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Spruce production power dependence on changes of water content in a soil

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Abstract

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Water is one of the limiting factors of plants existence. Also the highest production of tree species in Slovakia is mainly in connection with favourable water regime as well. Concerning changing of vegetation climate, water regime of soil is starting to change. Especially there is a risk of declining of water content utilisable by plants. It causes the degradation of the soil biotic activity, physiological weakening of the plants and decrease of their production power. The aim of this work is to investigate and to analyse the influence of the water content in soil on spruce production power. The water content was measured at a depth of 30 cm in particular months of vegetative periods during 10 years. The influence of these changes on a basal area increment of particular trees at forest ecosystems of higher altitudinal vegetation zones by regression model was investigated. Observation of the changes of the spruce basal area increment at higher altitudinal vegetation zones (above 800 m above sea level) in dependence of monthly water content in soil was done in the period of 1991–2000 in the region of Oravská Polhora.

Key words

spruce, increment, production power, water content

Introduction

Relevant management of the forest stands represents the highest possibilities and potential to increase production power of the forests. To allow planning of forest management steps using of which increasing of production power can be reached, it is necessary to know growth patterns of individual trees at concrete conditions and also factors as well as factors affecting them. The increment is one of the characters by which the importance of influence of particular factors and climatic changes on production power of forest stands can be demonstrated. Thus, the paper is aimed at investigation of the dependence of the spruce increment (basal area increment) on water content in soil during 10 vegetative periods.

Water is one of the limiting factors, which influence on growth and health state of the forest ecosystems.

Atmospheric precipitation is nearly the only water source in our country. To secure the maximum utilisation of precipitation means to retain their maximum rate and manage them in a optimal way. Along this line forests are very important because of their ability to accumulate atmospheric precipitation which comes from the favourable retentive properties of the forest soils.

Water balance in forest ecosystems is very important but also very complicated problem. Particularly forests soils moisture regime is the result of climatic and hydrological conditions, soils facilities and transformation influence of forest stand (Tužinský 1999).

In term of investigation of forest stands production the ability is needed to state that not only water balance in forest ecosystem is important but also the observing of mensurational data of trees and forest stands in dependence on some components of the ecotype (particular climatic factors and water content). In addition to the determination of mensurational variables of trees and forest stands to specific instant of time, to know changes (increment of these variables during the time) which resulted from natural growth process is also important for forest research. There is mostly paid attention to increment of height, diameter, form factor and volume in forest mensuration.

Generally growth defined by Bertalanfy (1951, in Šmelko et. al 1992) is "largeness enlargement of live systems which is creating by its assimilatory activities". Basically growth is the function of time and environment.

Increment is an enlargement of particular growth variable during one vegetative period or during more successive vegetative periods. The former is the current annual increment the latter is the current periodic increment. The mean increment is also known in addition to the current increment. This increment is calculated as rate of value of growth variable and years during which this variable was created. We know the periodic average increment and the mean annual increment.

While current increments present concrete changes of growth variable, mean increments are not in deed, they are only fictitious. Both of them have theoretical and practical importance.

The increment of basal area is also used except already mentioned increment of height, diameter, form factor and volume for the forestry research purpose. The reason is that the increment of basal area is biologically close to the increment of volume, which is suitable for watching of production ability of trees and the whole forest stands as a more complex of mentioned increments, but its utility is not possible because the missing height of the tree which is necessary for the calculation of volume in each time period.

Because of the missing tree height the increment of basal area was used in this work for the determination of production ability of spruce in relation to the changes of water content in soil. Also in this case just increments of width obtained from increment cores from selected trees and their diameter are available. To the difference of increment of volume, the increments of basal area are easy to calculate.

The increment of basal area is the increment responding to the area of annulus on the cross-section of tree specified by two basal areas in the end and in the beginning of the increment period (Šmelko 2000).

The advantage of the determination of basal area increment in compare to diameter increment is that not only the diameter increment but also tree diameter influences the measurement of increment of basal area. The sizeable diameter the sizeable perimeter for radial increment.

Aim of the work

To investigate and to analyse influence of water content in soil on spruce forest ecosystems production power at higher altitudinal vegetation zones (above 800 m above sea level) by verification of influence of these changes on basal area increment of individual trees generating forest ecosystem. For this purpose following steps were necessary to do:

– to gather empirical data from interest area in form of increment cores obtained from live standing trees 1.3 m above terrain,
– to gather data on water content in soil from interest area during at least 10 vegetative periods,
– to process of empirical data and to create model on the base of suggested methodology and to determine influence of changes of water content on production power specific tree species at mentioned conditions.

Material and methods

Observation of changes of basal area increment in spruce forest ecosystems at higher altidudinal vegetation zones in dependence on monthly water content in soil during 10 vegetation periods (April–September) from 1991 to 2000 was made in the region of Oravská Polhora.

After vegetation period in 2001 on the ground of securing the same or at least the similar climatic and growth conditions experimental material obtained in form increment cores. The increment core is bored roll of the wood with diameter of approximately 5 mm. There is often possible to see by eyes every year created annual rings on these cores. Width of the annual rings as the current annual diameter increment is possible to measure on the cores.

The increment cores were obtained from selected trees by Pressler's auger at height of 1.3 m above terrain.

Compartment no. 120B at Forest Eenterprise Námestovo, Forest District Oravská Polhora was used for increment cores obtaining.

At this compartment 50 increment cores, 41 from co-dominant and 9 from dominant trees, were obtained. These trees seemed to be healthy and in term of their competition they were not negatively influenced by surrounding trees.

Water content data in the soil determined to the depth of 50 cm in scale of 10 cm at mentioned compartment during mentioned vegetation periods were provided by prof. Tužinský.

Obtained increment cores were stuck into special wood laths and then cut. Width of annual rings (value of radial diameter increment) as difference of particular measured diameter values in radial direction was measured.

Digital positiometer made by Austrian firm Kuschenreiter was used to measure radial diameter increments. This instrument measures diameter and width of radial diameter increment by photo electric way with the precision of 0.01 mm.

Values of the measured radial diameter increments were saved in computer memory by DAS (Dendrochronological analysis system). The data were processed into the form of automatically created annual ring diagrams which on the ground of necessity to eliminate eventual disturbances in annual rings creation and on the ground of need to refer particular annual rings exactly have had to be synchronised.

Synchronised annual rings curves were fitted by Hugershoff's function:

$$y = a.t^{b.e^{(c.t)}} \quad (1)$$

were: y – fitted values of diameter increment,
a, b, c, – coefficients of the function,
e – the base of the natural logarithm,
t – age corresponds to created annual tree ring.

After fitting of annual rings curves the real and fitted values of basal area increments and their indices for period of 1991 to 2000 were calculated by using of DAS. Using of indices of basal area increment the influence of age on their values were removed. By this way values of measured increments on the increment cores obtained from trees of different age can be compared.

Calculated indices of the basal area increment were exported from DAS to EXEL where average indices were calculated.

Judgement of influence of water content in soil according to the particular month during ten vegetable periods on average indices of basal area increments was made by programme of STATISTICA in module of multiple linear regression. To determine multiple linear regression between the basal area increments and water content in soil, average indices of basal area increments in particular years as dependent variables were used. Water content in soil at a depth of 30 cm as independent variable was used.

Multiple linear regression between basal area increments and water content in soil at a depth of 30 cm according to particular month during ten vegetation periods are results obtained by programme of STATISTICA.

These results were finally imported to programme of EXEL in order to conveniently organise them to the table form. Regression between basal area increment and water content in soil was graphically designed.

Results

Spruce production power in dependence on water content in soil at a depth of 30 cm according to particular month during ten (from 1991 to 2000) vegetation periods (April to September).

Concrete evaluation of production power in dependence on water content in soil was made by calculated indices of annual increments of basal area of mean sample tree.

To evaluate influence of water content in soil on spruce production power at higher altidudinal vegetation zones, multiple linear regression by the following regression model was used:

$$y = a + b_1.x_1 + b_2.x_2 + b_3.x_3 + b_4.x_4 + b_5.x_5 + b_6.x_6 \quad (2)$$

where: y – index of basal area increment of mean sample tree,
a, b_1–b_6 – coefficients of regression,
x_1–x_6 – water content in soil in April to September.

Calculated model parameters for depth of 30 cm are in Table 1.

It is resulted from the calculated regression coefficients, that water content in soil in particular months during vegetation period influence on indices of annual increment of basal area in a different way. Most of partial regression coefficients are positive. Negative values of the coefficients were only obtained in May and September. It is illustrated in the Fig. 1.

Significance of regression coefficients in this regression model was evaluated by statistical test. Null hypothesis that regression coefficient is equal to zero was tested by statistical *t*-test. Calculated *t* values for particular regression coefficients are mentioned in Table 1. In comparison of these values with table value ($t_{0.05}(3) = 3.182$) it is possible to state that regression coefficients are not statistically significant from zero. It means that influence of particular factors (water content at a depth of 30 cm during ten vegetation periods) on index of annual increment of basal area is not significant.

To express closeness of regression by this model there is a coefficient R equal to 0.834. Its square is coefficient of determination R^2 equal to 0.696. It express that almost 70% of variance of empirical data around fitted values is explained by this model.

In spite of the relative high value of the correlation coefficient and coefficient of determination the statistic tests of partial regression coefficients proved that influence of investigated factors on indices of annual basal area increments is not significant.

Total influence of investigated factors was tested also by analysis of variance. It also confirmed that influence of water content in soil at a depth of 30 cm according to particular month during ten vegetation periods on indices of annual increments of basal area is not significant. Calculated, residual and total variance are presented in the Table 2. Calculated F-value (1.146) as a rate of mean square of investigated and residual variance is lower than criterion value ($F_{0.05}(6.3) = 8.94$). Although this test confirmed that influence of investigated factors on value of annual increment indices on basal area is not significant. Thus, spruce production in higher altitudinal vegetation zones is not influenced by these factors.

Table 1. Results of multiple linear regression of increment indices on water content in soil

Investigated factor and its mark	Regression coefficient a, $b_1 - b_6$	Standard error of regression coefficient	t-value
A	0.563561845	0.812	0.694
b_1 (April)	0.005658924	0.020	0.278
b_2 (May)	–0.015222647	0.018	–0.847
b_3 (June)	0.020666532	0.025	0.817
b_4 (July)	0.053608952	0.028	1.885
b_5 (August)	0.005020356	0.016	0.315
b_6 (September)	–0.063546568	0.027	–2.343
$R = 0.834$		$R^2 = 0.696$	

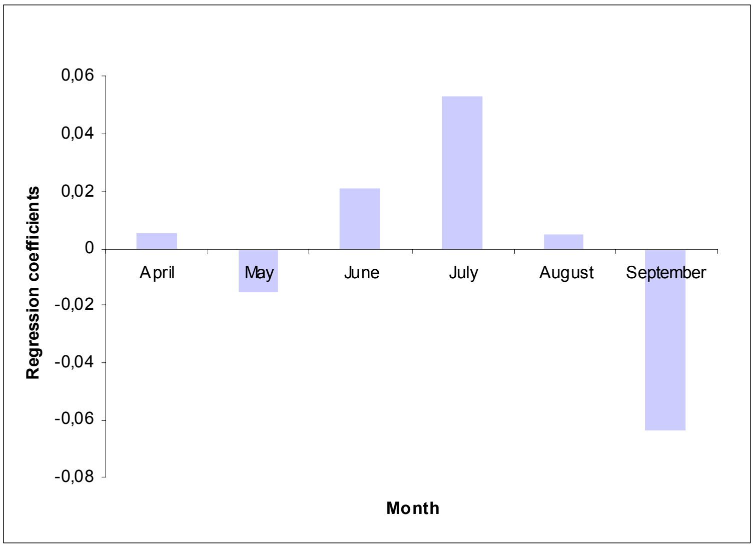

Fig 1. Values of regression coefficients of influence of water content in soil on indices of basal area increment in April to September

Table 2. Variance analysis of influence of water content in soil on basal area increment indices

Variance	Sum of squares	Deg. of freedom	Mean square	F
Investigated	0.201916175	6	0.033652696	1.146
Residual	0.088093350	3	0.029364450	
Total	0.290009525			

Discussion

By the statistic test it was shown that the influence of investigated factors (water content at a depth of 30 cm during ten vegetation periods) on value of annual increment indices of basal area and on spruce production in higher altitudinal vegetation zones was not significant. However this fact does not mean that water content in soil does not influence tree increment.

This conclusion does not look to be logical, even though many authors state that water is limited factor of plant existence especially at lower altitudinal vegetation zones (Bublinec 1990; Gregor 2000; Kantor 1989; Pichler, Gregor 2002; Soroková 2003; Soroková, Tužinský 2001; Tužinský 1993, 2000, 2003). Likewise Šály (1987) connects the highest production of forest trees in Slovakia in fertile B and B/D sites on the border of 4^{th} and 5^{th} altitudinal vegetation zones especially with favourable water regime. Tužinský (2003) mentioned that with regard to changeable vegetation climate it comes to the change of water regime. Mostly it is increasing of risk of available water content declining.

The results which confirmed that influence of water content in soil at a depth of 30 cm during ten vegetation periods is not significant it is possible logically explain by the fact that the watching of this influence was made in such climatic area where deficit of water content in soil in mentioned depth does not appear during the whole vegetation period.

Moderate decreasing of water content in soil was in this area measured in May. However this decline does not influenced significantly the value of annual indices of basal area of spruce. It is caused by the fact that in this month the significant higher temperatures do not appear in this region. In spite of its soft decline soil humidity was sufficient not to influence the index.

Significant decrease of water content in soil was obtained in September in this area. Neither this decline does not significantly influenced annual increment index of basal area of spruce because in the second half of this month the significant higher temperatures do not appear and the soil humidity was sufficient, so there was not visible its influence on value of annual increment indices of basal area thus on spruce production in this area.

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Produkčná schopnosť smreka v závislosti na množstve vody v pôde

Súhrn

Sledovanie zmien prírastku na kruhovej základni jednotlivých stromov tvoriacich lesné ekosystémy smreka vo vyšších lesných vegetačných stupňoch, pomocou indexov ročných prírastkov, v závislosti na množstve vody v pôde v hĺbke 30 cm počas vegetačných období po sebe idúcich desiatich kalendárnych rokov ukázalo štatistickú nevýznamnosť vplyvu skúmaného faktora na veľkosť ročných prírastkových indexov na kruhovej základni, teda na produkčnú schopnosť smreka v týchto lesných vegetačných stupňoch. Z vecného hľadiska to však neznamená, že množstvo vody v pôde neovplyvňuje veľkosť prírastku týchto stromov a ich produkčnú schopnosť. Preukázateľnú nevýznamnosť vplyvu množstva vody v pôde v hĺbke 30 cm v jednotlivých mesiacoch desiatich po sebe idúcich vegetačných období podľa odvodeného regresného modelu možno logicky vysvetliť iba tým, že sledovanie tohto vplyvu bolo vykonané v takej klimatickej oblasti, kde sa počas celého vegetačného obdobia deficit množstva vody v pôde v uvedenej hĺbke nevyskytuje. Mierny pokles množstva vody v pôde bol v tejto oblasti počas desiatich po sebe idúcich vegetačných období zaznamenaný v mesiaci máj a výrazný pokles v mesiaci september. Ani v jednom prípade tento pokles však veľkosť ročného prírastkového indexu na kruhovej základni smreka významne neovplyvnil, pretože ani v máji ani v septembri sa v tejto oblasti nevyskytujú výraznejšie vyššie teploty a zaznamenaná nižšia vlhkosť pôdy sa preto aj napriek tomuto poklesu ukázala dostatočná na to, aby nedošlo k preukázaniu významnosti jej vplyvu na veľkosť ročného prírastkového indexu na kruhovej základni, v konečnom dôsledku teda na produkčnú schopnosť smreka v tejto oblasti.

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Foraging and flight activity of bats in beech-oak forests (Western Carpathians)

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Abstract

Ceľuch M., Kaňuch P., 2004: Foraging and flight activity of bats in beech-oak forests (Western Carpathians). Folia oecol., 31 (1), p. 8–16.

Bat assemblage (14 species) was studied in beech-oak forests in south-eastern part of Kremnické vrchy Mts. (Central Slovakia) from May to September in 2002 and 2003. Mist-netting method, ultrasound bat-detectors and faecal pellets analyses were used for study of foraging and flight activity of bats. Bats were classified according to foraging strategies. Considering prey composition, 7 orders of insects and one order of arachnids were identified in examined bat droppings. The imagos of moths (Lepidoptera) were the most important component in diet of studied bat assemblage (V = 46%, F = 68%). All five basic foraging strategies were found in the studied bat assemblage. Almost the same portion took gleaning, slow hawking and fast hawking. Flight activity of bats during nights was recorded in 16% of observed 1505 minutes. Recorded bat passes were assigned to *Myotis* group (67%), and non-*Myotis* group (33%). All of seven studied habitat types were used by bats. The highest level of flight activity was recorded on small open areas and forest edges.

Key words

Chiroptera, assemblage, strategy, insects, hunting, diet

Introduction

Almost all of the European bat species are dependent on the forest ecosystems, to some extent. Forest provides both basic sources for bats – food and roosts. The fidelity to the forest is different for the individual species (Kulzer 1989; Zahn, Krüger-Barvels 1996; Meschede, Heller 2000). European bat species are exclusively insectivorous (cf. Vaughan 1997), have a high energy consumption, an extremely fast metabolism and ability to look for habitats with a high concentration of prey (Fenton 1982; Beck 1995). Important portion of pest insects is nocturnal (e.g. moths from family Lymantridae, Tortricidae, Geometridae, Noctuidae, Cossidae, Coelophoridae etc.; Novák et al. 1974). Therefore, bats belong to an important insect predators, they participate on ecological stability of forest ecosystems (Kulzer 1989; Meschede, Heller 2000).

Foraging activity of bats depends on foraging strategies of individual bat species. There are more approaches of foraging strategies classification based on the differences in echolocation calls and wing morphology, diet composition and visual observations (eg. Norberg, Rayner 1987; Beck 1995; Arlettaz 1996; Entwistle et al. 1996; Rydell et al. 1996; Siemers, Schnitzler 2000; Bontadina et al. 2002). Bats use five basic foraging strategies (Norberg, Rayner 1987): (1) Fast hawking – fast flight in pursuit of flying insects above treetops and use of loud, long-ranging echolocation calls of low frequency; (2) Slow hawking – slow flight and detecting prey at a short range; (3) Gleaning – taking roosting or non-flying prey from the ground or vegetation, use of broadband frequency modulated calls of low intensity; (4) Trawling – picking up the prey from water surface with its tail membrane or hind legs; (5) Perch hunting or fly-catching – waiting and seeking for the prey on a branch and flight after prey detection.

The using of all the bat detectors has revolutionised the field study of flight activity and habitat selection of bats (cf. Ahlén, Baagoe 1999). Activity of bats in the forest environment depends on many factors (eg. Barclay, Brigham 1996; Meschede, Heller 2000; Meschede et al. 2000). Factors, which significantly influence the activity of bats are: tree species composition (Rachwald 1992; Jung et al. 1999; Kalcounis et al. 1999), age (Erickson, West 1995; Crampton, Barclay 1996), forest structure (Humes et al. 1999; Jung et al. 1999), fragmentation (Crampton, Barclay 1996). One of the most important factors is insect activity and food supply (Rydell et al. 1996; Zahn, Krüger-Barvels 1996; Verboom, Spoelstra 1999). These factors are more complex and reflect a character of the foraging habitat. In general, activity and habitat selection of bats depends on insects availability and foraging strategies of individual bat species. There are no studies of habitat use and flight activity of individual bat species in the Western Carpathians (Central Europe) yet.

The purpose of this study was (1) to analyse a bat assemblage based on foraging strategies and food composition of individual bat species and (2) to assess the influence of habitat and insect activity on flight activity of bats in selected beech-oak forests.

Material and methods

Study area

The study area is located in south-eastern part of Kremnické vrchy Mts., Central Slovakia (48°34–40′ N, 19°00–07′ E; 300–550 m a. s. l.). It belongs to a warm climatic area with average temperature 4 °C in January (Gáborík, Macko 1981). With regard to the forest typology, the selected study area represents mainly the forest type Fageto-Quercetum and Querceto-Fagetum (sensu Zlatník 1959; Randuška et al. 1986). This study was performed in beech-oak (2nd) and oak-beech (3rd) forest vegetation tire. Forests are primarily managed for timber production but the tree species composition is semi-natural. It means, that the dominant tree species correspond to the habitat conditions (sensu Zlatník 1959). Fragments of coniferous forests (*Picea abies*, *Pinus silvestris* dominant) also appear in this area as unnatural stands with changed tree species composition in habitats of beech-oak forests.

To study flight activity of bats, five transects were selected. Each of them consist of the seven habitat types: (1) broad-leaved forest – mature harvested beech-oak forests stands, (2) coniferous forest – pine and spruce enclaves, (3) forest edge – between forest and meadows or clear cutting, (4) open area – meadows of minimum size of one hectare, (5) forest road – small roads inside the forest under tree crowns, (6) stream – small non-regulated streams inside the forests, (7) game mire – small water spots, mainly small pools on roads smaller than 20 m^2.

Field investigations and data analyses

The direct observation of foraging bats is problematic in the forest ecosystem conditions. The complicated techniques using infrared cameras or radio-telemetry make it possible to some extent (Kunz 1988). For this purpose, the flight and foraging activity was observed with help of bat-detectors and faecal pellets analyses.

The investigation was carried out from May to September 2002–2003. To know the species composition in the study area, was used mist-netting method (Kunz and Kurta 1988). A special, very soft-structured mist-nets were installed (Natur-Plan, Germany) on sites with high flight activity, mainly game mires, small pools and roads. These sites are very often used like water and prey source. Forest roads are also important flight corridors for bats (Walsh, Harris 1996; Zahn, Krüger-Barvels 1996). Netting started after the sunset and lasted until midnight. Caught individuals were immediately taken from the net. Bats were released after a species identification and collecting a sample of droppings. The main portion of the data was obtained by mist-netting (25 nights, 77 individuals). Other important data were obtained using bat-detectors (13 nights, 52 registrations) or roost control (nine roosts found). The heterodyning detector Pettersson D200 (Pettersson Elektronik AB, Uppsala, Sweden) was used and identification was made, if possible, based on call characteristics and visual observation (Limpens, Roschen 1995). Assemblage composition was assessed, based on relative abundance (n%) of caught individuals and detector registrations.

The food composition was examined using faecal pellets analyses. Arthropod fragments in bat droppings were analysed and identified using a method similar to McAney et al. (1991) and Whitaker (1988). Bats were released in 15 minutes after they were held in a textile bag. Then the droppings were collected. The fragments of the prey in the bat droppings were identified to taxon using binocular magnifying glass (25 ×). Moths were divided into two groups – imago and larva. The qualitative and quantitative structure of food composition was estimated through the volume of prey category in one dropping (V%) and frequency of occurrence in faecal pellets (F%) (cf. Rydell, Petersons 1998). In total, 117 pieces of droppings were collected from 38 individuals of 10 bat species.

Classification of bats into the foraging strategies was performed based on studies dealing with morphological adaptations for foraging (NORBERG, RAYNER 1987; HORÁČEK et al. 2000), analyses of diet composition (BECK 1995; VAUGHAN 1997) and partly with the support of the material collected in the study area. Some bat species use more strategies, therefore two species (*Myotis mystacinus* and *Plecotus austriacus*) were assigned into two strategies concurrently.

To determine relative levels of bat flight and foraging activity among habitat types, the heterodyne bat-detector Pettersson D200 was used. Each night (13 nights from 1th July to 1st September 2003) one selected transect was monitored for 150 minutes after sunset. When detecting in open area or in the forest interior, the distance of 50 m from the forest edge was important. In each habitat, the active minutes (at least one bat pass / minute) and number of bat passes was registered. Activity in each habitat was calculated as the number of bat passes per minute. In total, 1505 minutes of monitoring were obtained. Species identification in forest conditions based on echolocation calls is difficult – in most cases, the bat pass was registered only with few calls, without any chance to see the bat. Therefore, registered bats were divided only into groups based on call characteristics – *Myotis* group a non-*Myotis* group. A typical feature for the first group is strong frequency-modulated call. Non-*Myotis* group contains a part of the call with relatively constant frequency. The typical species of this group are *Nyctalus noctula*, *Nyctalus leisleri*, *Eptesicus serotinus* and *Pipistrellus pipistrellus*. Other species were assigned to *Myotis* group. Feeding buzzes (call signal characteristic for the closing part of attack on its prey) were also registered.

Flight activity of insect was studied in each visited habitat, based on counting of flying individuals in the beam of a strong torchlight. In 15 seconds, the torchlight was turned around in a horizontal circle and the insects flying closer than 10 meters were counted (cf. ZAHN, KRÜGER-BARVELS 1996). Activity was assigned to classes: 1 = 0–4 insects, 2 = 5–9, 3 = 10–14, 4 = 15–19, 5 = 20 and more.

The statistic software Statistica for Windows 5.1 (StatSoft, Inc.) was used for data analysis. When comparing bat and insect activity in different habitat types, Kruskal-Wallis oneway ANOVA combined with Kruskal-Wallis Multiple-Comparison Z-Value Test at $p = 0.05$ level were used.

Results

Species composition

Altogether fourteen bat species were recorded in the study area (Table 1). The most abundant mist-netted species were *Myotis daubentonii* and *E. serotinus*. The species *Myotis bechsteinii*, *M. myotis*, *M. mystacinus* and *P. auritus* were also dominant (> 5 %). There were big, between-night differences in netting success and species composition. More than one quarter of nights were negative and on the other hand in the most successful night (20th June, game mire) 28 individuals of eight species were captured.

Most detector registrations belong to species *N. noctula*, followed by *E. serotinus*, *Barbastella barbastellus*, *N. leisleri* and *P. pipistrellus*. Another three species (*Myotis nattereri, M. myotis*, *M. daubentonii*) were detected and identified only if observing conditions were sufficient (visual observation, more detections). It was not possible to identify other species in the forest conditions.

In the study area, eight potential roosts in churches were controlled. This type of habitat represents a typical summer roost for more species. No maternity roost was found, only sporadically some individuals of *M. mystacinus* and *Plecotus austriacus* were found. Four tree roosts were found occasionally, three were used by *N. noctula*, and one by *M. daubentonii.* One individual of *R. hipposideros* was found in a 12 m long mine.

Prey composition and foraging bat assemblage

One order of arachnids (Araneida) and 7 orders of insects (Homoptera, Heteroptera, Neuroptera, Coleoptera, Hymenoptera, Lepidoptera and Diptera, Table 2) were identified in examined bat droppings. In total, the moths imagoes (Lepidoptera) were the most important component in diet of studied bat assemblage (V = 46%, F = 68%). Other important diet components were beetles (Coleoptera) V = 23%, F = 43% and dipterans (Diptera) V = 11%, F = 50%. The frequency of dipterous insects was relatively high, however volume dominance was low. Underestimation of volume dominance could be caused by easier digestion of soft fly's bodies. The moths took up to 100% in frequency of diet components (found in droppings) of *M. nattereri*, *M. emarginatus*, *M. mystacinus*, *N. noctula*, *P. auritus* and *B. barbastellus*. Similarly, the moths had an important portion of volume dominance in diet composition of several species (*P. auritus* = 96%, *M. nattereri* = 68%, *M. mystacinus* = 65%). Just in *B. barbastellus* the moths had 100% of volume dominance (n = 3). Consuming of moth females (presence of eggs) and larvae was recorded. Especially, the larvae of geometrid moth *Lycia hirtaria* took up to 28% of diet volume dominance in *M. bechsteinii*. Another important diet component were beetles (*M. myotis* = 76% and *E. serotinus* = 58%). In *M. myotis* it was mainly beetles from Carabidae family and in *M. bechsteinii* and *E. serotinus* it was beetles from *Curculio* genus.

In the studied bat assemblage, all five foraging strategies were observed or assigned to individual species. Species *N. noctula* and *N. leisleri* were observed using the strategy "fast hawking". Foraging strategy "slow hawking" was typically observed by *E. serotinus* and *B. barbastellus*, also *P. pipistrellus* was assigned to this strategy and partly *M. mystacinus* and *P. austriacus*. "Gleaning" from the ground or vegetation is typical for species of *Myotis* genus – *Myotis emarginatus*, *M. myotis*, *M. bechsteinii*, *M. nattereri*, also for *P. auritus*, and partly for *M. mystacinus* and *P. austriacus*. Species *M. daubentonii* used mostly "trawling" from water surfaces. The last foraging strategy called "perch hunting" or "fly-catching" is typical for *R. hipposideros*. This species was registered just once, therefore this strategy was not included in further analyses. Based on literature and field observations, attempt to classify the foraging strategy composition of the bat assemblage was performed (Fig. 1).

Table 1. All bat species records in the study area. Data obtained by netting (number of caught individuals / %) batdetectoring (number of records / %) and control of roosts (number of roosts / %) are presented.

Species	Netting n / %	Detectoring n / %	Roosts n / %	All records N / %
Nyctalus noctula (Schreber, 1774)	3/4	28/53	3/34	34/26
Eptesicus serotinus (Schreber, 1774)	14/18	10/19		24/17
Myotis daubentonii (Kuhl, 1817)	14/18	2/4	1/11	17/12
Myotis myotis (Borkhausen, 1797)	12/16	3/6		15/11
Myotis bechsteinii (Kuhl, 1817)	13/17			13/9
Myotis mystacinus (Kuhl, 1817)	9/12		2/22	11/8
Barbastella barbastellus (Schreber, 1774)	3/4	5/10		8/6
Plecotus auritus (Linnaeus, 1758)	5/6			5/4
Myotis nattereri (Kuhl, 1817)	2/3	1/2		3/2
Rhinolophus hipposideros (Bechstein, 1800)	1/1		1/11	2/1
Nyctalus leisleri (Kuhl, 1817)		2/4		2/1
Plecotus austriacus (Fischer,1829)			2/22	2/1
Myotis emarginatus (Geoffroy, 1806)	1/1			1/1
Pipistrellus pipistrellus (Schreber, 1774)		1/2		1/1

Table 2. Food composition (volume dominance % / frequency of occurrence %) in the beech-oak forest bat assemblage (N = 38 bat individuals / n = 117 pellets)

Bat species	Prey category									
	Araneida	Homop.	Heterop.	Neurop.	Coleop.	Hymenop.	Lepidop.	Lepidop. (larvae)	Dip.	N/n
M. myotis					76/93	13/40		8/27	3/20	6/15
M. bechsteinii	5/31		1/3	1/3	6/26	2/11	49/60	28/40	9/49	10/35
M. nattereri	2/17				5/50	8/17	68/100		17/100	1/6
M. emarginatus							30/100	40/100	30/100	1/1
M. mystacinus				16/43			65/100		19/64	5/14
M. daubentonii									100/100	1/1
E. serotinus		1/5	3/19	3/24	58/95	5/19	19/62		11/67	6/21
N. noctula			25/56		4/33		54/100		17/67	2/9
P. auritus					1/11		96/100	1/11	2/22	3/9
B. barbastellus							100/100			3/6

The ratio of individual strategies was relatively equalled. The same portion took gleaning, slow hawking and fast hawking. Individual groups of bats (*Myotis* group, non-*Myotis* group) were registered not equally in all strategies by detectoring and netting. Fast hawking species were registered often by detectors and gleaners almost exclusively by mist-netting (Fig. 2).

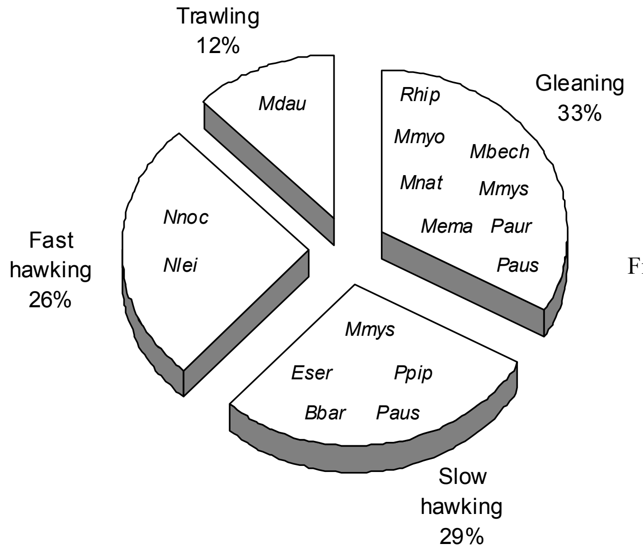

Fig. 1. Hypothetical structure of bat assemblage based on the foraging strategies in the selected beech-oak forests (n = 138). Abbreviations: Bbar = *Barbastella barbastellus*, Eser = *Eptesicus serotinus*, Mbech = *Myotis bechsteinii*, Mdau = *Myotis daubentonii*, Mema = *Myotis emarginatus*, Mmyo = *Myotis myotis*, Mmys = *Myotis mystacinus*, Mnat = *Myotis nattereri*, Nlei = *Nyctalus leislerii*, Nnoc = *Nyctalus noctul*a, Paur = *Plecotus auritus*, Paus = *Plecotus austriacus*, Ppip = *Pipistrellus pipistrellus*

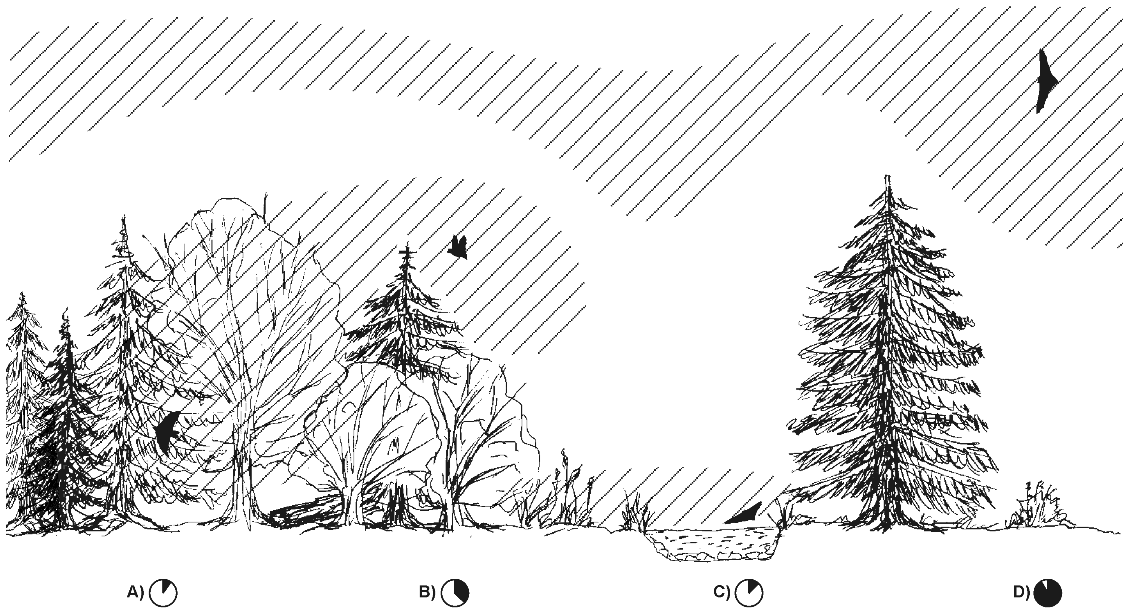

Fig. 2. The typical hunting space (hatches) of selected foraging strategies (A = gleaning, B = slow hawking, C = trawling, D = fast hawking) and relationship of such bat groups to recording in the field (by bat-detectoring – black percentage in the circle, by mist netting – white)

Flight activity

Of 1505 total assessed minutes, 16% were positive. In positive minutes 249 bat passes and 16 "feding buzzes" were recorded. Bat passes were assigned to *Myotis* group (67%), and non-*Myotis* group (33%). All of studied habitats were used by bats.

The highest level of activity (number of bat passes per minute) was recorded in open areas. Extreme values of activity were also typical for this habitat type (0.8 bat passes/minute). A relatively high level of flight activity was recorded on forest edges and forest streams (Fig. 3). Coniferous and broad-leaved forests had the lowest number of detections. No bat passes typical for non-*Myotis* group were in broad-leaved or coniferous forests. They were recorded often in the open area (61%) and on the forest edge (43%). The comparison of the number of bat passes per minute between all habitats made by Kruskal-Wallis *H*-test showed significant differences ($H = 33.61$, d. f. = 6, $p < 0.001$). Significant differences were found between the open area and coniferous forest (Z-Value Test, z = 3.59, $p < 0.05$), stream and coniferous forest (Z-Value Test, z = 3.61, $p < 0.05$). High activity was detected on the forest edge, but differences were significant only in relation to activity in broad-leaved forest (Z-Value Test, z = 3.36, $p < 0.05$) and coniferous forest (Z-Value Test, z = 5.03, $p < 0.05$). "Feeding buzzes" were recorded in open area and forest edge in very small numbers, in broad-leaved forest were recorded just once.

The flight activity of bats differed significantly in relation to flight activity of insects (Kruskal-Wallis *H* test, $H = 44.77$, d.f. = 4, $p < 0.001$). With increasing flight activity of insects, the flight activity of bats increased as well ($R = 0.34$; $p < 0.001$; n = 297).

Discussion

Proportional use of different investigation methods (mist-netting, bat-detectoring, roost controls) is necessary for study of bat assemblages and can provide an elementary view on the bat species composition in study area. Some species are easily recorded by mist-netting and another species with help of bat detectors (Gaisler 1973; Murray et al. 1999). Individual species are distinctive in their ecology, therefore it is important to take this fact into consideration. *M. daubentonii* hunts typically on the open water surfaces. Foraging of this species was recorded exclusively at one locality – Kováčovský rybník pond. It was probably a group of animals from a 1.5 km distant tree-hollow roost. It was confirmed by netting of nine individuals on a forest road between the roost tree and the pond. Similarly, the use of bat detectors can overestimate species with loud echolocation calls. It is possible to detect a *N. noctula* on 150 meters in contrast to *M. bechsteinii*, which could be usually detected only at 3–5 meters (Obrist 1995).

Food composition of bats in the study area did not differ significantly from findings of other authors in European countries (Gregor, Bauerová 1987; Beck 1995; Vaughan 1997). Foraging strategies of individual bat species (cf. Norberg, Rayner 1987) and seasonal food accessibility probably determined the prey type and composition.

Importance of different forest habitats for bats is still not clear. Our results correspond with another authors. Forest interior (broad-leaved or coniferous forests) had a low level of flight activity and the highest level of activity was typical for forest openings and edges. Some of the authors concluded, that bats

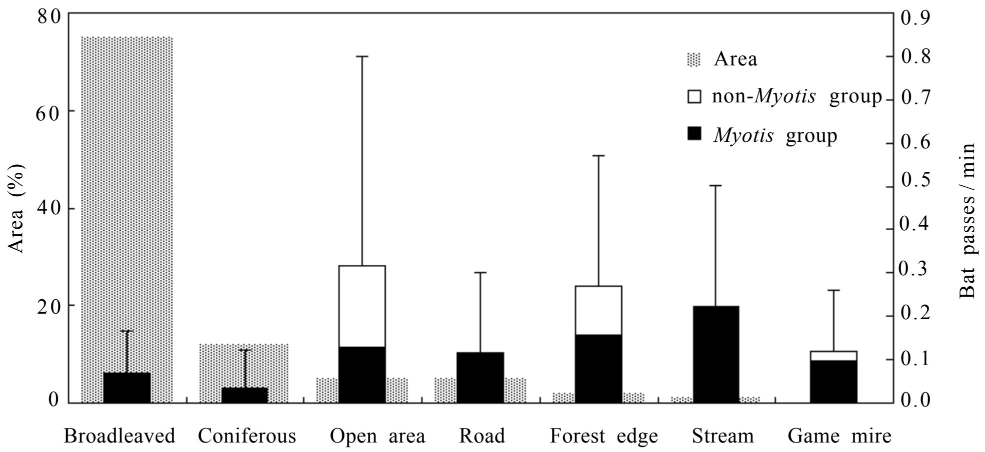

Fig. 3. Flight activity of bats in seven investigated habitat types (mean, +SD; proportion in percentage of *Myotis* group – black and non-*Myotis* group – white, 1505 minutes) and area of the habitat types (grey)

prefer hunting in these habitats and they are crucial for bats. They supposed that low clutter and therefore, easily accessible prey is the reason for this preference (Crampton, Barclay 1996; Krusic, Neefus 1996). We assume that interpretation of bat detector data is not so simple in these conditions. Studied habitats often have very unequal proportion in the study area and the function of habitats is also different. High activity in open areas and forest edge is caused by limited area of these habitats and bats do not spent much time in these habitats. On the other hand, there was recorded minimal activity in the forest. But these results must be handled carefully. The forest takes up a majority of the area and that is the cause of a big dispersion of individuals (Fig. 3). Studies combining radio-telemetry and bat detectors brought a controversial results (Cram-pton, Barclay 1998). Very low level of activity was detected in the forest interior, but the radio-telemetry data showed that bats did not leave the forests. Streams and small water pools are also a water source. Therefore, their presence could be crucial for bats, regardless to their negligible small surface.

There are other factors which have negative influences on the registered level of activity. The forests are mostly very cluttered habitats. Hunting in such habitat demands the use of high frequency calls, which are attenuated more in atmosphere (Obrist 1995; Patriquin et al. 2003). In more open areas, bats use low frequency calls within a long range. These frequencies are recorded at a farther distance by bat detectors. This fact can overestimate more open habitats, like cuttings or forest edges. In other respects, the crown layer of the forest could also be an important foraging area (Hayes, Gruver 2000). The bat detectors in this study were placed 1.5 m above the ground, so the crown layer was not surveyed at all.

Conclusions

Using different methods the wide spectrum of bat species was recorded in beech-oak forests in the Central Slovakia. Bats use forest ecosystems for hunting completely, in all dimensions – they hunt insects on the ground, on the trunks, in the crowns and also in free space above the forest and clearings. The dominant prey taken by bats were Lepidoptera, Coleoptera and Diptera. The flight activity of bats positively correlated with flight activity of insects, which confirms the opportunistic foraging strategy of bats. The highest level of flight activity of bats was recorded in open areas (meadows, clearings) and on the forest edges. But interpretation of these results must be handled carefully, because of very different size of individual habitats. We suggest that forest interior is an important foraging habitat for bats. It is not possible to assess importance of habitats or habitat preference based only on results from bat detectors. Higher activity need not mean the preference. There is a need for more studies or experiments in the future to know the real habitat preference of bats in forest ecosystems.

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Lovná a letová aktivita netopierov v bukovo-dubových lesoch (Západné Karpaty)

Súhrn

Kombináciou viacerých metód bolo v bukovo-dubových lesoch na skúmanom území zaznamenané pomerne široké druhové spektrum netopierov (14 druhov). Najvýznamnejší podiel v potrave tvorili Lepidoptera, Coleoptera a Diptera. Rozbor potravy a priame pozorovania ukázali, že netopiere využívali skúmané lesné ekosystémy ako zdroj potravy komplexne – od povrchu pôdy, cez korunovú vrstvu až po voľný priestor nad korunami stromov. Bola zistená pozitívna závislosť letovej aktivity netopierov od letovej aktivity hmyzu, čo potvrdzuje oportunistický spôsob lovu – vyhľadávanie lokálne bohatých zdrojov potravy. Najvyššia aktivita bola zistená na otvorených plochách v porastoch (čistinky, lúky) a na okrajoch porastov. Interpretáciu týchto výsledkov ako habitatovej preferencie je však potrebné robiť citlivo, vzhľadom na odlišný plošný podiel jednotlivých habitatov. Je pravdepodobne zjednodušené usudzovať o význame či preferencii habitatov len na základe hodnotenia aktivity získanej pomocou detektorov. Predpokladáme naopak, že interiér lesa je významným lovným habitatom netopierov. Pre poznanie skutočných habitatových preferencií netopierov v lesoch budú v budúcnosti potrebné porovnávacie štúdie vo viacerých územiach príp. modelových podmienkach.

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Heavy metals as contaminants of forest ecosystem in surroundings of the metallurgical plant Železiarne Podbrezová, holding

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Abstract

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The paper deals with the determination of heavy metals (zinc, cadmium, lead and copper) in assimilatory organs of Norway spruce (*Picea abies* (L.) Karst.) and European beech (*Fagus sylvatica* L.) taken from forest ecosystem situated in surroundings of the metallurgical plant Železiarne Podbrezová, holding. A local monitoring of a valley in the municipality Podbrezová was performed. Samples of needles and leaves were taken from 12 locations on both sides of the valley. At the same time reference samples from relatively undisturbed locality in the Protected Landscape Area (PLA) Poľana near the municipality Lom nad Rimavicou were taken. Concentrations of heavy metals mentioned above were determined in two-year-old needles of spruce and leaves of beech by means of the flow-through galvanostatic stripping chronopotentiometry.

Key words

heavy metals, spruce, beech, stripping chronopotentiometry

Introduction

Contamination of ecosystems with heavy metals becomes a global environmental problem. The cause is anthropogenic mobilisation of these metals from the ores and other mineral deposits and their forced redistribution over different constituents of the environment – soil, water, atmosphere, that means practically the whole biosphere. And namely within the biosphere, some heavy metals are to more or less extent bioaccumulated – resulting in local biospherical preconcentration. In question is a rather wide scale of contaminants, with different effects on organisms, different occurrence forms and toxicity. The worldwide monitoring is focussed on Hg, Cd, Pb, Cr, which are considered the most severe toxic for both people and animals (Ďurža, Kuhn 2002). Some heavy metals (As, Zn, Cu, Ni) accumulated in animal bodies can even turn more toxic than in the free form. Some heavy metals (Cu-Zn, Co-Ni…) can counterbalance each other; on the other hand, some chemicals combined with certain heavy metals, e.g. detergents, increase their toxicity.

The input of heavy metals into the environment takes place in natural processes (weathering in situ, atmospheric deposition, volcanism, leaching from the lithosphere, oceanic processes, etc.) and by anthropogenic activities (fossil fuels burning, solid waste – primarily plastic materials, transport, processing and treatment of metals, chemicalisation, waste water management etc.) (Blažej et al. 1981).

The valley of the River Hron in the village Podbrezová is half built-up with a metallurgical plant Železiarne Podbrezová, holding. So we suppose that the surrounding forest ecosystems are severely contaminated with heavy metals, most probably originated in the plant. Interesting is also the fact that the plant, a massive pollutant source, is not obliged to provide monitoring on emitted heavy metals. According to the Act No. 17/1992 about the human environment, it only reports emissions of solid pollutants, sulphur dioxide, nitrogen oxides (NO_x), carbon monoxide, hydrogen chloride and chromium (VI). In forest stands in the area, no direct measurements of air pollution are provided. The immission load is evaluated and the influence of pollutant sources in this area is assessed using mathematical models alone. On this background we have accomplished a local purpose-oriented monitoring of a selected locality. The results of the monitoring can contribute to the knowledge about the contamination of the forests with heavy metals and to point out the air quality at the site. In the frame of this local, purpose-oriented monitoring we sought to get together a set of data reflecting the health state and pollutant load to the forests in the selected locality. We hypothesised that this ecosystem is loaded more than is the average load on forests in Slovakia and also more in comparison with a chosen relatively undisturbed locality. According to the commonly recognised state following from the monitoring in Slovak forests, we supposed higher concentrations of heavy metals in needles compared to leaves. Further we tried to explore whether there exists dependence between the contamination grade and the distance from the pollution source at the local level, whether accumulation of heavy metals over a given time period would be evident and whether there is equal load to the both sides of the river valley.

Material and methods

The Podbrezová village is situated in the region of Banská Bystrica, 7.5–12.5 km west to the district centre Brezno, with cadastre territory on both sides of the Hron River. The major part of the built-up area of this part of the Upper-Hron valley comprises industrial and non-industrial buildings belonging to the former part of the metallurgical plant Železiarne Podbrezová, holding, the smaller consists of family houses and prefab-houses, motorways and roads – I/66 and a railway following the river course.

The angle between the valley slopes and the floodplain is 60%, locally, in sites with boulders and slides even 90%. The vegetation cover on both sides consists of mixed forest with prevailing broadleaved trees. The most abundant is beech, in lower amounts is present oak, hornbeam, birch, black locust; from conifers is dominant spruce. The River Hron represents a boundary between the Slovenské rudohorie Mts. (Veporské vrchy Mts. on the left side according to the river flow) and the National Park Nízke Tatry (NAPANT, right side of the river), consequently the territory of the village and also the territory where we observed the forest status belongs to both orographical units. We have subjected to analysis Norway spruce (*Picea abies* (L.) Karst.) and European beech (*Fagus sylvatica* L.) – the most abundant species in the territory of interest and, at the same time, the most important commercial species in Slovakia.

Issuing from the real estate and possibilities we decided to pursue the research in the following manner: The sampling sites were chosen in such a way as to cover an appropriate area in terms of local monitoring of forest health status. As there is discussed a river valley, we collected the samples on both sides of the river. We chose by three sampling sites on each side, 100 m from each other. The choice of sampling sites was determined by the occurrence of woody plants of interest, primarily of spruce that is only present in small amounts and, consequently, the sites for sampling of leaves were not the same as the sites for sampling of needles. So the local monitoring network consisted of twelve sampling sites, six on each river side – three for leaves and three for needles. The sampling was performed keeping with the Standard *STN 48 1001 – Sampling of assimilatory organs in assessment of forest health state*. According to this standard, we have chosen a plot where the influence of emissions is evident and the material was sampled from the stands facing the source of pollutants. As the blast furnace of the metallurgical plant is the dominant pollutant source, however, not single (transport), we also had to fulfil the point recommending choosing universally exposed localities (summits, ridges and basins) in the case when the dominant pollution source is in question. To comply with these recommendations, we took by two samples of beech leaves (one in the midst of vegetation period, one at the end) and two samples of needles (one at the beginning and one at the end of out-of-growing season). For comparison were also simultaneously taken samples in a remote, relatively undisturbed locality by the village Lom nad Rimavicou. In each sampling site we sampled assimilatory organs from four or five trees without symptoms of attack by fungi or insects. The distance between the trees was 15 m.

The sampled assimilatory organs (leaves and two-year needles) were dried without preliminary washing. The concentrations of zinc, cadmium, lead and copper in the dry mass were determined using the method of flow stripping chronopotentiometry. The samples were pulverised (ground in a planetary pulveriser) and precisely weighed amounts were subjected to microwave mineralization in nitric acid. The liquid component was evaporated under infra-red radiation and the reaction medium was transformed to chlorides by dissolution of the remnant in the hydrochloric acid. In such treated samples we determined the contents of heavy metals, with an EcaFlow (Istran, Slovakia) using the principle of galvanostatic stripping chronopotentiometry with galvanostatic accumulation of electro-chemical deposit and its subsequent anodic stripping by constant current of the opposite polarity (Beinrohr et al. 1999).

Results and discussion

The statistical characteristics of data sets collected in the territory of Podbrezová are listed in Table 1, the corresponding values from the relatively undisturbed territory of the Protected Landscape Area (PLA) Poľana near the village Lom nad Rimavicou are summarised in Table 2.

The result of the accomplished purpose-oriented monitoring is a complex set of data that can be explored from several points of view. The measured concentrations of selected heavy metals are in statistical processing recognised as data describing the load on a forest ecosystem, with a specified area, by airborn pollutants. We suppose that the load on the examined plot is uniform. However, if we suppose to discover certain temporal or spatial dependences (corroborating the over discussed hypotheses), we must handle the measured data as discrete values.

We have decided for non-parametrical statistical methods, because there was not sufficient data amount for parametric processing. The results of Shapiro-Wilkov test were not unambiguous for all sampling sets for the individual metals. A low probability of Normal distribution also followed from the modus absence. There were used wide-accepted methods of descriptive statistics, supplemented by values of arithmetical mean and median.

We have primarily focussed on comparison of our data with the corresponding data just published in the literature. In the case of zinc, only two from all the measured values exceed the critical limit as given in (Ďurža, Kuhn 2002), which means 100 mg.kg^{-1} (critical interval 100–400). The other values could be accepted as normal. However, a better criterion has been given according to the values collected by Maňkovská (Maňkovská 1997; Maňkovská 1996), listed in Table 3. These values reflect the actual occurrence of heavy metals in Slovak forests and analyses of the material from the chosen control territory in the PLA Poľana.

With one single exception, zinc concentrations in all needle and leaf samples were higher than is the average value reported for the Slovak Republic (38 mg.kg^{-1}), higher was also median value of Zn in needles, nine samples had higher concentration values than is the average value in the NAPANT (45.7 mg.kg^{-1}).

The median value of cadmium concentration in the examined needles and six values of Cd concentration in the individual samples exceeded average concentration in Slovak forests. Seven samples had this value higher than is the average value in the NAPANT. All samples of beech leaves had the values of cadmium concentration lower than the reference value (0.17 mg.kg^{-1}).

From all the measured concentrations of lead only one in needles was lower than the reference values. Also the median values were higher.

All copper concentrations in the beech leaves were lower than the average value for Slovakia. In the sampled needles were found concentrations higher than the Slovak average (average in the NAPANT) only in two cases.

Table 1. Descriptive statistics of measured heavy metals contents in sample dry weight / mg.kg^{-1}

	Norway spruce – needles				European beech – leaves			
	Zn	Cd	Pb	Cu	Zn	Cd	Pb	Cu
Size	11	11	10	12	11	11	12	12
Mean	65.761	0.188	2.2187	2.080	54.9717	0.0817	4.095	5.1183
Median	55.977	0.165	1.9785	1.6425	55.818	0.087	3.6625	5.152
Mean deviation	25.452	0.125	0.7739	1.040	11.492	0.0287	1.3117	1.0838
Interval of variation	77.101	0.700	2.573	2.940	42.866	0.006	4.376	2.983
Upper confidence limit	82.861	0.272	2.810	2.741	62.692	0.101	4.929	5.807
Lower confidence limit	48.663	0.104	1.627	1.419	47.251	0.062	3.262	4.430
Relative width of confidence interval	0.520	0.892	0.533	0.635	0.281	0.472	0.407	0.269
Minimum	36.216	0.041	1.171	1.265	34.137	0.039	2.421	3.608
Maximum	113.317	0.483	3.744	4.205	77.003	0.122	6.797	6.591

Table 2. Measured contents of selected heavy metals in spruce and beech assimilatory organs sampled in the PLA Poľana near Lom nad Rimavicou / mg.kg^{-1}

Sample	Zn	Cd	Pb	Cu
Beech – Sept.	55.373	0.041	2.024	4.724
Spruce – Sept.	99.609	0.152	1.166	1.823
Spruce – Jan.	18.747	0.157	1.237	2.013

Table 3. Values of endogenous concentrations of selected heavy metals obtained in national monitoring / mg.kg^{-1} (median)

	SR		NAPANT
	spruce	beech	spruce
Zn	38	33	45.7
Cd	0.15	0.17	0.13
Pb	1.2	2.0	1.57
Cu	3.8	8.8	3.63

The result of just performed analysis is unambiguous – the studied locality is loaded with heavy metals more than is the average load on forests in Slovakia. Most of the measured values can be considered normal, as compared with published threshold concentrations (ĎURŽA, KUHN 2002) that we, however, use for orientation only, because the presence of heavy metals (primarily lead and cadmium) in plants is not a natural phenomenon. Even trace amounts of these chemical elements have disturbing effects on biochemical processes in plant cells which is no profit for the plant, but a chronic load, in spite of the fact that no visible symptoms (defoliation) need to be present. Consequently, the presence of measurable concentrations of heavy metals alone can indicate considerable or lower contamination of the plants with these chemical elements.

The extreme, far outlying values were excluded (Dixon's test) from further statistical processing, however, not excluded from our further considerations. Interesting is namely the fact that all these values were recorded in sites nearest to the supposed principal pollutant source. In the same manner, the maximum values obtained by the statistical processing were practically in all the cases found in samples labelled by number 1 what means the first sampling site in terms of the distance from the pollution source. At the same time, these sites are situated on forest border – ecotone zone of forest ecosystem, commonly recognised as the most sensitive, the most open and exposed to highest external stress. On the just opposite, the majority of samples with minimum heavy metal concentrations and concentrations below the Slovak average or the average in the NAPANT were taken at the largest distance from the pollution source. So the hypothesis about decreasing forest contamination with increasing distance from the pollution source cannot be rejected unambiguously. This dependence seems to be valid and confirmed. Therefore our values could point out a very strong dependence of contamination on the distance from the pollution source.

Visual representation of the measured values in graphs provides a suitable background for comparison of contamination of beech and spruce with the individual heavy metals. In the case of zinc and cadmium were higher concentrations measured in Norway spruce, in the case of lead and copper, in European beech. The hypothesis about higher contamination of spruce with

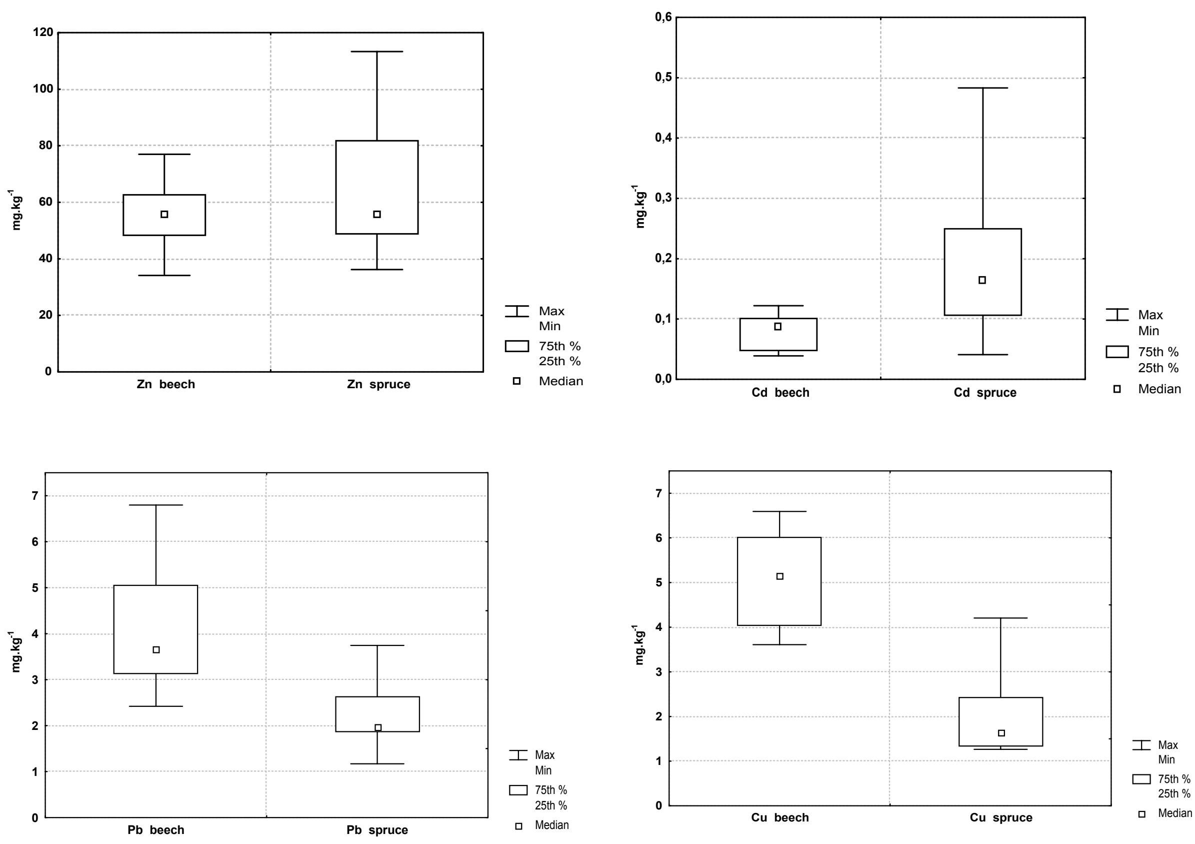

Fig. 1. Amounts of chemical elements in mg.kg^{-1} of dry weight of assimilatory organs of Norway spruce and European beech visualised with STATISTICA software

all heavy metals has not been corroborated, however, it does not mean that our results can be generalised as rejecting the fact that the situation in conifers is worse compared to the broadleaved species. The concentrations of heavy metals in assimilatory organs of broadleaved woody plants is dependent on deposition in the given vegetation period. This fact is reflected in larger fluctuations between years in deciduous trees. On the other hand, conifers are not only provided with nutrients by assimilatory activities of two-year needles (analysed in our research) but, naturally, also older needles and the needles in the process of creation. We have not information about the concentrations of the discussed heavy metals in the soil substrate in the studied territory, so we cannot assess its influence and rate on contamination of woody plants with the heavy metals of interest.

Comparisons between the values measured in samples took in different time did not reveal an unambiguous increase influenced by accumulation in the period between the samplings. Higher probability of such an accumulation was in the case of beech because the needle sampling was performed out of the growing seasons. The differences between the samples took from one sampling site in different months were positive in only about one half of the pairs SAMPLE_Jan.–SAMPLE_Sept. in the case of spruce and SAMPLE_Sept. – SAMPLE_Aug. in the case of beech. This could possibly be caused by climate conditions, primarily long drought. The lower values found in January spruce needles could follow from natural washing with thawing snow, either directly on the plant or during drying the sampled needles when the frozen ice layer was melting. The samples were processed as native, without washing.

Further we focussed on the difference between the contamination levels on the left and right side of the valley. We issued from the differences between the values found in the corresponding pairs, e. g. NEEDLE_A1jan.–NEEDLE_B1jan. The results showed that heavy metals concentrations in spruce needles were in general higher on side B, i.e. on the right side according the flow direction of the River Hron. On the other hand, beech leaves were more contaminated on side A, the right bank of the river. This difference can partially be caused by the fact that the spruce abundance in the left part of the valley is lower and the distances between the sampling sites and the pollution source are larger than in the right part of the valley. In addition, the pair differences were in most cases lower than is the corresponding allowance for the confidence interval for the given measured values. Consequently, because the local wind conditions, the difference between loads on the left and right sides of the valley can be supposed as actual, however, not conspicuous.

Correlation analysis revealed a significant correlation between zinc and cadmium in both spruce and beech, between typical heavy metals cadmium and lead in spruce and between Zn-Cu and Cd-Cu in beech. In these cases we can conclude about moderate ($0.3 \leq |r_{x,y}| < 0.5$) or significant degree ($0.5 \leq |r_{x,y}| < 0.7$) of bonding which can be explained by similar mechanisms of the uptake (primarily in copper and zinc as essential biogenic microelements) or by similar chemical nature.

Consistent with our expectations are the results obtained in comparison between the values measured in the surroundings of Podbrezová and the values obtained analysing assimilatory organs of woody plants growing in a relatively unpolluted area, in our case a forest in the cadastre of the village Lom nad Rimavicou, belonging to the PLA Poľana. From this comparison it follows that this territory is less loaded with pollutants than our studied locality. The most remarkable differences were found in the case of cadmium and lead, for which all the values in needles and leaves were higher than the corresponding values found in Poľana. Less conspicuous were differences in copper and the lowest in zinc – with the values of arithmetical mean and median similar to the zinc concentrations found in Poľana, however, this is less significant than the case of cadmium, lead and other typical toxic heavy metals.

We need to mention here some other factors with possible effects on the analysis results. The point is at, in addition to external influences, possible mutual interactions between certain chemical elements in conditions of the given analysing method – as it is reported mainly for Zn-Cu, in the case when the proportion Zn:Cu is greater than 1:4. This phenomenon can be explained by creation of intermetallic compounds of Cu-Zn in the process of the chemical analysis (Beinrohr et al. 1999). As important influence is possible only under higher copper concentrations, this endogenous factor can be excluded from our considerations.

Conclusions

In this paper we have discussed the issue of contamination of forest ecosystems in the surroundings of the metallurgical plant Železiarne Podbrezová, holding, with selected heavy metals – zinc, cadmium, lead and copper. We have accomplished a local purpose-oriented monitoring of the forest in the touched area, according to the standards specifying forest monitoring in Slovakia. Both sides of the river valley were monitored. On each side, there were chosen by three sampling sites for sampling of Norway spruce needles and three sites for sampling of European beech leaves – according to the methods precised by the given standard. The heavy metals contents in the plant assimilatory organs were determined using the method of galvanostatic dissolution chronopotentiometry with an instrument EcaFlow. In the sampled assimilatory organs were found the following average (median) concentrations of individual heavy metals in $mg.kg^{-1}$ of dry weight:

In beech leaves: Zn 54.971 [55.818]; Cd 0.0817 [0.087]; Pb 4.095 [3.662]; Cu 5.118 [5.152];

In spruce needles Zn 65.761 [55.977]; Cd 0.188 [0.165]; Pb 2.2187 [1.9785]; Cu 2.08 [1.642].

As there do not exist legislation limits for heavy metal contents in plant assimilatory organs, the main evaluation tool for the degree of forest contamination in the discussed area was the comparison of the measured values with the published values of the whole-territory monitoring in Slovak forests and with the values measured in samples taken from a relatively unpolluted territory in the PLA Poľana. The studied area was revealed to be loaded more than is the average load on the Slovak territory as found in the national monitoring (Maňkovská 1997, Maňkovská 1996) and also higher than the load on the control, relatively unpolluted area. The results of this local purpose-oriented monitoring reflect the forest health state; reveal one of primary causes of the actual decline that can secondarily be reflected on increased defoliation and other visible symptoms. They also reflect the air quality in the studied locality, however, the precision of impact of airborn pollutants on the forest ecosystem contamination in the studied locality also requires to know the influence of other constituents of the environment, primarily the soil substrate. It follows that the touched area needs to be devoted with a closer care in terms of prevention, monitoring and control of risks entailed by the presence of heavy metals.

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Ťažké kovy ako kontaminanty ekosystému lesa v okolí hutníckeho závodu Železiarne Podbrezová, a. s.

Súhrn

Práca rieši problematiku kontaminácie ekosystému lesa v okolí hutníckeho závodu ťažkými kovmi.

Bol vykonaný lokálny účelový monitoring doliny v obci Podbrezová. Odber vzoriek asimilačných orgánov smreka obyčajného (*Picea abies* L. Karst.) a buka lesného (*Fagus sylvatica* L.) bol vykonaný dvakrát na oboch stranách doliny celkom na 12 odberových miestach. Zároveň bola odobratá vzorka z porovnávacej relatívne čistej oblasti v ChKO Poľana neďaleko obce Lom nad Rimavicou.

Metódou galvanostatickej rozpúšťacej chronopotenciometrie boli stanovené koncentrácie zinku, kadmia, olova a medi v dvojročnom ihličí smreka a listoch buka.

Namerané hodnoty boli porovnané s publikovanými výsledkami celoslovenského monitoringu lesa a s hodnotami nameranými vo vzorkách z realtívne čistej oblasti v CHKO Poľana. Z výsledkov porovnania vyplýva, že horšia situácia, než je celoslovenský priemer je v prípade smreka u zinku, kadmia a olova. V listoch buka boli namerané vyššie hodnoty u zinku a olova, u kadmia boli namerané hodnoty nižšie, v prípade oboch drevín boli koncentrácie medi nižšie ako je celoslovenský priemer.

Najväčšie rozdiely pri porovnaní nameraných hodnôt s výsledkami analýz vzoriek z Poľany sa prejavili u typických ťažkých kovov kadmia a olova, koncentrácie zinku a medi sú porovnateľné. Medzi obidvomi stranami doliny nie je výrazný rozdiel v úrovni kontaminácie ťažkými kovmi. Zmena úrovne kontaminácie vplyvom lokálneho transportu bola potvrdená, avšak nie je výrazná. U smreka obyčajného nachádzame výrazne väčšiu akumuláciu u zinku a kadmia, naopak v prípade olova a medi výrazne vyššie koncentrácie namerané v listoch buka lesného. Nedá sa teda jednoznačne povedať, že situácia u smreka je horšia v prípade všetkých kovov. To však nie je v rozpore so všeobecným poznatkom o horšom zdravotnom stave ihličnanov.

Z výsledkov výskumu vyplýva, že sledovaná oblasť je kontaminovaná, a teda aj zaťažovaná viac ako porovnávacia oblasť v ChKO Poľana a zároveň viac, ako je priemerné celoslovenské zaťaženie územia.

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Site characteristics and ecological stability of forest ecosystems on permanent monitoring plots in the Protected Landscape Area – Biosphere Reserve Poľana

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Abstract

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The paper deals with habitat characteristic and ecological stability of forest ecosystems in the Protected Landscape Area Poľana in working-plan area Slovenská Ľupča and Osrblie. Ecological stability means that ecosystem is able to return to its dynamic equilibrium or to normal evolution state by means of its own internal mechanisms. There are two components of ecosystem stability: ecosystem resistance and ecosystem resilience. To determine ecological stability there is used the method presented in this thesis. The quantification and classification of the forest ecostability is very important for planning of the ecosystem management, especially in protected areas. Bad condition of forest ecosystems in Poľana requires effective measures, ways and methods to prevent the ecological destruction and preserve ecological balance.

Key words

forest ecosystem, ecological stability, ecosystem management

Introduction

Inappropriate measures and methods applied in forest management and in wood harvesting, together with changes in natural conditions and with disturbance of ecological equilibrium because of human influence, have negative impacts on forest ecosystems and cause their devastation and degradation. That is why the present state of things requires enforcing an intensive care over the ecosystems, applying effective management measures, ways and methods that can their protection and ecological balance. Equally important is to restore the disturbed ecological stability through restoration, regulation and revitalization.

Since the last years of the 20th century, the ecological stability has become one of core problems in ecology. Ecological stability of forests is the capacity of forest ecosystems to maintain, under influence of external factors, its own dynamic homeostasis by means of internal auto-controlling mechanisms (resistance) and to return, after a disturbance, to the original dynamic equilibrium (elasticity – resilience) or to resume the original normal developmental trend. The faster is the given ecosystem capable to return and the lesser are deviations from the normal state; the higher is its stability (Vološčuk 2000b).

The original natural ecosystems are being replaced by new, artificially created ecosystems with a low auto-controlling capacity. That means they are ecologically unstable.

The preservation of these ecosystems requires an artificial control by man. The necessary condition for success of such a control is a high amount of energy and human labour. However, the idea about restoration of the "original" forests is not realistic, because of immense changes in climate, site and intra-system conditions and relations. Different from this static understanding, it is possible to mean under the ecological term “forest close to nature” the forests best corresponding to the current site conditions. The nature would need very long periods to create these ecosystems. The man can, in process of secondary succession, in relation to the rapid changes, to help the nature to reduce (mainly form the viewpoint of time relations) the consequences of his negative activities (Križová et al. 1992).

The understanding of ecosystems as the unity between the abiotic and living nature requires, apart from others, their unambiguous spatial identification according to the main criterion – ecological stability. The synthetic criterion of the ecological homogeneity of an ecosystem is in structural properties of the vegetation. The only correct reference basis, in terms of natural sciences, for ecological evaluation of changes in the land performed by human generations are the types of natural vegetation (both potential and actual) connected with certain types of ecotops (Vološčuk 2000a).

In the Protected Landscape Area – Biosphere Reserve Poľana (PLA – BR), was designed a network of permanent monitoring plots (PMP) 2 x 2 km, linked up to the network 4 x 4 km. This network is intended for long term and full-area monitoring of forests providing us with information about the state and development of forest ecosystems followed by proposal of practical measures in the management (Šmelko in Midriak et al. 1997).

Material and methods

The research into the ecological stability of forest ecosystems run in the territory of the Protected Landscape Area – Biosphere Reserve Poľana (CHKO – BR Poľana) on 8 permanent monitoring plots (PMP), belonging to the Forest Management Units Osrblie (PMP A5, PMP B5, PMP A6, PMP B6) and Slovenská Ľupča (PMP B2, PMP B4, PMP C3, PMP C4). These monitoring plots were established in July–October 2001.

All the plots have the same area of 0.1 ha. The woody plants with diameter more than 6 cm were numbered and subjected to biometric measurements and to the assessment of physiological characteristics: species; d. b. h. diameter ($d_{1.3}$) – accuracy 2 cm; height (h) – accuracy 1 m; crown height – accuracy 0.5 m; health state or damage type and degree; defoliation (SAO) and depigmentation – only visually, without special methods included in the ICP-Forests program. The values obtained by dendrometrical measurements were evaluated statistically. We calculated weighted arithmetical mean, mean deviation and the coefficient of variation (Šmelko 1995).

The state of the natural regeneration was assessed on ten randomly selected non-fixed mini-plots with dimensions 1 x 1 m. The trees on these plots were recorded according to two diameter categories: a) less than 30 cm; b) 30–130 cm. We also recorded the number, length and diameter of lying trees (windfalls and dead stems). The stands were characterised and the phytocoenoses were described according to Križová (1991) et al.

The data were obtained in the field research running in 2001–2002. They were used for the evaluation of the ecological stability of PMP following the methods by Vološčuk (2000a). It was necessary to obtain quantitative values of the following indices:

1. deviation of the current wood species composition from the original (potential) – approximation (a),
2. degree of static stability expressed through crown index (ci) and slenderness coefficient (sc),
3. sanitary quotient (sq),
4. deviation of the current vertical structure from the three-layer structure model, determined using the classification scale by Zlatník – coefficient of layering (cl),
5. deviation of the current natural regeneration from the potential natural regeneration according the vegetation tiers and ecological orders.

To obtain the approximation, it is necessary to know both the current stand composition and original stand composition on the relevant monitoring plot. The species composition of the stands was given in per-cents converted per volume. The original (potential) stand composition was deduced from the valid forest management plans (FMP) documenting the presences of individual forest types in the individual compartments. The validity period for the FMP for the FMU Slovenská Ľupča: is 2000–2009, for the FMU Osrblie: 1995–2004. The layout of stand composition for each forest type in per-cents was used as in Vološčuk (2000b). Because one forest compartment in general contains several forest types, at first it was necessary to calculate the areas in the compartment covered by the separated forest types. Then, the original stand composition was converted according to the proportions covered with the corresponding types. The sums of areas belonging to the separate target species in the individual forest types in a compartment served as the base for calculating the total percentual composition of the original woody plants over the whole compartment area.

The per-cent of approximation “a”, that means the degree of suitability of the current stand composition in relation to the original species composition was expressed through the following relation as in Papánek (Vološčuk 2000b):

$$a = 100 \cdot \left(1 - \frac{SD}{200}\right)$$

where SD is sum of deviations.

Based on the per-cent of approximation, the forest stands were classified to the following degrees of ecological stability:

1. high stable over 91%
2. very stable 71–90%
3. medium stable 51–70%
4. low stable 31–50%
5. unstable less than 30%

Static stability of woody plants was expressed through the crown index (ci) and slenderness coefficient (sc). The sanitary quotient is the ratio of ill, pest-attacked, dry and mechanically damaged trees to the total number of trees on the plot. Coefficient of layering expressed the deviation of the current stand structure from the three-layer model of the stand that is ecologically the most stable on the relevant PMP. The final value of the ecological stability was obtained as the sum of indices of the individual relative scales of ecological stability according to approximation (a), crown index (ci), slenderness coefficient (sc), sanitary quotient (sq) and coefficient of layering (cl). Because the ecological stability of forest ecosystems is primarily determined by the original stand composition and the health state, the approximation index was provided with a weight 5 and the sanitary index with the weight 3. The final ecological stability was obtained according to the formula (Vološčuk 2000b):

$$IES = \frac{\sum n_i \cdot x_i}{N}$$

where:

IES – final index of ecological stability,

n_i – weight of the i-th index of ecological stability (5a, 3 sq, 1ci, 1sc, 1cl),

x_i – value of the partial index of ecological stability (1, 2, 3, 4, 5),

N – sum of the weights of partial indices of ecological stability (N = 11) (Table 1).

Table 1. Degrees of ecological stabilty

Final index	Ecological stability
to 1.5	high
1.6–2.5	good
2.6–3.5	medium
3.6–4.5	low
above 4.6	labile ecosystem

Assessment of restoration capacity of a forest ecosystem is an ancillary index for the assessment of autoregulation capacity of the ecosystem in its climax phase. The field data found on the PMP about the natural regeneration in each woody plant were converted to the number per one m^2 and the number per one ha, as to obtain the data comparable with the published data about potential natural regeneration of the principal woody species according to the individual forest vegetation tiers, ecological orders and groups (Vladovič et al. 1998).

The last cited work contains data about ecological stability of forest stands on two permanent monitoring plots: B5 and C3. PMP B5 is situated in the locality Chata pod Veprom, Stand No. 349, altitude 1080 m a. s. l, exposure NW, inclination 15°, stocking 0.6. PMP C3 is situated in Ponická Bukovina, Compartment No. 5043, altitude 1140 m a. s. l., exposure NNW, inclination 5°, stocking 0.5.

We also ascertained area and percentage composition of forest types in the FMU Slovenská Ľupča and FMU Osrblie, according to the formula:

$$P_{FT} = \sum_{i=1}^{n} p_{FTi}$$

where:

P_{FT} – area covered with the forest type (FT) in all the stands,

p_{FTi} – area FT in the i-th stand where the type FT occurs.

The percentage is obtained in the following way:

$$\%p_{FT} = \frac{P_{FT}}{p} \cdot 100$$

where:

P_{FT} – area covered with the forest type (FT) in all the stands in the FMU,

$p_{FT}\%$ – percentage of the given FT,

P – total area of all the FT in the FMU.

Calculating approximation values for both FMU Slovenská Ľupča and Osrblie, it was necessary to determine the mean percentage of approximation for each forest type occurring in the FMU:

$$\bar{a}FT = \frac{\sum_{i-1}^{n} a_i \cdot p_{FTi}}{P_{FT}}$$

where:

a_{FT} – mean percentage of approximation for the FT,

a_i – percentage of approximation of the i-th compartment in that the FT occurs,

p_{Fti} – area FT in the i-th stand where the type FT occurs,

P_{FT} – total area of the FT in the whole FMU.

The final percentage of originality for the whole FMU is determined as:

$$A = \frac{\sum_{i-1}^{n} a_i \cdot p_i}{\sum_{i-1}^{n} p_i}$$

where:
a_i – approximation of the i-th stand,
p_i – area of the i-th stand.

Results and discussion

The assessment of state of forest ecosystems on permanent monitoring plots resulted in finding that the highest ecological stability had the stand on PMP B5 in FMU Osrblie. The stand was classified as Forest Type No. 6401 – Fageto-Aceretum superiora with the phytocoenosis type *Galium odoratum – Mercurialis perennis – Petasites albus*. The present stand composition is: *Fagus sylvatica* (69%), *Acer pseudoplatanus* (20%), *Picea abies* (6%), *Abies alba* (5%). The characteristics measured on PMP B5 are in Table 2. The final index of ecological stability is 2.36, which is a very high stability, primarily reflecting the appropriate stand composition (a = 89%). The highest presence was found in beech trees (69%). From the allochtonous species occurs only spruce (6%), on the other hand, elm is lacking (5% in the original composition). There is practically no difference between the current and the potential percentage in beech, maple and fir. As for the static stability, the tree crowns should also have lower set branches (ci = 4), the slenderness coefficient value is 3, which is an average value (Table 3). The vertical structure of the stand is also average (cl = 3). The health state is relatively good according to sanitary quotient. Sound regeneration is in beech (11 000 ts per ha) and sycamore maple (21 000 ts per ha), however, up to 30 cm only. There is no remarkable regeneration over 30 cm. Under 30 cm is also found regenerating rowan. There is full absence of regenerating fir trees.

A moderate restoration measure would be suitable – to reach gradually the appropriate diversity in the height and age structure of the stand. In the same manner, it is also possible to force regeneration in fir and to reach more intensive regeneration in beech by improving the conditions in the crown layer for natural seeding.

Ištoňa (2000), studying the natural regeneration in forest stands on research plots in the PLA Poľana, found that the regeneration of rare broadleaved species in the understorey in the stand type beech forest was in general good. Consistent protection against the game and stand opening can ensure whole-area natural regeneration in these stands. In such a way, the immense value of the original genetic material will be used with profit and, at the same time, the overall diversity of the natural ecosystems will be preserved.

On the other hand, the lowest ecological stability was found on PMP C3, belonging to the FMU Slovenská Ľupča. The forest type is No. 6304 – Abieto-Fagetum superiora (nitrophilous), phytocoenosis: *Filices – Galium odoratum – Senecio fuchsii – Petasites albus*. In the present stand composition dominates *Picea abies* (99%), admixed is *Fagus sylvatica* (1%) (Table 4). The final index of ecological stability was 4.64, so the system was classified as unstable. The low ecological stability is primarily caused by improper wood species composition. According to the original composition of the forest type at the site, the spruce should not exceed 10%, what is in sharp contradiction to the present state of 99%. There are lacking precious broadleaved species and beech, which presence should be 40%, reaches 1% only. The slenderness coefficient and crown index (sc = 2, ci = 4), indicate poor vertical structure of the stand (Table 5). The health state of the stand is bad (sq = 5). The mechanical damage to trees is a consequence of cutting followed by a rot attack. The natural regeneration lower than 30 cm consists mainly of spruce (48 000 ts per ha), which reflects the far highest percentage of this woody plant on the plot. We can also observe the regeneration in sycamore maple and in fir. The last two species are not present in the current stand composition; however, they are present in its potential composition. The seeds of these species have probably been transported by wind from the surrounding stands. Beech trees are completely absent in the regeneration. The regeneration higher than 30 cm is scarce, probably because game browsing.

A restoration measure is necessary to remove the great spruce proportion. It is equally important to support the natural regeneration in beech and precious broadleaved species.

The static or better the whole ecological stability of the BR Poľana is a consequence of three crucial presumptions. The first factor is a high stock of red deer and subsequent damage to forest stands. The second is insufficient ecological stability connected with height differentiation of young stands (younger than 50 years) which is further reflected on wind and, to some extent, also snow damage. The third factor is rather homogeneous species composition with dominant spruce – explicitly predicting extensive damage. It is evident that it is necessary to increase the biodiversity, mainly in the woody plants composition, by increasing the proportions of beech, fir, maple, elm and ash (Saniga 1997*)*.

Further, in both forest management units, for each stand belonging to the territory of the PLA-BR Poľana, we determined the deviations "SD" of the current stand composition from the original and calculated aproximation percentage "a", that means the degree of correspondence of the current species composition to the potential species composition according to the formula discussed in "Methods".

Table 2. Diameter classes, standardised height, production indices and their statistical characteristics on PMP B5

Species	$d_{1.3}$	N	h (m)	V_j (m^3)	g (m^2)	V (m^3)	G (m^2)	N/ha	V/ha (m^3)	G/ha (m^2)
beech	10	3	9	0.03	0.00785	0.09	0.02355	30	0.9	0.2355
	12	3	10	0.05	0.01131	0.15	0.03393	30	1.5	0.3393
	14	4	12	0.08	0.01539	0.32	0.06156	40	3.2	0.6156
	16	2	13	0.12	0.02011	0.024	0.04022	20	2.4	0.4022
	18	1	15	0.17	0.02545	0.17	0.02545	10	1.7	0.2545
	20	3	16	0.23	0.03142	0.69	0.09426	30	6.9	0.9426
	22	1	17	0.29	0.03801	0.29	0.03801	10	2.9	0.3801
	24	3	19	0.39	0.04524	1.17	0.13572	30	11.7	1.3572
	26	2	20	0.48	0.05309	0.96	0.10618	20	9.6	1.0618
	30	2	21	0.68	0.07069	1.36	0.14138	20	13.6	1.4138
	32	4	22	0.81	0.08042	3.24	0.32168	40	32.4	3.2168
	36	3	23	1.09	0.10179	3.27	0.30537	30	32.7	3.0537
	40	2	24	1.41	0.12566	2.82	0.25132	20	28.2	2.5132
	42	2	24	1.57	0.13854	3.14	0.27708	20	31.4	2.7708
	48	1	25	2.17	0.18096	2.17	0.18096	10	21.7	1.8096
	50	2	25	2.36	0.19365	4.72	0.3927	20	47.2	3.927
	60	1	26	3.63	0.28274	3.63	0.28274	10	36.3	2.8274
	62	1	26	3.89	0.30191	3.89	0.30191	10	38.9	3.0191
	64	1	26	4.16	0.32170	4.16	0.32170	10	41.6	3.2170
Sum:		41				36.5	3.33572	410	365	33.3572
x:	28.59		18.44	0.890	0.0814					
sx:	14.79		5.62	1.062	0.0810					
sx%:	51.74		30.47	119.4	99.58					
syc. map	64	1	29	4.63	0.3217	4.63	0.32170	10	46.3	3.2170
	84	1	23	6.36	0.55418	6.36	0.55418	10	63.6	5.5418
Sum:		2				10.99	0.87588	20	10.99	8.7588
spruce	58	1	2	3.17	0.26421	3.17	0.26421	10	31.7	2.6421
fir	14	1	8	0.05	0.01539	0.05	0.01539	10	0.5	0.1539
	50	1	30	2.44	0.19635	2.44	0.19635	10	24.4	1.9635
Sum:		3				2.49	0.21174	20	24.9	2.1174
Total		46				53.15	4.68755	460	531.5	46.8755

$d_{1.3}$ – diameter class
N – tree number
h – standardised height
V_1 – volume of the i-th diam. class
g – basal area of the i-th diam. class
V – total volume
G – total basal area
x – weighed arithmetical mean
sx – mean deviation
sx% – variation coefficient

Table 3. Values of coefficients of relative scales of ecological stability on PMP B5

PMP	Coefficient of approximation		Crown index		Slenderness coefficient		Sanitary coefficient		Coefficient of layering
	value %	index	value %	index	value %	index	value %	index	index
B5	89	2	47	4	70	3	26	2	3

Table 4. Diameter classes, standardised height, production indices and their statistical characteristics on PMP C3

Species	**$d_{1.3}$**	**N**	**h (m)**	**V_j (m^3)**	**g (m^2)**	**V (m^3)**	**G (m^2)**	**N/ha**	**V/ha (m^3)**	**G/ha (m^2)**
spruce	36	2	28	1.15	0.10179	2.30	0.20358	20	23	2.0358
	40	1	30	1.50	0.12566	1.50	0.12566	10	15	1.2566
	42	1	30	1.64	0.13854	1.64	0.13854	10	16.4	1.3854
	44	2	31	1.85	0.15205	3.70	0.30410	20	37	3.0410
	46	1	32	2.08	0.16619	2.08	016619	10	20.8	1.6619
	48	2	32	2.25	0.18096	4.50	0.36192	20	45	3.6192
	50	3	33	2.51	0.19635	7.53	0.58905	30	75.3	5.8905
	52	1	33	2.70	0.21237	2.70	0.21237	10	27	2.1237
	56	3	34	3.19	0.24630	9.57	0.73890	30	95.7	7.3890
	58	2	35	3.52	0.26421	7.04	0.52842	20	70.4	5.2842
	60	3	35	3.74	0.28274	11.22	0.84822	30	112.2	8.4822
	62	4	35	3.97	0.30191	15.88	1.20764	40	158.8	12.0764
	64	1	36	4.34	0.32170	4.34	0.32170	10	43.4	3.2170
	70	1	37	5.28	0.38484	5.28	0.38484	10	52.8	3.8484
Sum:		27				79.28	6.13113	270	792.8	61.3113
x:	53.04		33.19	2.936	0.2271					
sx:	8.85		2.29	1.042	0.0723					
sx%:	16.69		6.91	35.48	31.85					
beech	10	1	5	0.02	0.00785	0.02	0.00785	10	0.2	0.0785
	22	1	12	0.18	0.03801	0.18	0.03801	10	1.8	0.3801
	28	1	11	0.31	0.06158	0.31	0.06158	10	3.1	0.6158
Sum:		3				0.51	0.10744	30	5.1	1.0744
x:	20.00	9.33	0.17	0.0358						
sx:	7.48	3.09	0.12	0.0220						
sx%:	37.42	33.12	69.77	61.40						
rowan	12	1	6.00	0.01	0.01131	0.01	0.01131	10	0.1	0.1131
Total		31				79.80	6.24988	310	798	62.4988

$d_{1.3}$ – diameter class
N – tree number
h – standardised height
V_1 – volume of the i-th diam. class
g – basal area of the i-th diam. class
V – total volume
G – total basal area
x – weighed arithmetical mean
sx – mean deviation
sx% – variation coefficient

Table 5. Values coefficients of relative scales of ecological stability on PMP C3

TMP	Coefficient of approximation		Crown index		Slenderness coefficient		Sanitary coefficient		Coefficient of layering
	value %	index	value %	index	value %	index	value %	index	index
C3	11	5	45.2	4	64.0	2	67.7	5	5

According to the calculated values of coefficient of approximation, in the FMU Slovenská Ľupča, the majority – 80 stands (540.55 ha, representing 45.52% of the total area of the FMU) are unstable. The second position is occupied by low stable stands – 73 (422.04 ha, 35.54%). Medium stable are 25 stands (158.59 ha, 13.35%) and very stable 8 stands (66.44 ha, 5.59%). Not even one stand could be classified as high stable (Table 6). The final percentage of originality, that means the weighed of approximation coefficient of all the examined stands in the FMU Slovenská Ľupča belonging to the PLA – BR Poľana is 36.13%. It follows that from the viewpoint of relative scale of ecological stability according to the approximation, this forest management unit can be classified as low stable.

Table 6. Stands on FMU Slovenská Ľupča according approximation index

Approximation index	Number stands	Area (ha)	Proportion (%)
1	0	0.00	0.00
2	8	66.44	5.59
3	25	158.59	13.35
4	73	422.04	35.54
5	80	540.55	45.52
Σ	186	1187.62	100.00

In the FMU Osrblie, the majority, 77 stands (433.94 ha, 40.77% of the FMU total area) are low stable. Medium stable are 75 stands (394.78 ha, 37.09%). Unstable are 35 stands (166.00 ha, 15.6%), 10 stands (67.45 ha, 6.34%) are very stable. High stable is one stand (2.11 ha, 0.2%) (Table 7). The final percentage of approximation with the value of 47.16% was obtained in the same way as in the case of the FMU Slovenská Ľupča. The result show that also the forest management unit Osrblie can be classified as low stable.

The obtained results allow us to draw conclusions about causes of lowering the ecological stability in the two given FMU. In the examined stands frequently dominate species that should be present in only a low percentage or even should absent (the species not native for the given stand). One of principal causes can be the inappropriate management applied in these ecosystems in the past. For example: artificially planted woody species with high production value. In this context, we would like to underline the importance of natural regeneration of forest stands.

Representativeness of the PMP in the FMUs Slovenská Ľupča and Osrblie was evaluated based on two criteria:

a) approximation of the current stand composition in relation to the target composition,
b) presence of forest types.

Table 7. Stands on FMU Osrblie according approximation index

Approximation index	Number stands	Area (ha)	Proportion (%)
1	1	2.11	0.20
2	10	67.45	6.34
3	75	394.78	37.09
4	77	433.94	40.77
5	35	166.00	15.60
Σ	198	1064.28	100.00

The FMU Slovenská Ľupča involves 4 permanent monitoring plots: B2, B4, C3, C4. Unstable ecosystems cover 50% of the PMP and 45.52% of the total FMU area. In the case of low stable ecosystems we obtained figures 25% and 35.54%, respectively, for medium stable ecosystems 25% and 13.35%. Very stable ecosystems are not present on PMP, from the total FMU area, they represent only 5.59%. The PMP have the mean approximation value of 30.5%. The whole FMU has the mean approximation 36.13%. Both values indicate low stable forest stands. As we can see, from this viewpoint, the representativeness of the PMP established in the FMU Slovenská Ľupča is excellent.

According to the presence of forest types, the representativeness of the PMP in this FMU is very good. Three monitoring plots (75%) involve three most frequent forest types occurring in the FMU territory: 5303 (21.03%), 5304 (17.93%) and 6304 (9.59%). On plot B2 is present forest type 314 (25%), representing 5% of the given FMU.

In the FMU Osrblie, with mean percentage of approximation 47.16% (low stable ecosystem) are also 4 PMP: A5, B5, A6, B6. Their mean approximation is 58.25% which means medium stable ecosystems. The proportion of low stable stands on PMP is 50%, medium stable 25% and very stable also 25%. In relation to the whole FMU area we obtained the following corresponding ciphers: 40.77%, 37.09%, 6.34%. Unlike the PMP, the whole unit also contains unstable ecosystems (15.6%) and ecosystems with high stability (0.20%). PMP established in the FMU represent the species composition in the whole FMU only to a certain extent.

On the plots occur forest types No. 5301, 5402, 6303 and 6401, each of them in 25%. On one plot is the second the most frequent type in the FMU – 5301 (8.09%), on the second is present the fourth most frequent type – 6303 (5.89%). The type 5402 is in the whole FMU only present in 3.17%, forest type 6401 in 0.82%. The difference between the percentage representation of forest types on the PMP and in the whole FMU is also caused by the considerable difference between the number of forest types present on the

PMP and in the whole FMU. The representativeness of then PMP in relation to the presence of separate forest types in the whole FMU is only average.

Conclusions

The results obtained in observation of the studied territory show that the examined ecosystems are low stable or unstable because an intensive human impact. It is evident that the restoration of these ecosystems to the original state, in which they are capable to fulfil their functions, is an imperative. The question remains open if it is necessary to take artificial restoration measures – always adjusted to the given ecosystem or to leave the problems to the natural auto-regeneration and autoregulation capacity of the discussed ecosystems. We mean that it is necessary to join the appropriate restoration activities on the side of man with natural regeneration capacity of the forest, for example, by providing more favourable conditions for the forest natural regeneration in the changed environment.

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Analýza ekologickej stability lesných ekosystémov trvalých monitorovacích plôch Chránenej krajinnej oblasti Biosférickej rezervácie Poľana

Súhrn

Práca sa zaoberá problematikou ekologickej stability lesných ekosystémov v Chránenej krajinnej oblasti – Biosférickej rezervácii Poľana. Výskum prebiehal v lesnom hospodárskom celku (LHC) Slovenská Ľupča a LHC Osrblie na 8 trvalých monitorovacích plochách (TMP). Posúdená bola aj reprezentatívnosť zastúpenia lesných typov na TMP, ako aj aproximácia týchto TMP z hľadiska LHC Slovenská Ľupča a LHC Osrblie. Na základe hodnotenia stavu lesných ekosystémov trvalých monitorovacích plôch možno konštatovať, že prevládajú málo stabilné a labilné lesné ekosystémy. V porastoch sa vyskytujú dreviny, ktoré by tu mali byť z hľadiska pôvodnosti zastúpené iba malým percentom, prípadne by v niektorých porastoch nemali byť zastúpené vôbec. Jednou z hlavných príčin je nesprávne hospodárenie v týchto lesných ekosystémoch, ktoré sa v minulosti uplatňovalo.

Evaluation of organic substances and dissolved oxygen concentrations in a water course in the Tribeč Mountains

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Abstract

Noskovič, J., Sozanský, P., Babošová, M., 2004: Evaluation of organic substances and dissolved oxygen concentration in a water course in the Tribeč Mountains. Folia oecol., 31 (1), p. 31–35.

In the water course Hostiansky potok in the Tribeč Mountains over the period of the years 1995–1998 were evaluated organic substances and dissolved oxygen concentrations. For determination of the organic substances concentration was used indirect method based on the oxidation of the organic substances with the potassium permanganate and it is represented as a chemical oxygen demand with potassium permanganate. Results were presented in mg $O_2.dm^{-3}$. The results show that the lowest mean values of the chemical oxygen demand (COD_{Mn}) during the research period were recorded in the winter season. That is connected with the unsuitable thermal conditions for the organic matter decomposition in the water course. The lowest COD_{Mn} value during the research period was ascertained in the first sampling site which is located in the forest. The mean dissolved oxygen concentration in the whole research period was 10.53 mg $O_2.dm^{-3}$. Seasonal dynamic regularity in the concentration of the dissolved oxygen during the research period has not been manifested. The sampling sites exercise a weak influence on their changes. According to the calculated COD_{Mn} and dissolved oxygen characteristic values (STN 75 7221), the waters in all sampling sites were included in the 1st class of the surface water quality (very clean water).

Key words

mountain, water course, dissolved oxygen, COD_{Mn}, surface water quality

Introduction

Organic substances belong to the most significant compounds of the water pollution (Hyánek et al. 1991). The origin of these compounds can be of natural or anthropogenic origin. The natural organic pollution is caused by soil and sediment leaches and by products of life activity of plant and animal organisms living in water. Organic substances of the anthropogenic origin originate from the sewage and industrial waste waters, wastes from the agricultural activity and they can be originated by water treatment (Šebíková, Noskovič 1997).

By the ability of the micro-organisms to utilise the organic substances as a source of energy and to degrade them to simpler compounds, the organic substances are divided into the easy degradable, difficult degradable and non-degradable (Hyánek et al. 1991).

The organic substances concentration in the water varies in the large scale. In the drinking water they occur in order of the tenth to units of $mg.dm^{-3}$, in the surface waters approximately in ten times higher concentration and in the highly polluted industrial waste waters they occur in order of $g.dm^{-3}$. In the surface waters as many as hundreds or thousands of the organic substances are found (Tölgyessy et al. 1984).

Individual determination of the individual organic substances is very complicated and therefore the methods were sought making possible to use representation of the total organic substances concentration in the water and to describe the rate of total water pollution. The most expanded were indirect methods based on chemical or biological oxidation of the organic substances (Pitter 1999).

For aerobic biological decomposition of the organic substances in the water, the dissolved oxygen is of decisive importance. According to Hyánek (1991), the most important role by the organic substances degradation in the water have the micro-organisms, especially bacteria. The oxygen passes into the water through diffusion from the atmosphere and through photosynthetic assimilation of the water plants and algae (Pitter 1999). The oxygen sources in the water are also substances which after depletion of the dissolved oxygen can reduce, e. g. nitrates and sulphates (Tölgyessy et al. 1997).

Material and methods

The catchment characteristic

Organic substances and dissolved oxygen concentration have been monitored and evaluated in the upper part of the Hostiansky potok. This stream is situated in the Tribeč Mountains where it also springs. The lower part of the stream is situated in the upland Žitavská pahorkatina. The water course belongs to the catchment area of the Žitava river, in which it emanates under the town Zlaté Moravce – part Chyzerovce. The whole catchment of the water course has the area of 120 km^2. The mean annual overflow in the influx to the river Žitava is 0.94 m^3.s^{-1}.

The catchment of the water course in the Tribeč Mountains is represented by forest ecosystem and the ecosystems of the permanent lawn overgrowth. In the forest ecosystem occur, above all, these pulps: *Fagus sylvatica, Quercus cerris, Quercus petraea, Quercus robur, Quercus daleschampii* and *Carpinus betulus*. The characteristic representatives of the pulps in the water course of bottom land are: *Alnus glutinosa, Alnus incana, Fraxinus excelsior, Salix eleagnos* and *Salix triandra*.

The Tribeč Mountains belong to the Secondary saccharoid zone of the whole Carpathian Mountains. The soils are represented by ranker, rendzina, pararendzina, cambisoil and luvisoil.

In the climatic respect, the catchment in the Tribeč Mountains belongs to a transition and partially to a warm region that is represented by the subhumic lowland area. Depending on the relief, the transition region which covers the biggest part of the catchment is divided into the moderate warm subhumic valley with ability of the frost hollow and the mountain area.

Taking and treating samples

Taking water samples from the water course were carried out regularly in the last decades on monthly schedule over the years 1995–1998. The samples were taken from the streamline. In the research part of the water course we have defined the following three sample sites:

1. The forest ecosystem in the height of 300 m above sea level. From the viewpoint of operating files it concerns about the high-stem forests.
2. Below the ecosystem of permanent grass overgrow on the left side and forest ecosystem on the right side of the water course. The length of the segment is 1.6 km.
3. Below the ecosystem of permanent grass overgrow on the both sides of water course closely above the village Hostie. The length of the segment is 1.6 km.

From the samples taken have been determined organic substances (by oxidation with potassium permanganate) and dissolved oxygen (by Winkler's method). The classification of water in the sample sites to the classes of the surface water quality was accomplished by comparing the calculated characteristic values of the COD_{Mn} and dissolved oxygen with their corresponding systems of the limit values for several classes of the surface water quality (STN 75 7221).

Results and discussion

Indicator COD_{Mn} is served to the organic substances statement in the water. It expresses the quantity of the oxygen that is used by the exactly concluded conditions for the oxidation of organic substances in the water with the potassium permanganate (Pitter 1999).

The results given in Fig. 1 show that the mean COD_{Mn} values in the experimental years were from 1.80 (year 1997) to 2.87 mg O_2.dm^{-3} (year 1996). The mean COD_{Mn} value for the whole research period has represented 2.49 mg O_2.dm^{-3}.

The COD_{Mn} values in each experimental year have fluctuated depending on the sampling time (Fig. 2). The lowest mean values during the research period were recorded in the winter season. The minimum mean value for the whole research period was in the month of February (1.81 mg O_2.dm^{-3}) and maximum in the month of September (3.68 mg O_2.dm^{-3}). We suppose that the decrease of the COD_{Mn} values in the winter season is related to the unsuitable thermal conditions for the organic matter decomposition in the water flow.

The sampling sites in the research part of the water flow have influenced differently the COD_{Mn} value in the individual experimental years (Fig. 3). For the whole research period the lowest mean value was in the 1st sampling site. The COD_{Mn} mean values for the whole research period were identical in the 2nd and 3rd sampling sites.

The COD_{Mn} calculated characteristic values according to STN 75 7221 Classification of the surface water quality (Table 1) include the waters in all the sampling sites in the research part of the water course into the 1st class of surface water quality (very clean water).

For aerobic biological organic substances decomposition in the processes of surface water self-cleaning the dissolved oxygen is of definite importance (Pitter 1999).

From the results described in the Fig. 4 it follows that the mean dissolved oxygen concentrations in the experimental years were from 9.59 (year 1995) to 11.62 mg $O_2.dm^{-3}$ (year 1998). For the whole research period the mean dissolved oxygen concentration value represented 10.53 mg $O_2.dm^{-3}$.

The sampling time in the experimental years has not influenced equally the dissolved oxygen concentration (Fig. 5). On the basis of these data it may be stated that the seasonal dynamic regularity was not manifested. The mean dissolved oxygen concentrations during the research period have fluctuated depending on the sampling time from 8.90 (August) to 12.37 mg $O_2.dm^{-3}$ (December). Noskovič (1999) presents that the decrease of the dissolved oxygen concentrations in the water course during the summer season is related to a more intensive biological decomposition of the organic substances.

The sampling sites in the experimental years have insignificantly influenced the dissolved oxygen concentration changes (Fig. 6). For the whole research period the mean dissolved oxygen concentrations in the research part of the water course fluctuated from 10.53 (3rd sampling site) to 10.65 mg $O_2.dm^{-3}$ (1st sampling site).

On the basis of calculated characteristic dissolved oxygen values (Table 1), according to STN 75 7221, the waters in all the sampling sites are involved in the 1st class of the surface water quality (very clean water).

Conclusions

To determine the concentration of organic substances in the water samples taken was used indirect method based on the oxidation with potassium permanganate and is represented as a chemical oxygen demand with potassium permanganate. The results achieved are presented in mg $O_2.dm^{-3}$. The results show that the lowest mean values of chemical oxygen demand (COD_{Mn}) during the research period were recorded in the winter

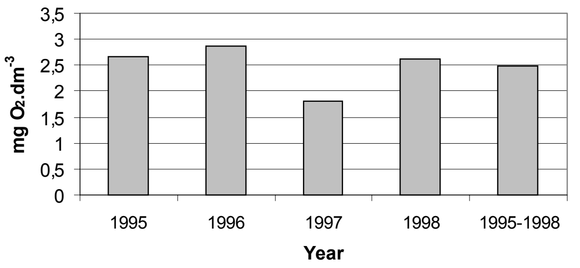

Fig. 1. The mean annual COD_{Mn} concentrations

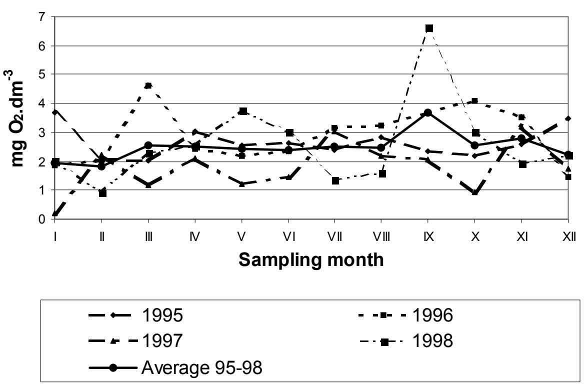

Fig. 2. The mean COD_{Mn} concentrations depending on the sampling time

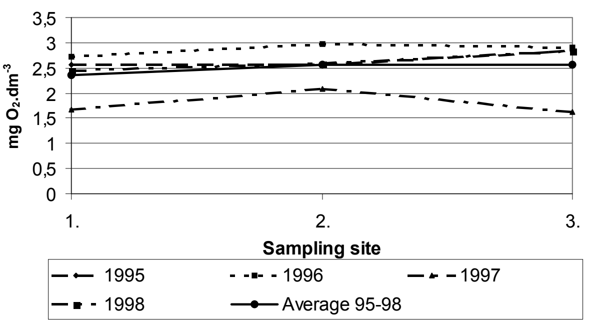

Fig. 3. The mean COD_{Mn} concentrations depending on the sampling site

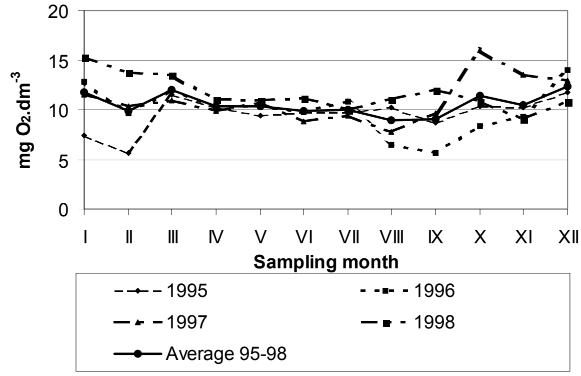

Fig. 4. The mean annual dissolved O_2 concentrations

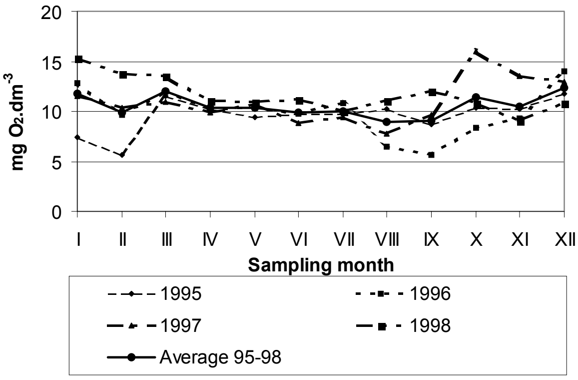

Fig. 5. The mean dissolved O_2 concentrations depending on the sampling time

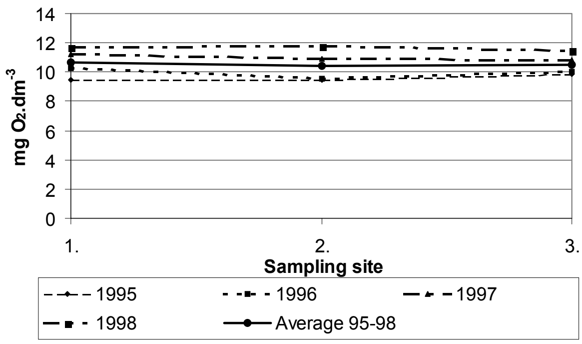

Fig. 6. The mean dissolved O_2 concentrations depending on the sampling site

Table 1. Calculated dissolved oxygen and COD_{Mn} characteristic values

Indicator	Sampling sites		
	1.	2.	3.
Dissolved oxygen	8.12	7.08	7.87
COD_{Mn}	3.58	3.75	3.94

season. This is connected with unsuitable thermal conditions for the organic matter decomposition in the water course. The lowest COD_{Mn} value during the research period was ascertained in the first sampling site, which is localised in the forest. The mean dissolved oxygen concentration in the whole research period was 10.53 mg O_2.dm^{-3}. Seasonal dynamic regularity in the concentration of the dissolved oxygen during the research period has not been manifested. The sampling sites have weak influence on its changes. According to calculated COD_{Mn} and dissolved oxygen characteristic values (STN 75 7221), the waters in all the sampling sites were included in the 1st class of the surface water quality (very clean water).

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Hodnotenie koncentrácie organických látok a rozpusteného kyslíka vo vodnom toku v pohorí Tribeč

Súhrn

Vo vodnom toku Hostiansky potok v pohorí Tribeč sa v rokoch 1995–1998 hodnotila koncentrácia organických látok a rozpusteného kyslíka. Na určenie koncentrácie organických látok sa použila nepriama metóda, ktorá je založená na oxidácii organických látok manganistanom draselným a označuje sa ako chemická spotreba kyslíka manganistanom draselným. Výsledky sa uvádzajú v mg O_2.dm^{-3}. Z výsledkov vyplýva, že najnižšie priemerné hodnoty $CHSK_{Mn}$ za celé pokusné obdobie sa vyskytovali v zimnom období, čo súvisí s nevhodnými termickými podmienkami pre rozklad organickej hmoty vo vodnom toku. Najnižšia hodnota $CHSK_{Mn}$ za celé pokusné obdobie sa zistila v odberovom mieste, ktoré sa lokalizovalo v lesnom poraste. Priemerná koncentrácia rozpusteného kyslíka za celé pokusné obdobie bola 10.53 mg O_2.dm^{-3}. Zákonitosť v sezónnej dynamike koncentrácie rozpusteného kyslíka v pokusnom období sa neprejavila. Odberové miesta vplývali na zmeny jeho koncentrácie nevýrazne. Podľa vypočítaných charakteristických hodnôt $CHSK_{Mn}$ ale aj rozpusteného kyslíka (STN 75 7221) sa vody na všetkých odberových miestach zaraďujú do I. triedy kvality povrchových vôd (veľmi čistá voda).