimed contained evaluation of the whole coverage of undergrowth and coverage of occurring plant species by Braun-Blanquet scale refined by Zlatník (1953). Evaluation of these parameters was carried out on stabilized monitoring plots. The aim of this research was to propose concrete forest measures for stands damaged by fire.

Key words: *forest fire, monitoring, succession, revitalization*

V príspevku prezentujeme monitoring stavu lesných porastov v Národnom parku Slovenský raj po požiari (2000), ktorý poškodil asi 64 ha lesa. Monitoring zdravotného stavu lesa sa vykonával na dvoch úrovniach. Na prvej úrovni sa sledoval proces odumierania lesa v jednotkách priestorového rozdelenia lesa, na druhej úrovni zdravotný stav jednotlivých stromov na 52 trvalých monitorovacích plochách, a to prostredníctvom hodnôt ich defoliácie a ďalších charakteristík (napadnutie hubami, hmyzom). Monitoring sukcesie drevinovej (krovitej) a bylinnej zložky sa zameral na zisťovanie celkovej pokryvnosti podrastu a pokryvnosti vyskytujúcich sa druhov pomocou Braun-Blanquetovej stupnice zjemnenej Zlatníkom (1953). Tieto parametre sa sledovali na stabilizovaných monitorovacích plochách. Cieľ výskumu spočíval v návrhu konkrétnych lesníckych opatrení v požiarom zasiahnutých porastoch.

Kľúčové slová: *lesný požiar, monitoring, sukcesia, revitalizácia*

1. Introduction

Causes and consequences of forest fires are very actual topic of discussions nowadays. Prevention and control of forest fires is the main issue of various scientific activities and scientific conferences, where intentions and obtained results of solved projects are presented. In framework of European research on forest fires control there were solved several projects as e.g. SPREAD, FIRE STAR, ERAS and WARM. Slovakia with other 5 countries has been involved in the project WARM. The FP5 and FP6 of the EU has given a priority to projects oriented to the research of forest fires and supported these projects by 2.7 billion EUR (Škvarenina, Holécy 2003).

After the fire, which in autumn 2000 damaged about 64 hectares of the forest in the National Park Slovenský raj, in the first half of 2001 there was proposed at FRI Zvolen a project of revitalization of forest stands damaged by fire (Kamenský *et al.* 2001). The project was aimed mainly at optimisation of measures directly resulting from valid legislation. Further revitalization of stands damaged by fire is conditioned considerably by the course of decline and revitalization of individual tree species as well as the course of succession of tree species and herbs on damaged plots. It may be conditioned also by erosion in some areas. Monitoring of these processes on stabilized forest plots and subsequent proposal of forestry measures was the objective of the task, which was solved in 2002 within the framework of the contract between State Nature Conservation and Forest Research Institute Zvolen. The aim of research consisted in monitoring of the succession of herbaceous and tree species component of phytocoenoses and intra-soil erosion on permanent monitoring plots damaged by fire and obtaining of the data on health condition of forests by means of field investigations.

A type of forest fires can be characterized according to the kind of burning material, it means according to which layer of the stand was affected by fire. From forestry viewpoint, we classify forest fires into underground, ground crown fires and fire of a hollow tree. Ground fire can damage or destroy forest litter, herbs, tree seedlings, shrubs, and animals, mainly invertebrate. It can also damage great part of trees regardless their size. Ground fire also affects soil flora and fauna and water chemistry. We ascertained all three types of fires on studied sites.

Underground fire occurs under the level of soil surface. It is slow (2–10 m per day) characteristically by very high temperatures. During this fire the accumulated organic matter most frequently peat is burning but the underground fire can also occur on some other grounds, where besides combustible organic substrate the roots of healthy trees, herbs, young tree species and shrubs can also burn. This type of fire similarly to surface fire also causes damage to soil flora and fauna even in greater extent. Underground fire can be a reason of surface fire or crown fire. During crown fire the assimilatory organs of trees are destroyed. When more than 75% of tree crown is damaged, tree usually dies. The fire of a hollow tree causes damage to individual trees. Wood attacked by rot is on fire and it destroys everything living in tree and on tree as well. Mentioned types of fire can form various combinations or one type of fire can change into another one. The most frequent type of forest fire is surface fire, which usually becomes total fire, burning not only tree crowns, but also soil cover.

It occurs in stands with neglected tending with high grass and low-branched trees. Its danger lies in a high speed of spreading, its difficult control and a possibility of turbulence formation, during which burning parts of trees are transported into the distance of several tens of meters.

As there was very bad access to the area in the National Park Slovenský raj (cliff terrain, steep slopes) there were used also helicopters with special "bambi-sack" with the volume of 800–3,000 litres and turbo "bumblebee" aircrafts with water tanks with the volume of 1,000 litres in addition to traditional methods of extinguishing forest fire (digging around the fire site). Expensive and heavy helicopters, which were used in Slovakia, had at that time only one 1,0001 "bambi sack" (Bevilaqua 2000). It was obviously one of reasons of such high damage, which exceeded 100 million SKK at the first estimate (Dražil 2000, 2001, 2002), but in fact it is more than 354 million SKK (Leskovjanská 2001). By Palúch (2001 in Hlaváč 2003), total damage including the damage to the environment was estimated at 366 161 100 SKK.

2. Problems

2.1. Revitalization of territory damaged by fire

It is needful to say whether it is necessary to carry out some measures in damaged stands or to leave them to natural development. On one side the principle of restoration of ecological stability of the landscape and its components, it means the capability of ecological systems to compensate disturbing civilization influences by own mechanisms, is being proclaimed broadly. We must be aware that there are available only little exact data (especially in Slovakia) on stabilization mechanisms and processes in forest ecosystems damaged by fire. Practical experience from purposeful implementation of the knowledge on the restoration of ecological stability of damaged forests is lacking as well, because even exactly proven ecological and environmental knowledge still remains only in the position of proclamations. On the other side there are forest functions whose fulfilment is required by a society and exactly proven knowledge on the structure of stands, which secure optimal fulfilment of required functions, and relatively limited knowledge on natural development of forest stands with changed structure left to their natural development.

Our research is focused on finding the methods of care aimed at restoration of sustainable functional capability of forest ecosystems, and effective way of regulation of ecosystem damaged by fire through its reconstruction to the auto-regulative development with the aim to restore its functionality as soon as possible.

We come out from the generally accepted opinion that ecologically stable stands will fulfil required functions to an appropriate extent. Fire disturbs ecological stability of stands and their dynamic equilibrium as well. No doubt that in case of leaving such stands to self-development, dynamic equilibrium will be created on the damaged territory, and in a substantial part of the territory the ecosystem will return to the development course of the time before the fire. In a smaller part of the territory there can occur irreversible changes in the soil as erosion or karstic formations. But probably, man can contribute by his purposeful activities to restoration of the former development of ecosystem. Providing we respect an idea that the quicker the ecosystems returns to its original development stage the more stable they are, then active protection must be considered with regard to restoration and increasing ecological stability of ecosystem.

With regard to lack of knowledge on the processes of self-development in forests with changed structure due to human activity as well as insufficiently known methods of the reconstruction of stands damaged by fires there is a need to leave a smaller part of damaged stands to self-development. In that way it will be also possible to investigate self-development by intentional measures to influence development of forest ecosystems damaged by fire.

The framework of revitalization of damaged ecosystems is specified by legislation, namely the Act no. 1000/1977 of the Code on the management in forests and state administration of forestry in wording of following regulations and the Act no. 543/2002 of the Code on nature and landscape conservation. The solution is based on the analysis of present state of fire site, particularly from differentiation of the territory (units of spatial forest arrangement – JPRL) according to the degree of damage to soil and vegetation and following rate of soil endangerment by erosion. The solution lies in a proposal of revitalization measures for forest stands damaged by fire, particularly a proposal of differentiated methods of the restoration of disturbed forest ecosystems including sanitation, biotechnical and protective measures.

Site conditions

About 56% of plots affected by fire are classified into the forest type 5603 – grassy limestone beech stand, slt (group of forest types) Fagetum dealpinum, HSLT (management set of forest types) 501 – extreme limestone fir beech forests. Soils below cliffs have characters of Lithic Leptosols, and on the slopes with debris and Rendzi-Lithic Leptosols. In former stands beech had a dominant position. Admixed tree species were fir (within 20%), maples, and linden, occasionally spruce. In more extreme, rocky places pine and larch were growing. On more coarse debris the stand was more open, and in rocky places trees were growing only sporadically or in groups. Endangerment of stands by wind, drought and rime was considerable. Some localities were deforested in past, and due to erosion they transformed into karst and shifted to the category of soils, which can be reforested only with difficulties. The stands are classified into the category of protective forests with soil protective function. Regeneration composition is of stands following: beech 3, spruce 2, fir 3, and other coniferous 1, other broadleaves 1.

About 25% of plots are classified into the forest type 3621 – dealpinum pine forest, slt Pinetum dealpinum superiora, HSLT 203 – limestone pine forests. They are relict pine forests on rocky limestone slopes or on slopes with partially reinforced debris. Former stands were formed of Scots pine with an admixture of beech, white beam, linden and wild auxiliary tree species. The stands had many gaps. They are formed of smaller or larger groups of trees, or individual trees on limestone cliffs. Stands are endangered considerably by drought, frost, but especially erosion, which cause karstification of the surface of terrain in most of the localities. Therefore the stands are classified into the category of protective forests with soil protective function. Regeneration composition of stands: pine 8, broadleaves 2.

About 16% of plots are classified into the forest type 5306 – stony fir beech forest, slt Abieto-Fagetum inferiora, HSLT 516 – stony fir beech forests. Soils are formed of permeable gravel and stones, with various moisture contents and with the character of Rendzi-Lithic Leptosols. In former stands, in addition to beech, there were growing in a great extent valuable broadleaved species, mainly Scotch elm and Sycamore maple. Fir, sporadically spruce and larch, in lower locations pine as well, were admixed tree species. The stands are endangered by erosion, drought and wind and they are classified into the category of commercial forests. Regeneration composition of these stands is following: beech 2, valuable broadleaved species 2, spruce 3, fir 2 and larch 1.

The smallest area, about 3% of damaged forests, is classified into the forest type 5308-limestone fir beech forests inferiora, slt Abieto-Fagetum inferiora, JPRL 502 – fresh limestone fir beech forests. Soils are moderately deep, rich in gravel, on undisturbed stony grounds stony, mostly with favourable moisture content. In former stands mostly fir, spruce and beech, sporadically larch and sycamore maple were growing. Wind, rots and erosion endanger the stands and they are classified into the category of commercial forests. Regeneration composition of stands is following spruce 3, fir 3, beech 2, other conifers 1, and valuable broadleaves species 1.

Structure and tree species composition of current stands differ from former stands. Crucial changes in the structure of forest stands and soil degradation occurred probably due to production of charcoal (charcoal burning) in past. Even today there can be seen pits after "charcoal kilns" and roads to them. Beech wood was used for the production of charcoal. Logging was probably done in a harmful way, what under given site conditions had to lead to strong soil erosion, that former stands with beech prevalence were unable to regenerate and better conditions for the regeneration of less demanding pine and also partially larch were formed. In most of current stands there is higher proportion of pine and larch as well as spruce in comparison with former stands. Abundance of beech, partially fir, linden tree and maple tree is lower considerably. Some parts of stands with pine prevalence started to grow mainly with spruce and beech (as undergrowth) within its natural succession. This process has been going on more intensively in the localities with deeper soil and more favourable moisture conditions (western and northern aspects).

3. Methodology

3.1. Monitoring of forest health condition

Monitoring of forest health condition was carried out on two levels. The first level included the monitoring of the process of forest decline in the units of spatial arrangement of forest to demarcate those parts in individual JPRL, where stocking dropped inappropriately due to fulfilment of required functions (soil protective, water protective) as well as the parts where clearing with the area of 0.03 ha or more has arisen or where a risk of forming such clearings was present.

The second level was monitoring of health condition of individual trees on 50 permanent monitoring plots by means of observing their defoliation and other characteristics of damage (fungi infestation, insect infestation).

3.2. Monitoring of the succession of herbaceous and tree species component of phytocoenoses and subsoil erosion on monitoring plots

The names of the groups of forest types (slt) are by Zlatník (1959). The names and numbers of forest types and of applied typological units – management sets of forest types (HSLT) are by Hančinský (1972, 1977). Used soil units are by the team of authors Collective (2000).

The plots for observing succession of herbaceous component of phytocoenoses were established in accordance with the methodology of the approved project for fire site revitalization (Kamensky *et al*. 2001). In total, there are 52 plots in total, each one with the area of 5 × 2 m and at the same time it is a centre of another plot (15 × 4 m) for monitoring succession of tree species component (except for Plot no. 39 and 40). Four one-meter high wooden poles stabilize individual corners of plots. Each monitoring plot was sighted by GPS instrument and map digitisation of measured points was processed. We stabilized centres of plots by 1-meter long metal poles (roxor), and wooden sticks marked the corners of plots. Their spatial arrangement is from Alexander ridge (stands 123, 124) across Predná Krompľa (stand 125) to Vyšná Krompľa (stands 126, 127, 128, 129, 131) and ends in the reserve Tri kopce (stands 132 and 136). Plots are located in localities with various intensity of fire, in various forest communities, different tree species and age composition as well.

Monitoring of succession of tree species component was carried out on 50 monitoring plots, each of them with the area of 15 × 4 m. They are localized in a way that their centres are equal to the centres of monitoring plots for monitoring of herbs succession. In autumn 2001 and 2002, there was monitored abundance of seedlings of individual tree species and shrubs on individual plots. In 2002, there were distinguished seedlings by tree species germinated in 2002 and in 2001.

We estimated visually on each plot a total coverage of undergrowth, recorded coverage of occurring tree species by means of Braun-Blanquet scale refined by Zlatník (1953). Names of species are given by Marhold, Hindak (1998), Dostál (1989). What concerns phytocenological conditions we must note that intensity of fire in relation to plants must be understand as the area of burnt whole layer of forest floor down to mineral soil on respective phytoplot. Plots without fire served as control plots. With aim of statistical assessment and graphical illustration we marked them by the number 1. Plots with burning within 5% are marked by the number 2. They represent very low fire intensity. Plots with burning of 5% – 30% represent low burning (number 3), from 30% to 60 % intermediate (number 4), 60% – 90% strong (number 5), and 90% – 100% very strong burning (number 6). From this point of view it may happen that in some stands, which were very heavily damaged by fire, we have on smaller parts also the plots with small damage and thus the evaluation of fire intensity can differ from intensity in the whole stand and vice versa.

We observed the process of subsoil erosion (vertical shift of upper soil particles) in a way that we made a permanent mark on wood pins, marking the corners of monitoring plots, 1 cm above the ground level in autumn 2001 and in autumn 2002 we measured the height of this mark from the level of terrain.

4. Results

4.1. Health condition of stands

Plots, where reforestation had to be performed immediately after the fire, were determined in the Project of revitalization of forest stands damaged by fire in the National Park Slovenský raj (proposed in 2001). To the end of October 2002 similar new plots had not arisen but as we supposed already during 2003 they arose, as the process of the dieback of individual tree species has not finished yet.

In the second half of 2002 a considerable dieback of pine trees was recorded. It was mostly dispersed dieback, only in stands 131 and 136 the plots were large about 0.05 ha (Fig. 1, 2). In spring 2003, a part of the stand 128 was affected by windfall (ridge western part) and all uprooted pine trees had about 70% of burnt roots. Re-

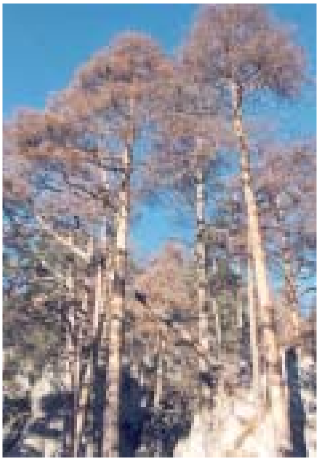

Fig. 1. and 2. Damaged and dry spruce and pines after 1st year (Photo: Tučeková, April 2003).

garding that we suppose that the reason of further dieback was burning of the root system of pine trees.

Beech is following tree species, for which an acceleration of dieback was recorded in 2002. In spring months about 80% of individuals damaged by fire showed damage by fungi (bark), while many thicker individuals were attacked by woodborers. Some changes were observed also in foliage, namely in degree of defoliation and decrease of the size of leaves. During summer, discolouration of leaves in some parts of trees was observed. In autumn falling of bark from respective damaged beech trees was observed, mostly to the height of 3 m from the ground (in stand 126 about 8 m) (Fig. 3). Many thinner individuals died. Dieback also continued in case of spruce (Fig. 4). In

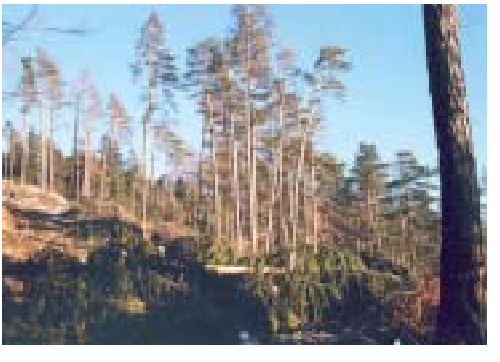

Fig. 3. Damaged beech (Photo: Ištoňa, March 2003) Fig. 4. Damaged spruce (Photo: Tučeková, March 2003).

Table 1. Regeneration of tree species and shrubs below damaged parent stands on 6 selected monitoring plots

Number of Plot	Number of Forest type	Natural regeneration Taxon	Natural regeneration Number in 2001 (Pcs)	Natural regeneration Number in 2002 (Pcs)	Tree species Taxon	Tree species Number in 2001 (Pcs)	Tree species Number in 2002 (Pcs)	Damage to tree species in 2001 by	Defoliation in 2001 (%)	Defoliation in 2002 (%)	Damage by fire
126	5603	*Rubus* sp. *Sambucus racemosa* *Clematis alpina* *Salix caprea* *Fagus sylvatica*	1 1 1 – –	118 24 – 15 1	*Picea abies* *Larix decidua* *Fagus sylvatica*	1 4 1	1(dried) 4 1	– – Insects, fungi	90 80 80	100 90 90	Heavy (soil erosion)
126	5603	*Corylus avellana* *Acer pseudoplatanus* *Clematis vitalba* *Rubus* sp. *Sambucus racemosa*	2 4 4 2 –	1 – – 66 19	*Fagus sylvatica*	1	1	Drying	80	80	Slight (soil erosion)
126	5603	*Salix caprea* *Rubus idaeus* (15 pcs) *Sambucus racemosa*	33 50> –	10 83 7	*Picea abies* *Larix decidua*	5(dr.) 1	5(dried) 1(dried)	Crown fire	100 –	100 100	Very heavy (soil erosion)
126	5603	*Sambucus racemosa* *Rubus* sp. *Cotoneaster tomentosus* *Corylus avellana* (sprouts from the root) *Betula* sp.	1 15> 1 1 –	2 8 – – 7	Remains of burnt species: *Picea abies* *Larix decidua*	–	–	– Afforested: *Picea abies* *Larix decidua* *Pinus sylvestris*	–	–	Slight (soil erosion: lost herb coverage)
126	5603	Picea abies *Sambucus* sp. *Salix caprea* *Rubus* sp.	1 1 5 3	– – 2 8	Cut species: *Picea abies*	–	–		–	–	Heavy (soil erosion)
125	5603	*Salix caprea* *Clematis alpina* *Acer pseudoplatanus* (sprouts) *Fagus sylvatica* (sprouts) *Populus tremula* *Pinus sylvestris*	10 3 1 – – 1 1	4 – 1(2y) 1(1y) 1 1 1(2y)	Cut species: *Pinus sylvestris* *Picea abies* Burnt underplanting: *Larix decidua*	–	–		–	–	ModerateSlide rock–burnt down to mineral soil

this case it was a combination of the damage by fire and bark beetles. Some larch trees died as well. We suppose that in case of older individuals a burning of roots caused it, and in case of younger ones damage to conductive tissues.

Data on the damage of trees on 6 selected monitoring plots (damaged the most) are given in Table 1.

In 2001, there were evaluated 90 spruce trees on all plots, 62 of them were living and 28 dead (31.1%). In 2002 the number of dead trees increased to 47 (52.2%). For larch, 53 trees were evaluated. In 2001 they were all living, and 11 trees died (20.8%) in the course of 2002 year. Of 113 beech trees 6 were dead (5.3%) in 2001, and 59 (52.2%) were dead in 2002. Dieback has progressed also in case of pine. Of 46 evaluated trees, 4 trees (8.7%) were dead in 2001, 12 trees (26.1%) in 2002.

Based on the defoliation assessment we can state that the health condition of most of trees worsened in 2002 when compared with 2001. Of the individuals evaluated on monitoring plots, 17 trees (7.9%) has improved foliage, 58 kept the same level of foliage (27.0%) and 140 trees had worse foliage (65.1%).

4.2. Succession of herbs, shrubs and tree species

Herbs

According to phytogeographical classification (Futák 1980) the territory of Slovenský raj belongs to the region of Western Carpathian flora. Forests cover 90% of this territory. Stage of vegetation development started one year after the fire with late budding and germination of most of plants on the affected territory. Despite that a certain part of evaluated vegetation had in September 2001 unusually great formation of assimilatory organs as a result of excessive amount of available mineral nutrients.

Figures 5 and 5a illustrate the abundance of species on individual plots during the observation. The course of the species abundance according to plots shows that except for two plots (25 and 37) the abundance of species has increased, on average from

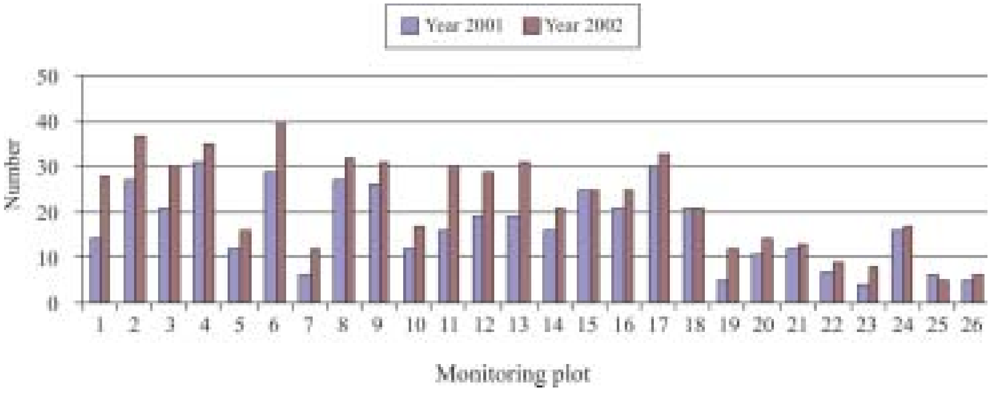

Fig. 5. Changes in the abundance of species on fire-burnt site Krompľa (monitoring plot 1–26).

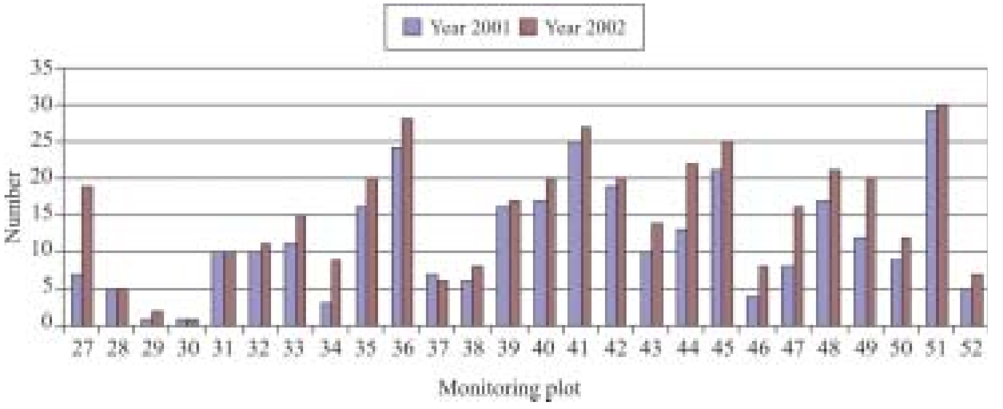

Fig. 5a. Changes in the abundance of species on fire-burnt site Krompľa (monitoring plot 27–52).

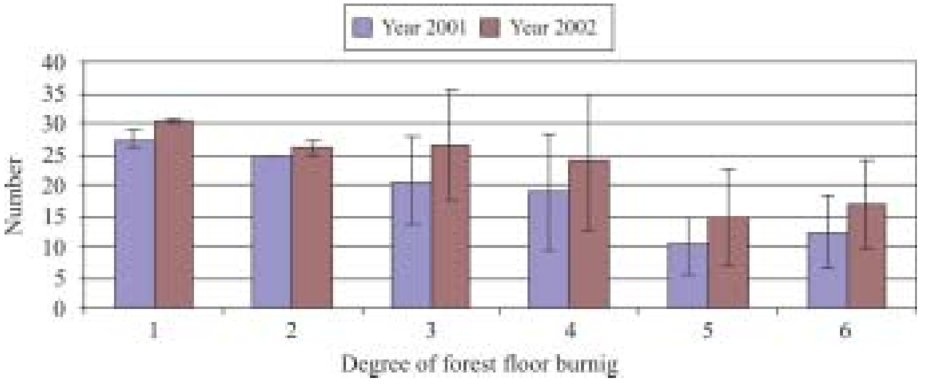

Fig. 6. Average abundance of species (± sx) in dependence on the degree of forest floor burning.

14 to 19 species, whereas standard deviation of these values has ranged from 8 to 10. The change is more marked if we group the plots by intensity of forest floor burning into classes (Fig. 6). The results show the highest abundance of species on control plots and the plots with very weak burning of forest floor. The lowest abundance was on the plot with strong and very strong burning, whereas variability of species represented in abundance differs significantly between grouping of plots under No. 1, 2 and 3, 4, 5 and 6. Canopy, age of tree species in respective stand and loss of foliage have a significant effect on light conditions and development of undergrowth. The development of the intensity of changes in species abundance confirms that the smallest changes were only on control plots and on the plots with very weak burning

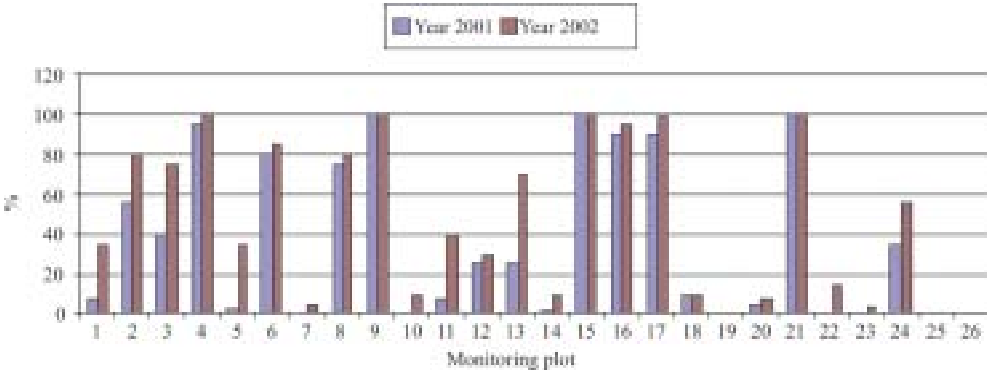

Fig. 7. Changes in herbs coverage on fire-burnt site Krompľa (monitoring plot 1–26).

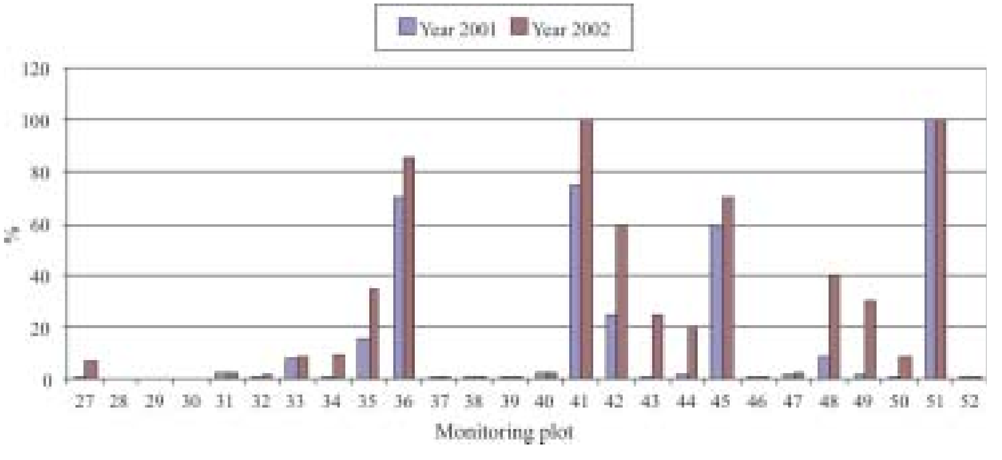

Fig. 7a. Changes in herbs coverage on fire-burnt site Krompľa (monitoring plot 27–52).

of forest floor (within 5%). The greatest changes were from the 3rd degree up to the highest degree of burning.

Changes in total coverage of undergrowth are illustrated in figure 7, 7a and 8. Average values of the set of plots for the years of observation confirm the coverage has increased from 25% to 36%, whereas standard deviation with the value of 37 demonstrates a high variability of total coverage on individual plots in both years. It follows from figure 8 that average values of the coverage according to the degree of burning of forest floor confirm the relation the more burned floor the lower coverage of undergrowth. Canopy of stand and loss of tree species foliage play an important role as well.

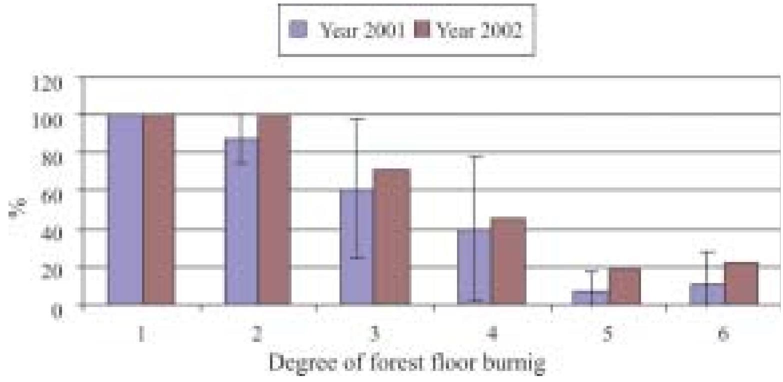

Fig. 8. Average coverage of herbs (± sx) in dependence on the degree of forest floor burning.

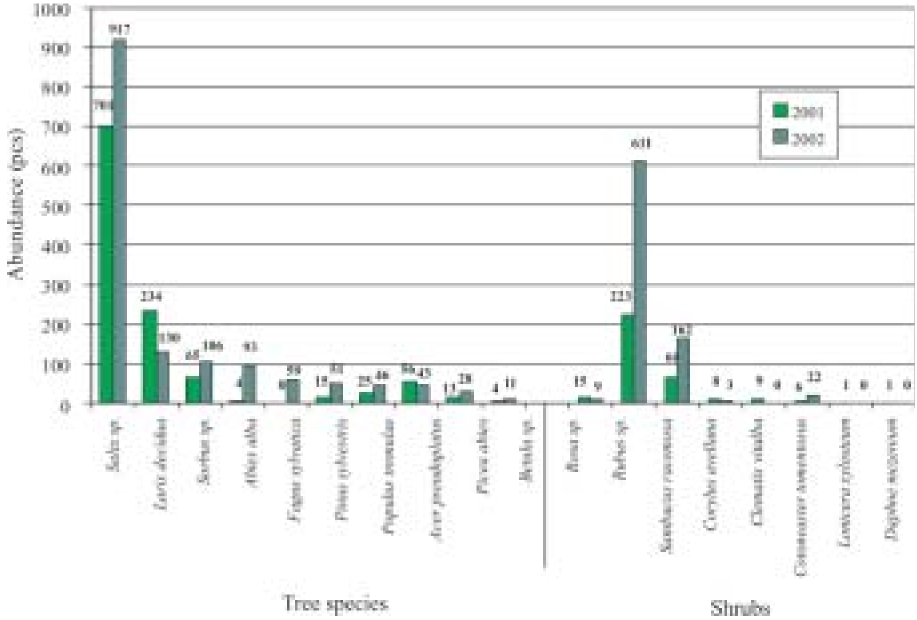

Fig. 9. Average abundance of tree species on 52 monitoring plots after the fire in 2000 (site Krompľa in the National park Slovenský raj).

Monitoring of undergrowth regeneration at fire sites confirms that succession starts most frequently with appearance of following species: *Campanula rapunculoides, Vicia tenuifolia, Carduus glaucinus, Lembotropis nigricans, Tithymalus cyparissias, Geranium robertianum, Securigera varia, Taraxacum officinale, Galium schultesiii,* what concerns grasses mainly *Calamagrostic varia* and on more exposed localities also *Brachypodium pinnatum, Carex alba* and less frequently *Poa stiriaca species*.

In the second year, above mentioned species mostly preserved their coverage from the last year or their coverage was increased slightly up to moderately. We found higher presence for species as *Chamerion angustifolium, Mercurialis perennis, Cirsium erisithales, Taraxacum officinale, Verbascum densiflorum, Viola hirta, Carex digitata* and *Rubus idaeus.* Those species as well as other herbaceous species had in the first year after the fire very low coverage. Only coverage of grasses was substantially higher on the forest floor burnt to smaller extent. Mosses only occurred very sporadically on the plots with slight damage. In more detailed analysis we can find that stands with their tree species composition and spatial structure influenced the fire intensity significantly. In older and more open pine and beech stands a synusia of undergrowth burned mostly very easily and quickly together with the shrubby layer of natural regeneration of beech, but fire spread to their crowns only rarely. On these plots the plants in underground was damaged less. They preserved more own germination capability and thus their regeneration has been going on. Spruce stands were damaged the most followed by pine stands, where crown fire was spreading as well. On these sites the temperature of fire was in the whole stand so high that undergrowth with forest floor burned down to mineral soil. Also in these stands the occurrence of species and their coverage is increasing slowly, especially in the second year.

Regarding rare and protected species we must note the occurrence of *Geranium bohemicum, Corydalis capnoides, Adenophora liliifolia, Aconitum moldavicum, Cimicifuga europaea, Lilium martagon* and *Erysimum wittmannii.* Also the occurrence of *Geranium bohemicum* and *Corydalis capnoides* (Cerovsky *et al.* 1999) deserves a special mention.

Geranium bohemicum has a status of critically threatened species in the flora of Slovakia. By its natural distribution it represents a boreal European element, which by its isolated occurrence spreads up to Central and Southern Europe. In Slovakia there is known local occurrence in Spišská kotlina (basin) and in some parts of Slovenský raj. Its ecological requirements cause its connection not only with sunny openings and clearings but also mostly with fire sites, where it finds optimal ecological conditions and thus it represents typical anthracophilous species (Pyrophyte), whose seeds must exceed the temperature of 35 °C before the germination.

In Slovakia, *Corydalis capnoides* has a status of critically endangered or even rare species with distribution from Chočské vrchy Mts. through eastern part of the Low Tatra Mts. to Slovenský raj and ends in southeastern direction in Slovenský kras Mts. and in the northern part of the Belianske Tatra Mts. It has optimal existence conditions in shaded, more or less scarce, forest communities growing on limestone in submountain and mountain zone. It survives the best during regeneration under shelterwood.

Tree species

In 2002 the highest number of seedlings on monitoring plots was recorded for willow (*Salix caprea*) – 917 trees. In 2001 their number already reached 701 trees.

Larch (*Larix decidua*) followed with 130 trees. In 2001 we recorded almost 234 seedlings but except for one all of them died. Also rowan (*Sorbus aucuparia*) and whitebeam (*Sorbus aria*) have had quite a large number of seedlings (106 in 2002 and 65 in 2001). In 2002 we have found also a considerable number of seedlings of fir (*Abies alba*), 93, but only 4 of them were older than 1 year. For beech (*Fagus sylvatica*) we found 59 seedlings, mostly root sprouts. The similar number was found also for seedlings of pine (*Pinus sylvestris*) – 51. For this tree species it is interesting that of 15 seedlings found in 2001 only 3 died, and 12 were found as 2-year old in 2002. The similar number of seedlings was also found for aspen (*Populus tremula*) – 46, and maple (*Acer pseudoplatanus*) – 43 individuals. But in comparison with the year 2001 the number of seedlings for aspen increased (from 25) while for maple dropped (from 65). In 2002, the smallest number of seedlings was found for spruce (*Picea abies*) – 28, of them one 2-year old, and for birch (*Betula pendula*) – 11 (Table 1 and Fig. 2). Willow also regenerated on the greatest number of plots – 38, followed by larch on 27 plots, pine and rowan on 19 plots, beech on 17 plots, aspen on 16 plots, fir on 14 plots, maple on 12 plots, spruce on 11 plots and birch on 5 plots.

It is interesting to compare under which conditions individual tree species regenerated with regard to the degree of damage to the soil. We divided the plots into groups. Then we had for individual tree species following average damage degrees (weighted arithmetic mean); rowan 3.52, maple 3.54, spruce 3.64, birch 4.20, beech 4.24, willow 4.92, fir 4.93, pine 4.95, larch 5.11, and aspen 5.38.

Shrubs

Rubus sp. is the most important of shrubs that occurred on 37 plots. In 2001 we found 223 individuals while in 2002 almost 611. *Rubus idaeus* prevails over *Rubus saxatilis.*

The abundance of the seedlings of elder (*Sambucus racemosa*) is also important. In 2001, there were 66 individuals and one year later 162 individuals on 23 plots. Abundance of *Lembotropis nigricans* is relatively high as well. Occurrence of *Chamaecitisus ratisbonensis* and other shrubs has been relatively low up to now. It is more significant for biodiversity than for soil protection.

5. Conclusion

In the project of 2001 there was proposed artificial regeneration on the area of 3.72 ha with the use of various reforestation technologies. There were proposed measures against injurious biotic and abiotic factors including erosion control measures. There were calculated increased costs of above-standard measures aimed preferentially at the preservation and restoration of required non-production forest functions.

Forest science has not sufficient exact results, on which a reliable predicting of the development of forest ecosystems damaged by fires could be based with regard to natural conditions of Slovakia. Therefore we solved in the project only the measures following from currently valid legislation and measures, which we consider inevitable

Table 2. Characteristics of 9 phytocenoses located on the fire-burnt site Krompľa (selection from 52reléves according to the degree of forest floor burning)

Number of plot	1		2		3		6		7		8		9		49		51	
Degree by damage	Heavy		Slight		Very heavy		Moderate		Very heavy		Slight		Control		Very heavy		Control (in NPR)	
Altitude [m]	895		890		900		920		880		890		890		930		775	
Exposure	ENE		E		SE		SW		SE		SW		SW		E		S	
Slope [%]	80		50		60		35		25		60		50		50		70	
Group of forest types	vst higher																vst / Pine	
Stand type	Spruce, larch, beech		Beech		Spruce – burnt		Pine – burnt		Spruce, beech		Pine –fire brand		Pine, larch, beech		Spruce-cut		Pine	
Year	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Coverage of herb layer [%]	7	35	55	80	30-50	75	80	85	<1	5	75	80	100	100	2	30	100	100
Coverage of mosses layer [%]	0	<1	<1	<1	0	0	0	0	0	0	<1	<1	3	3	0	0	5	5
Number of species in undergrowth	14	28	27	37	21	30	29	40	6	12	27	32	26	31	12	20	29	30
Species	Coverage																	
Abies alba						–												
Acer pseudoplatanus				–				–									+	+
Acinos alpinus							–	+										
Adenophora liliifolia	–	–	–	–														
Achillea distans							+	1			+	+		–				
Allium ochroleucum							–	–			+	+					–	–
Anthericum ramosum								1					+	+			+	+
Aquilegia vulgaris					–	+		–			+	+	1	1				
Asperula cynanchica							+	+			1/-2	1/-2		1			$+^{1}$	$+^{1}$
Asperula tinctoria					–	–											+	1
Asplenium ruta-muraria																	+	+
Atropa bella-donna						–			–	+								
Bellidiastrum michelii																	–	–
Betula pendula															–	–		
Brachypodium pinnatum							1	1			+	1						
Bupleurum falcatum							+	1			+	+	+					
Calamagrostis varia			+2	+2	+	+	+3/-4	+3/-4			+3	+3	+3/-4	+4			+2/-3	+2/-3
Campanula carpatica					$+^{1}$	1/+2												
Campanula rapunculoides		+	1^{-2}	+2	1/-2	1/+2	1	1			1	1			–	–	–	–
Campanula trachelium				$+^{1}$														
Cardaminopsis arenosa											+	–				1		
Carduus glaucinus	–	–			+/1	+/1	1/-2	-2			1^{-2}	1^{-2}	1	1^{-2}			$+^{1}$	1
Carex alba	–	–									+	+	1^{-2}	1/-2			+4	+4
Cimicifuga europaea		–	+	–														
Cirsium erisithales		–	$+^{1}$	+/1						–								
Clematis alpina						–	+	+										
Corydalis capnoides					+	+												
Cotoneaster integerrimus											–	–		–				
Digitalis grandiflora			–	–	+	+/1	–									–		
Dryopteris filix-mas			–	–														
Fragaria vesca			$+^{1}$	$+^{1}$			+	+				–						
Galium album							+	–			+	+	–	+			+	–
Galium schultesii			+	+/1	+	1												
Geranium bohemicum															–			

Table 2. Continued

Number of plot	1		2		3		6		7		8		9		49		51	
Geranium robertianum	+/1	1^{-2}	1^{-2}	1/-2	-3	+3/-4												
Heracleum sphondylium							+	+/1										
Larix decidua													+			1		
Laserpitium latifolium							+/1	+2/+3			+/1	+/1					+	+
Lembotropis nigricans	–	+								+	+			–	–	–		
Leucanthemum vulgare					–	+					–	–	–	–			–	–
Lotus corniculatus						+	–					–						
Melampyrum pratense						–		+					+	$+^{1}$			1	1
Melica nutans		–	+2	1^{+2}			+	+		–								
Mycelis muralis			1	1^{-2}		–												
Phyteuma orbiculare																	+	+
Picea abies		–												–			+	+
Pimpinella major											–	+	+	+				
Pinus sylvestris																	+	+
Poa stiriaca			+	+		+	1	+			+	+	+	+				
Polygonatum odoratum								–				+					–	–
Prenanthes purpurea	–	–	+	+														
Pulmonaria obscura			1	1														
Rubus idaeus	1	+2		-2	1/-2	1/-2												
Rubus saxatilis			+	1							+/1	+/1	+	+			–	+
Salix caprea						–									$+^{1}$	$+^{1}$		
Securigera varia	+	–		+	–	+		+										
Senecio ovatus			-/+	+/1												+		
Silene nemoralis		–	+															
Sorbus aria								–			+/1	+/1	–	–			+	1
Sorbus aucuparia														–			–	–
Taraxacum officinale		–				+	–	–		+/1	–	–			–	+		
Teucrium chamaedrys							+	+					–	–	+	–		
Thalictrum minus																	+	+
Thesium alpinum								1/+2				–					–	–
Thymus pulegioides											+	+	+	+			+	+
Tithymalus amygdaloides	+	1	+	+														
Tithymalus cyparissias					–	–					+	+	$+^{1}$	+			+	+
Tussilago farfara															+	1		
Valeriana tripteris			–	$+^{1}$														
Verbascum densiflorum					+	+	–	–					–	–				
Verbascum lychnitis							+	+										
Veronica chamaedrys								+					–	–				
Vicia sylvatica	–	–														+		
Vicia tenuifolia	+	+		1	1	+2	+	+		+					$+^{1}$	1/-2		
Vincetoxicum hirundinaria			+	+			+	+				+	+/1	+/1			+	+
Viola hirta	–	–			1	+2				–			–	–	–	+		
Viola mirabilis				+										+	–	–		
Viola reichenbachiana								–		+								

Following species are scarce or rare in the set of plots:
Aconitum moldavicum, Actaea spicata, Ajuga reptans, Arabis hirsuta, Anthyllis vulneraria, Astragalus glycyphyllos, Betonica officinalis Campanula persicifolia, Capsella bursa-pastoris, Cardamine impatiens, Carex digitata, Carlina acaulis, Cirsium eriophorum, Convallaria majalis, Cruciata glabra, Cyanus montanus, Cyanus triumfettii, Daphne mezereum, Dentaria bulbifera, Epilobium montanum, Epipactis sp., Erysimum wittmannii, Eupatorium cannabinum, Fagus sylvatica, Festuca pallens, Festuca tatrae, Frangula alnus, Galeopsis tetrahit,

Galium anisophyllon, Galium aparine, Genista tinctoria, Gentiana asclepiadea, Hieracium murorum, Hieracium umbellatum, Hylotelephium maximum, Hypericum perforatum, Chamaecytisus ratisbonensis, Chamerion angustifolium, Chelidonium majus, Inula sp., Jovibarba hirta, Knautia arvensis, Knautia drymeia, Lathyrus pratensis, Lathyrus vernus, Lapsana communis, Leontodon incanus, Lilium martagon, Lonicera xylosteum, Maianthemum bifolium, Melittis melissophyllum, Mercurialis perennis, Neottia nidus-avis, Origanum vulgare, Oxalis acetosella, Orobanche sp., Paris quadrifolia, Pimpinella saxifraga, Polygala amara, Polygala brachyptera, Populus tremula, Primula auricula, Pyrethrum corymbosum, Ribes uva-crispa, Rosa pendulina, Sambucus racemosa, Scabiosa lucida, Seseli osseum, Sesleria albicans, Sonchus sp., Thymus pulcherrimus, Trifolium pratense, Veronica officinalis, Urtica dioica.

Explanatory notes: vst – altitudinal vegetation zone, NPR – national nature preserve

from the viewpoint of predicting irreversible changes, mainly in forest soils (formation of karst on respective territory).

We can state with a certainty that during following years it will be necessary to carry out other measures, especially to do planting in advance for damaged open stands. It will be possible to calculate their extent reliably as well as the most suitable technologies on the basis of monitoring of the development of stands minimally during following years. The results of monitoring may be in future very valuable for proposing measures for similar situations as the ones that occurred in the National Park Slovenský raj.

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Resumé

Cieľom práce bolo monitorovať stav lesných porastov v Národnom parku Slovenský raj po požiari (2000), ktorý poškodil približne 64 ha lesa. Projekt revitalizácie požiarom poškodených porastov sa vypracoval na LVÚ vo Zvolene v prvom polroku 2001. Predmetom projektu bola najmä optimalizácia opatrení bezprostredne vyplývajúcich z platných legislatívnych predpisov. Ďalší postup revitalizácie požiarom poškodených porastov závisel v značnej miere od priebehu odumierania a revitalizácie jednotlivých drevín, aj od priebehu sukcesie drevín i bylín na poškodených plochách (na niektorých miestach

i od priebehu erózie). Tieto procesy boli sledované na 52 stabilizovaných monitorovacích plochách za účelom návrhu konkrétnych lesníckych opatrení v požiarom zasiahnutých porastoch.

Monitoring zdravotného stavu lesa sa vykonával na dvoch úrovniach. Prvá úroveň zahŕňala sledovanie procesu odumierania lesa v jednotkách priestorového rozdelenia lesa, druhá sledovanie zdravotného stavu jednotlivých stromov na 52 trvalých monitorovacích plochách, a to prostredníctvom hodnôt ich defoliácie a ďalších charakteristík (napadnutie hubami, hmyzom). Monitoring sukcesie drevinovej (krovitej) a bylinnej zložky sa zameral na zisťovanie celkovej pokryvnosti podrastu a pokryvnosti vyskytujúcich sa druhov pomocou Braun-Blanquetovej stupnice zjemnenej Zlatníkom (1953).

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