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Cultural characteristics of *Phytophthora* fungi – causal agents of ink disease on chestnut trees (*Castanea sativa* Mill.) in Slovakia

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Abstract

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Several important characteristics of cultures of two species of *Phytophthora* genus – *Ph. cambivora* (Petri) Buism. and *Ph. cinnamomi* Rands – causal agents of ink disease on chestnuts in Slovakia were investigated in laboratory conditions. We observed growth rate, formation of sporangia and oospores and dimensional differences in reproductive structures of these species in their pure hyphal cultures on selected types of cultivation media. Non-parametric Mann-Whitney U-test has confirmed statistically significant differences in growth rates (average daily growth) within the same *Phytophthora* sp. between two different cultivation media at significance level $p < 0.05$ for both examined species. Differences in growth of mycelia between the two *Phytophthora* sp. on the same cultivation medium were significant at significance level $p = 0.001$; it was confirmed for both tested media. Testing using a t-test also confirmed significant differences in sporangium length ($t = 6.19$; $p = 0.001$) and width ($t = 7.03$; $p = 0.001$) between *Ph. cambivora* and *Ph. cinnamomi* and a significant difference in oospore diameter ($t = –3.16$; $p = 0.003$) between *Ph. cambivora* and *Ph. cinnamomi*.

Key words

formation of sporangia, growth rate, *Phytophthora*, production of oospores

Introduction

Many species of the *Phytophthora* genus are important plant pathogens that attack a wide variety of crops, trees and shrubs throughout the world. During the recent years, an alarming resurgence of ink disease was reported in chestnut stands in Central and Southern Europe (Abreu, 1992; Abreu et al., 1993; Cvjetkovič and Jurjevič, 1993; Branzanti et al., 1999; Anselmi et al., 2000; Newell, 2001).

In association with *Cryphonectria parasitica* Murr. (Barr) (chestnut blight), *Phytophthora* sp. (Oomycetes, Peronosporales, Pythiaceae) plays a significant role in all areas of cultivation of *Castanea sativa* – a fruitbearing and silviculturally important woody plant in Slovakia (Juhásová and Hrubík, 1984; Juhásová et al., 1987; Juhásová, 1992, 1999).

Causal agents of chestnut ink disease, soil-borne micro-organisms of *Phytophthora* sp., mainly *Ph. cambivora* (Petri) Buism and *Ph. cinnamomi* Rands cause root and collar rots, necrotic lesions on stems of chestnut trees in orchards, coppices and forest stands, and their identification in abundant root systems is difficult (Werres et al., 1997). According to Themann and Werres (1998) both isolation and identification of *Phytophthora* based on its morphological characteristics is rather difficult, especially time-consuming and it requires considerable experience. Some recent studies have pointed out that the knowledge on biological features and cultural characteristics of soil fungal pathogens is very important for simpler identification of the *Phytophthora* soil fungi (Ho, 1992; Brasier et al., 1993; Cahill and Hardham, 1994).

According to Vedenjapina (1985), Hamm and Hansen (1987), the species identification is possible on various types of growth media on the basis of data on the colony morphology and on the attributes of oospores and sporangia.

Much work has been accomplished on the dimensional characteristics of *Phytophthora* reproductive structures (Příhoda, 1981; Alizadeh and Tsao, 1982; Hamm and Hansen, 1990). Differences in oospores and sporangia size and shape can contribute to easier *Phytophthora* identification (Weste and Marks, 1987; Agrios, 1988).

Various studies based on laboratory and field tests have pointed out the influence of nutrition (culture medium) (Duncan, 1988), temperature (Zentmyer et al., 1979; Phillips and Weste, 1985), length of incubation period (King and Zentmyer, 1981), pH (Benson, 1984) and other factors (Newhook et al., 1981) on variability in *Phytophthora* growth and formation of its reproductive structures.

Information on myceliar growth, characteristics of oospores and sporangia, differences in size nad shape of reproductive structures can contribute to identification and specification of biology of *Phytophthora* soilborne pathogens in specific conditions (Bernadovičová, 2003).

The present work is focussed on specification of biological characteristics of the soil fungi *Ph. cambivora* and *Ph. cinnamomi* – causal agents of ink disease on the *Castanea sativa* Mill. in ecological conditions of Slovakia and on extending knowledge of *Phytophthora* biology, with the results of laboratory tests.

Material and methods

We investigated cultures of pathogens in laboratory conditions, and specified in details their characteristics. The study material was sampled from roots of host trees with visible symptoms of ink disease on the trunk base. *Phytophthora* isolates obtained from infected tissues of symptomatic chestnut trees were subjected to preliminary identification (Bernadovičová, 2003).

We studied some important characteristics of the *Phytophthora* biology as its growth in cultures, formation of sporangia and oospores and differences in size of reproductive structures in pure hyphal cultures of *Ph. cambivora* and *Ph. cinnamomi* cultivated on various types of cultivation media.

Growth rates of *Phytophthora cambivora* and *Phytophthora cinnamomi* isolates

Growth rate of mycelia of the *Phytophthora* species was evaluated on two types of cultivation media (carrot agar and rice agar) prepared according to Brasier et al. (1993). Colony morphology was observed on 10-day-old pure cultures grown on carrot agar (CA) (200 g of blended carrots, 15 g of agar in 1000 ml H_2O) and rice agar (RA) (200 g of rice, 20 g of agar in 1000 ml H_2O) in Petri dishes, at 22 ºC, in darkness. Growth rates were evaluated based on daily records of mycelium increments (mm day^{-1}; precision 0.5 mm) for 4 days. We made altogether 20 measurements, each of them on five dishes with fungal colonies.

The results were processed using non-parametric Mann-Whitney U-test (statistical package STATISTICA-6) with the aim to verify statistical significance of differences in myceliar growth rates of investigated species.

Formation of reproductive structures of *Phytophthora cambivora* and *Phytophthora cinnamomi*

We stimulated formation of sporangia in colonies cultivated on pea broth (PB) (150 g of split peas, 20 g of agar in 1000 ml H_2O) in soil extract water (SEW) (filtered mixture of sandy-loamy soil/distilled water, ratio 1 : 1) prepared according to Érsek and Bakonyi (1997). Sporangia were produced on a disc of mycelium cut from a 6-day-old culture grown on PB in the soil extract. Colonies cultivated for 4 days on PB, at 25 °C, in the dark were carefully washed with distilled water to a container with prepared soil extract. Formation of sporangia was evaluated after 3–4 days. Their morphology was examined using light microscopy (AXIOPLAN 2, Zeiss), and dimensions (length x width) of 30 sporangia were measured in the isolates of the two *Phytophthora* species.

Production of oospores was asessed on 12-day-old cultures grown on carrot agar (CA) at 20 °C, in the dark. From the medium surface we took the culture (about 1 cm from the centre of colony) from three spots. Formation of oospores was assesed microscopically (AXIOPLAN 2, Zeiss) and dimensions (diameter) of 30 oospores were measured for isolates of both *Phytophthora*.

The measured values were processed using a t-test (statistical package STATISTICA-6).

Results

Growth rates of *Phytophthora cambivora* and *Phytophthora cinnamomi* isolates

Comparing the growth rates of the tested isolates of *Ph. cambivora* and *Ph. cinnamomi* we always found faster growth on RA. Differences in average daily growth (ADG) in comparison with the growth on CA were 0–1.0 mm day^{-1}, 0.34 mm day^{-1} on average. ADG of the tested fungal isolates ranged between 2.5–4.5 mm day^{-1} on CA and between 3.0–5.0 mm day^{-1} on RA.

Differences between *Ph. cambivora* and *Ph. cinnamomi* isolates in radial growth of their mycelia were noticeable. The fungus *Ph. cinnamomi* showed in general faster radial growth (3.5–5.0 mm day^{-1}, 4.23 mm day^{-1} on average) in comparison with *Ph. cambivora* (2.5–4.0 mm day^{-1}, 3.22 mm day^{-1} on average) on both media. *Ph. cinnamomi* isolates grew faster than *Ph. cambivora* on average by 1 mm day^{-1}on both media (Table 1).

Non-parametric Mann-Whitney U-test was used for verification of statistical significance of differences, and it confirmed that differences in growth values for the same *Phytophthora* sp. caused by using two types of cultivation media were significant at significance level $p < 0.05$ for both fungal species. Differences in average daily growth values between the two *Phytophthora* sp. on the same cultivation medium were significant at a significance level of $p = 0.001$; for both tested media.

Differences in average daily growth values (two types of cultivation medium in interaction with two *Phytophthora* species) and the internal variability are shown in Fig. 1.

Table 1. Average daily growth of *Phytophthora cambivora* and *Phytophthora cinnamomi* isolates on two types of cultivation media

	Number of replications	Isolate			
		PCA		PCI	
		CA	RA	CA	RA
Average daily growth (mm day^{-1})	1	3.0	3.5	4.5	4.5
	2	2.5	3.5	4.0	4.0
	3	3.0	3.5	4.0	4.5
	4	3.0	3.0	3.5	4.5
	5	3.5	3.5	4.0	4.5
	6	3.0	3.5	4.5	4.5
	7	2.5	3.0	4.0	4.0
	8	3.0	3.5	4.0	4.5
	9	3.5	4.0	4.5	4.5
	10	3.0	3.5	4.0	4.0
	11	3.0	3.5	4.5	4.5
	12	3.0	3.0	3.5	4.0
	13	3.5	3.5	4.5	5.0
	14	3.5	3.5	4.0	4.5
	15	3.0	3.5	4.0	4.5
	16	2.5	3.0	3.5	4.0
	17	3.0	3.5	4.0	4.5
	18	2.5	3.0	4.0	4.0
	19	3.5	3.5	4.0	4.5
	20	3.0	3.5	4.5	4.5
	Average	3.03	3.40	4.08	4.38

PCA – isolates of *Phytophthora cambivora*
PCI – isolates of *Phytophthora cinnamomi*
CA – carrot agar
RA – rice agar

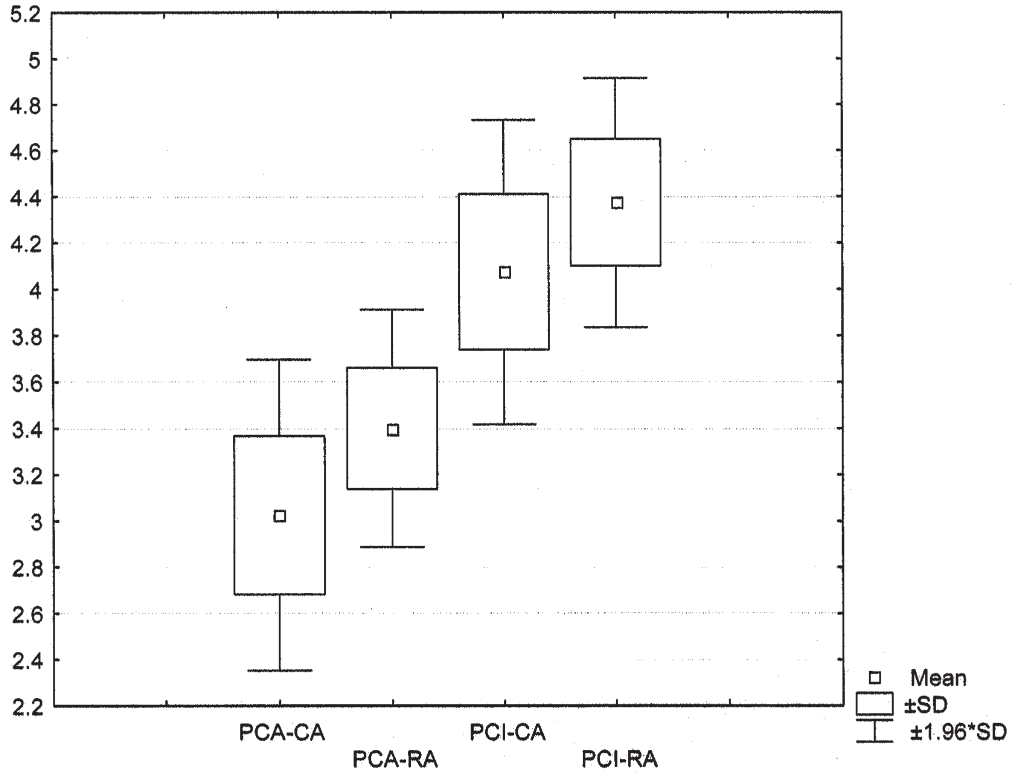

Fig.1. Effect of fungal isolate and culture medium on average daily growth of *Phytophthora* mycelium
y-axis: average daily growth (ADG) of mycelium (mm)
x-axis: PCA-CA – ADG of *Ph. cambivora* on carrot agar (CA)
PCA-RA – ADG of *Ph. cambivora* on rice agar (RA)
PCI-CA – ADG of *Ph. cinnamomi* on carrot agar (CA)
PCI-RA – ADG of *Ph. cinnamomi* on rice agar (RA)

Formation of reproductive structures of *Phytophthora cambivora* and *Phytophthora cinnamomi*

Dimensional characteristics of sporangia (length x width) and oospores (diameter) were determined microscopically (AXIOPLAN 2, Zeiss) and dimensions of 30 reproductive structures were measured for isolates of both *Phytophthora* species (Table 2).

Dimensions of sporangia of *Ph. cambivora* isolates produced on PB in water soil extract reached on average 66.0 x 45.0 μm, in *Ph. cinnamomi* it was 57.0 x 36.0 μm. Significant differences in sporangial length ($t = 6.19$; $p = 0.001$) and width ($t = 7.03$; $p = 0.001$) between PCA and PCI was confirmed using the t-test (Table 3).

Diameter of oospores in *Ph. cambivora* isolates produced on CA varied from 21.0 to 28.0 μm. Diameter of *Ph. cinnamomi* oospores varied from 24.0 to 28.0 μm. The average diameter of oospores was 24.1 μm for *Ph. cambivora* and 25.5 μm for *Ph. cinnamomi*. Significant difference in oospore diameter between PCA and PCI was confirmed by using the t-test ($t = –3.16$; $p = 0.003$) (Table 4).

Discussion

Both isolation and identification of *Phytophthora* pathogens are difficult tasks. The isolation of *Phytophthora* can be intricate, due to a number of factors such as the involved *Phytophthora* species, the presence of fastgrowing contaminants and the condition of the material from which isolations were taken (Hamm and Hansen, 1990). In spite of high aggressiveness of *Ph. cambivora* associated with ink disease, the pathogen can only hardly survive in soil environment and it can only be isolated from small proportion of the soil samples taken by the symptomatic trees (Vettraino et al., 2001). Werres et al. (1997) and Themann and Werres (1998) reported that only a small number of direct isolations sampled from roots allowed *Phytophthora* recovery.

Table 2. Dimensions of reproductive structures of *Phytophthora cambivora* and *Phytophthora cinnamomi*

Number of replications	Sporangium (length x width in µm)		Oospora (diameter in µm)			
	PCA	PCI	PCA		PCI	
	PB		CA	RA	CA	RA
1	59 x 48	52 x 39	21.0	24.0	25.0	24.0
2	64 x 39	63 x 44	26.0	24.0	24.0	26.0
3	60 x 42	57 x 41	26.0	23.0	26.0	26.0
4	57 x 47	49 x 39	24.0	26.0	26.0	27.0
5	68 x 41	53 x 43	28.0	22.0	26.0	24.0
6	71 x 38	51 x 38	22.0	21.0	27.0	25.0
7	64 x 41	59 x 36	23.0	21.0	24.0	25.0
8	69 x 44	56 x 29	22.0	25.0	25.0	23.0
9	66 x 39	60 x 43	26.0	24.0	25.0	24.0
10	58 x 42	51 x 45	24.0	23.0	26.0	24.0
11	71 x 47	56 x 37	23.0	25.0	23.0	26.0
12	62 x 40	64 x 41	23.0	25.0	28.0	23.0
13	74 x 51	53 x 34	27.0	22.0	25.0	27.0
14	69 x 39	56 x 35	24.0	23.0	25.0	27.0
15	62 x 46	58 x 32	22.0	24.0	27.0	24.0
16	65 x 43	52 x 41	22.0	26.0	26.0	27.0
17	66 x 50	61 x 38	25.0	26.0	24.0	25.0
18	73 x 53	57 x 37	21.0	24.0	24.0	25.0
19	75 x 51	49 x 28	26.0	25.0	26.0	26.0
20	69 x 49	58 x 36	26.0	25.0	24.0	27.0
21	71 x 51	62 x 38	23.0	21.0	25.0	27.0
22	76 x 43	60 x 38	25.0	23.0	26.0	25.0
23	59 x 46	56 x 31	26.0	26.0	27.0	27.0
24	64 x 41	54 x 29	26.0	26.0	24.0	26.0
25	58 x 39	59 x 34	27.0	21.0	27.0	26.0
26	59 x 44	63 x 38	21.0	23.0	26.0	25.0
27	60 x 42	66 x 32	23.0	27.0	25.0	26.0
28	73 x 48	56 x 29	23.0	25.0	25.0	25.0
29	69 x 52	61 x 31	24.0	25.0	26.0	25.0
30	62 x 47	67 x 33	25.0	23.0	27.0	26.0
Average	66 x 45	57 x 36	23.9	24.3	25.5	25.4

PCA – isolates of *Phytophthora cambivora*
PCI – isolates of *Phytophthora cinnamomi*
PB – pea broth
CA – carrot agar
RA – rice agar

Table 3. Basic parameters characterising differences in length and width of sporangia between two *Phytophthora* species cultivated on pea broth and soil extract water

	t-test of independent groups					
Variable	Average PCA	Average PCI	Standard deviation PCA	Standard deviation PCI	t	p
Length	65.77	57.30	5.71	4.79	6.19	0.001
Width	44.77	36.30	4.53	4.84	7.03	0.001

PCA – *Phytophthora cambivora*; PCI – *Phytophthora cinnamomi*

Table 4. Basic parameters characterising differences in oospore diameter between two *Phytophthora* species on carrot agar

	t-test of independent groups			
Species	Average diameter of oospores	Standard deviation	t	p
PCA	24.13	1.98	–3.16	0.003
PCI	25.47	1.20		

PCA – *Phytophthora cambivora*; PCI – *Phytophthora cinnamomi*

On the base of data on colony morphology, sporangial and oogonal characteristics, investigated species is possible to identify on various types of growth media. According to Juhásová et al. (1987), Juhásová (1992, 1999), the growth characteristic and distinguishing features of *Phytophthora* mycelium are very important for microscopical identification of *Phytophthora* isolates. Generally slow growth in cultures is characteristic for all *Phytophthora*. Isolates of *Pythium* sp. in comparison with *Phytophthora* show noticeably faster growth (Hansen et al., 1979). Within the *Phytophthora* genus, the fungus *Ph. cambivora* belongs to the medium-fast growing, whereas *Ph. cinnamomi* on Difco cornmeal agar shows from medium-fast to fast growth. In contrast, average daily growth of *Pythium* isolates cultivated on different media varied from 8–16 mm day^{-1} (Hamm and Hansen, 1987).

Several authors (Honour and Tsao, 1974; Benson, 1984; Vedenjapina, 1985; Érsek and Bakonyi, 1997) studying influence of the used medium have confirmed the suitability of five types of cultivation media (carrot agar, rice agar, cornmeal agar with pimaricin, pea broth, soil leachate) for *Phytophthora* fungi. With our observations of growth of *Phytophthora* mycelia on two different media we confirmed slower growth of *Ph. cambivora* (3.22 mm day^{-1} on average) than *Ph. cinnamomi* and suitability of both selected media – carrot agar and rice agar for *Phytophthora* cultivation. The positive results obtained with soil leachate as a stimulating agent for formation of sporangia in colonies grown on pea broth have confirmed that liquid medium is suitable for production of sporangia.

We have also confirmed the results obtained in a number of hitherto studies dealing with characteristics of *Phytophthora* reproductive structures (Novoteľnova, 1974; Příhoda, 1981; Hamm and Hansen, 1987, 1990).

Příhoda (1981) reports that sporangia of *Ph. cinnamomi* reach a size of 60 x 30 µm on average. Novoteľnova (1974) quotes 68 x 47 µm on average for *Ph. cambivora* and 61 x 33 µm on average for *Ph. cinnamomi*. Another author found average sporangia dimensions 65 x 41 µm in *Ph. cambivora*, whereas in *Ph. cinnamomi* 70 x 45 µm (Hamm and Hansen, 1987). According to HO (1992) sporangia of *Ph. cinnamomi* were 35–55 µm in size.

As for the *Phytophthora* oospores, Novoteľnova (1974) quotes the diameter for *Ph. cambivora* 20–27 µm, for globular oospores of *Ph. cinnamomi* on average 25.7–27.2 µm. Ho (1992) reports for the latter 29–35 µm in diameter.

According to Weste and Vithanage (1979) *Phytophthora* sporangia together with zoospores are the principal means of dispersal of the organism and as the most potent means ensuring penetration of the host. Size and shape differences among sporangia and oospores can contribute to easier identification of *Phytophthora* species from infected tree tissues (Agrios, 1988; Hardham et al., 1994; Hardham, 1995).

Detailed recognition of features of mycelia and characteristics of sexual structures is very important for correct understanding of the whole infectious process and disease development in connection with the withering and dieback of the European chestnut – a woody plant species of high utility value.

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Kulturálne vlastnosti druhov rodu *Phytophthora* – pôvodcov atramentovej choroby jedlých gaštanov (*Castanea sativa* Mill.) na Slovensku

Súhrn

Prezentovaná práca rozširuje poznatky o biológii dvoch druhov koreňových patogénov rodu *Phytophthora*, húb *Ph. cambivora* a *Ph. cinnamomi* izolovaných z pletív gaštana jedlého (*Castanea sativa* Mill.) na stanovištiach napadnutých atramentovou chorobou, ktorá predstavuje vážnu hrozbu pre zachovanie výsadieb tejto všestranne využiteľnej dreviny na Slovensku. Rozšírenie poznatkov o morfológií kolón, rýchlosti rastu hýf mycélia, oogonálnych a sporangiálnych charakteristikách, veľkostných a tvarových rozdieloch rozmnožovacích štruktúr napomáha náročnej identifikácii pôdnych húb rodu *Phytophthora*. Pri stanovení rýchlosti rastu hýf mycélia húb sa priemerný denný prírastok izolátov húb rodu *Phytophthora* testovaný na dvoch druhoch živných médií pohyboval v rozmedzí 2,5–4,5 mm (mrkvový agar) a 3,0–5,0 mm (ryžový agar). Neparametrický Mann-Whitney U-test použitý na overenie štatistickej významnosti rozdielov preukázal signifikantné rozdiely ($p < 0,05$) medzi prírastkami toho istého druhu *Phytophthora* sp. spôsobené použitím dvoch druhov živných médií, čo platí pre obidva druhy testovaných húb. Rozdiely v raste dvoch druhov *Phytophthora* sp. na tom istom druhu živnej pôdy sú signifikantné na hladine $p < 0,001$, čo sa potvrdilo pre obidva druhy živných pôd. Rozmery sporangií produkovaných na hrachovom agare použitím vodného extraktu pôdy a meraných z izolátov *Ph. cambivora* dosahovali v priemere 66,0 x 45,0 µm, priemerná veľkosť sporangií izolátov *Ph. cinnamomi* dosahovala 57,0 x 36,0 µm. Signifikantný rozdiel v sporangiálnej dĺžke ($t = 6,19$; $p = 0,001$) a šírke ($t = 7,03$; $p = 0,001$) bol povrdený medzi izolátmi *Ph. cambivora* a *Ph. cinnamomi* použitím t-testu.

Veľkosť oospór izolátov huby *Ph. cambivora* produkovaných na mrkvovom agare dosahovala priemerne 24,1 µm a 25,5 µm pri izolátoch huby *Ph. cinnamomi*. T-test potvrdil signifikantný rozdiel v priemere pohlavných spór medzi izolátmi *Ph. cambivora* a *Ph. cinnamomi* ($t = –3,16$; $p = 0,003$).

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Community structure of small mammals (Insectivora, Rodentia) in the Kľačianska Magura National Nature Reserve (Malá Fatra Mts., Western Carpathians)

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Abstract

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The small mammal (Vertebrata) communities in the Kľačianska Magura National Nature Reserve (Malá Fatra Mts., Western Carpathians) have been surveyed systematically in 2000–2001. In the research we used the quantitative quadrate method; i.e. quantitative evaluations performed in a square grid with dimensions of ca 75 × 75 m. 72 small collapsible traps were displaced uniformly at 36 trap spots with a spacing of about 15 x 15 m. Apart from quantitative figures obtained immediately in the field, we calculated density values for each plot separately. The dimensions of the examined plot we enlarged by the observed range length (ORL) values, i.e. by bands in width equal to the radius of the individual district of the given species. The inferred influence of changes in atmospheric pressure on small mammal activity and on the catch success rate of specimens of arbitrary species has not been confirmed. Any influence of increased moisture content in soil and air on the activity of small terrestrial mammals in the relevant geobiocoenosis would not have been detected. The number of the trapped exemplars (n = 5) was statistically significantly different from the numbers of exemplars trapped on the other experimental plots where the influence of atmospheric precipitation was already evident at the beginning of the trapping period ($\alpha = 0.05$; $P = 0.0095$). Over the two-year period of the study we have collected a sample of altogether 45 individuals, belonging to four species (*Sorex araneus*, *Clethrionomys glareolus*, *Microtus (Pitymys) subterraneus* and *Apodemus flavicollis*. The conservation considerations of macro- and micro-habitats need to take into account findings such as the occurrence of a stabilised community of the insectivorous Sorex araneus, whose population density in the climax spruce forest community on a crystalline complex was higher (7.8 ind./ha) than the corresponding values for the rodents *Clethrionomys glareolus* and *Apodemus flavicollis*.

Key words

small mammals, forest, Malá Fatra Mts.

Introduction

The small mammal (Vertebrata) communities in the Kľačianska Magura National Nature Reserve (NNR) have been surveyed systematically on several occasions. The first overall picture of the structure and species composition of the small mammal communities in this region had been gained from Štollmann's (1962) faunistically oriented field research activities. This and other material documenting the available research was incorporated into the Považské museum collections in Žilina, in the department of zoology. Obuch (1998) developed a species spectrum of the small mammals in the Kľačianska Magura NNR based on the osteological material found in the debris of breeding boxes occupied by Tengmalm's owl *Aegolius funereus*. This analysis, performed within the framework of a study of the diet ecology of owls, ran over quite a long period (the breeding season) and produced much valuable data about temporal and spatial changes in the population dynamics of the communities of small terrestrial mammals. At the same time, we can obtain an actual-state reflecting pattern of changes running under influence of simultaneously present ecological factors of the environment, in connection with the species and individual's variability reflected on preferring certain prey spectra.

Despite the disproportion between the various research methods that have been employed, the results from the Boreal Owl diet ecology study can be taken as a reference standard for the purposes of our study.

Material and methods

Investigations of the small mammal communities were carried out in the Malá Fatra Mts., the Western Carpathians (49º08´ N, 18º50´ E), and data from two study period 2000–2001 were used for the present paper. The parameters, such as sampling days and periods, are given in Table 1. Four sampling plots, each ca 0.5 ha in area, were localised in two biotopes which were physically different, representing the most important forest communities in the Kľačianska Magura NNR. Two of the study localities lie in the mountain vegetation tier and the other two in the supra-mountain vegetation tier – the relative forest geobiocoenoses belong either to the spruce-beech-fir forest vegetation tier at an average altitude of 1,240 m a.s.l. or to the spruce vegetation tier at about 1,300 m a.s.l.

In the research we used the quantitative quadrate method; i.e. quantitative evaluations performed in a square grid with dimensions of ca 75 × 75 m. 72 small collapsible traps were displaced uniformly at 36 trap spots with a spacing of about 15 x 15 m (Pelikán, 1975). The trapping was always carried out continually, over three-day periods. The traps were baited with a pasty mixture of walnuts and thinned sardines by adding sunflower oil. This mixture was applied on small squares of green felt tissue. The obtained biological material of micro-mammals was processed following the commonly used taxonometric methods. The primary classification criterion was gender, which was determined from anatomic examination, followed by the age categories of juvenile, sub-adult and adult exemplars. The research task was to assess the actual structure of micro-mammal communities in various forest geobiocoenoses. Apart from quantitative figures obtained immediately in the field, we calculated density values for each plot separately. The dimensions of the examined plot we enlarged by the ORL values, i.e. by bands in width equal to the radius of the individual district of the given species (Pelikán et al., 1974). Based on the calculated values of density (D) and mean fresh weight of the examined exemplars (W), we determined the biomass values according to the formula: B = D.W; in g ha^{-1} (Dykyjová et al., 1989). From other quantitative features of small-mammal populations we considered dominance (%) and biomass energy value (kJ ha^{-1}). The energy bound in the fresh biomass of each of the studied species of the small mammal populations is expressed as energy biomass value, which was determined on the basis of the biomass energy value data reported by Górecki (1965) and Myrcha (1969).

The parameter ranging bands of the studied populations observed over the two years allow us to estimate, implicitly, with a certain probability, not only population trends in the individual species populations, but also as a consequence, population trends in the whole study community. Furthermore, we could derive predictions about forthcoming population development. Moreover, we examined the affinity of individual species to certain habitat gradients, e.g. height and extent of cover of the vegetation layers and the structure of vegetation associated with the stratifying diversification.

An important ecological factor, governing the rhythm and expressing of the biotic potential in small terrestrial mammals, is the summit climate (summit phenomenon), which has an important influence on the biota throughout the study territory. We therefore had to take into consideration climate history over the trapping period, recording all basic meteorological variables.

Table 1. Habitat, plot number and trapping dates for the 72 traps in the study plot area of 4,900m^2 where exposure length was 3 days (Kľačianska Magura NNR, Western Carpathians, 2000–2001)

Habitat	Plot number	a.s.l	Trapping dates
(Sorbeto-Piceetum)	32	1,280 m	11.–14. 07. 2000
(SorbetoPiceetum)	35	1,300 m	26.–29. 09. 2000
(Fageto-Abietum)	38	1,240 m	26.–29. 06. 2001
(Fageto-Abietum)	49	1,255 m	23.–26. 10. 2001

In the case of categorical variables we used for the hypotheses testing the Chi-square test. For the non-parametric methods, we used Mann-Whitney test (Lepš, 1996). The statistical analysis of the data was performed using the statistical program NCSS ´97 (Hintze, 1997).

Results and discussion

Climate history over the research period

Table 2 gives the basic meteorological variables recorded during the field research. We recorded the complete sequence and actual state of the climate (weather) over interrupted periods of 14 days, always at intervals of four or three succeeding trapping days. The changes in weather are closely connected to changes in troposphere pressure, primarily at its boundary layer. On 5 of the 14 days, the governing feature was an area of atmospheric low pressure with prevailing cyclonic weather conditions. On the other 9 days (some summery, the others autumnal) the weather was anticyclonic in character. Analysing low pressure days (n = 5) versus high pressure days (n = 9) produced no statistically significant effect ($\chi 2 = 0.5833$, df = 1, $P > 0.05$), the sequence of cyclonic and anticyclonic days being well equilibrated.

The inferred influence of changes in atmospheric pressure on small mammal activity and on the catch success rate of exemplars of arbitrary species has not been confirmed. The numbers of exemplars (per 0.5 ha) on cyclonic and anticyclonic days were 2.6 and 2.4, respectively. Any disproportion was eventually calculated after analysis of a larger sample size. The number of days with precipitation (rain) over the 14-day period was 4 (28.6%).

During the two trapping periods, (the second ten-day period of July 2000 and the last ten-day period of October 2001), we applied the same research method and trapped a sample set of 27 small mammals, without distinguishing between the species. In each trapping period we recorded at least one day with rain, which increased soil moisture content and air humidity inside the study's forest stands. The number of specimens in the communities expressed through the average number of trapped individuals per experimental plot reached a value of 13.5/0.5 ha. The actual values of exemplars sampled from the individual plots (13 and 14/0.5 ha) were well comparable and the differences, if any, were not significant.

On the study plot where we carried out the research in the last ten-day period of October 2001, rain was present only on the last day of the trapping period. Overall, it was warm and dry. Consequently, any influence of increased moisture content in soil and air on the activity of small terrestrial mammals in the relevant geobiocoenosis would not have been detected. The number of the trapped exemplars (n = 5) was statistically significantly different from the numbers of exemplars trapped on the other experimental plots where the influence of atmospheric precipitation was already evident at the beginning of the trapping period ($\alpha = 0.05$; $P = 0.0095$).

These results point out a possible dependence between the spatial activity of small mammals and the increased moisture content in the environment from rain (vertical precipitation). There evidently exists a certain positive correlation between the intensity of these animals' mobility, as expressed via the mammals' action radius size and the increased probability of trapping following from their in spatial activity related to rain. A reduction in the moisture content of the environment has the just opposite effect on small-mammal activity. However, to corroborate or disprove this hypothesis, it would be necessary to process data from a sample set of larger size.

As for the trapping periods with rain, in autumnal conditions the intensity of these mammals vagility is promoted by the fog or haze created in the colder ground level of the atmosphere. The number of exemplars trapped on this study plot in autumn was easily comparable to the numbers obtained on rainy-day squares (n = 13).

Systematic classification and species spectra of the sampled small mammals

The sampling of populations of small mammals over the two-year research period resulted in a final sample set of 45 exemplars. From this number, 11 exemplars (24.4%) were Insectivora and the other 34 (75.6%) Rodentia. There was one species in Insectivora, in the Soricidae family, namely Eurasian shrew *Sorex araneus* Linnaeus, 1758. Small rodents (Rodentia) were represented by two species belonging to the families Cricetidae – bank vole *Clethrionomys glareolus* (Schreber, 1780) and European pine vole *Pitymys subterraneus* (De Sélys-Longchamps, 1836) and one species of the family Muridae (yellow-necked mouse *Apodemus flavicollis* (Melchior, 1834). As for the ecological classification of the above small mammal species, they are considered forest species, representing the arboreal fauna typical of broadleaved and mixed forests in Central Europe.

Age and sexual structure of the small mammal study communities

From the community of rowan-spruce forest (Sorbeto-Piceetum) sampled in the second ten-day period of July 2001 we obtained 14 exemplars of small mammals belonging to three species. The major part (78.6%) of the total sample set comprised sexually immature exemplars. As for the age category of sexually mature, adult exemplars was represented in this phenophase by only 3 individuals (21.4%). A larger proportion of juvenile and sub-adult exemplars ($\chi^2 = 4.5714$, df = 1, $P < 0.05$) is characteristic for developing populations at the phase of progressive growth.

Based on the morphology and development phase of the gonads, the original sample set was differentiated to three age classes, separately for each of the species.

The species population of *Apodemus flavicollis* was represented in the original sample set (n = 8) by two adult individuals (25.0%). The age class of subadults was represented by a single exemplar (12.5%). Five individuals (62.5%) belonged to the juvenile age-class. However, this dominance of sexually immature exemplars was not verified as statistically significant ($\chi^2 = 1.2857$, df = 1, $P > 0.05$). If we consider this overall population structure of *Apodemus flavicollis* in connection with the seasonality (the 2nd 10-day period of July) and with the reduced length of the vegetation period, due to the shift of beginning corresponding to the relevant vegetation tier (mountain vegetation tier), we can assess the study species' population as a cohort in the initial phase of reproduction. The empirically obtained ratio between the genders was the same as the theoretical value of 1 : 1.

The second sample population of the *Clethrionomys glareolus* community in terms of age classification, had, as a local population, the same proportion of sexually mature (adult) and immature (sub-adult and juvenile) individuals ($\alpha = 0.05$; $P = 0.3173$) as the first sample population. The sex ratio for *Clethrionomys glareolus* during the research period was 1 : 1.

The species *Sorex araneus* was present with two subadult exemplars in the material sampled in climax spruce forest.

In the material sampled in the geobiocoenosis of climax spruce forest (Sorbeto-Piceetum) on the experimental plot 35 (Table 1), we identified in total 13 small mammal individuals whose species spectrum was identical to that obtained on plot 32. In this case we also observed confirmed dominance of sexually immature individuals (n = 9) over the individuals in the adult age class (n = 4); however, testing revealed that the difference was not significant ($\chi^2 = 0.9615$, df = 1, $P > 0.05$).

The local population of *Apodemus flavicollis* was represented in the sample by only two sexually immature individuals, one of them a male.

The local population of *Clethrionomys glareolus* (n = 3) was differentiated according to the age of 2 juveniles (1 male + 1 female) and an adult female, whose mammary glands were in the lactation phase, confirming reproduction activity and parental care within the functional pattern of parental behaviour.

The highest degree of diversification (all age classes present) occurred on this study plot in the local population of the insectivorous *Sorex araneus*. The sample contained sexually immature exemplars (n = 5), in sex ratio similar to that found for mature exemplars (n = 2), and any difference found was confirmed as not significant ($\chi^2 = 0.6267$, df = 1, $P > 0.05$). In the autumn study period the adult individuals were found to be sexually inactive.

The age and gender structure of the small mammal community in the beech fir forest of the higher tier (study plot 38) was examined from material sampled in spring. The micro-population of *Apodemus flavicollis* comprised 4 individuals, 3 of them adults, the other a sub-adult. The age category of adults comprised both sexes. Two were female and displayed signs of sexual activity, both being in the reproduction phase of their life cycle, one lactating, the other pregnant (E: 3 + 3). Sexually immature individuals were represented by a single sub-adult male. During the study period, the local population of this species was typical, with an increasing intensity of biotic potential in the population. One female adult of *Microtus subterraneus* was found to be sexually active.

From the total number of 13 small mammals, 8 were sexually mature (adults) and 5 sub-adults.

The species local population of *Apodemus flavicollis* comprised 3 exemplares, all adults. From the viewpoint of sexual and reproduction activity, two of them were in the phase of inactive and one female was lactating. This is an indirect confirmation that by this time (the last ten-day period of October) and at this altitude (supra-mountain vegetation tier) sexual activity in *Apodemus flavicollis* has ended for the year, the animals parenting the young of autumnal broods.

More complex analysis of the age and gender structure of small mammal species populations in the study community was achieved with the larger sample of *Clethrionomys glareolus* (n = 9). In terms of age aspect, the sample of this species uniformly comprised the age classes of adults (n = 5) and sub-adults (n = 4). The age class of adult individuals comprised 2 males and 3 females, all of which were pregnant. The average number of embryos per female in this type of forest community was 2.7, a rather low value, indicating the extreme nature of the physiotope under the influence of the summit phenomenon. Of the two males, one was sexually active, the other passive. These findings reflect the reproduction activity of the adults in this species.

In the age class of subadults the empiric ratio between the sexes was M : F 3 : 1, against a theoretical 1 : 1.

Based on the presented data we can conclude that the *Clethrionomys glareolus* local population we examined was increasing.

One individual of *Sorex araneus* was a sexually immature male, but overall, the limited extent of the sample obtained does not allow us either to establish a pattern reflecting the actual age and gender structure of the micro-population or to outline hypotheses in connection with prognostics of the developmental trends within the temporal and spatial context.

Table 2. Climate history at the study sites over the research period (2000–2001)

Experiment plot No./Date	Actual state of weather	Weather pattern (6-hr intervals)	Weather type	Type of clouds	Sky cover in eights	Precipitation 0 = No 1 = Yes	Wind force and direction (Beafort scale)
32/11. 7. 2000	Overcast	Cyclonic character	Cyclonic	St, Sc, As, Ac	8	1	2 NE
32/12. 7. 2000	Overcast	Showers	Cyclonic	St, haze and orographic	8	1	3-4 SSE
32/13. 7. 2000	Overcast	Low barometric pressure	Anticyclonic	St, Sc, haze clou-diness	3–8	0	4 SE
32/14. 7. 2000	Little clouds	Increasing barometric pressure	Anticyclonic	As, Ac	2–8	0	1-2 NW
35/26. 9. 2000	Almost fine	Anticyclone dominant	Anticyclonic		1	0	2 N
35/27. 9. 2000	Almost fine	Anticyclone dominant	Anticyclonic	Cs	1	0	3 SW
35/28. 9. 2000	Little cloud	Increasing clouds	Anticyclonic	Ci, Cs, Cc	2	0	3-4 S
38/26. 6. 2001	Semicloudy	No precipitation	Anticyclonic	Cu, Ac or St	4	0	4 N
38/27. 6. 2001	Little clouds	Anticyclonic character	Anticyclonic	Ac, Cu	2	0	3 NE
38/28. 6. 2001	Fine weather	Anticyclonic character	Anticyclonic		0	0	3 W
38/29. 6. 2001	Overcast	Approaching frontal system	Cyclonic	Ns, St	8	1	3 NW
49/23. 10. 2001	Cloudy	Atmospheric front passing	Cyclonic	Cu, Sc	6	1	0
49/24. 10. 2001	Semicloudy	Atmospheric front departed	Cyclonic	Sc, Cu	5	0	1 SW
49/25. 10. 2001	Hazy cloud	Anticyclonic, early ground frost	Anticyclonic	Hazy clouds	Ground visibility ca 10 m	0	1 SE

Density, biomass and their dynamics over the study period

Population parameters calculated from the data obtained in field research into the micro-mammals community in the climax spruce forest are summarized in Table 3. In the aestival season, the highest density was found in *Apodemus flavicollis*. This species had also the highest biomass value (86.07), but this was not greatly different from the sympatric *Clethrionomys glareolus*, whose population density was 3.6 ind. ha^{-1} in that period. The density value for Sorex araneus was 2.0 ind. ha^{-1}.

In the analogous geobiocoenosis in the climax spruce forest on the slopes of Svrčník, *Sorex araneus* was dominant, having the highest density and biomass values (Table 4). In contrast, rather low values of these quantitative characteristics of taxocoenoses were found for the rodent species: *Clethrionomys glareolus* and *Apodemus flavicollis*. The values recorded for both during autumn were lower overall than the corresponding population parameters of these species observed in the aestival aspect.

In the summer (aestival) of 2001 we studied the structure of the beech-fir forest small mammal community, which comprised only two species (Table 5). The density of *Microtus subterraneus* was low in this community (1.2 ind. ha^{-1}). Higher values of density and biomass were observed for *Apodemus flavicollis*.

The beech-fir geobiocoenosis suffers from considerable summit phenomena impact in the Kľačianska Magura Mountains. Large-scale wind-throws contain much decomposing organic matter that provides optimum conditions *Clethrionomys galreolus*, allowing it to attain the highest density value we found for this species (Table 6). Here, *Apodemus flavicollis* and *Sorex araneus* reached lower values of both density and biomass.

Table 3. Selected population parameters of the small mammal (Insectivora, Rodentia) community in climax spruce forest (Sorbeto-Piceetum) in the Kľačianska Magura NNR, Western Carpathians, 11.–14. 07. 2000

Species	n	H	D	B	B_{kJ}
Clethrionomys glareolus	4	3.6	28.57	78.92	480.43
Apodemus flavicollis	8	4.2	57.14	86.07	577.42
Sorex araneus	2	2.0	14.29	14.31	91.81
Sum	14	9.8	100.00	179.31	1,149.66

n – sample size, H – density (ex./1 ha), D – dominance (%), B – fresh biomass (g/1 ha), B_{kJ} – energy value of biomass (kJ/1 ha)

Table 4. Selected population parameters of the small mammal (Insectivora, Rodentia) community in climax spruce forest (Sorbeto-Piceetum) in the Kľačianska Magura NNR, Western Carpathians, 26.–29. 09. 2000

Species	n	H	D	B	B_{kJ}
Clethrionomys glareolus	3	2.7	23.08	44.78	272.63
Apodemus flavicollis	2	1.0	15.38	15.60	104.67
Sorex araneus	8	7.8	61.54	63.45	406.99
Sum	13	11.6	100.00	123.84	784.28

Abbreviations: See Table 3.

Table 5. Selected population parameters of the small mammal (Insectivora, Rodentia) community in climax spruce forest (Sorbeto-Piceetum) in the Kľačianska Magura NNR, Western Carpathians, 26.–29. 06. 2001

Species	n	H	D	B	B_{kJ}
Pitymyx subterraneus	1	1.2	20.00	28.82	
Apodemus flavicollis	4	2.1	80.00	77.07	517.01
Sum	5	3.3	100.00	105.89	517.01

Abbreviations: See Table 3.

Table 6. Selected population parameters of the small mammal (Insectivora, Rodentia) community in beech-fir forest (Fageto-Abietum) in the Kľačianska Magura NNR, Western Carpathians, 23.–26. 10. 2001

Species	n	H	D	B	B_{kJ}
Clethrionomys glareolus	9	8.1	69.23	204.49	1244.83
Apodemus flavicollis	3	1.6	23.08	67.02	449.61
Sorex araneus	1	1.0	7.69	9.80	62.88
Sum	13	10.7	100.00	281.31	1757.33

Abbreviations: See Table 3.

Differences in preference to micro-habitat variables

In the study areas, we measured the height and the extent of cover of the various vegetation layers to produce the first testing set of habitat variables to determine the preferences of individual micro-mammal species populations. The arithmetical means of these variables are given in Table 7.

We concentrated on those three small mammal species where we had trapped more than 5 individuals (n > 5) in an attempt to find significant differences in the height and extent of cover of the vegetation layers.

The height of the tree layer (E_3) influences the light and moisture regimen of the forest interior. The insectivorous *Sorex araneus* preferred a lower mean height of micro-habitat than did the rodents *Clethrionomys glareolus* and *Apodemus flavicollis*, and this difference was also found to be statistically significant for these two species ($Z_{0.05(2),16,\ 11} = -2.7582$; P = 0.0058 and $Z_{0.05(2),15,\ 11} = -3.4612$; P = 0.0005). The differences in E_3 cover were found not to be statistically significant.

Clethrionomys glareolus and *Apodemus flavicollis* in all studied biocoenoses preferred microhabitats with identical values of height and cover E_2. Statistically significant differences in these variables were found only for *Clethrionomys glareolus* and *Sorex araneus*, to an equal extent for E_2 height ($Z_{0.05(2),15,\ 11} = -2.7243$; P = 0.0064), and E_2 cover ($Z_{0.05(2),15,\ 11} = -2.4695$; P = 0.0135).

Apodemus flavicollis preferred microhabitats with a significantly higher herbal synusia layer (E_1) and lower extent of cover than did *Clethrionomys glareolus*. The values of these variables in microhabitats occupied by *Apodemus flavicollis* were more or less identical to those observed at sites that held *Sorex araneus*. *Sorex araneus*, on the other hand, preferred microhabitats with significantly higher values of E_1 than *Clethrionomys glareolus*.

The insectivorous *Sorex araneus* in all habitats examined demonstrated a conspicuous affinity for micro-sites with higher cover of moss synusia (E_0) than did the rodents, and this difference was found statistically significant.

Conclusions

Over the two-year period of study we have collected a sample of altogether 45 individuals, belonging to four species (*Sorex araneus*, *Clethrionomys glareolus*, *Microtus subterraneus* and *Apodemus flavicollis*).

The conservation considerations of macro- and micro-habitats need to be taken into account findings such as the occurrence of a stabilised community of the insectivorous *Sorex araneus*, whose population density in the climax spruce forest community on a crystalline complex was higher (7.8 ind. ha^{-1}) than the corresponding values for the rodents *Clethrionomys glareolus* and *Apodemus flavicollis*. For the species *Clethrionomys glareolus* we have identified affinity for micro-biotopes with dead and decomposing organic matter (e.g. rotting stumps and wind-thrown trees, dry branches), where this species reached its highest density (8.1 ind. ha^{-1}).

Table 7. Mean values of the habitat variables in samples of the small mammals (NNR Kľačianska Magura, 2000–2001)

Species/Variable	hE_3	pE_3	hE_2	pE_2	hE_1	hE_1	hE_0	n
Apodemus flavicollis	145	288.0	1.2	8.80	0.6	59.1	8.7	17.0
Clethrionomys glareolus	15.1	25.9	1.8	9.5	0.5	69.0	5.3	16.0
Sorex araneus	9.2	21.4	0.3	3.00	0.6	705	14.2	11.0

h – height (m), p – cover (%), E_x – vegetation storey, n – interval collection

Unlike the rodents, *Sorex araneus* preferred microhabitats with a greater moss-layer cover, to an extent that was statistically significant.

The results from our research into the populations and ecological conditions of small mammal communities in the Kľačianska Magura NNR corroborate the hypothesis that well-preserved forest biotope communities that possess natural species compositions and spatial structures are stable. It is therefore important to ensure the continuing functioning of the cycles of growth and decline of natural forest communities, keeping to minimum direct human intervention.

For the preserved forest ecosystems of the NNR Kľačianska Magura we have found positive correlation between the moisture content of the occupied habitat and the spatial activity of the examined communities of small mammals. The influence of precipitation amount and of other climatic factors on fluctuations and species spectre of small mammals in the Orlické hory Mts. is discussed in Porkert (1989). This author suggests that the negative influence of vertical atmospheric precipitation is higher in more destroyed habitats and also depends on the species-specific thermoregulation demands and nutrient supply. The mountain forests, with their highly diversified structure, probably provide small mammals populations with more favourable conditions for the survival – also in the case of cyclonic meteorological situations or in the case of presence of horizontal precipitation (fog), and at mezzo- and microclimate levels they can mitigate the negative impact of unfavourable meteorological situations on the small mammals spatial activities.

Over the period of study, forest species of small rodents (*Clethrionomys glareolus*, *Apodemus flavicollis*) showed low values of density and biomass amount, which is typical for the latent phase of their population cycles. The population cycles of small rodents in forest habitats show significant periodical changes. Namely these fluctuations can be considered characteristic for genuine population cycles in conditions of Central Europe (Hansson and Henttonen, 1988). According to the same authors, the seasonal fluctuations in many rodent populations can be influenced by biotopes changes to such an extent that there can occur massive outbreaks or cycles with a proper specific type of regulation processes. For the population cycles identified in the mountain forests of the Krivánska Fatra mountains, in general 4–6 year period is typical. However, the oscillations in population cycles of *Clethrionomys glareolus* and *Apodemus flavicollis* can be remarkable even at two-year periods – as it was reported by Darola and Štollman (1981). While in the gradation year 1972, the authors caught 86% of the total number of the small mammals. In the following year, when the retrograde phase of the population cycles in the dominant species populations became to be evident, it was only 14% of the total number.

In the habitat of climax spruce forest in the territory of the NNR Kľačianska Magura, three species were found dominant in the examined vegetation layer of small mammals in the study period. The ecological group of rodents was represented in the sample by two species (*Clethrionomys glareolus* and *Apodemus flavicollis*), insectivorous species was only one (*Sorex araneus*). Almost identical species and ecological compositions of small mammals in climax spruce forests in the mountain massive Veľký Rozsutec was also reported by Darola and Štollmann (1981), who recorded, in addition, occurrence of the species *Muscardinus avellanarius*.

From the viewpoint of preference of the examined habitat variables in mountain forest biotopes, we have identified significant differences in the values of abundance and cover of vegetation tiers between the omnivorous *Clethrionomys glareolus* and insectivorous *Sorex araneus*, with higher values of abundance and cover in the frame of micro-habitats preferred by the species *Sorex araneus*. The highest abundance of the last species was found at sites with massive growth (i.e. higher vegetation cover) of pestilence-wort, also in the case of the study on micro-mammals performed in the NNR Rozsutec, by the two already cited authors (Štollmann and Darola, 1981).

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Štruktúra drobných zemných cicavcov (Insectivora, Rodentia) v Národnej prírodnej rezervácii Kľačianska Magura (Malá Fatra, Západné Karpaty)

Súhrn

Výskum spoločenstiev drobných zemných cicavcov sa uskutočnil v rokoch 2001–2002 na území NPR Kľačianska Magura, nachádzajúcej sa v NP Malá Fatra. Kvadrátovou metódou odchytu boli v dvoch odlišných typoch lesných geobiocenóz zistené 4 druhy (*Clethrionomys glareolus*, *Microtus subterraneus*, *Apodemus flavicollis* a *Sorex araneus*). Najvyššia denzita (8,1 ex. ha^{-1}) bola v období výskumu zaznamenaná u druhu *Clethrionomys glareolus* v spoločenstve bukovej jedliny (Fageto-Abietum). V jarabinovej smrečine (Sorbeto-Piceetum) bol dominantným členom synúzie drobných cicavcov druh *Sorex araneus* s denzitou 7,8 ex. ha^{-1}.

Testovanie hypotézy možného vplyvu vlhkosti prostredia na aktivitu, resp. chytavosť drobných cicavcov, naznačuje pravdepodobnú pozitívnu koreláciu medzi ich priestorovou aktivitou a vlhkosťou prostredia ($P < 0{,}01$). Zníženie vlhkosti prostredia má na aktivitu drobných cicavcov pravdepodobne opačný efekt.

Na základe testovania rozdielov v preferencii habitatových premenných boli zistené medzi druhovými populáciami drobných cicavcov viaceré diferencie. Drobné hlodavce druhov *Clethrionomys glareolus* a *Apodemus flavicollis* uprednostňovali mikrohabitaty s vyššou priemernou výškou stromového poschodia ako druh *Sorex araneus* ($Z_{0,05(2),16,\,11} = -2{,}7582$; $P = 0{,}0058$ a $Z_{0,05(2),15,\,11} = -3{,}4612$; $P = 0{,}0005$).

Hlodavce (*C. glareolus* a *A. flavicollis*) preferovali v skúmaných biocenózach mikrohabitaty s rovnakými hodnotami premenných výšky a pokryvnosti E_2. Štatisticky významne sa odlišovali uvedené premenné iba u *C. glareolus* a *Sorex araneus*, rovnako v prípade výšky E_2 ($Z_{0,05(2),15,\,11} = -2{,}7243$; $P = 0{,}0064$), ako aj pokryvnosti E_2 ($Z_{0,05(2),15,\,11} = -2{,}4695$; $P = 0{,}0135$).

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Tree alleys in selected localities of the Nitra town

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Abstract

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Tree alleys are trees planted in rows. They can be situated along streets or in open landscape. In housing estates, tree alleys are planted between the blocks. The result is a closed space of greenery with pedestrian ways bordered with tree lanes. In most cases, tree lanes are planted with domestic, naturally occurring woody plants, but also with introduced species, cultural species and for-this-purpose cultivated cultivars. Dominant are broadleaved species, conifers are used rarely. The extent of greenery puts the town of Nitra to a leading position in Slovakia. There are in average 25 m^2 of greenery per one citizen. However, this value is somewhat blurred because the quality is very different and the distribution is not proportional. The species composition in the examined territory is not very various. There are dominant domestic woody plants: *Tilia cordata* Mill., *Acer platanoides* L., *Acer pseudoplatanus* L., *Fraxinus excelsior* L., *Quercus cerris* L. Some introduced species are present also: *Gleditsia triacanthos* L., *Platanus occidentalis* L., *Celtis occidentalis* L., from cultivars with small crown diameter are represented by: *Acer platanoides* cv. Globosum, *Tilia americana* cv. Nova L.

Key words

tree alleys, street lanes, selection of suitable woody plants

Introduction

Tree alleys are trees planted in rows. They can be situated along streets or in open landscape. In housing estates, tree alleys are planted between the blocks. The result is a closed space of greenery with pedestrian ways bordered with tree lanes.

The most discussed issue in the species composition of urban greenery is the assortment of woody plants for planting in streets. Specific conditions of urban streets are a factor limiting the choice of woody plant species for tree alleys. In nowadays the greenery is planted in borders separating the pavement from the road and in borders separating the opposite lanes of the road. Most often are these borders only seeded with grass, and pedestrians very often devastate them. Consequently, planting with dense shrubs is getting more preferred. The shrubs require less upkeep and they prevent crossing the road apart from the labelled passages. Dominant become characters of external look – height of tree, width, shape and density of crown, texture, seasonal effects (flowering, fruits, leaf coloration) and also internal genetic properties of the woody plants (ecological amplitude, resistance against high temperatures, drought), resistance against noxious influences (air pollution, salts), low demands on soil quality, tolerance of compaction, regeneration ability of damaged aboveground and underground organs, longevity, etc.

The specialists are showing increasing interest in selection of suitable woody plants for urban streets – proportionally to the worsening conditions influencing the health status and existence of plants in this environment. The present state of the urban environment has been reflected in the shift towards plants with lower demands, tolerating extreme conditions. There are mostly domestic woody plants, occurring in the nature. On the other hand, also introduced species and cultivars cultivated for this purpose are of increasing importance, also.

In most cases, tree lanes are planted with domestic, naturally occurring woody plants, but also with introduced species, cultural species and for-this-purpose cultivated cultivars. Dominant are broadleaved species, conifers are only used rarely.

After the planting a trimming is necessary for all broadleaved trees planted without the root ball. All the shoots in crown must be shortened by 1/3–2/3 of their length. In case of spring planting and in case of damaged root system, it is necessary to remove somewhat longer parts. The bud directed outside the crown is shortened. The cut is situated immediately under the bud, only in trees with large pith by about 1 cm higher. Already the first trimming must consider the characteristic shape of crown that is why the terminal shoot should be always somewhat longer. It always holds: the weaker tree, the stronger trimming and vice versa.

The roots are supplied by water by means of an irrigation system consisting of a 10 m long drainage PVC tube closed with an aluminium lock. The tube is placed on a layer of gravel for better aeration and higher water accumulation. This equipment is built at the mid-level of the root system.

PEJCHAL (1995) notes that the irrigation systems are especially important in town centres. The disadvantage of this system is that the perforated tube is gradually choked with deposits and removed from function.

Trees can obtain nutrients and substances necessary for their healthy growth and development by natural way, through leaf mineralisation, or from mineral fertilizers added to the soil. The amount of necessary nutrients depends on the stem diameter.

Material and methods

The amount of its greenery puts the town of Nitra in a leading position in Slovakia. There are in average 25 m^2 of greenery per one citizen. However, this value is somewhat blurred because the quality is very different and the distribution is not proportional.

The surface area and distribution of greenery over the town are determined with its urbane structure and type of building-up. The town is differentiated into several zones – residential and industrial complexes; however, from the greenery viewpoint, the accent has been put on zones promoting differentiated greenery development. Besides this influence, the state and quality of greenery in residential complexes is a result of the without-precedence approach to maintain creation and protection of greenery – primarily the way of management.

The complex of Old Town consists of the historical core dense built-up with low houses. The area of greenery represents only 13% of the total. The housing estate Chrenová has 70% of its area covered by greenery. The housing estates Klokočina and Diely have a dense, vertical-oriented architecture, with only 30% of the area covered by greenery (BALKO, 1997).

We evaluated tree lanes in eleven streets in the urban parts Klokočina, Diely, Chrenová. In the housing estates Diely and Klokočina we focussed on streets in which full-grown trees were planted: Kmeťova, Partizánska, Mikovíniho, Dolnočermánska, Hviezdoslavova and Pražská. In the housing estate Chrenová we evaluated the tree lane in the street Výstavná. We have analyzed of 184 trees in total.

Intensive urbanisation and industrialisation initiate considerable changes in the environment. In large cities – having character of a metropolis or mega-polis, worsened quality of the life environment with dominance of technical artificial elements is evident.

The surface area of greenery in the town of Nitra is influenced by the urbane structure and type of town architecture, also. The town has very differentiated greenery, however, not to such extent as it could actively influence the life environment and improve substantially its quality. The value of greenery depends on a range of factors. Apart from their differentiated functions, the greenery can survive in difficult vegetation and spatial conditions. In order to decrease of negative influences and partial improvement of this impaired environment, it is inevitable to reevaluate the existing system of greenery and consequently to penetrate this man-made environment with elements of green vegetation, primarily trees.

Evaluation of the tree lanes planted in Nitra has driven us to the conclusion that the problem of alley planting is a very complex one, in terms of both technology and biology, and that it needs more attention.

We have recognised the following factors as the main causes of inadequate health state of tree alleys in the streets of town:

1. Unsuitable species and their inappropriate maintenance.
2. Considerable soil moisture deficit, worsening environmental conditions.
3. Increasing air pollution, soil and water contamination by airborne pollutants (traffic).
4. Damage of woody plants in alleys caused by building, reconstruction and maintenance of aboveground and underground communications and engineering structures.
5. Extending bitumen communications to close proximity of trees causing considerable limitation of water and air supply.
6. Penetration of most animal pests into urban greenery – in plant material from nurseries, from neighbouring forests, orchards, agricultural land, etc.
7. Damage of woody plants by microscopic fungi, mainly wood-decaying, attacking the woody plants through untreated wounds created during the trimming and shaping of crowns as a result of lack of water (asphalt and concrete plots frequently reaching the stem base).

Results and discussion

The tree alleys in several town districts, in the residential areas Diely, Klokočina and Chrenová were evaluated. We were focussing on tree alleys planted in 1992–2001. We examined the species composition, age structure, growth parameters, health state and landscaping value of the individual trees. Analyzed trees are young ones in their 1-st and 2-nd growth phases, and they are supposed to create, in a few years, one of the core frameworks of the town greenery. We have found that the stands on examined plots are rather homogeneous, most woody plants are vital – reaching a landscaping value of 3.

The architecture of housing estates Diely and Klokočina is very dense and vertical-oriented, the greenery area represents only 30% of the total. They are situated in worse conditions in comparison with the housing estate Chrenová, because they are exposed against the prevailing winds. Chrenová is situated on more favourable territory, both in terms of climate and soil, with the greenery area representing up to 70%. The woody plants for Chrenová were chosen primarily from the commercial viewpoint, on the other hand, it is necessary to say that there were also considered: ecological similarity, degree of resistance and the degree of load by airborne pollutants. The species selection was oriented towards those having lower requirements, tolerant, resistant to drought, polluted air and overall extreme character of the site.

Based on the evaluation of street alleys in the town we present a list of factors contributing to improvement of the environment:

1. The important fact is that for planting have been used full grown trees. Their advantage is in faster adaptation to the environment and immediate aesthetic effect (e.g. *Tilia cordata* Mill. in the street Kmeťova).
2. Another profit is that planted cultivars have had spherical, hemispherical and narrow crowns, with small crown diameter and small fruits. They are especially suitable for narrow streets (*Acer platanoides* cv. Globosum in the Trieda P. O. Hviezdoslava). However, the town can sometimes be too narrow, where the trees are reaching big dimensions and suffering from lack of space for their growth and development. They have been turned to an obstacle in view, they endanger neighbouring buildings, and the fallen fruits are bothering vehicles. In such cases, it is inevitable to intervene with cutting or trimming, and to clear – manually or mechanically, the concerned communications (e.g. *Gleditsia triacanthos* Linn in the Partizánska street is causing problems with fallen fruits each year). In this case, it is suitable to prefer species and cultivars with small crowns and woody plants with smaller fruits. The reduced expenses should be used for acquiring new plants for establishment of new alleys.
3. For the optimum growth and progress of trees, it is necessary to provide them with suitable conditions. Together with using the full-grown trees, it has been started to use perforated materials securing improvement of moisture conditions, PVC protectors protecting stems against mechanical damage, woody poles securing stability, and grass turf ensuring air supply to the root systems.

The species composition in the examined territory is not very variable. There are dominant domestic woody plants: *Tilia cordata* Mill., *Acer platanoides* L., *Acer pseudoplatanus* L., *Fraxinus excelsior* L., *Quercus cerris* L. Some introduced species are present also : *Gleditsia triacanthos* L., *Platanus occidentalis* L., *Celtis occidentalis* L., as well as cultivars with small crown diameter: *Acer platanoides* cv. Globosum, *Tilia americana* cv. Nova L.

Based on our results of tree alleys assessment in the streets of Nitra, we recommend to proceed with planting of: *Acer platanoides*, *Acer platanoides* cv. Globosum, *Acer pseudoplatanus* L., *Celtis occidentalis* L., *Fraxinus excelsior* L., *Gleditsia triacanthos* L., *Tilia americana* L., *Tilia cordata* Mill.

Furher, we suppose that other proposed woody plants resistant towards inadequate conditions in the urban environment should be certified in near future: *Acer pseudoplatanus* cv. Erectum L., *Fraxinus excelsior* cv. Globosum, *Prunus avium* L., *Prunus serrulata* cv. Hisakura, *Robinia pseudoacacia* cv. Pyramidalis, *Robinia pseudoacacia* cv. Umbraculifera, *Sophora japonica* L., *Sorbus aria* cv. Magnifica, *Sorbus aucuparia* L., *Sorbus intermedia* Ehrh, *Tilia x europaea* L., *Tilia x euchlora* Koch, etc. These species are suitable for the climate of Nitra. They are resistant against air pollution, sprinkling salts, drought and they are also suitable for their proportion.

Vreštiak (1997) submits the following list of taxons suitable for street alleys. The species are differentiated according the width of street:

1. For extremely narrow streets are recommended trees with regular crowns

– Spherical, hemispherical:
Acer campestre cv. Compacta, *Acer platanoides* cv. Globosum, *Catalpa bignonioi* cv. Nana, *Crataegus laevigata* cv. Paul Scarlet, *Fraxinus excelior* cv. Nana, *Fraxinus ornus*, *Morus alba* cv. Nana, *Prunus cerassifera* cv. Atropurpurea, *Prunus fruticosa*, *Robinia hispida*, *Robinia pseudoacacia* cv. Bessoniana, *Robinia pseudoacacia* cv. Umbraculifera, *Ulmus carpinifolia* cv. Umbraculifera.

– Narrow and fusiform:
Acer platanoides cv. Columnare, *Acer platanoides* cv. Olmstedt, *Acer pseudoplatanus* cv. Erectum, *Acer rubrum* cv. Armstrong, *Betula verrucosa* cv. Fastigiata, *Carpinus betulus* cv. Fastigiata, *Crataegus* monogyna cv. Stricta, *Pyrus alleriana* cv. Chanticleer, *Quercus robur* cv. Fastigiata, *Robinia*

pseudoacacia cv. Pyramidalis, S*orbus aucuparia* cv. *Fastigiata, Sorbus x thuringiaca* cv. Fastigiata, *Tilia platyphylla* cv. Orebro.

2. For narrow and medium wide streets are recommended trees with compact crowns

– Narrow and conical:
Alnus cordata, *Carpinus betulus* cv. Columnaris, *Crataegus x prunifolia* cv. Splendens, *Fraxinus angustifolia* cv. Roywood, *Ginkgo biloba* cv. Fastigiata, *Platanus x acerifoliacv*. Dortmund, *Robinia pseudoacacia* cv. Monophylla, *Sorbus aria* cv. Magnifica.

3. For medium wide streets are recommended trees with mostly compact crowns

– Narrow, oviform:
Acer campestre cv. Elsrijk, *Acer platanoides* cv. Cleveland, *Acer platanoides* cv. Farlake´s Green, *Acer platanoides* cv. Reitenbachii, *Acer platanoides* cv. Reitenbachii, *Acer platanoides* cv. Swedleri, *Aesculus x carnea* cv. Briotii, *Aesculus hippocastanum* cv. Baumanii, *Catalpa speciosa*, *Tilia cordata* cv. Erecta.

– Conical and pyramidal:
Acer platanoides cv. Deborah, *Acer pseudoplatanus* cv. Negenia, *Acer sachcarinum* cv. Pyramidalis, *Acer hippocastanum* cv. Pyramidalis, *Betula verrucosa*, *Corylus colurna*, *Fraxinus ornus* cv. Rotterdam, *Gleditsia triacanthos* cv. Skyline, *Liquidambar styraciflua*, *Platanus x acerifolia* cv. Pyramidalis, *Tilia cordata* cv. Greenspire, *Tilia x flavescens* cv. Glenleen, *Ulmus carpinifolia* cv. Sarniensis, *Ulmus x hollandica* cv. Groeneveld, *Ulmus x hollandica* cv. Pantija.

4. For middle medium and wide streets are suitable higher trees (about 20 m)

– With regular, more compact, oviform crowns:
Acer platanoides cv. Fassen´s Black, *Acer pseudoplatanus* cv. Rotterdam, *Fraxinus excelsior* cv. Althena, *Fraxinus excelsior* cv. Westhof´s Gloire, *Robinia pseudoacacia* cv. Casque Rouge, *Tilia x euchlora*, *Tilia platyphylla* cv. Rubra, *Tilia tomentosa*, *Ulmus x hollandica* cv. Commelin.

– With oval (almost spherical), thinner, medium-sized crowns:
Acer campestre cv. Elsrjk, *Acer platanoides* cv. Emerald Queen, *Acer platanoides* cv. Summershad, *Ailianthus altissima* cv. Erithrocarpa, *Celtis occidentalis*, *Fraxinus excelsior* cv. Diversicifolia, *Fraxinus excelsior* cv. Jaspidea, *Phellodendron amurens*e, *Prunus padus* cv. Watereri, *Sophora japonica* cv. Regent.

5. High trees (over 20 m) with wide oval, irregular crowns in maturity. They are suitable for wide streets and boulevards: *Gleditsia triacanthos* cv. Inermis, *Fraxinus excelsior* cv. Atlas, *Juglans regia*, *Quercus cocciniea*, *Quercus robur, Quercus rubra*.

The selection of suitable woody plants must always be carried out in accordance with the specific landscape character and treatment, the site and local conditions (Machovec et al., 2000).

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Uličné stromoradia na vybraných lokalitách mesta Nitra

Súhrn

Stromoradia sú radové výsadby stromov. Z hľadiska ich uplatnenia sa rozlišujú uličné stromoradia a krajinné stromoradia. Na sídliskách miest sa uličné stromoradia vyskytujú v medziblokových priestoroch. Vznikajú tak uzatvorené priestory, prepojené spojovacími chodníkmi, lemované stromoradím.

Vo väčšine prípadov sa do uličných stromoradí vysádzajú domáce, prirodzene sa vyskytujúce druhy drevín, ale aj introdukované druhy drevín, kultúrne druhy a kultivary a kultivary špeciálne vyšľachtené na tieto účely. Uplatňujú sa hlavne listnáče. Ihličnany sa tu využívajú len vo výnimočných situáciách.

Z hľadiska množstva zelene je mesto Nitra na poprednom mieste na Slovensku. Na jedného obyvateľa pripadá v priemere 25 m^2 verejnej zelene. Tento údaj však skresľuje skutočný stav, lebo kvalita je rôzna a jej rozloženie je proporciálne.

Druhová skladba na sledovaných územiach nie je veľmi pestrá. Prevládajú domáce druhy drevín, ako: *Tilia cordata* Mill., *Acer platanoides* L., *Acer pseudoplatanus* L., *Fraxinus excelsior* L., *Quercus cerris* L. Z introdukovaných druhov drevín boli vysadené: *Gleditsia triacanthos* L., *Platanus occidentalis* L., *Celius oxcidentalis* L. Z kultivarov s malým priemerom koruny, ktoré sú z priestorového hľadiska najvhodnejšie, sú použité v uličných stromoradiach: *Acer platanoides* Globosum, *Tilia americana* Nova L.

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Dynamics of inorganic forms of nitrogen in soil of the Nature Reserve Žitavský luh

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Abstract

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The soils of the Nature Reserve Žitavský luh were sampled over the years 2003 and 2004, and the dynamics of their inorganic nitrogen forms was evaluated. Changes in inorganic nitrogen forms were observed in connection with several variables as the sampling depth, soil moisture content, soil pH value and others. The higher contents of both nitrogen forms – nitrate and ammonium nitrogen were determined in the first year (2003). The contents of nitrate nitrogen in this year ranged between 1.18–9.76 mg kg^{-1} with the average of 3.62 mg kg^{-1} of soil. The average content of ammonium nitrogen was 5.78 mg kg^{-1}. The lower contents of both nitrogen forms were determined in the second year (2004). The nitrate nitrogen achieved an average content of 2.42 mg kg^{-1} (0.85–8.57 mg kg^{-1}) and the average content of ammonium nitrogen was 4.44 mg kg^{-1} (3.24–6.85 mg kg^{-1}). From all the statistical indicators, the year and sampling depth had statistically high significant effects, and the sampling date had a statistically significant effect on the contents of nitrate nitrogen. The year and to a certain extent also the sampling site had statistically high significant effects on the contents of ammonium nitrogen. The depth had a statistically significant effect on the contents of ammonium nitrogen. Statistically significant positive correlation was only found between the nitrate and ammonium nitrogen. No correlation was found between the nitrate nitrogen and moisture content and pH value of soil. The same was situation concerning the examined correlations in case of ammonium nitrogen. The presented work was accomplished within the grant project VEGA 1/0196/03.

Key words

nitrate nitrogen, ammonium nitrogen, wetland, soil

Introduction

Nitrogen is a nutrient which induces both positive and negative approaches inside and also outside the scientific community.

Characteristic property of soil inorganic nitrogen is its quantitative and qualitative seasonal variability reflecting natural events and human activities (Pačuta, 1989).

Changes in the content, forms and dynamics of inorganic nitrogen in the soil depend on the quantity of the applied nitrogen (agriculture) and soil properties influencing the microbial process (Paul and Clark, 1996; Ivanič and Pačuta, 1988; Bielek, 1984, 1998; Demo, 1990; Ondrišík et al., 1998).

Production and ecological functions of nitrogen in the soil are especially connected with inorganic nitrogen. The most important source of soil nitrogen is the mineralization process (ammonification) followed by an eventual biological transformation (nitrification). Nitrogen also enters the soil from the atmosphere (deposition, biological fixation) (Števlíková et al., 2001).

For all this reasons, it is necessary to recognize behaviour of nitrogen also in soils in areas undisturbed by human activities, which is also the case of the Nature Reserve Žitavský luh.

Material and methods

This experiment was pursued in the Nature Reserve Žitavský luh. Detailed description of this area can be found in Beňačková and Noskovič (2004).

Contents of inorganic nitrogen forms ($N\text{-}NO_3^-$ and $N\text{-}NH_4^+$) were determined in soil samples taken from six sampling sites located along the boundary of the Nature Reserve. The soil was sampled from two depths (0.0–0.3 m and 0.3–0.6 m). In these soil samples we determined the contents of inorganic nitrogen forms in 1% solution of potassium sulphate (K_2SO_4), using the following methods:

° $N\text{-}NO_3^-$-colour method by acid phenoldihydrosulphide,
° $N\text{-}NH_4^+$-colour method by Nessler test solution.

The moisture of the soil was determined by gravimetric method (in percentage by weight). For evaluation of pH value, the 1 mol dm^{-3} solution of potassium chloride was used.

The obtained contents of inorganic nitrogen forms were evaluated in tables, figures and statistically. From the statistic methods, we used analyses of variance and Sperman rank correlation for determination of bilateral correlation between the chosen evaluated factors (Program Statgraphics Plus 5.0.1).

Results and discussion

The average contents of ammonium and nitrate nitrogen, pH values and soil moisture values are summarized in Tables 1, 2, 3.

Over the whole research period was the average content of ammonium nitrogen ($N\text{-}NH_4^+$) 5.11 mg kg^{-1} with standard deviation of 0.92065 mg kg^{-1}. Minimum content was 3.24 mg kg^{-1} and maximum 7.04 mg kg^{-1} (Table 4). Coefficient of variation of the determined ammonium nitrogen contents was for all the research period 18.0%.

From the monitored variables, statistically high significant effects on the contents of ammonium nitrogen in soil were found for the year and to some extent also for the sampling site. Statistically high significant differences were determined between the sampling sites 1 and 3, 1 and 5, and also between 1 and 6. Statistically significant effect ($\alpha = 0.01$) on the contents of ammonium nitrogen was found for the depth and sampling site.

Summarizing, we can say that higher contents of $N\text{-}NH_4^+$ were observed in the year 2003 (5.78 mg kg^{-1}) (Table 5). In the first year (2003), the dynamics of ammonium nitrogen at both examined soil depths was steady, the average content at the first depth was 5.89 mg kg^{-1} whereas at the second depth it was 5.68 mg kg^{-1}. The steady dynamics of $N\text{-}NH_4^+$ in the year 2003 at the two depths (0.0–0.3 m and 0.3–0.6 m) is shown in Fig. 1 and 2. Similar results were obtained by Ložek et al. (1991) and Ondrišík (1998).

From these figures (1 and 2) it follows, that in the second year (2004) the dynamics of ammonium nitrogen was fairly higher. Primarily, on the first sampling date of the year 2004, marked decrease of ammonium nitrogen contents was found at the both depths. Exceptions were the second and fifth sampling sites, the first depth. The average content of $N\text{-}NH_4^+$ in the year 2004 was in the first depth 4.58 mg kg^{-1}, and in the second depth somewhat lower: 4.31 mg kg^{-1}. These contents of ammonium nitrogen correspond to the investigations of Gábriš et al (1995) and Kopčanová (1987). According to these authors, the contents and changes in soil ammonium nitrogen are less expressive in comparison with nitrate nitrogen. They also detected $N\text{-}NH_4^+$ content in soil ranging from 0.37 mg kg^{-1} to 13.73 mg kg^{-1}. Also other authors (Števlíková and Kopčanová, 1996; Ondrišík and Černý, 2002) indicated a lower dynamics in $N\text{-}NH_4^+$ compared to nitrate nitrogen. Ložek et al (1991) reported that concerning the dynamic of ammonium nitrogen, the strongest influence was found for year (81–86%), followed by fertilization (11.5–17.9%) and sampling date (2–2.5%).

The dynamics of nitrate nitrogen was different than the dynamics of ammonium nitrogen. The average content of nitrate nitrogen over the whole research period (2003 and 2004) was 3.02 ± 2.09672 mg kg^{-1}. The interval in both years was the same 0.85–9.76 mg kg^{-1} (Table 4). In the case of nitrate nitrogen we determined higher coefficient of variance (68.53%) than for ammonium nitrogen.

In case of nitrate nitrogen contents in the soil, from the monitored variables, significant level $\alpha = 0.01$ (99%) and statistically high significant effect were identified for the year and depth, and to some extent also for the sampling date. At the significance level $\alpha = 0.05$ (95%), a statistically significant effect on the contents of $N\text{-}NO_3^-$ had only the sampling site. Differences were determined between the sampling sites 1 and 3, 2 and 3. Similarly like in ammonium nitrogen, the average contents of nitrate nitrogen were higher in the year 2003 (3.62 mg kg^{-1}) (Table 5) compared to the year 2004 (2.42 mg kg^{-1}).

The most marked dynamics of nitrate nitrogen was determined at the first depth (0.0–0.3 m) in the year 2003, where the average content of nitrate nitrogen was 4.40 mg kg^{-1}1. It is illustrated in Fig. 3. Beginning with the first sampling date (April) the nitrate nitrogen contents increased until the second sampling date (August), reflecting suitable temperature and moisture conditions in this period. The same nitrates dynamics was also observed by Prugar and Prugarová (1985) and Bízik et al. (1996). These authors show that the activities of nitrifying bacteria and contents of nitrate nitrogen increase in spring season (April, May) in consequence of increasing soil temperatures (spring maximum). Then the contents of nitrates decrease, exploitated by plants and also reduced by nitrification in the summer season, and increase again in consequence of suitable soil moisture conditions in autumn (September). The content of nitrate nitrogen in the soil is lower again before the winter season.

The second part of Fig. 3 shows the dynamics in the year 2004. The average content was 2.98 mg kg^{-1} and dynamics of nitrate nitrogen was not such distinct as in the previous year, although in all the sampling sites we observed increasing contents from April to July followed by a decrease in August. Slight increase of contents observed on the second sampling date of 2004 could have been influenced by the earlier sampling date (by about one month compared to the year 2003). The temperature and moisture conditions in period for nitrification were not favourable in this year and, consequently, lower contents of N-NO_3^- were determined. The fourth sampling site had a different dynamics. This sampling site is occasionally inundated which can be reflected on lower contents of nitrate nitrogen. According to Úlehlová (1989) and Bielek (1998), the structure, physical status and water regimen of the soil affect the intensity of its nitrification process. Unstructured and also very moist soil had not suitable conditions for nitrification process.

In the depth of 0.3–0.6 m was determined the same dynamics in both years, especially in the sampling sites 3, 5 and 6. Almost steady contents of nitrate nitrogen in this depth were determined in the sampling sites 1, 2 and 4 (Table 5, Fig. 4). The average content of N-NO_3^- in this depth was 2.84 mg kg^{-1} 1 in the year 2003 and 1.85 mg kg^{-1} in the year 2004. These lower contents in comparison with ammonium nitrogen could have been caused by lower intensity of nitrification process in consequence of lower contents of oxygen in the soil, but also possibly through exploitation by plants.

The evaluation through Spearman rank correlations revealed statistically significant positive relation between nitrate and ammonium nitrogen, with coefficient of variation R = 0.5429, indicating intensive mineralization and nitrification processes. Correlation between N-NO_3^- and N-NH_4^+ is illustrated in Fig. 5. No correlation could be found between the nitrate nitrogen contents and pH values and soil moisture content. The same absence of correlation between these variables was found for the ammonium nitrogen.

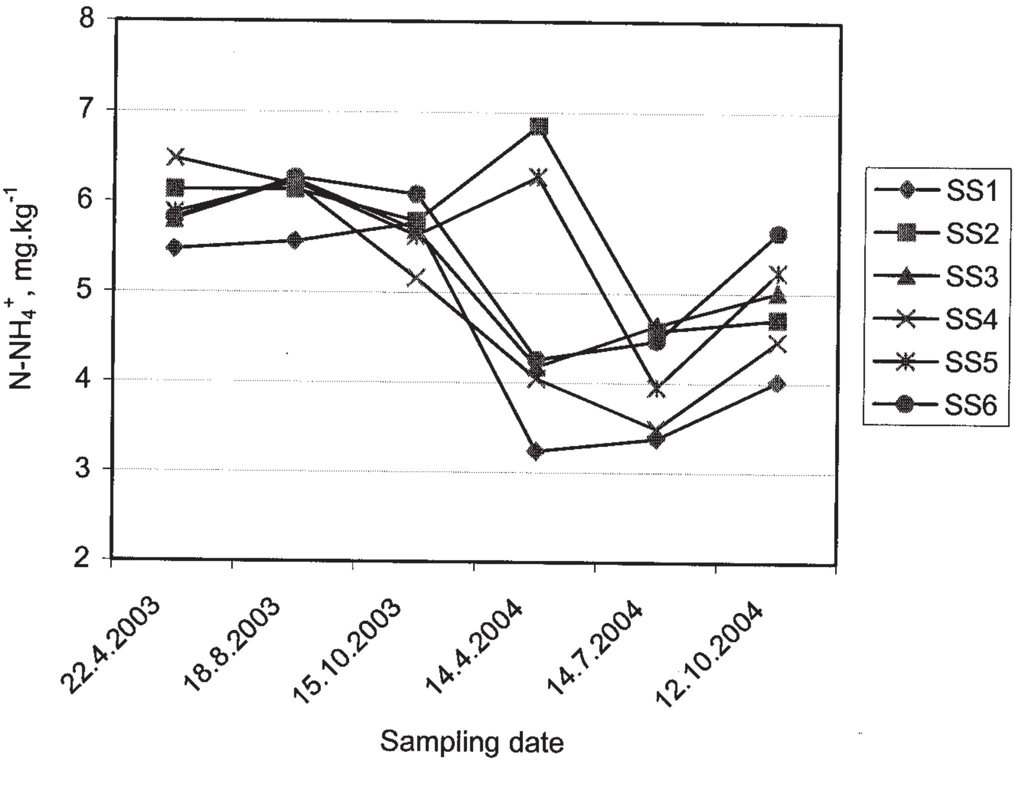

Fig. 1. Dynamics of ammonium nitrogen in depth of 0.0–0.3 m over the whole research period

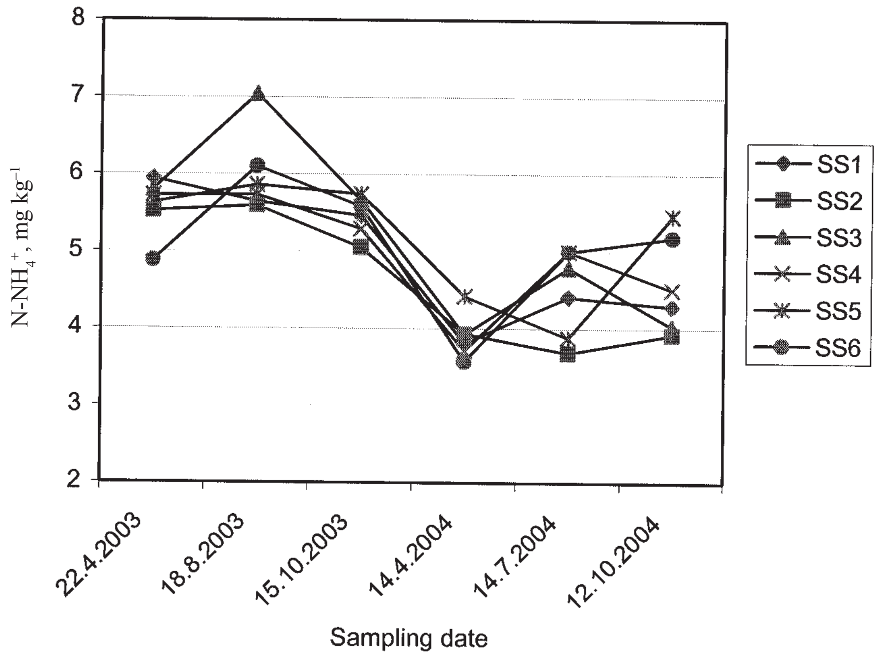

Fig. 2. Dynamics of ammonium nitrogen in depth of 0.3–0.6 m over the whole research period

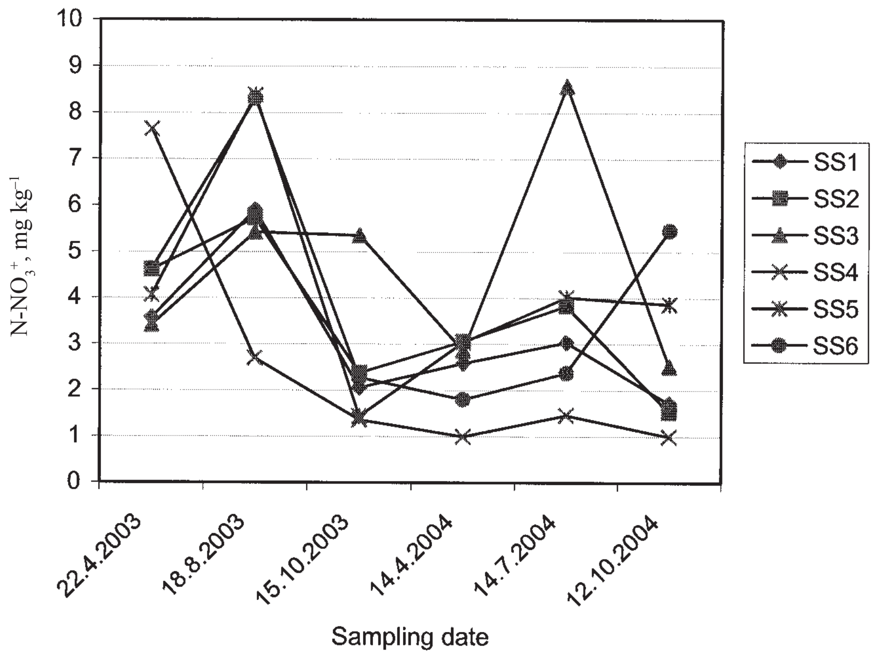

Fig. 3. Dynamics of nitrate nitrogen in depth of 0.0–0.3 m over the whole research period

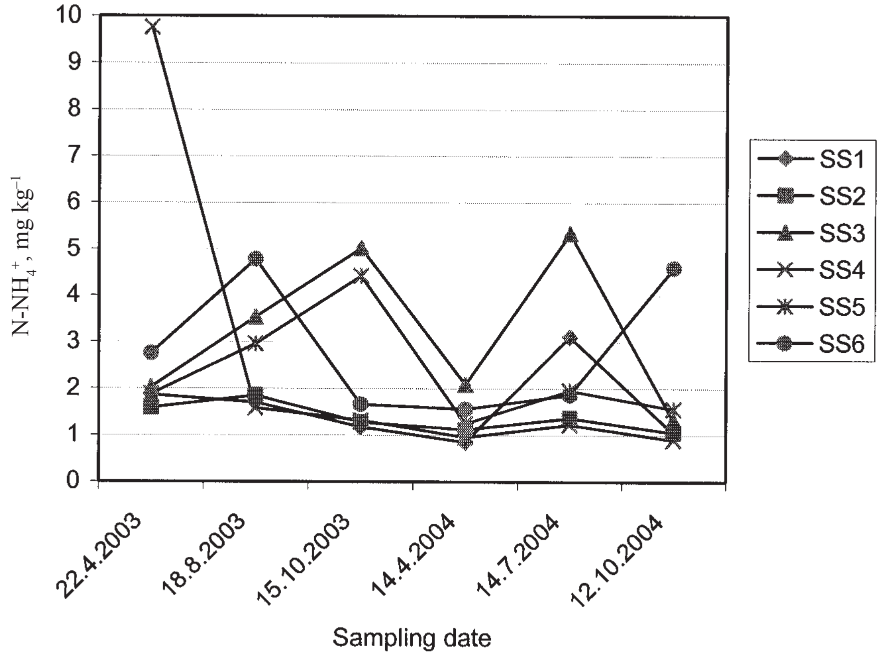

Fig. 4. Dynamics of nitrate nitrogen in depth of 0.3–0.6 m over the whole research period

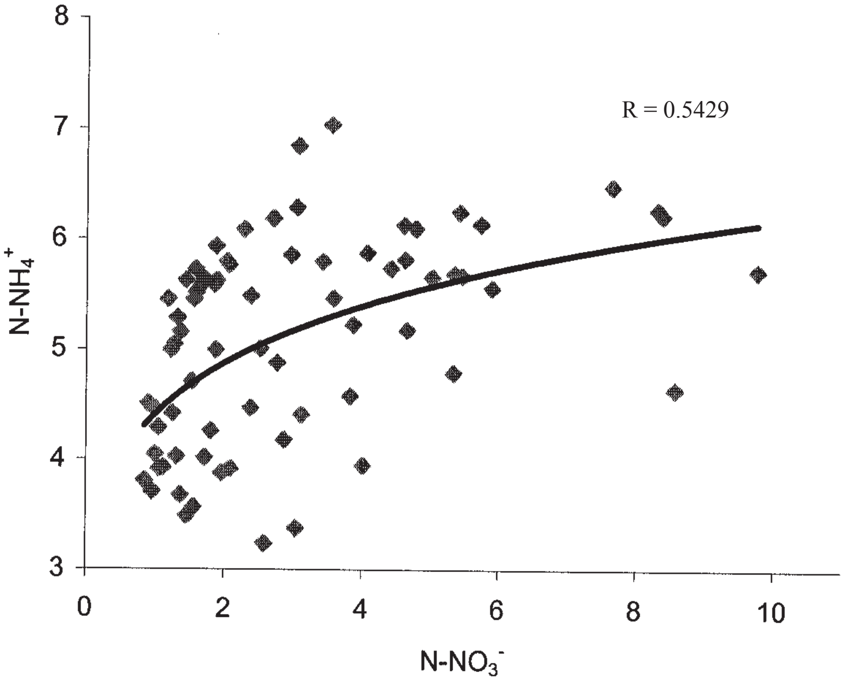

Fig. 5. Correlation effect between nitrate and ammonium nitrogen over the whole research period

Table 1. Contents of inorganic nitrogen forms in the soil (mg kg^{-1})

Sampling site	Depth	Sampling date 22. 4. 2003			18. 8. 2003			15. 10. 2003		
		Form of nitrogen								
		$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}
1	0.0–0.3	5.47	3.58	9.05	5.56	5.90	11.46	5.77	2.06	7.83
	0.3–0.6	5.94	1.87	7.81	5.64	1.70	7.34	5.46	1.18	6.64
2	0.0–0.3	6.13	4.61	10.74	6.14	5.73	11.87	5.79	2.38	8.17
	0.3–0.6	5.52	1.59	7.11	5.59	1.85	7.44	5.05	1.28	6.33
3	0.0–0.3	5.80	3.42	9.22	6.25	5.42	11.67	5.69	5.35	11.04
	0.3–0.6	5.80	2.03	7.83	7.04	3.54	10.58	5.66	5.02	10.68
4	0.0–0.3	6.48	7.65	14.13	6.19	2.70	8.89	5.16	1.36	6.52
	0.3–0.6	5.72	9.76	15.48	5.73	1.58	7.31	5.29	1.32	6.61
5	0.0–0.3	5.88	4.07	9.45	6.22	8.38	14.60	5.63	1.44	7.07
	0.3–0.6	5.63	1.88	7.51	5.86	2.96	8.82	5.74	4.42	10.16
6	0.0–0.3	5.82	4.63	10.45	6.27	8.31	14.58	6.09	2.28	8.37
	0.3–0.6	4.88	2.76	7.64	6.10	4.78	10.88	5.58	1.66	7.24

Table 1. Continued

Sampling site	Depth	Sampling date 14. 4. 2004			14. 7. 2004			12. 10. 2004		
		Form of nitrogen								
		$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{an}
1	0.0–0.3	3.24	2.58	5.82	3.38	3.04	6.42	4.02	1.72	5.74
	0.3–0.6	3.81	0.85	4.66	4.41	3.11	7.52	4.29	1.05	5.34
2	0.0–0.3	6.85	3.06	9.91	4.58	3.83	8.41	4.71	1.53	6.24
	0.3–0.6	3.93	1.12	5.05	3.68	1.37	5.05	3.92	1.06	4.98
3	0.0–0.3	4.18	2.86	7.04	4.64	8.57	13.21	5.01	2.52	7.53
	0.3–0.6	3.92	2.09	6.01	4.79	5.34	10.13	4.03	1.31	5.34
4	0.0–0.3	4.05	1.00	5.05	3.49	1.46	4.95	4.46	1.00	5.46
	0.3–0.6	3.71	0.96	4.67	5.00	1.23	6.23	4.51	0.90	5.41
5	0.0–0.3	6.29	3.04	9.33	3.95	4.02	7.97	5.23	3.87	9.10
	0.3–0.6	4.42	1.25	5.67	3.88	1.96	5.84	5.46	1.56	7.02
6	0.0–0.3	4.26	1.80	6.06	4.47	2.38	6.85	5.67	5.46	11.13
	0.3–0.6	3.57	1.56	5.13	5.00	1.87	6.87	5.18	4.60	9.78

Table 2. Moisture of soil samples from the sampling sites

Sampling site	Depth	22. 4. 2003	18. 8. 2003	15. 10. 2003	14. 4. 2004	14. 7. 2004	12.10.2004
		Sampling date / Moisture %					
1	0.0-0.3	17.10	15.70	20.80	21.50	15.70	20.30
	0.3-0.6	17.10	11.40	11.80	19.10	17.40	16.50
2	0.0-0.3	21.30	15.10	17.20	22.40	16.70	15.00
	0.3-0.6	18.10	10.80	11.30	22.10	18.40	12.90
3	0.0-0.3	20.70	13.60	18.60	22.20	16.80	22.30
	0.3-0.6	20.70	20.30	17.70	21.90	22.60	18.70
4	0.0-0.3	19.70	14.30	11.50	19.50	13.80	16.90
	0.3-0.6	18.50	13.10	17.10	19.00	16.00	14.70
5	0.0-0.3	22.10	16.00	14.10	23.90	16.70	24.00
	0.3-0.6	18.30	14.60	21.00	21.30	17.90	19.70
6	0.0-0.3	16.30	13.00	19.50	19.90	19.20	18.90
	0.3-0.6	6.90	13.80	15.60	19.10	20.10	18.20

Table 3. pH values of soil samples from the sampling sites

Sampling site	Depth	22.4. 2003	18. 8. 2003	15. 10. 2003	14. 4. 2004	14. 7. 2004	12. 10. 2004
		Sampling date / pH					
1	0.0-0.3	7.40	7.15	7.15	7.03	7.15	7.20
	0.3-0.6	7.70	7.60	7.40	7.53	7.35	7.48
2	0.0-0.3	6.25	5.80	5.95	5.60	5.78	5.45
	0.3-0.6	6.93	6.20	5.95	5.85	6.45	6.00
3	0.0-0.3	6.45	6.10	6.10	5.10	5.90	6.10
	0.3-0.6	6.45	6.10	6.20	6.60	6.13	6.20
4	0.0-0.3	5.10	5.95	5.80	5.55	5.75	6.48
	0.3-0.6	6.23	6.40	5.50	6.18	6.25	6.85
5	0.0-0.3	7.30	7.00	7.25	6.98	6.85	7.03
	0.3-0.6	7.65	7.30	7.20	7.40	7.23	7.35
6	0.0-0.3	5.40	5.25	6.20	5.10	5.95	5.20
	0.3-0.6	5.90	6.35	6.80	6.15	6.85	6.53

Table 4. Basic statistical characteristics of measured data (N-NO_3^-, N-NH_4^+ and N_{an})

Statistical characteristic	Nitrogen form		
	N-NH_4^+	N-NO_3^-	N_{an}
Number of observations (n)	72	72	72
Average (x)	5.11	3.02	8.14
Standard deviation (s)	0.92065	2.06972	2.61305
Standard error (S_x)	0.1085	0.243919	0.37951
Minimum	3.24	0.85	4.66
Maximum	7.04	9.76	15.48
Coefficient of variation. % (V)	18.0	68.537	32.109

Table 5. Average contents of inorganic nitrogen forms over the whole research period mg kg^{-1}

Monitored parameters		Average contents mg kg^{-1} of soil		
		N-NH_4^+	N-NO_3^-	N_{an}
Year	2003	5.78	3.62	9.42
	2004	4.44	2.42	6.86
Depth	0.0–0.3	5.24	3.69	8.94
	0.3–0.6	4.99	2.35	7.34
Sampling date	22. 4. 2003	5.76	3.99	9.74
	18. 8. 2003	6.05	4.40	10.45
	15. 10. 2003	5.55	2.48	8.06
	14. 4. 2004	4.35	1.85	6.20
	14. 7. 2004	4.27	3.18	7.45
	12. 10. 2004	4.71	2.22	6.93
Sampling site	1	4.75	2.39	7.14
	2	5.13	2.45	7.61
	3	5.23	3.96	9.19
	4	4.98	2.58	7.56
	5	5.35	3.24	8.59
	6	5.24	3.51	8.75

Conclusions

In the years 2003–2004 we investigated contents and dynamics of inorganic nitrogen forms in the Nature Reserve Žitavský luh. From the obtained results we can derive the following conclusions: Higher contents of both nitrogen forms (nitrate and ammonium) were determined in the first year (2003). The dynamics of ammonium nitrogen was steady and its contents were very similar in both depths over the whole research period. The dynamics of nitrate nitrogen had a different course. The most noticeable nitrates dynamics was in the depth 0.0–0.3 m in the first year. A considerable effect of soil conditions (moisture, pH) on intensity of nitrification process was indicated, but we have not found any correlation between the studied variables.

Table 6. Analyses of variance of $N\text{-}NO_3^-$, $N\text{-}NH_4^+$ and N_{an}

Nitrogen form	Source of variability	Test statistics (F)	Significance level
$N\text{-}NH_4^+$	Depth	2.79	0.0119
	Sampling site	1.48	0.0150
	Sampling date	0.19	0.5512
	Year	84.51	0.0000
$N\text{-}NO_3^-$	Depth	10.44	0.0002
	Sampling site	1.60	0.0124
	Sampling date	4.04	0.0015
	Year	8.35	0.0004
N_{an}	Depth	11.28	0.0000
	Sampling site	1.93	0.0031
	Sampling date	3.26	0.0015
	Year	28.72	0.0000

> 0.05 -; < 0.05 > 0.01 +; < 0.01 ++

Table 7. Limit values of monitoring factors at $F_{0.05}$ and $F_{0.0}1$

Monitored parameter	Limit values					
	$N\text{-}NH_4^+$		$N\text{-}NO_3^-$		N_{an}	
	$F_{0.05}$	$F_{0.01}$	$F_{0.05}$	$F_{0.01}$	$F_{0.05}$	$F_{0.01}$
Depth	0.291622	0.387689	0.834968	1.11003	0.954314	1.26869
Sampling site	0.505105	0.671498	1.44621	1.92262	1.65292	2.19743
Sampling date	0.357163	0.47482	1.02262	1.3595	1.16879	1.55382
Year	0.291622	0.387689	0.834968	1.11003	0.954314	1.26869

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Dynamika anorganických foriem dusíka v pôde prírodnej rezervácie Žitavský luh

Súhrn

V rokoch 2003 a 2004 sme skúmali dynamiku hlavných foriem anorganického dusíka v pôde prírodnej rezervácie Žitavský luh. Zmeny obsahov anorganického dusíka sme sledovali na základe viacerých faktorov ako hĺbka odberu pôdnych vzoriek, vlhkosť pôdy, pH a iné. Vyššie obsahy oboch hlavných foriem dusíka – dusičnanového a amónneho sme zistili v prvom roku pokusu (2003). V tomto roku boli obsahy dusičnanového dusíka (N-NO_3^-) v rozmedzí 1,18–9,76 mg kg^{-1} s priemernou hodnotou 3,62 mg kg^{-1}. Priemerný obsah amónneho dusíka (N-NH_4^+) bol v roku 2003 5,78 mg kg^{-1}, kde minimálna hodnota predstavovala 4,88 mg kg^{-1} a maximálna 7,04 mg kg^{-1}. V druhom roku (2004) boli zistené nižšie obsahy oboch foriem dusíka. Dusičnanový dusík dosiahol priemerný obsah 2,42 mg kg^{-1} s rozmedzím hodnôt od 0,85 mg kg^{-1} do 8,57 mg kg^{-1} a priemerný obsah amónneho dusíka bol 4,44 mg kg^{-1}, pričom obsahy sa pohybovali v rozmedzí 3,24 mg kg^{-1} až 6,85 mg kg^{-1}. Zo štatistických ukazovateľov mali na obsahy dusičnanového dusíka štatisticky vysoko preukazný vplyv rok a hĺbka odberu pôdnych vzoriek (hladina $\alpha = 0{,}01$) a štatisticky preukazný vplyv dátum odberu pôdnych vzoriek (hladina $\alpha = 0{,}05$). Na obsahy amónneho dusíka mal štatisticky vysoko preukazný vplyv ($\alpha = 0{,}01$) len rok a čiastočne aj miesto odberu pôdnych vzoriek. Štatisticky preukazný vplyv na obsahy amónneho dusíka na hladine $\alpha = 0{,}05$ bol zistený pri hĺbke odberu pôdnych vzoriek. Z vyhodnotených Spearmanových korelácii vyplynulo, že medzi obsahmi dusičnanového a amónneho dusíka bol štatisticky vysoko preukazný kladný korelačný vplyv. Rovnako štatisticky vysoko preukazný kladný korelačný vplyv bol zistený medzi dusičnanovým a anorganickým, ale i medzi amónnym a anorganickým dusíkom. Žiadny korelačný vplyv nebol v priebehu pokusu zistený medzi obsahmi dusičnanového, resp. amónneho dusíka a vlhkosťou a pH pôdy. Práca vznikla v rámci grantového projektu VEGA 1/0196/03.

Notes on the fauna of moths in an air-polluted area with a dominant proportion of birch

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Abstract

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The research was carried out in 1989–2004, in an air-polluted area with a dominant proportion of stands of a substitute tree species (*Betula pendula* Roth). Altogether 1,272 species of Lepidoptera were caught by means of light trap. From this number, 246 species show trophic association with birch (22 monophagous species, 51 disjunctive oligophagous species, 52 oligophagous species and 121 polyphagous species). Caterpillars of 92 species were recorded in crowns of birch trees. Some generally indifferent species of moths can be regarded as pests in birch stands (e.g. *Cabera pusaria* L.). Results obtained using light trap do not correspond to the method of beating off branches.

Keywords

birch, light trap, moths, northern Bohemia, air-polluted area

Introduction

The areas of the eastern part of the Krušné hory Mts. and of the Děčínská vrchovina Upland are characterized by biotopes disturbed in consequence of a longterm impact of anthropogenic air pollution. Changes in site conditions display a wide variety, according to different stages and rates of die-back of the spruce stands and creation of stands of the substitute tree species (Kubelka et al., 1992). The study of the entomofauna of air-polluted areas was neglected, because the attractiveness of its spectrum was concerned lower. The long-term systematic study of the arachnoentomofauna of birch stands of the concerned air-polluted region (1986–2005) provides us with information on soil, epigeic and crown fauna, its populations, seasonal dynamics and economic importance. The published contributions refer to the fauna of ground beetles (Carabidae), rove beetles (Staphylinidae), snout beetles (Curculionidae), hover flies (Syrphidae), Cicadoidea, true bugs (Heteroptera), spiders (Araneidea) etc. (Kula, 1997a, 1997b, 1997c, 1997d, 1999a, 2004a). From the viewpoint of species diversity, Lepidoptera occupy a specific position. About 1,503 Lepidoptera species were reported from the region of Děčín (Sterneck, 1929; Sterneck and Zimmermann, 1933; Zimmermann, 1940, 1944; Vlach, 1950; Vávra, 2000, 2002, 2004; Černý, 1996, 1998, 2001). These data were supplemented with 161 species (Kula et al., 2005) caught into light traps (the Děčín Sněžník forest).

The aim of this paper is to characterize the moth fauna associated with birch in the studied air-polluted locality.

Material and methods

Moth trapping was carried out using a Minnesota light trap with a RVL 250 W vacuum tube. The trap was hanged 3.5 m above the ground in the open air under a power line, in the birch stand at the Sněžník locality (cadastral territory Jílové-Sněžník, 50°46´ N, 14°04´ E, faunistic square 5250). The trap was checked each day over the period April-October, 1989–2004. Site conditions in the trap vicinity were: pollution damage zone A, altitude 570 m, forest consisting of European birch, European larch, Norway spruce, blue spruce, Scots pine, oak, ash, linden and alder. In the herb layer with 100% coverage, predominanted *Calamagrostis villosa* Gmel. and *Senecio* sp.

From more than 400 thousand caught moth imagoes, we only present here the species associated with birch. Doc. Dipl. Ing. M. Králíček, CSc. (Mendel University of Agriculture and Forestry in Brno), V. Elsner (Museum of SE Moravia in Zlín), J. Černý (Děčín), J. Spružina (Ústí nad Labem) participated in the determination of moths. The nomenclature of Laštůvka and Liška (2005) was used.

The collection of crown fauna was carried out in the same area of Forest Enterprise Děčín in the period 1986–2004 in a 14-day interval in a period from 1 April to 31 October using the method of shaking off insect in six stands of *B. pendula* Roth aged 5–15 years (Kula, 2004b).

Description of the study area

The area of Forest District Děčín is situated in the Děčínská vrchovina Upland, mostly on a plateau within 450–700 m a.s.l. It is characterized by cold mountain climate with the mean annual temperature of 6–7°C, total annual precipitation of 700–800 mm, and growing season with 110–120 days with mean daily temperature exceeding 15°C.

The concerned air-polluted area is stressed by pollutants, primarily SO_2 with mean annual concentrations exceeding 60 g m^{-3} in 1969–1987. According to the monitoring stations placed 15 km from the light trap, the period 1988–1993 was characterized by a slight decrease in the air-pollution stress. However, daily absolute maximum values exceeded 600 g m^{-3} SO_2. For example, the SO_2 values in the Děčín Sněžník forest in 1993, amounted to 783 g m^{-3} and NO_x values reached 188 g m^{-3}. Based on the mean annual concentrations (air pollution monitoring by the Czech Hydrometeorological Institute – ČHMÚ, Sněžník), a positive air-pollution development can be deduced (1995 – 44.1; 1998 – 22.4; 2001 – 12.4 g m^{-3} SO_2) which manifested the partial decrease of industrial melanism in *Biston betularius* L. (Kula, 2005a).

Results

In total, 1,272 Lepidoptera species were caught over 1989–2004. From this number, 1,138 species (89.5%) were classified as indifferent species and only 54 species (4.2%) could be regarded as forest pests (5.81% of the caught individuals), 52 species (4.1%) as agriculture pests. Other 28 species (2.2%) are related to the forest environment, ornamental trees and agricultural crops. The species with trophic association to birch (246 species) participated by 19.3% in the overall fauna and by 38.7% in the number of the caught individuals. With decreasing trophic specialization, the proportion of these birch species and individuals increased: monophages – 8.9% and 8.2%, respectively; disjunctive oligophages – 20.7% and 12.2%, respectively; oligophages – 21.1% and 22.6%, respectively and polyphages – 49.2% and 57.0%, respectively. The proportion of forest pest species was low in all these trophic groups – three monophages, two disjunctive oligophages, one oligophage and 12 polyphages (Table 1). We recorded larvae of 92 species in crowns of birch trees (Kula, 1999b, 2004b) – it is 36.6% of the species caught by the light trap.

The number of monophagous species was low – 22. Three of them (*Eriocrania* spp. and *Ectoedemia occultella*) are important for forestry (Table 2). Most of the birch monophages were recorded in imaginal stadium only – 15 species. Several common species, such as *Pheosia gnoma* (Fabr.), *Ortholepis betulae* (Goeze) and *Swammerdamia caesiella* (Hb). were found in both larval and imaginal stadiums, but some abundant species [e.g. *Apotomis betuletana* (Haw.) and *A. sororculana* Zett.] were represented in the light trap samples only (Table 2).

Table 1. Characteristics of the lepidopteran fauna associated with birch (Sněžník, 1989–2004, light trap)

	S	N	S	N	S	N	S	N	S	N	S	N	S	N
Trophic groups	Σ	Σ	FP*	FP*	FP**	FP**	FP***	FP***	AP	AP	I	I	CP	CP
Monophages	22	12,681	3	26							19	12,655	7	7,570
Disjunctive oligophages	51	18,979	2	49					1	26	48	18,904	14	13,429
Oligophages	52	35,119	1	4,545							51	30,574	22	28,426
Polyphages	121	88,344	7	10,340	2	934	3	7,742	8	7,331	101	61,997	49	48,268
Total	246	155,123	13	14,960	2	934	3	7,742	9	7,357	219	124,130	92	97,693

S – number of species, N – number of individuals, FP* – low severe forest pest, FP** – medium severe forest pest, FP*** – severe forest pest, AP – low severe agricultural pest, I – indifferent species, CP – data concerning species caught in the light trap, which were recorded also in larval stadium

From the 51 disjunctive oligophagous species, there were 14 species recorded also in larval stadium on birch. The most numerous of these were *Cabera pusaria* (L.), *Chiasmia notata* (L.), *Cyclophora pendularia* (Cl.).*Cosmia trapezina* (L.) and *Geometra papilionaria* L. Other abundant species [e.g. *Epinotia brunnichana* (L.) and *Cyclophora albipunctata* (Hufn.)] were not found in larval stadium by shaking off birch trees (Table 3).

Almost one half of the caught oligophagous species (22) were also recorded in larval stadium. Most significant were *Drepana falcataria* (L.), *Apotomis turbidana* Hb., *Pheosia tremula* (Cl.), *Teleiodes proximellus* (Hb.), *Campaea margaritata* (L.), *Enargia paleacea* (Esper), *Ochropacha duplaris* (L.), *Achlya flavicornis* (L.). *Epinotia ramella* (L.). and *Lomaspilis marginata* (L.) were the most abundant species recorded in imaginal stadium only (Table 4).

From the 121 polyphagous species caught by our research team in the light trap, 49 species were recorded as larvae on birch trees. It signifies the importance of birch as a food plant for this group of moths in this polluted area. The species with high abundance in the light traps were *Orthotaenia undulana* (Den. & Schiff.), *Orthosia gothica* (L.), *Alcis repandata* (Fabr.), *Biston betularius* (L.), *Pandemis corylana* (Fabr.), *Phalera bucephala* (L.) etc. (Table 5).

Table 2. The fauna of monophagous moths associated to birch (Sněžník, 1989–2004, light trap)

Importance	CP	Species	N	%
I	x	*Pheosia gnoma*	3,757	2.422
I		*Apotomis betuletana*	3,278	2.113
I	x	*Ortholepis betulae*	2,956	1.905
I		*Apotomis sororculana*	809	0.521
I	x	*Swammerdamia caesiella*	608	0.391
I		*Parornix betulae*	398	0.256
I	x	*Leucodonta bicoloria*	225	0.145
I		*Argyresthia retinella*	169	0.108
I		*Caloptilia betulicola*	158	0.101
I		*Anacampsis blattariella*	76	0.048
I		*Phyllonorycter ulmifoliellus*	70	0.045
I		*Epinotia bilunana*	54	0.034
I		*Coleophora betulella*	41	0.026
I	x	*Teleiodes alburnellus*	24	0.015
FP*	x	*Eriocrania sparrmannella*	23	0.014
I		*Caloptilia populetorum*	21	0.013
I		*Phylloporia bistrigella*	4	0.002
I		*Coleophora cornutella*	3	0.001
I		*Stigmella luteella*	3	0.001
FP*	x	*Eriocrania semipurpurella*	2	0.001
I		*Pammene obscurana*	1	0.001
FP*		*Ectoedemia occultella*	1	0.001
		Total	12,681	8.175

N – number of individuals, CP – species recorded also in larval stadium, I – indifferent species, FP* – low severe foret spest

Table 3. The fauna of disjunctive oligophagous moths associated to birch (Sněžník, 1989–2004, light trap)

Importance	CP	Species	N	%
I	x	*Cabera pusaria*	6,917	4.459
I	x	*Chiasmia notata*	2,250	1.450
I	x	*Cyclophora pendularia*	1,853	1.194
I		*Epinotia brunnichana*	1,397	0.900
I	x	*Cosmia trapezina*	1,393	0.897
I		*Cyclophora albipunctata*	1,230	0.792
I		*Papestra biren*	580	0.373
I		*Parastichtis suspecta*	521	0.335
I		*Eulithis populata*	445	0.286
I		*Laothoe populi*	264	0.170
I		*Olethreutes umbrosanus*	263	0.169
I	x	*Geometra papilionaria*	247	0.159
I	x	*Epinotia tenerana*	233	0.150
I	x	*Endromis versicolora*	203	0.130
I	x	*Biston stratarius*	202	0.130
I	x	*Metendothenia atropunctana*	105	0.067
I		*Cyclophora linearia*	99	0.063
I		*Hydrelia flammeolaria*	80	0.051
I		*Stauropus fagi*	80	0.051
I		*Neofaculta infernella*	73	0.047
I		*Hypatima rhomboidella*	53	0.034
I		*Teleiodes paripunctellus*	51	0.032
I		*Rheumaptera undulata*	43	0.027
I		*Ancylis uncella*	41	0.026
I		*Hypomecis roboraria*	40	0.025
FP*		*Bucculatrix thoracella*	39	0.025
I		*Cyclophora annularia*	34	0.021
I		*Pyla fusca*	26	0.016
I		*Trichopteryx carpinata*	26	0.016
AP		*Smerinthus ocellatus*	26	0.016
I		*Lobophora halterata*	24	0.015
I		*Coleophora ibipennella*	22	0.014
I		*Abraxas sylvatus*	18	0.011
I		*Cyclophora porata*	14	0.009
I	x	*Alcis bastelbergeri*	14	0.009
FP*		*Acrobasis obtusella*	10	0.006
I		*Acleris sparsana*	9	0.005
I		*Apocheima hispidarium*	8	0.005
I		*Euzophera pinguis*	8	0.005
I		*Roeslerstammia erxlebella*	8	0.005
I	x	*Ennomos quercinarius*	6	0.003
I		*Agonopterix ocellana*	4	0.002
I		*Harpyia milhauseri*	4	0.002
I		*Eulithis testata*	3	0.002
I		*Lobesia reliquana*	3	0.002
I	x	*Epirrita christyi*	3	0.002
I		*Trachonitis cristella*	2	0.001
I	x	*Asthena albulata*	2	0.001
I		*Nymphalis antiopa*	1	0.001
I		*Sabra harpagula*	1	0.001
I	x	*Parectropis similaria*	1	0.001
		Total	18,979	12.234

N – number of individuals, CP– species recorded also in larval stadium, I – indifferent species, FP* – low severe forest pest, AP – low severe agricultural pest

Table 4. The fauna of oligophagous moths associated to birch (Sněžník, 1989–2004, light trap)

Impor-tance	CP	Species	N	%
FP*	x	*Argyresthia goedartella*	4,545	2.930
I	x	*Drepana falcataria*	4,410	2.843
I	x	*Apotomis turbidana*	3,775	2.433
I		*Epinotia ramella*	2,960	1.908
I	x	*Pheosia tremula*	2,659	1.714
I	x	*Teleiodes proximellus*	2,110	1.360
I	x	*Campaea margaritata*	1,886	1.216
I	x	*Enargia paleacea*	1,695	1.093
I		*Lomaspilis marginata*	1,518	0.978
I	x	*Ochropacha duplaris*	1,453	0.936
I	x	*Achlya flavicornis*	1,257	0.810
I	x	*Falcaria lacertinaria*	1,072	0.691
I	x	*Notodonta dromedarius*	965	0.622
I		*Argyresthia brockeella*	766	0.494
I	x	*Tetheella fluctuosa*	572	0.369
I	x	*Odontosia carmelita*	430	0.277
I	x	*Euchoeca nebulata*	429	0.277
I	x	*Epinotia tetraquetrana*	405	0.261
I		*Drymonia dodonaea*	339	0.218
I	x	*Epinotia trigonella*	319	0.206
I		*Lyonetia pulverulentella*	314	0.202
I	x	*Cabera exanthemata*	219	0.141
I		*Epinotia demarniana*	187	0.120
I		*Epinotia maculana*	146	0.094
I		*Epinotia immundana*	86	0.055
I		*Cochylis nana*	77	0.05
I	x	*Furcula bicuspis*	71	0.046
I	x	*Operophtera fagata*	63	0.04
I		*Watsonalla binaria*	61	0.039
I	x	*Cyclophora punctaria*	52	0.033
I		*Acronicta megacephala*	43	0.028
I		*Ancylis upupana*	43	0.028
I		*Coleophora alnifoliae*	40	0.026
I	x	*Furcula furcula*	31	0.02
I		*Lithophane furcifera*	28	0.02
I		*Coleophora milvipennis*	26	0.02
I		*Acleris emargana*	15	0.01
I		*Notodonta tritophus*	13	0.01
I	x	*Teleiodes luculellus*	8	0.005
I		*Drepana curvatula*	5	0.003
I		*Apotomis lineana*	4	0.003
I		*Caloptilia stigmatella*	4	0.003
I		*Cryptoblabes bistriga*	3	0.002
I		*Furcula bifida*	3	0.002
I		*Strophedra weirana*	3	0.002
I		*Caloptilia elongella*	2	0.001

Table 4. Continued

Impor-tance	CP	Species	N	%
I		*Coleophora albidella*	2	0.001
I		*Bucculatrix demaryella*	1	0.001
I		*Coleophora binderella*	1	0.001
I		*Coleophora orbitella*	1	0.001
I		*Episcythrastis tetricella*	1	0.001
I		*Parastichtis ypsillon*	1	0.001
		Total	35,119	22.639

N – number of individuals, CP – species recorded also in larval stadium, I – indifferent species, FP*– low severe forest pest

Table 5. Selected polyphagous moth species associated to birch which were recorded also in larval stadium (Sněžník, 1989-2004, light trap)

Impor-tance	CP	Species	N	%
FP*	x	*Pandemis cerasana*	8,550	5.512
I	x	*Orthotaenia undulana*	7,485	4.825
I	x	*Orthosia gothica*	7,294	4.702
I	x	*Alcis repandata*	4,698	3.028
I	x	*Biston betularius*	3,604	2.323
I	x	*Pandemis corylana*	2,947	1.899
I	x	*Orthosia incerta*	2,055	1.324
I	x	*Lycia hirtaria*	1,559	1.005
I	x	*Conistra vaccinii*	1,032	0.665
FP**	x	*Phalera bucephala*	931	0.6
I	x	*Eulia ministrana*	916	0.59
I	x	*Pandemis heparana*	678	0.437
I	x	*Aethalura punctulata*	638	0.411
I	x	*Colocasia coryli*	572	0.368
I	x	*Ptilodon capucina*	563	0.363
I	x	*Ennomos alniarius*	543	0.35
I	x	*Polia bombycina*	526	0.339
FP*	x	*Calliteara pudibunda*	468	0.302
I	x	*Acronicta leporina*	393	0.253
I	x	*Mimas tiliae*	360	0.232
I	x	*Syndemis musculana*	326	0.21
I	x	*Acleris notana*	304	0.196
I	x	*Ectropis crepuscularia*	261	0.168
I	x	*Choristoneura hebenstreitella*	213	0.137
I	x	*Colotois pennaria*	177	0.114
FP*	x	*Coleophora serratella*	160	0.103
FP*	x	*Epirrita dilutata*	118	0.076
I	x	*Polia nebulosa*	92	0.059
AP	x	*Archips rosanus*	90	0.058

Table 5. Continued

Importance	CP	Species	N	%
I	x	*Selenia dentaria*	88	0.056
I	x	*Chiasmia alternata*	85	0.055
I	x	*Acronicta auricoma*	82	0.053
I	x	*Amphipyra pyramidea*	71	0.046
I	x	*Ypsolopha parenthesella*	64	0.041
I	x	*Acronicta psi*	50	0.032
FP*	x	*Epirrita autumnata*	50	0.032
I	x	*Diurnea fagella*	45	0.029
I	x	*Alsophila aescularia*	40	0.026
I	x	*Agriopis aurantiaria*	33	0.021
I	x	*Lasiocampa quercus*	28	0.018
AP	x	*Choristoneura diversana*	19	0.012
I	x	*Cosmia pyralina*	13	0.008
I	x	*Chloroclysta siterata*	10	0.006
I	x	*Pseudoips prasinanus*	10	0.006
I	x	*Agriopis marginaria*	7	0.005
I	x	*Cleora cinctaria*	7	0.005
I	x	*Hypomecis punctinalis*	7	0.005
I	x	*Ennomos autumnarius*	5	0.003
I	x	*Jodis lactearia*	1	0.001
		CP on the birch	37,518	24.186
		Total	49,547	31.940

N – number of individuals, CP– species recorded also in larval stadium, I – indifferent species, FP* – low severe forest pest, AP – low severe agricultural pest

Discussion

The original spruce and beech stands, dominant in the region of the Krušné hory Mts. in the past, were relatively poor ecosystems from the viewpoint of fauna. In the air-polluted region, they were replaced by stands of substitute woody plants (*Betula*, *Sorbus*, *Alnus*, *Salix*, *Larix*, *Picea pungen*s Engelm. etc.) (Moravčík, 1994). Some of them have been provided with the status of target species (Kubelka et al., 1992) requiring a certain degree of protection. Consequently, it was necessary to provide control against the outbreak of moths *Erannis defoliaria* (Cl.) and *Operophtera brumata* (L.) in birch stands in the eastern part of the Krušné hory Mts. and the Děčínská vrchovina Upland at the earliest 80s of the last century. This control was carried out using planes (Badalík, 1988). Long-term studies of the degree of damage to assimilatory organs carried out on permanent sample trees (1994–2004) demonstrate that the highest losses are caused by free-living caterpillars (Kula, 2005b).

Krampl (1978) first recorded 75 Lepidoptera species occurring in the studied locality, and Kula (1997d, 1999b) found adults of 861 species and caterpillars of 119 species in the crown fauna of birch. From the total number of 1,272 species that we recorded in the Děčín Sněžník forest, 246 species are trophic associated with birch, in sense of classification by Reiprich (2001) and 219 of them are indifferent. However, abundance of these species indicates that their gradation potential and economic importance increase with the increasing proportion of birch in the region. Species such as *C. pusaria*, *O. undulana*, *A. repandata*, *D. falcataria*, *B. betularius*, *Ch. notata*, *T. proximellus*, *C. margaritata*, *C. albipunctata*, *O. duplaris* can be ranked among the potential forest pests commonly occurring in the region (based on samples caught in light trap). At the same time, their caterpillars were recorded in crowns of birch trees (Kula, 1999b, 2004b).

Using the method of beating off branches of birch trees, it is not possible to catch the mining species. There is also question about adequacy of catching these species by light traps. Special studies have demonstrated that there is a local danger of the gradation of species of the genus *Eriocrania* (Kula, 2000) and *Coleophora serratella* (L.) (Kula and Vaca, 1995). Based on the birch-crown fauna studies (Kula, 2004b), *Operophtera fagata* (Scharf.) was found more important early spring phytophage than *O. brumata* and *E. defoliaria*. Populations of *O. fagata* developing in birch stands could also threaten beech trees. At present, beech is used in the regeneration of forest stands in the Krušné hory Mts. and in the Děčínská vrchovina Upland. The samples of moths associated with birch, obtained using the light trap do not correspond to the data on the proportion of caterpillars occurring in crowns of birch over the studied region, e.g., *A. betuletana*, *A. sororculana*, *C. albipunctata*, *P. tremula*, *P. gnoma* etc. (Kula, 2004a).

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Poznámky k fauně motýlů imisní oblasti s dominantním zastoupením břízy

Souhrn

V imisním území děčínského Sněžníku (severní Čechy, Děčínská vrchovina) byla sledována fauna motýlů (1989–2004) světelným lapačem. Ze zachycených 1272 druhů je u 246 druhů (19,3%) známa potravní vazba na břízu, přičemž u 92 druhů byl potvrzen výskyt housenek v korunové fauně bříz sledovaného území.

Se snižující se specializaci se podíl druhů i odchycených imag zvyšuje – monofágové 8,9 % druhů a 8,2 % ulovených jedinců, disjunktní oligofágové (20,7 % a 12,2 %), oligofágové (21,1 % a 22,6 %) a polyfágové (49,2 % a 57,0 %), přičemž zastoupení druhů řazených k lesním škůdcům bylo nízké.

Některé indiferentní druhy (89,5 %) mohou být v podmínkách porostů náhradních dřevin klasifikovány jako škůdci (*Cabera pusaria* L., *Orthotaenia undulana* Den. & Schiff., *Alcis repandata* Fabr., *Drepana falcataria* L., *Biston betularius* L. etc.) a mohou se vytvářet předpoklady pro budoucí ohrožení např. buku (např. druhem *Operophtera fagata* Scharf.).

Metoda světelného lapače doplňuje výsledky stanovené pro korunovou faunu bříz sklepáváním, přičemž se ukazují významné diference mezi odlovem do světelného lapače a sklepáváním z korun i u některých monofágů břízy – *Pheosia gnoma* Fabr., *Apotomis betuletana* Haw. aj.

The beetle (Coleoptera) assemblages in various biotopes in the surroundings of the Domica cave (National Park Slovenský kras)

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Abstract

Majzlan, O. 2005. The beetle (Coleoptera) assemblages in various biotopes in the surroundings of the Domica cave (National Park Slovenský kras). *Folia oecol.*, 32: 90–102.

In the period of 2003–2004, I studied assemblages of beetles in several biotopes in the surroundings of the Domica cave (S Slovakia). The beetles captured in the pit falls dislocated over 12 study sites represented 309 species. From the total of 41 recorded families, Curculionidae (65 species), Carabidae (65 species), and Staphylinidae (40 species) were dominant ones and shared 56% of all the observed species. I have obtained data on the structure of epigeous beetles in dependence on shadowiness. Moreover, I have focussed at ecosozologically and faunistically significant beetle species as indicators for nature conservation according to the Natura 2000 System.

Key words

beetle communities, ecology, indication, Natura 2000

Introduction

Apart from the species cataloguing in nature reserves, there is a plea for more intensive research on interactions between habitat conditions and structure of the associated zoocoenoses. The environment of the Domica cave, providing a variety of ecological conditions in various biotopes, has encouraged us to study assemblages of epigeous arthropods. I was particularly focussing on assemblages of epigeous beetles and on influence of ecological conditions on quantitative and qualitative structure of the assemblages. There have been published several papers on beetles from the National park Slovenský kras (e.g. Majzlan, 1995; Majzlan and Rychlík, 1993). The beetles from the surroundings of Jasov have been analysed by Cunev (2000). All the obtained data may considerably contribute to the knowledge on beetle fauna and have direct consequences for the European Project Natura 2000.

Characterization of the study sites

The study sites were established in such a way as to cover diverse habitats in the surroundings of the Domica cave. Moreover, the selection reflected the aims of the project: to define a natural recipient unit of surface water for needs of hydrological research on the cave system.

The study plots can be characterized as:

1. Wet meadow without management, with features of wet to mesophilous meadows. Shrubs with dominating *Salix cinerea.*
2. Xerotherm – W-exposed, karst, xerothermic grassland assemblages on limestone, shrubs.
3. Forest sinkhole, oak – hornbeam forest with dominant hornbeam.
4. Dry basin, with poplars and hygrophilous vegetation at higher altitudes.
5. Sinkhole with xerothermic grassland assemblages with common *Prunus* sp., and *Juniperus* sp.
6. Orchard, apple trees, mowed herbal floor.
7. Xerothermophilous oak stands, exposition towards NW.
8. Well developed Molinietum with birches around.
9. Intensively managed mesophilous meadow.
10. Pasture with solitaire *Juniperus* sp. and *Crataegus* sp.
11. Xerotherm on karst, E-exposed.

Material and methods

In 2003, I placed pit falls over the 10 study sites (Fig. 1). The material was sampled on October 8 and November 26, 2003. Furthermore, I used the method of sieving upper soil horizons for 3 study sites (3, 4, 6). In 2004 the method was extended to 2 other plots (11, 12). The pit falls were placed by two at each study site, and consisted of glass jars (0.7 l) with 4% formaldehyde with admixture of antifreeze Fridex in traps exposed during the wintertime (November 26, 2003–May 20, 2004). The next sampling was performed in the period between July 30 and November 5, 2004. The captured beetles were identified and deposed in a dry form in the Slovenské múzeum ochrany prírody a jaskyniarstva (Slovak Museum of Nature Protection and Caves Investigation) in the town of Liptovský Mikuláš.

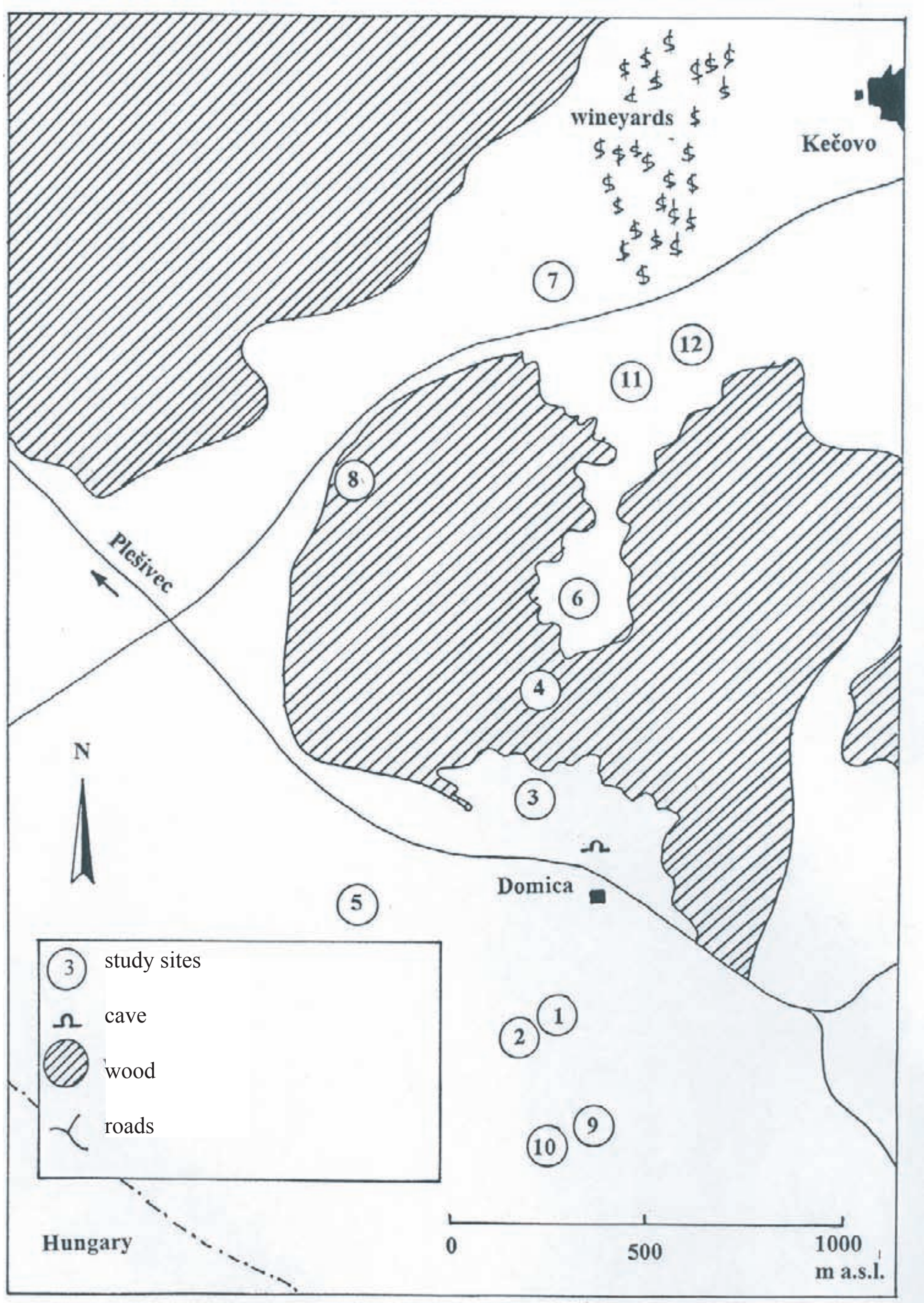

Fig. 1. A sketch of the study area in the surroundings of the Domica cave with the study sites marked

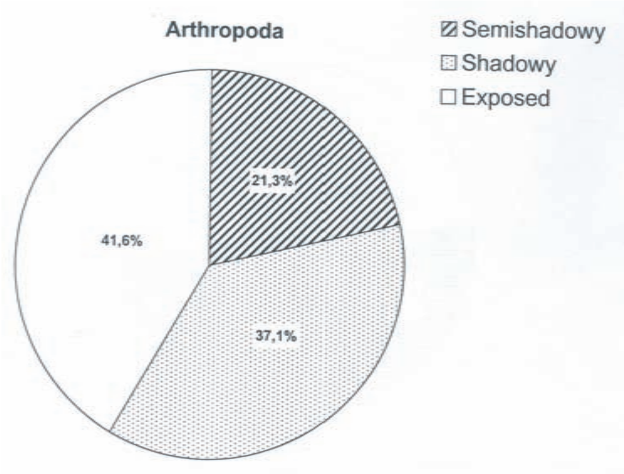

Fig. 2. Percentual structure of epigeous Arthropoda in 3 groups of biotopes (exposed, semi-shadowy, shadowy)

Results and discussion

Arthropoda

We have gathered a large amount of material of arthropods, including larvae of holometabolous insects (45–51%), Araneae (15–16%), Opiliones (3–5%), Hymenoptera – Formicidae (14.5–15%), Oniscoidea (4.5%), Collembola (5–6%) as the dominant groups (an average dominance is presented). The other groups (Diplopoda, Chilopoda, Acarina) were represented in lower abundance (1.5–2%). The lowest abundance (0.5–2%) was found in Thysanura, Plecoptera, Ensifera, Caelifera, Blattodea, Heteroptera, Auchenorrhyncha, Diptera and Aphaniptera. I even recorded a sporadic presence of Lumbricidae, Hirudinea, Amphibia, Reptilia and Mammalia (Insectivora, Rodentia) in the traps.

The structure of arthropods was evaluatedindependence on the intensity of shadowiness. The biggest portion of the study material comes from the light-exposed sites (41.6%), the rest from woody (37.1%) and semi-shadowy habitats (21.3%), Fig. 2.

Insect larvae were dominant (77%) in forest stands (sites 4, 8). The analysis confirmed occurrence of Araneae (2%), Hymenoptera (particularly ants) (3%) and Coleoptera (17%). The other specimens represented 1% (Fig. 3) altogether.

Araneae (27.6%), larvae (25.3%), Hymenoptera (11.4%) and Coleoptera (8.1%) dominated at semi-shadowy sites (2, 5, 7, 9), with the other groups representing 27.6%.

The exposed sites (1, 3, 6, 10, 11, 12) are inhabited by Hymenoptera (24.5%), Araneae (20.6%), larvae (24.5%) and Coleoptera (4.4%). The other groups are represented by 23.8%. The following survey declares that shadowy habitats are preferred by numerous larvae, particularly these of Carabidae. These sites are usually inhabited by Araneae and Hymenoptera.

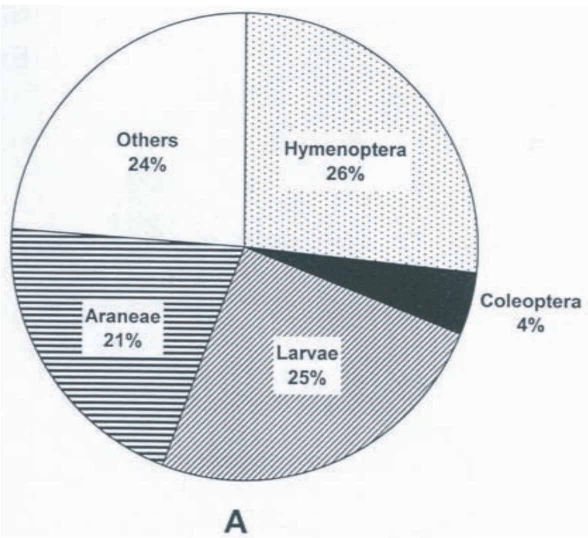

Fig. 3. Percentual structure of dominant groups of epigaeon (Araneae, Hymenoptera, Coleoptera, larvae diversae) in the groups of biotopes:
A – exposed (open area)

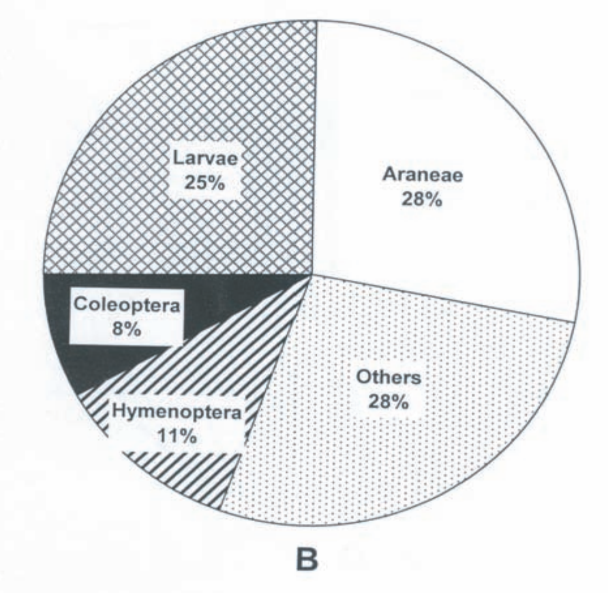

Fig. 3. Percentual structure of dominant groups of epigaeon (Araneae, Hymenoptera, Coleoptera, larvae diversae) in the groups of biotopes: B – semi-shadowy

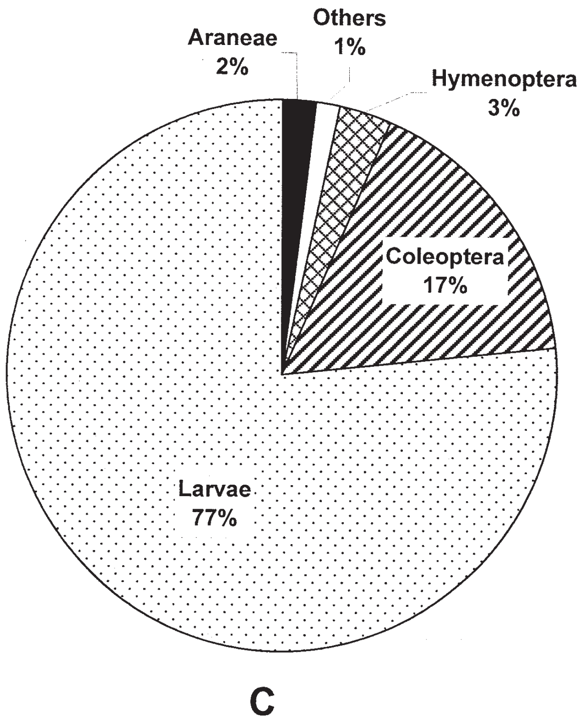

Fig. 3. Percentual structure of dominant groups of epigaeon (Araneae, Hymenoptera, Coleoptera, larvae diversae) in the groups of biotopes: C – shadowy (forest)

Coleoptera

I have recorded altogether 309 beetle species (Coleoptera) at 12 study sites (Table 1). The beetles of 41 families particularly belong to Curculionidae (65 sp.), Carabidae (65 sp.), and Staphylinidae (40 sp.), representing in total 56 percents of the all recorded species.

Despite the same methods, I didn't record the same species richness at all the sites, what may correspond to different habitat conditions. The species richness reached the following values: Site 1 – 58 species, 2 – 50, 3 – 41, 4 – 42, 5 – 54, 6 – 30, 7 – 68, 8 – 42, 9 – 45, 10 – 37, 11 – 27, 12 – 10.

According to the species diversity, the study sites have been classified into 3 categories:

- º Sites with more than 50 species: 7, 1, 5, 2.
- º Sites with 40–50 species: 3, 9, 4, 8.
- º Sites with less than 40 species: 10, 6, 11, 12.

According to the intensity of sunshine, the sites can be divided into 3 categories:

- º Shadowy (forest assemblages) sites: 4, 8.
- º Semi-shadowy (shrubs and sparse woods) sites: 2, 5, 7, 9.
- º Exposed (meadow, woody steppe) sites: 1, 3, 6, 10, 11, 12.

The analyses have revealed a certain dependence of the species richness on the intensity of sunshine. The open sites (typical xerotherms) are inhabited by lower numbers of species; hence the diversity is lower. An intensity of shadowiness corresponds to the moisture content of the upper soil horizons.

Significant differences in quantitative variables of the beetle assemblages cannot reliably be explained. However I present the evaluation of the species and their diversity in assemblages. Some of them may indicate specific ecological requirements on the habitat. For instance, *Sisyphus schaefferi* detects pastures with a sufficiency of ship, goat or other excrements. *Molops piceus* indicates forest stands with humic soil and sufficient amount of fallen leaves. *Meloë rugosus* as well as *Dapsa denticollis* detect naturally managed habitats.

Characterization of the sites according to the associated beetle assemblages

Based on the beetle species diversity, their quantitative proportions and the type of habitat, the study plots can be defined as:

Site 1
Exposed, humid, 58 species.
Typical species: *Carabus violaceus*
Indicative species: *Carabus scabriusculus*, *Trachyphloeus aristatus*, *Cicindela germanica*
Common species: *Pseudoophonus rufipes*, *Scaphidium quadrimaculatum*, *Drusilla canaliculata*, *Byrrhus fasciatus*.

Site 2
Semi-shadowy, humid, 50 species.
Typical species: *Carabus convexus, Xantholinus linearis*
Indicative species: *Platambus maculatus*, *Othiuspunctulatus*, *Lythraria salicariae*
Common species: *Pterostichus niger*, *Pseudoophonus rufipes*.

Site 3
Exposed, xerotherm, 41 species.
Typical species: *Sisyphus schaefferi*, *Athous silicensis*, *Staphylinus winkler*i
Indicative species: *Clitosthetus arcuatus*, *Mesagroicus obscurus*, *Orobitis cyaneus*
Common species: *Dorcadion pedestre.*

Site 4
Shadowy, humid, 42 species.
Typical species: *Apion holosericeum*
Indicative species: *Barypeithes interpositus*
Common species: *Pterostichus oblongopunctatus, Calosoma inquisitor, Molops piceus, Pseudoophonus rufipes.*

Site 5
Semishadowy, gently humid, 54 species.
Typical species: *Dacne bipustulata*
Indicative species: *Stenus ochropus*
Common species: *Otiorhynchus ovatus, Sciaphilus asperatus, Brachysomus echinatus*.

Site 6
Exposed, mesophilous to dry, 30 species.
Typical species: *Trachys fragariae, Carabus convexus*
Indicative species: *Carabus scabriusculus*, *Dorcadion aethiops*, *Brachysomus slovacicus* – a species described recently in terra typica (Košťál, 1991)
Common species: *Stomis pumicatus*, *Chaetocnema aridula*.

Site 7
Exposed, orchard, dry to mesophilous, 68 species.
Typical species: *Dapsa denticollis*
Indicative species: *Choleva paskoviensis*, *Meloë rugosus*, *Brachysomus slovacicus*
Common species: *Brachysomus slovacicus*.

Site 8
Shadowy, mesophilous, 42 species.
Typical species: *Aptinus bombarda*, *Molops piceus*
Indicative species: *Carabus montivagus blandus, Barypeithes interpositus*
Common species: *Calosoma inquisitor*, *Nargus brunneus*.

Site 9
Semishadowy, mesophilous to humid, 45 species.
Typical species: *Philonthus decorus*, *Byrrhus fasciatus*, *Alophus triguttatus*
Indicative species: *Meloe rugosus*, *Trachyphloeus aristatus*
Common species: *Amara aenea*, *Harpalus rubripes*, *Mesagroicus obscurus*.

Site 10
Exposed, xerotherm, 37 species.
Typical species: *Trachyphloues asperatus*
Indicative species: *Staphylinus pedator*, *Brachysomus setiger*
Common species: *Mesagroicus obscurus*, *Otiorhynchus ovatus*.

Site 11
Exposed, xerotherm, 27 species.
Typical species: *Sisyphus schaefferi*
Indicative species: *Harpalus serripes*, *Comanisus setiger*
Common species: *Platydracus stercorarius*.

Site 12
Shadowy, humid, 10 species.
Typical species: *Dibolia schillingi*
Indicative species: ?
Common species: *Dorcadion pedestre*.

Analysis on typical, indicative and dominant species is important for a consequent biomonitoring.

The samples included dominant beetles, particularly necrophagous *Silpha carinata*, *Drusilla canaliculata* and *Dermestes laniarius* and coprophagous *Trypocopris vernalis*, *Onthophagus ovatus* species, which have not been analysed. They inhabit a niche without a direct topical interaction. These species are ubiquists with an occurrence in numerous biotopes from hilly to mountainous zones.

Significant faunistic and indicative beetle species

Carabus scabriusculus
Distribution: Central and E Europe. Indicative species of naturally managed xerotherms.

Carabus convexus
Distribution: Central and N Europe. At present its distribution area gets smaller in Slovakia.

Carabus montivagus blandus
Distribution: Pontic element, Banát, Hungary. Typical species of karst areas. In Slovakia very rare.

Licinus depressus
Distribution: Europe, Caucasus, Siberia. Typical species of limestone and karst areas. In Slovakia very rarely and locally distributed.

Choleva paskoviensis
Distribution: Central Europe. Local and rare species in Slovakia.

Staphylinus winkleri
Distribution: Balcae, E Carpathians, Turkey, Greece. In Slovakia rare and only in karst areas of S Slovakia.

Athous silicensis
Distribution: Described recently, in 1975, with a lack of sufficient data on its distribution.

Dapsa denticollis
Distribution: Central Europe. Mycetophagous species living in soil. In evenings it occurs on vegetation. Rarely and localy in naturaly managed areas of Slovakia.

Otiorhynchus hungaricus
Distribution: Romania, Banát, Hungary. Only in karst areas in Slovakia. Typical species of Silická and Plešivecká uplands. In Slovakia with the most northern boundary of its distribution.

Otiorhynchus roubali
Distribution: Slovakia, terra typica Silica, Zádiel. Endemic species for this region.

Brachysomus slovacicus
Distribution: Slovakia, terra typica Domica, nowhere else recorded yet. In Domica common even in habitats which are not typically xerothermous. For example at the site 7, in the abandoned apple tree orchard I obtained 170 specimens.

Mesagroicus obscurus
Distribution: Pontic element, Romania, Turkey, Croatia, with the most northern boundary in Slovakia. Rarely and locally in Slovakia, however very frequently in the surroundings of Domica.

Table 1. A systematic survey of the recorded beetle (Coleoptera) species at the study sites (1–12) in the surroundings of the Domica cave in 2003–2004 (number of caught specimens is presented for each site)

Family Species	Site/specimens	Total
Carabidae		
Cicindela germanica Linnaeus, 1758	1/1	1
Calosoma inquisitor (Linnaeus, 1758)	2/1,4/12,5/5,7/12,8/25	55
Carabus hortensis Linnaeus, 1758	4/1,8/1	2
Carabus scheidleri Panzer, 1799	7/1	1
Carabus violaceus Linnaeus, 1758	1/15,6/2,7/1,8/1	19
Carabus coriaceus Linnaeus, 1758	7/1	1
Carabus intricatus Linnaeus, 1761	4/1,7/1,8/1	3
Carabus hortensis Linnaeus, 1758	4/1,7/1	2
Carabus scabriusculus Olivier, 1795	1/1,6/7	8
Carabus montivagus blandus Frivaldszky, 1865	8/1	1
Carabus convexus Fabricius, 1775	2/2,4/1,6/2,8/1	6
Leistus rufomarginatus (Duftschmid, 1812)	4/1	1
Leistus ferrugineus (Linnaeus, 1758)	7/2	2
Notiophilus biguttatus (Fabricius, 1779)	2/1	1
Loricera pilicornis (Fabricius, 1775)	5/1	1

Continued

Family Species	Site/specimens	Total
Dyschirius globosus (Herbst, 1784)	2/1	1
Aptinus bombarda (Illiger, 1800)	4/1,8/10	11
Brachinus crepitans (Linnaeus, 1758)	4/1,7/55	56
Brachinus explodens Duftschmid, 1812	10/1	1
Epaphius secalis (Paykull, 1790)	5/2	2
Asaphidion flavipes (Linnaeus, 1761)	5/1	1
Bembidion obtusum Audinet-Serville, 1821	7/1	1
Bembidion guttula (Fabricius, 1792)	1/1	1
Patrobus atrorufus (Stroem, 1768)	1/1,5/1	2
Stomis pumicatus (Panzer, 1796)	5/1,6/7,7/1	9
Poecilus cupreus (Linnaeus, 1758)	1/1,2/1	2
Poecilus versicolor (Sturm, 1824)	1/3	3
Pterostichus pumilio (Dejean,1828)	7/1	1
Pterostichus diligens (Sturm, 1824)	5/1	1
Pterostichus ovoideus (Sturm, 1824)	7/3	3
Pterostichus melanarius (Illiger, 1798)	2/2,5/1	3
Pterostichus oblongopunctatus (Fabricius, 1787)	4/40	40
Pterostichus niger (Schaller, 1783)	1/1,2/25,5/1,8/1,10/2	30
Abax parallelepipedus (Piller et Mitterpacher, 1783)	2/1,4/1,7/1,10/1	4
Abax parallelus (Duftschmid, 1812)	4/1	1
Abax ovalis (Duftschmid, 1812)	8/1	1
Molops piceus (Panzer, 1793)	2/2,4/21,8/2,6/1,8/6	32
Platyderes rufus (Duftschmid, 1812)	2/1,9/1	2
Calathus fuscipes (Goeze, 1777)	6/1,7/5,10/1	7
Calathus erratus (Sahlberg, 1827)	5/2	2
Calathus melanocephalus (Linnaeus, 1758)	1/1,2/5,4/8	11
Anchomenus dorsalis (Pontoppidan, 1763)	7/2,9/1	3
Oxypselaphus obscurus (Herbst, 1784)	2/3,5/1	4
Platynus assimilis (Paykull, 1790)	2/2	2
Amara aenea (De Geer, 1774)	9/16	16
Amara communis (Panzer, 1797)	5/1	1
Amara majuscula (Chaudoir, 1850)	2/1	1
Amara consularis (Duftschmid, 1812)	3/1	1
Diachromus germanus (Linnaeus, 1758)	2/2	2
Bradycellus ruficollis (Stephens, 1828)	3/2	2
Acupalpus flavicollis (Sturm, 1825)	9/1	1
Trichotichnus laevicollis (Duftschmid, 1812)	5/1	1
Ophonus sabulicola (Panzer, 1796)	3/1	1
Pseudoophonus rufipes (De Geer, 1774)	1/23,2/42,5/1,7/13,8/1,11/1	81
Harpalus distinguendus (Duftschmid, 1812)	8/1	1
Harpalus luteicornis (Duftschmid, 1812)	1/1	1
Harpalus rubripes (Dufstchmid, 1812)	3/1,9/10	11
Harpalus serripes (Quensel, 1806)	11/1	1
Harpalus tardus (Panzer, 1797)	3/1	1
Licinus depressus (Paykull,1790)	1/3,4/1	2
Demetrias atricapilus (Linnaeus, 1758)	10/1	1
Demetrias monostigma Samouelle, 1819	10/1	1
Dromius agilis (Fabricius, 1787)	7/1	1
Philorhizus notatus (Stephens, 1827)	6/1	1
Microlestes minutulus (Goeze, 1777)	7/1	1
Dytiscidae		
Platambus maculatus (Linnaeus, 1758)	2/2	2
Hydrophilidae		
Anacaena globulus (Paykull, 1798)	1/1	1
Histeridae		
Margarinotus purpurascens (Herbst, 1792)	4/1	1
Atholus corvinus (Germar, 1817)	7/2	2
Atholus bimaculatus (Linnaeus, 1758)	10/1	1

Continued

Family Species	Site/specimens	Total
Silphidae		
Thanatophilus sinuatus (Fabricius, 1775)	2/1,11/1	3
Xylodrepa quadripunctata (Linnaues, 1761)	5/1,4/1,8/1	3
Silpha carinata Herbst, 1783	1/8,2/22,3/1,5/2,10/5,9/1	39
Nicrophorus vespillo (Linnaeus, 1758)	6/2	2
Nicrophorus humator Olivier, 1790	5/1	1
Leiodidae		
Sciodrepoides watsoni (Spence, 1815)	1/1	1
Nargus brunneus (Sturm, 1839)	8/24	24
Nargus anisotomides (Spence, 1815)	8/1	1
Choleva oblonga Latreille, 1807	5/1	1
Choleva paskoviensis Reitter, 1913	7/1	1
Sciodrepoides watsoni (Spence, 1815)	5/1,7/2	3
Catops nigricans (Spence, 1815)	3/1,10/1	2
Catops fuscus (Panzer, 1794)	1/1,2/1,5/1,7/2	5
Catops picipes (Fabricius, 1792)	8/1	1
Anisotoma humeralis (Fabricius, 1792)	4/1	1
Amphicyllis globus (Fabricius, 1792)	8/1,2/1,10/1	3
Amphicyllis globiformis (Sahlberg, 1833)	3/3	3
Agathidium nigrinum Sturm, 1807	7/1,9/1	2
Agathidium nigripenne (Fabricius, 1792)	1/1	1
Leiodes lucens (Fairmaire, 1855)	3/1	1
Leiodes flavescens (Schmidt, 1844)	3/2	2
Leiodes badia (Sturm, 1807)	1/1,9/1	2
Colenis immunda (Sturm, 1807)	5/1	1
Colon affine Sturm, 1839	2/1	1
Colon appendiculatum (Sahlberg, 1834)	3/2,5/1	3
Colon calcaratum Erichson, 1837	6/1	1
Scaphidiidae		
Scaphidium quadrimaculatum Olivier, 1790	1/5,4/1	6
Scaphisoma agaricinum (Linnaeus, 1758)	1/3	3
Staphylinidae		
Anthobium florale (Erichson, 1840)	8/1	1
Oxytelus sculptus Gravenhorst, 1806	8/1	1
Stenus ochropus Kiesenwetter, 1858	5/2,8/2	4
Stenus humilis Erichson, 1839	1/1	1
Astenus gracilis (Paykull, 1789)	1/1	1
Astenus brevelytratus Coifait, 1960	3/1,5/1	2
Rugilus erichsoni (Fauvel, 1867)	1/3	3
Medon ferrugineus (Erichson, 1840)	3/1	1
Domene scabricollis (Erichson, 1840)	3/5,4/1,7/5	11
Xantholinus tricolor (Fabricius, 1787)	8/1	1
Xantholinus longiventris Heer, 1839	1/2	2
Xantholinus linearis (Olivier, 1794)	2/3,10/1	4
Othius punctulatus (Goeze, 1777)	2/2	2
Othius myrmecophilus Kiesenwetter, 1843	4/1	1
Philonthus lepidus (Gravenhorst, 1802)	2/1,7/1	2
Philonthus debilis (Gravenhorst, 1802)	7/1	1
Philonthus carbonarius (Gravenhorst, 1802)	3/1	1
Philonthus decorus (Gravenhorst, 1802)	4/1,8/2,9/11	14
Platydracus strecorarius (Olivier, 1795)	11/15	15
Staphylinus melanarius Heer, 1839	2/3,8/2	5
Staphylinus pedator Gravenhorst, 1802	10/1	1
Staphylinus brunnipes Fabricius, 1781	3/1	1
Staphylinus fulvipennis Erichson, 1840	5/1	1
Staphylinus nero semialatus Mueller, 1904	1/2,3/1,7/1,9/2	6
Staphylinus caesareus Cederhjelm, 1798	1/1,2/2,5/1,7/1	5

Continued

Family Species	Site/specimens	Total
Staphylinus biharicus Mueller, 1926	4/1	11
Staphylinus mus Brullé, 1832	4/1	1
Staphylinus fossor Scopoli, 1772	8/2	2
Staphylinus chloropterus Panzer, 1796	4/1,8/1	2
Staphylinus winkleri Bernhauer, 1906	3/1	1
Quedius nemoralis Baudi di Selve, 1848	3/1	1
Quedius fuliginosus (Gravenhorst, 1802)	10/1	1
Mycetoporus forticornis Fauvel, 1875	3/1	1
Mycetoporus longicornis Maeklin, 1847	4/2	2
Leptusa fumida (Erichson, 1839)	7/1	1
Geostiba chyzeri (Epplesheim, 1883)	4/1	1
Drusilla canaliculata (Fabricius, 1787)	1/33,2/8,4/1,5/8,9/19,10/10	79
Zyras humeralis (Gravenhorst, 1802)	2/1	1
Zyras limbatus (Paykull, 1789)	10/1	1
Zyras lugens (Gravenhorst, 1802)	4/1	1
Oxypoda lividipennis Mannerheim, 1830	5/2	2
Pselaphidae		
Amauronyx maerkeli (Aubé, 1844)	7/1	1
Brachygluta fossulata (Reichenbach, 1816)	7/4	4
Pselaphus heisei Herbst, 1792	7/1	1
Lucanidae		
*Platycerus caraboide*s (Linnaeus, 1758)	4/1	1
Trogidae		
Trox hispidus (Pontoppidan, 1763)	3/1,6/1,11/1	3
Geotrupidae		
Odonteus armiger (Scopoli, 1772)	10/3,12/2	5
Trypocopris vernalis (Linnaeus, 1758)	1/9,2/10,3/23,4/13,6/61, 7/58,9/10,10/2,11/5	191
Scarabaeidae		
Sisyphus schaefferi (Linnaeus, 1758)	2/10,3/14,4/1,6/3,7/3,11/7	38
Copris lunaris (Linnaeus, 1758)	3/1	1
Onthophagus ovatus (Linnaeus, 1767)	1/5,3/1,6/3,7/12,9/5,11/17	43
Onthophagus fracticornis (Preyssler, 1790)	7/3,11/1	4
Onthophagus coenobita (Herbst, 1783)	7/1	1
Oxyomus sylvestris (Scopoli, 1763)	2/1	1
Miltotrogus aequinoctialis (Herbst, 1790)	7/1	1
Melolontha melolontha (Linnaeus, 1758)	4/1	1
Oxythyrea funesta (Poda, 1761)	9/3	3
Cetonia aurata (Linnaeus, 1758)	1/1,3/1,12/2	4
Byrrhidae		
Lamprobyrrhulus nitidulus (Schaller, 1783)	9/1,11/1	2
Byrrhus pilula (Linnaeus, 1758)	11/1	1
Byrrhus fasciatus (Forster, 1771)	1/5,2/3,9/4,	12
Buprestidae		
Trachys fragariae Brisout, 1874	3/1,6/6,11/1	8
Elateridae		
Agrypnus murinus (Linnaeus, 1758)	1/1,9/3,10/1	5
Cidnopus pilosus (Leske, 1977)	12/1	1
Athous subfuscus (Mueller, 1767)	7/1	1
Athous silicensis Laibner, 1975	3/1,7/2	3
C*idnopus pilosus* (Leske, 1785)	11/1	1
S*elatosomus latus* (Fabricius, 1801)	11/1	1
Ampedus sinuatus Germar, 1844	3/1	1
Ampedus elongatulus (Fabricius, 1787)	3/1	1
Dalopius marginatus (Linnaeus, 1758)	4/1	1
Agriotes lineatus (Linnaeus, 1767)	7/2	2
Agriotes gallicus Lacordaire, 1835	9/1,10/1	2

Continued

Family Species	Site/specimens	Total
Agriotes sputator (Linnaeus, 1758)	6/1	1
Melanotus castanipes (Paykull, 1800)	7/1	1
Throscidae		
Trixagus duvali (Bonvouloir, 1859)	6/1	1
Eucnemidae		
Eucnemis capucina Ahrens, 1812	8/1	1
Cantharidae		
Cantharis annularis Ménétriés, 1836	5/2	2
Rhagonycha lignosa (Mueller, 1864)	2/1	1
Dermestidae		
Dermestes laniarius Illiger, 1801	1/6,3/1,6/18,7/10,9/42, 10/42,11/10	129
Ptinidae		
Ptinus rufipes Olivier, 1790	8/2	2
Malachiidae		
Charopus concolor (Fabricius, 1801)	1/1	1
Charopus graminicola (Dejean, 1833)	1/1	1
Malachius aeneus (Linnaeus, 1758)	3/1	1
Nitidulidae		
Epuraea longula Erichson, 1845	6/1	1
Carpophilus bipustulatus (Heer, 1841)	2/1	1
Pria dulcamarae (Scopoli, 1763)	5/1	1
Cybocephalidae		
Cybocephalus politus (Gyllenhal, 1813)	4/1,11/1	2
Rhizophagidae		
Monotoma brevicollis Aubé, 1837	9/1	1
Monotoma bicolor Villa, 1835	2/1	1
Sphindidae		
Aspidiphorus orbicularis (Gyllenhal, 1808)	2/1,4/4,8/1	10
Phalacidae		
Phalacrus corruscus (Panzer, 1797)	5/2	2
Cryptophagidae		
Cryptophagus affinis Sturm, 1845	8/5,10/1	6
Ootypus globosus (Waltl, 1838)	5/1	1
Ephistemus globosus (Paykull, 1798)	7/1	1
Erotylidae		
Tritoma bipustulata Fabricius, 1775	5/1	1
Dacne bipustulata (Thunberg, 1781)	2/1,4/1,5/2,7/1,10/1	6
Combocerus glaber (Schaller, 1783)	1/1,7/2,9/1	4
Endomychidae		
Dapsa denticolis (Germar, 1817)	7/18	18
Lycoperdina succincta (Linnaeus, 1767)	1/1,7/2	3
Coccinellidae		
Clitostethus arcuatus (Rossi, 1794)	3/1	1
Scymnus apetzi Mulsant, 1846	9/2	2
Scymnus frontalis (Fabricius, 1787)	6/1	1
Scymnus rubromaculatus (Goeze, 1777)	3/1	1
Platynaspis luteorubra (Goeze, 1777)	9/2	2
Coccinella septempunctata Linnaeus, 1758	5/1	1
Coccinula quatuordecipustulata (Linnaeus, 1758)	6/1	1
Propylea quatuordecimpunctata (Linnaeus, 1758)	2/2	2
Tytthaspis sedecimpuncatata (Linnaeus, 1758)	9/1,10/2	3
Subcoccinella vigintiduopunctata (Linnaeus, 1758)	7/1	1
Corylophidae		
Sericoderus lateralis (Gyllenhal, 1827)	7/1	1
Lathridiidae		
Cartodere contricta (Gyllenhal, 1827)	8/1	1

Continued

Family Species	Site/specimens	Total
Corticaria umbilicata (Beck, 1817)	11/1	1
Corticaria crenulata (Gyllenhal, 1827)	7/1	1
Ciidae		
Cis boleti (Scopoli, 1763)	7/1	1
Anthicidae		
Anthicus antherinus (Linnaeus, 1761)	1/1	1
Meloidae		
Meloë rugosus Marsham, 1802	6/1,7/3,9/3	7
Salpingidae		
Vincenzellus ruficollis (Panzer, 1794)	1/1	1
Tenebrionidae		
Crypticus quisquilius (Linnaeus, 1761)	10/1	1
Myrmechixenus subterraneus Chevrolat, 1835	10/2	2
Cylindronotus dermestoides (Illiger, 1798)	5/1	1
Cerambycidae		
Pachytodes erraticus (Dalman, 1817)	8/1	1
Dorcadion pedestre (Poda, 1761)	3/10,7/1,7/1,12/17,	29
Dorcadion aethiops (Scopoli, 1763)	1/1,6/1,7/1	3
Pogonocherus hispidus (Linnaeus, 1758)	7/1,8/1	2
Tetrops praeusta (Linnaeus, 1758)	3/1	1
Chrysomelidae		
Smaragdina affinis (Illiger, 1794)	1/1	1
Chrysolina sanguinolenta (Linnaeus, 1758)	9/1	1
Chrysolina staphylea (Linnaeus, 1758)	1/2	2
Galeruca pomonae (Scopoli, 1758)	3/1,1/1,6/1,7/1,12/1	5
Phyllotreta exclamationis (Thunberg, 1784)	1/1	1
Phyllotreta nemorum (Linnaeus, 1758)	4/2	2
Phyllotreta armoraciae (Koch, 1803)	4/1	1
Phyllotreta vittula (Redtenbacher, 1849)	1/1	1
Aphthona semicyanea Allard, 1859	8/1	1
Longitarsus brunneus (Duftschmid, 1825)	3/1	1
Crepidodera plutus (Latreille, 1804)	2/1	1
Lythraria salicariae (Paykull, 1800)	2/6	6
Asiorestia ferruginea (Scopoli, 1763)	5/2	2
Chaetocnema aridula (Gyllenhal, 1827)	6/8	8
Dibolia femoralis Redtenbacher, 1849	3/2	2
*Dibolia schilling*i Letzner, 1846	12/2	2
Psylliodes affinis (Paykull, 1799)	5/1	1
Psylliodes chrysocephala (Linnaeus, 1758)	7/1	1
Cassida nebulosa Linnaeus, 1758	1/1	1
Curculionidae		
Apion holosericeum Gyllenhal, 1833	4/6	6
Apion haematodes Kirby, 1808	8/1	1
Apion hookeri Kirby, 1808	5/2	2
Apion simile Kirby, 1811	6/2	2
Apion pomonae (Fabricius, 1798)	3/1	1
*Otiorhynchus hungaricu*s Germar, 1824	8/1	1
Otiorhynchus ligustici (Linnaeus, 1758)	1/1	1
Otiorhynchus roubali Penecke, 1931	8/2	2
Otiorhynchus ovatus (Linnaeus, 1758)	5/19,7/7,9/5,10/21	52
Otiorhynchus orbicularis (Herbst, 1795)	1/1,6/1,11/1	3
Otiorhynchus multipunctatus (Fabricius, 1792)	12/1	1
Otiorhynchus laevigatus (Fabricius, 1792)	5/1,9/2	3
Stomodes gyrosicollis (Boheman, 1843)	2/1,7/1,11/1	3
Phyllobius oblongus (Linnaeus, 1758)	5/8	8
Phyllobius maculicornis Germar, 1824	1/1,5/1	2
Phyllobius argentatus (Linnaeus, 1758)	2/1	1
Phyllobius pyri (Linnaeus, 1758)	9/1	1

Continued

Family Species	Site/specimens	Total
Trachyphloeus alternans Gyllenhal, 1834	7/1,12/1	2
Trachyphloeus angustisetulosus Hansen, 1915	9/1	1
Trachyphloeus aristatus (Gyllenhal, 1827)	1/7,3/2,4/1,5/5,9/19,10/3, 12/2	39
Trachyphloeus asperatus Boheman, 1843	10/5	5
Liophloeus tessulatus (Mueller, 1776)	8/1	1
Sciaphilus asperatus (Bonsdorff, 1785)	1/1,2/1,5/7,9/1	10
Brachysomus echinatus (Bonsdorff, 1785)	1/6,2/19,3/1,4/1,5/29,7/24, 8/1,9/6,10/12	99
Brachysomus slovacicus Košťál, 1991	3/1,6/75,7/160	236
Brachysomus setiger (Gyllenhal, 1840)	10/2,11/1	3
Brachysomus hispidus (Redtenbacher, 1849)	9/1	1
Barypeithes interpositus Roubal, 1920	4/3,6/1,8/6	10
Sitona lineatus (Linnaeus, 1758)	1/5	5
Sitona humeralis Stephens, 1831	1/1	1
Sitona hispidulus (Fabricius, 1776)	9/1	1
Mesagroicus obscurus Boheman, 1840	1/13,2/21,5/16,7/21,9/59, 10/43,11/10	183
Tropiphorus micans Boheman, 1842	1/1,10/2	3
Mecaspis caesus (Gyllenhal, 1834)	9/1	1
Rabdorhynchus varius (Herbst, 1795)	7/1	1
Cleonis pigra (Scopoli, 1763)	9/1	1
Dorytomus rufatus (Bedel, 1888)	2/1	1
Comanisus setiger (Beck, 1817)	9/1,11/1	2
Tychius quinquepunctatus (Linnaeus, 1758)	7/1,10/2	3
Tychius squamulatus Gyllenhal, 1836	1/1	1
Anthonomus rubi (Herbst, 1795)	7/1	1
Anthonomus pedicularius (Linnaeus, 1758)	4/1	1
Anthonomus pomorum (Linnaeus, 1758)	7/2	2
Lepyrus capucinus (Schaller, 1783)	6/3	3
Lepyrus palustris (Scopoli, 1763)	11/1	1
Hylobius transversovittatus (Goeze, 1813)	9/1	1
Alophus triguttatus (Fabricius, 1775)	6/1,7/1,9/2	4
Alophus kaufmanni Stierlin, 1884	9/1	1
Donus tesselatus (Herbst, 1795)	3/1	1
Hypera fuscocinerea (Marsham, 1802)	11/1	1
Hypera arator (Linnaeus, 1758)	1/1	1
Hypera postica (Gyllenhal, 1813)	9/3,11/1	4
Hypera zoila (Scopoli, 1763)	10/1	1
Acalles echinatus (Germar, 1824)	2/1,4/3,5/1,10/1	6
Acalles hypocrita Boheman, 1837	8/1	1
Neophytobius quadrinodosus (Gyllenhal, 1813)	11/1	1
Rhinoncus castor (Fabricius, 1792)	2/1	1
Rhinoncus bruchoides (Herbst, 1784)	10/1	1
Ceutorhynchus picitarsis Gyllenhal, 1837	2/1	1
Glocianus punctiger (Gyllenhal, 1837)	2/1,9/1	2
Mogulones euphorbiae (Brisout, 1866)	9/1	1
Nedyus quadrimaculatus (Linaneus, 1758)	1/1,2/2,5/1	4
Orobitis *cyaneus* (Linnaeus, 1758)	3/1	1
Mecinus pyraster (Herbst, 1795)	11/1	1
Gymnetron linariae (Panzer, 1792)	10/1	1

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Spoločenstvá chrobákov v rôznych biotopoch v okolí jaskyne Domica (Národný park Slovenský kras)

Súhrn

Počas dvoch rokov sme študovali spoločenstvá chrobákov na viacerých biotopoch v okolí jaskyne Domica (južné Slovensko). Metódou zemných pascí sme získali na 12 študijných plochách lokality Domica 302 druhov chrobákov. V rámci jednotlivých čeľadí (41) dominujú čeľade: Curculionidae (65 sp.), Carabidae (65 sp.), a Staphylinidae (40 sp.). Druhy týchto troch čeľadí tvoria 56 % všetkých zistených druhov. Získali sme údaje o štruktúre epigeických chrobákov v závislosti od stupňa zatienenosti. Poukázali sme aj na ekosozologicky a faunisticky významné druhy chrobákov, indikačné pre potvrdenie územnej ochrany v systéme Natura 2000.

Na biotopoch zatienených (les) dominujú larvy holometabolného hmyzu, najmä bystruškovitých (Carabidae). Na biotopoch polozatienených (riedke kriačiny, lesíky) dominujú pavúky (Araneaea). Na otvorených biotopoch (stepné bezlesie, škrapové polia) dominujú blanokrídlovce (Formicidae) a pavúky (Araneae).

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Macrofungi succession in differently aged Norway spruce monocultures

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Abstract

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The present contribution deals with the succession of macrofungi in differently aged Norway spruce monocultures having been planted on the former arable land. During the investigation, the group of most dominant macrofungi in each study plots changed in dependence on the stand age and climatic and edaphic conditions modified by the Norway spruce monoculture. The most frequent changes in species diversity were recorded in younger stands. On the contrary, the oldest stands were most stable. The unexpected calamity in the oldest stands considerably influenced species diversity, structure and succession of macrofungi.

Key words

Picea abies (L.) Karst., macrofungi, succession, monocultures, Slovakia

Introduction

Mycocoenoses can be characterized by several significant parameters like species diversity of macrofungi, trophic structure, dominance structure, succession of macrofungi, abundance of fruiting bodies, distribution or dispersion and production of macrofungi fruiting bodies.

Succession of macrofungi can be evaluated on the base of changes of the above parameters during a given time interval. It is to be added that the problem of succession of macrofungi represents a complex set of relationships, as there are many factors which the succession can be referred to. Such relationships are for example: succession of macrofungi, – wooden plant species composition and phytocoenological structure of forest stands, – age of forest stand, – anthropogeneous influences (e.g. immissions, timber exploitation, trampling, collection of fruiting bodies), – climatic factors, – decomposition of wooden substrate and others.

In Norway spruce and beech stands the succession of saprophytic macrofungi was studied by CHASSEUR (1992) and PONGE (1991), dependence of succession of mycorrhizal symbionts on different age of spruce forests was studied by FELLNER (1987), GÁPER (1992a, b, 1994), GÁPER and LIZOŇ (1995, 1997), GÁPER and MOLNÁROVÁ (2000), GÁPER and ŠURJANSKÁ (2000), LAGANA et al. (2002), MIHÁL (1998a, b, 2002), MIHÁL and GÁPER (1995). In mixed stands, the succession of ectomycorrhizal macrofungi was investigated by HESLIN et al. (1992) and MIHÁL (1993). Succession of macrofungi in mycorrhizal stands of birches and pines was studied for example by FLEMING et al. (1986) and THERMOSHUIZEN and SCHAFFERS (1989).

The present paper focuses on succession of macrofungi in differently aged Norway spruce monocultures having been planted on the former arable land. We expect a long-termed process of re-colonisation of this newly formed ecosystem by a high number of fungal species.

Materials and methods

Characteristics of investigation plots

The investigation was carried out in the study and demonstration plot at the Vrch Dobroč hill (VDO) situated in the Slovenské Rudohorie Mts., in the Veporské vrchy hills, in the spring area of the river Ipeľ. The forest stands in this area grow on the former arable land. Since the beginning of the 1960-ies, the large areas have been afforested. A total of 8,000 ha been afforested by different trees using various silvicultural methods. The conifers cover 75.9% of the stands surface (among them: spruce 55.8%, pine 7.8%, European larch 7.4% and fir 3.3%) while the broad-leaved trees 24.1% (among them: beech 12.7%, oak 3.9% and ash 4.7%). The average annual temperature in the study plot VDO is +6 °C (during vegetation period +12 °C) and annual rainfall is 900 m (during vegetation period 300 mm).

In 1989, four permanent mycological study plots (PMSP A, PMSP B, PMSP C, PMSP D) were founded in the spruce plantations. The main characteristics of all these plots are given in Table 1.

Method of investigation

During September–November of 1993–2003, hence during the autumnal aspect, species diversity, abundance and distribution of sporocarps were recorded once a month. Because of different reasons, the investigation was not made in the years 1995, 2000 and 2002 in all plots, while only in the plot PMSP D in 2003, when the thinning was carried out in this stand and cut trees were left there.

Succession of macrofungi is understood as a set of values of abundance and distribution of a given species which together determine species dominance in the whole mycocoenoses studied. Dominance (Do) is expressed as sum of abundance (A) and distribution (D) of sporocarps of a species in a study plot. Values of dominance (Do = A + D) exhibited by a species during the whole investigation period ranks this species among the successionally significant macrofungi. To ascertain the dominance of macrofungi, it is necessary to record abundance as well as distribution of sporocarps in each plot. As distribution means number of places of occurrence of sporocarps, it expresses degree of colonisation of the substrate by a species. In combination with abundance of a species it describes the mycocoenoses as from the view of species diversity and abundance of sporocarps as from the view of most distributed dominants on given locality. This method was described by Mihál (1994) and it was also applied in other papers (Mihál, 1995; Mihál and Gáper 1995). The criterion of spatial distribution of sporocarps was also used in the above study plots by Gáper and Molnárová (2000) and Gáper and Šurjanská (2000). In a beech stand after timber exploitation, Mihál (1992) used frequency and constancy of species occurrence to express dominance of macrofungi. Values of both parameters together gave rank of a species in the group of dominant macrofungi.

The concrete mode of evaluation of dominance on the base of which succession of species was evaluated is exemplified by the following case of a one year of investigation:

YEAR 1993

September: *Ciboria bulgaroides* (Abundance = 6, Distribution = 6, Dominance = 12), *Marasmiellus perforans* (A = 2, D = 1, Do = 3), *Lepista flaccida* (Do = 3), *Calocera viscosa* (2), September altogether: Dominance = 20

October: *Marasmiellus perforans* (Do = 417), *Lepista flaccida* (298), *Lycoperdon umbrinum* (149), *Clitocybe metachroa* (144), *Collybia butyracea* (102), October altogether: Do = 1110

November: *Hygrophorus pustulatus* (66), *Lepista flaccida* (57), *Hypholoma fasciculare* (28), *Lycoperdon umbrinum* (28), *Collybia butyracea* (24), November altogether: Do = 203.

Note: Because of space reasons, in individual

Table 1. Characteristics of permanent mycological study plots (PMSP)

Characteristics	PMSP			
	A	B	C	D
Area [m^2]	1,250	1,250	1,250	1,250
Tree species	spruce	spruce	spruce	spruce
Stand age [years in 2005]	39	9	22	15
Plantation spacing [m]	1.4 x 1.4	1.4 x 1.4	1.4 x 1.4	1.9 x 1.2
Altitude [m a. s. l.]	820–835	820–835	810–815	860
Exposition	SW	SW	SW	E
pH (H_2O) /October 1994/	4.28	4.56	5.44	5.27
Soil type	cambisol typical	cambisol typical	cambisol typical	cambisol typical
Humus form	mull moder	mull moder	mull moder	mull moder
Geological substrate	granodiorit	granodiorit	granodiorit	granodiorit

In 1994 and 1995 the PMSP A nad B were damaged by snow and wind. The PMS B was almost destroyed and the PMSP A was strongly damaged. After relief of calamity impact, Norway spruce plants were planted in PSMP B in 1995.

months of investigation we give some most dominant species only.

Numeric values of dominance of individual species obtained during the whole investigation serve as basis for ranking of a species among the species used for evaluation of succession and, at the same time, among the species playing the most important role in the succession.

Nomenclature of all macrofungi mentioned in this paper was taken from Marhold and Hindák (1998) and Škubla (2003). Herbarium specimens of some interesting macrofungi are deposited in the author´s collection at the Institute of Forest Ecology of the Slovak Academy of Sciences in Zvolen.

Results and discussion

During investigation we have recorded in all study plots 162 species of macrofungi: 62 species in PMSP A, 44 in PMSP B, 69 in PMSP C and 74 in PMSP D. The concrete survey of species, in particular of saprophytic and ectomycorrhizal species is given in the papers by Mihál (1998a, b, 2002).

Survey of species showing the highest values of dominance in individual plots is given in Tables 2–5. Besides this, the Table 6 includes 10 most dominant species from each study plot.

Comparison of species diversity of the most dominant species in individual PMSP shows that there are differences in representation of dominant macrofungi as within individual years as between individual PMSP. For example, the species typical of mature Norway spruce stand occurred in the oldest PMSP A and B, especially the species *Marasmiellus perforans*, *Lepista flaccida*, *Hypholoma fasciculare*, *Lycoperdon umbrinum*, *Clitocybe metachroa*. The species typical for PMSP C and D are species occurring in younger growing phases of natural Norway spruce stands. In PMSP the typical species were representatives of the genus *Mycena*, *Heyderia abietis*, *Amanita muscaria*, *Hygrophorus pustulatus* atc., while for PMSP D the species *Marasmiellus perforans*, *Cortinarius cinnamomeus*, *Laccaria laccata*, *Mycena alcalina* agg., *Amanita muscaria*, *Thelephora terrestris*.

A similar trend in dominance and succession of macrofungi in individual PMSP was also found by Gáper (1992a), according whom the genus *Laccaria* is characteristic of the youngest growth phase, genus *Cortinarius* for the middle and genus *Lycoperdon* for the oldest phase. Gáper (1994) described succession of genera of saprophytic macrofungi from the youngest up to the oldest growing phase in the sequence: *Agrocybe*, *Mycena*, *Coprinus*, *Agaricus*, *Calocera*, *Lepista*, *Marasmiellus*. Gáper and Šurjanská (2000) give the species *Cortinarius alboviolaceus*, *C. cinnamomeus* and *C. sommerfeltii* to be characteristic of PMSP D, the species *Amanita muscaria*, *Boletus edulis*, *Chalciporus piperatus* for PMSP C and the species *Hygrophorus pustulatus, Lactarius mitissimus, and Xerocomus chysenteron* for PMSP A and B.

Gáper and Lizoň (1997) studied dynamics of colonisation of the study plots by ectomycorrhitic macrofungi. They consider the species *Amanita muscaria*, *Amanita rubescens*, *Chalciporus piperatus*, *Laccaria laccata*, as well as species of the genus

Table 2. Group of the most dominant species recorded during the investigation period in PMSP A

Years	Species of macrofungi
1993	*Marasmiellus perforans* (Do = 420), *Lepista flaccida* (358), *Lycoperdon umbrinum* (177), *Clitocybe metachroa* (144), *Collybia butyracea* (126)
1994	*Marasmiellus perforans* (864), *Lycoperdon umbrinum* (314), *Laccaria laccata* (195), *Clitopilus prunulus* (119), *Clitocybe metachroa* (74)
1996	*Hypholoma fasciculare* (324), *Lycoperdon umbrinum* (126), *Hygrophorus pustulatus* (54), *Laccaria laccata* (37), *Xerocomus badius* (29)
1997	*Lycoperdon umbrinum* (24), *Bjerkandera adusta* (6), *Exidia pithya* (4), *Russula mustelina* (4), *Trichaptum abietinum* (4)
1998	*Mycena atropapillata* (105), *Laccaria laccata* (85), *Dacrymyces stillatus* (48), *M. perforans* (42), *Clitocybe metachroa* (40)
1999	*Dacrymyces stillatus* (42), *Lycoperdon umbrinum* (9), *Rhizina undulata* (9), *Trichaptum abietinum* (6), *Gomphidius glutinosus* (4)
2001	*Marasmiellus perforans* (121), *Collybia butyracea* (102), *Laccaria laccata* (102), *Hypholoma fasciculare* (81), *Gomphidius glutinosus* (56)
2003	*Dacrymyces stillatus* (6), *Xerocomus badius* (5), *Russula mustelina* (4), *Schizophyllum commune* (4), *Trichaptum abietinum* (4)

Do – numeric value of dominance calculated as sum of abundance (A) and distribution (D) of sporocarp of each species (see Material and methods)

Cortinarius to be macrofungi characteristic of the primary succession in the process of colonisation of spruce monocultures. GÁPER (1992b) also found interesting data in connection with dynamics of species diversity. He gives that number of species increases with increasing age (most expressively at the genera *Amanita, Clitocybe*, *Collybia* and *Cortinarius*), increases and later decreases at the beginning of succession (genera *Hebeloma* and *Marasmiellus*) or does not change in the course of time (genera *Chalciporu*s and *Laccaria*).

Different results were obtained in the youngest stand in PMSP D in comparison with the oldest stands in PMSP A and B before the calamity and after it. In PMSP D a dense crown canopy prevails and in such stands, according to JANSEN and DE NIE (1988), most sporocarps of ectomycorrhizal macrofungi occur. This phenomenon was also observed by GÁPER and LIZOŇ (1995), who recorded occurrence specially species of the genera *Hebeloma* and *Cortinarius*. Just in the genus *Hebeloma*, AL ABRAS et al. (1988) discovered forming of mycorrhizal symbiosis of roots of 4-year old spruce plants. Our results as well results of GÁPER (1994) show that species of the genus Hebeloma abundantly occurred as in the young stand in PMSP D as well as in the older stand on PMSP C.

Other situation arose in the oldest stand in PMSP A and B, especially in connection with the calamity which almost destroyed the stand on PMSP B. It is to be noted that KONÔPKA (1992) observed most rots and reduced ecological stability on older spruce stands

Table 3. Group of the most dominant species recorded during the investigation period in PMSP B

Years	Species of macrofungi
1993	*Lepista flaccida* (470), *Hypholoma fasciculare* (235), *Clitocybe metachroa* (100), *Collybia butyracea* (83), *Lycoperdon umbrinum* (70)
1994	*Hypholoma fasciculare* (80), *Marasmiellus perforans* (74), *Laccaria laccata* (71), *Lycoperdon umbrinum* (67), *Lepista flaccida* (61)
1996	*Lycoperdon umbrinum* (120), *Hypholoma fasciculare* (94), *Tubaria conspersa* (45), *Laccaria laccata* (19), *Trichaptum abietinum* (10)
1997	*Schizophyllum commune* (10), *Bjerkandera adusta* (8), *Trichaptum abietinum* (8), *Dacrymyces stillatus* (2), *Russula mustelina* (2)
1998	*Hypholoma fasciculare* (168), *Dacrymyces stillatus* (50), *Laccaria laccata* (39), *Lycoperdon umbrinum* (33), *Calora viscosa* (8)
1999	*Hypholoma fasciculare* (111), *Dacrymyces stillatus* (8), *Bjerkandera adusta* (2), *Trichaptum abietinum* (2)
2001	*Hypholoma fasciculare* (255), *Laccaria laccata* (33), *Lycoperdon umbrinum* (27), *Lactarius rufus* (25), *Cortinarius colus* (11)
2003	*Schizophyllum commune* (4), *Trichaptum abietinum* (4), *Dacrymyces stillatus* (2)

Table 4. Group of the most dominant species recorded during the investigation period in PMSP C

Years	Species of macrofungi
1993	*Collybia cookei* (1001), *Amanita muscaria* (636), *Chalciporus piperatus* (301), *Hebeloma crustuliniforme* (189), *Marasmiellus perforans* (175)
1994	*Mycena alcalina* agg. (8281), *Heyderia abietis* (8088), *Mycena cinerella* (2962), *Amanita muscaria* (931), *Lactarius deterrimus* (544)
1996	*Mycena cinerella* (cca 400 000), *Mycena alcalina* agg. (cca 200 000), *Mycena rosella* (cca 30 000), *Marasmiellus perforans* (cca 10 000), *Heyderia abietis* (4538)
1997	*Lycoperdon umbrinum* (637), *Mycena pura* (194), *Mycena cinerella* (66), *Mycena alcalina* agg. (60), *Clitocybe clavi pes* (34)
1998	*Mycena cinerella* (cca 50 000), *Clitocybe metachroa* (3676), *Hygrophorus pustulatus* (1350), *Lycoperdon umbrinum* (861), *Marasmiellus perforans* (304)
1999	*Mycena alcalina* agg. (569), *Lycoperdon umbrinum* (511), *Mycena cinerella* (373), *Collybia butyracea* (96), *Marasmiellus perforans* (89)
2001	*Marasmiellus perforans* (1039), *Lycoperdon umbrinum* (268), *Collybia buryracea* (143), *Clitocybe brumalis* (107), *Laccaria laccata* (98)
2003	*Marasmiellus perforans* (1287), *Mycena cinerella* (451), *Mycena alcalina* agg. (230), *Lycoperdon umbrinum* (108), *Mycena citrinomarginata* (96)

planed on the former non-woody land, just as in the case of our study plots. Mihál (1998a) found out that species diversity of macrofungi considerably decreased after the calamity in the stand in PMSP A and B. A similar decrease (most in PMSP B) was also recorded in abundance, distribution and production of sporocarps, especially of the ectomycorrhizal macrofungi. Lagana et al. (2002) studied succession of macrofungi in an artificially planted fir stand. In contrast with the original stand they recorded increase in ectomycorrhizal species from 22.2% up to 72.4%. The dominant genera in the artificially planted fir stand were *Cortinarius*, *Hygrophorus*, *Inocybe, Laccaria, Marasmiellus* and others. Similarly, Mihál and Gáper (1995) compared species diversity of macrofungi in the natural Norway spruce forests with diversity in an artificially planted stand. They found out that *Xerocomus chrysenteron, X. badius, Mycena alcalina* agg., *M. pura*, *Calocera viscosa* and other belonged to the most dominant species.

Skalický (1985) mentioned, that species diversity can not be used as the only parameter for assessing stability and general condition of an ecosystem. For example, also the whole internal environment of the stand is also to be considered. Rarer fungi of the Norway spruce cultures are mostly saprophytic, but not so closely bound to the Norway spruce, as to the specific environment created by the spruce cultures together with other conditions (Skalický, l.c.). Similarly, Mihál (1998b, 2002) selected as criteria of evaluation of mycocoenoses in individual PMSP beside the species diversity abundance, distribution and production of sporocarps of macrofungi. He found out that the highest production of sporocarps in the oldest stands was reached by *Lepista flaccida, Hypholoma fasciculare, Gomphidius glutinosus, Lycoperdon umbrinum* and others, while in the youngest stands by *Mycena alcalina* agg., *Amanita muscaria, Cortinarius cinnamomeus, Chalciporus piperatus* and others.

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Table 5. Group of the most dominant species recorded during the investigation period in PMSP D

Years	Species of macrofungi
1993	*Laccaria laccata* (206), *Cortinarius cinnamomeus* (150), *Thelephora terrestris* (76), *Amanita muscaria* (48), *Tubaria conspersa* (24)
1994	*Thelephora terrestris* (484), *Laccaria laccata* (244), *Cortinarius cinnamomeus* (204), *Hygrocybe ceracea* (93), *Hypholoma fasciculare* (32)
1996	*Cortinarius cinnamomeus* (699), *Laccaria laccata* (376), *Hypholoma fasiculare* (69), *Amanita muscaria* (48), *Cortinarius anomalus* (48)
1997	*Laccaria laccata* (100), *Cortinarius cinnamomeus* (75), *Amanita muscaria* (32), *Cortinarius sommerfeltii* (10), *Leccinum versipelle* (4)
1998	*Cortinarius cinnamomeus* (1898), *Laccaria laccata* (298), *Amanita muscaria* (126), *Cortinarius varius* (100), *Tricholoma imbricatum* (40)
1999	*Hypholoma fasciculare* (186), *Laccaria laccata* (90), *Lycoperdon umbrinum* (79), *Amanita muscaria* (42),
2001	*Mycena cinerella* (11470), *Marasmiellus perforans* (6870), *Mycena alcalina* agg. (1200), *Mycena atropapillata* (1140), *Amanita muscaria* (586)
2003	not evaluated – see Material and methods

Table 6. Group of 10 most dominant species of macrofungi in PMSP during the whole investigated period

PMSP	Most dominant species of macrofungi
A	*Marasmiellus perforans*, *Lycoperdon umbrinum*, *Laccaria laccata*, *Hypholoma fasciculare*, *Lepista flaccida*, *Clitocybe metachroa*, *Collybia butyracea*, *Clitopilus prunulus, Mycena atropapillata*, *Dacrymyces stillatus*
B	*Hypholoma fasciculare, Lepista flaccida, Lycoperdon umbrinum, Laccaria laccata, Clitocybe metachroa, Collybia butyracea, Marasmiellus perforans, Dacrymyces stillatus, Tubaria conspersa, Lactarius rufus*
C	*Mycena cinerella, Mycena alcalina agg., Mycena rosella, Marasmiellus perforans, Heyderia abietis, Clitocybe metachroa, Lycoperdon umbrinum, Amanita muscaria, Hygrophorus pustulatus, Collybia cookei*
D	*Mycena cinerella, Marasmiellus perforans, Cortinarius cinnamomeus, Laccaria laccata, Mycena alcalina, Mycena atropapillata, Amanita muscaria, Thelephora terrestris, Hypholoma fasciculare, Cortinarius varius*

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Sukcesia makromycétov v smrekových monokultúrach rôzneho veku

Súhrn

V predloženom príspevku sa venujeme sukcesným pomerom druhovej diverzity makromycétov v podmienkach rôznovekých smrekových monokultúr, ktoré boli vysadené na bývalej poľnohospodárskej pôde. Počas doby výskumu sa na každej výskumnej ploche sukcesne menila skupina najdominantnejších druhov makromycétov v závislosti od veku porastu a klimaticko-ekologických podmienok prostredia vytváraných porastom smrekovej monokultúry. Najvýraznejšie zmeny v sukcesii makromycétov boli zaznamenané vo vekovo mladších porastoch a pomerne sukcesne stabilné boli najstaršie porasty. Kalamita vo vekovo najstarších porastoch do značnej miery ovplyvnila aj druhovú diverzitu, dominanciu a sukcesiu makromycétov.

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Biological evaluation of the water quality of the Hostiansky potok stream in the Tríbeč Mountains

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Abstract

Rakovská, A., Noskovič, J., Beňačkova, J. 2005. Biological evaluation of the water quality of the Hostiansky potok stream in the Tríbeč Mountains. *Folia oecol.*, 32: 110–115.

In the paper we evaluate surface water quality by the method of the saprobity index determination. Over the period 1997–1998 were taken totally 72 water samples from three sampling sites in the Hostiansky potok stream. In the sampled water were identified 8,534 benthic animals. 62 determined macrozoobenthos species were divided into 10 systematic groups. The water of the studied segment of the Hostiansky potok contained general representatives of the systematic groups Amphipoda, Plecoptera, Ephemeroptera and Trichoptera. From the results of the saprobiological evaluation of the water quality in the studied segment it follows that the water maintained approximately the same quality over the two years. The values of the saprobity index ranged from 0.7034 to 1.5923, therefore, in accordance to the Standard STN 75 7221 the water of Hostiansky potok flowing through the forest ecosystem was ranked to the 1st and 2nd classes, i.e. classified as a very clear or clear in terms of oligosaprobity zone.

Key words

water quality, zoobenthos, dominant species, saprobity, saprobity indicators

Introduction

One of the most important today problems, with significant impact on the development of the modern society, is the continual increase in pollution of water in surface watercourses. It is most commonly caused by different waste materials with fatal effects to water organisms. However, also without the waste materials, it very often occurs a water course pollution, the so-called self-pollution. Therefore, from the viewpoint of possible use of water courses in future by the human population, but also by other living organisms, the regular monitoring of the pollution level and the evaluation of the surface water quality are key-important. In the last years, thanks to a considerable world-wide recognition in saprobiology, there is high importance given to the biological evaluation of the pollution level and surface water quality, through qualitative and quantitative evaluation of the organisms occupying the bottom of water biotopes, the so-called benthic organisms. To contribute to the actual knowledge in the area (Bitušík, 1990; Elexová and Ardó, 1998; Elexová, 2001; Krno, 1992, 1993, 2003; Moravcová, 1986; Nagy, 2003; Rakovská et al., 2002; Sládeček, 1981; Soldán et al., 1998 and others), we have submitted this paper presenting the results of evaluation of the water quality in the water stream Hostiansky potok.

Material and methods

The catchment characteristic

We monitored and evaluated the surface water quality in the upper part of the stream Hostiansky potok in (Tribeč Mts.) by the method of the saprobity level determination. The lower part of the stream is situated in the upland Žitavská pahorkatina. The watercourse belongs to the catchment of the Žitava River, in which it issues under the town Zlaté Moravce – part Chyzerovce. The entire catchment of the watercourse has an area of 120 km^2 and its annual contribution to Žitava is 0.94 $m^3 s^{-1}$.

The catchment of the watercourse in Tribeč consists of a forest ecosystem and an ecosystem with permanent grass cover. In the forest ecosystem are dominant *Fagus sylvatica* L., *Quercus cerris* L, *Quercus petraea* (Mattusch.) Liebl, *Quercus robur* L., *Quercus dalechampii* Len, *Carpinus betulus* L. For the down-stream area are characteristic *Alnus glutinosa* (L) Gaertn, *Alnus incana* (L) Moench, *Fraxinus excelsior* L, *Salix eleagnos* Scop and *Salix triandra* L.

The Tribeč Mts. belongs to the Secondary zone of the whole Carpathians Mountains. From the soils there occur ranker, rendzina, pararendzina, cambisol and luvisol.

In terms of climate, the catchment in Tribeč belongs for the most part to the transition and partially to the warm region represented by subhumic lowland area. The transition region consists of a moderate warm subhumic valley (potential frost hollow) and a mountain.

Material sampling and processing

The water samples from the stream were taken regularly, over 1997–1998, always within the last ten days of the current month. The material was sampled in the three following sites:

1. Forest ecosystem situated at 300 m above sea level. The site is covered with a high forest.
2. Below the permanent grass ecosystem on the left side and the forest ecosystem on the right side of the water flow. The length of the segment is 1.6 km.
3. Below the permanent grass ecosystem on both sides of the stream near the municipality of Hostie. The length of the segment is 1.6 km.

All the studied parts of the stream are situated near to an asphalt road, the bottom is covered with gravel and sand.

Biological material – organisms from the macrozoobenthos, was sampled with a hydrobiological net postured opposite to the water flow. The organisms, tight stuck the substrates (stones, tree roots or branches), were carefully scraped with a scraper. The sampled material was fixed in 4% formaldehyde solution. It was consequently processed in the laboratory by usual methods and saved in 80% gasoline-alcohol. Clarified and partially classified material was finally determined by means of a binocular magnifier and a stereomicroscope. For the determination were used the commonly used determination keys (Hrabě et al., 1954; Kratochvíl et al., 1959; Rozkošný et al., 1980; Waringer and Graf, 1997 and other). The determined macrozoobenthic organisms were used for calculation of the modified Pantle-Bucke's index (Sládeček et al., 1981) the saprobity index. The final class of water quality and the saprobity level were identified according to STN 75 7221.

Calculation of the saprobity index:

$$Sj = \frac{\Sigma S_i . h_i . I_i}{\Sigma h_i . I_i}$$

where is: S_j – saprobity index of the community
h_i – individual species frequency
I_i – individual indicator species value
S_i – individual species saprobity index

Results and discussion

In regular monthly sampling over the years 1997 and 1998 we took totally 72 samples of the water in which we determined 8,534 macrozoobenthic organisms belonging to 62 taxons and 10 systematic groups: Turbellaria, Hirudinea, Gastropoda, Amphipoda, Ephemeroptera, Plectoptera, Megaloptera, Coleoptera, Trichoptera and Diptera (flowing across the forest ecosystem). Over the whole monitoring period and in all the sampling sites, there was found simultaneous and very high occurrence of representatives of the order Amphipoda (phylum Arthropoda, subphylum Branchiata, class Crustacea, subclass Malacostraca). The percentage of Amphipoda from the total macrozoobenthos was quite high: in 1997 they represented 50.39% (by 2,100 ex. m^{-2}) from the total number of 4,168 benthic organisms, in 1998 it was 59.37% (2,592 ex. m^{-2}) from the total number of 4,366 benthic organisms (Figs 1–2). The most widespread species of this systematic group was *Gammarus fossarum* – a characteristic representative of the xeno to oligosaprobic waters that is simultaneously our most common species from the order Amphipoda. Similarly, as in Deván (1999) thanks to its massive occurrence, we have evaluated it as an eudominanting species. From this systematic group was also present in a lower in the monitored localities the characteristic species of the betamezosaprobic waters – *Gammarus roeselii*. Both these species are relatively good indicators of saprobity. To others, almost regularly occurring macrozoobenthic species belonged: Plecoptera of which mainly *Perla marginata* and *Perla burmesteriana* and Ephemeroptera. Occurrence of the Ephemeroptera was recorded in all the sampling sites, with regularly occurring representatives of this systematic group *Habroleptoides modesta*, *Ephemera danica* and *Epeorus assimilis* (syn. *Epeorus sylvicola*). These organisms were also determined in the stream Hostiansky potok by Deván (1989). For the author, the abundant occurrence of the last listed species in this locality was a surprise, because the species especially occurs in more watery flows. Because it belonged to the species with high occurrence, we can agree with the author that its occurrence indicates high water amount and quality in a particular watercourse.

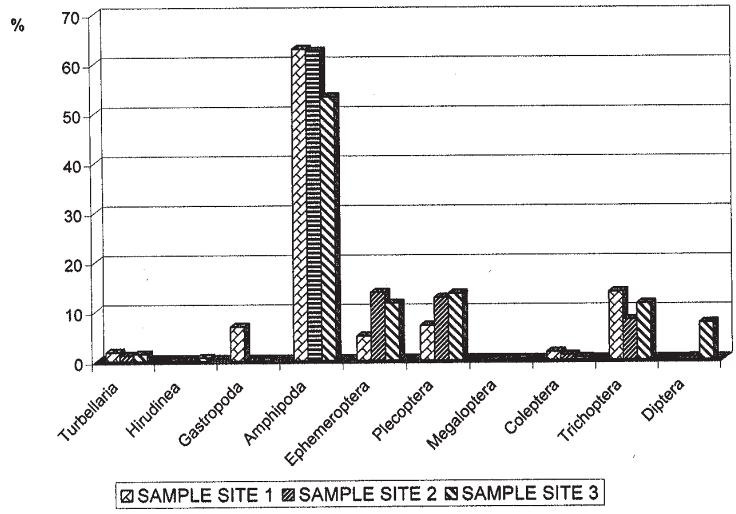

Fig. 1. Relative abundance of systematic groups in the macrozoobenthos in 1997

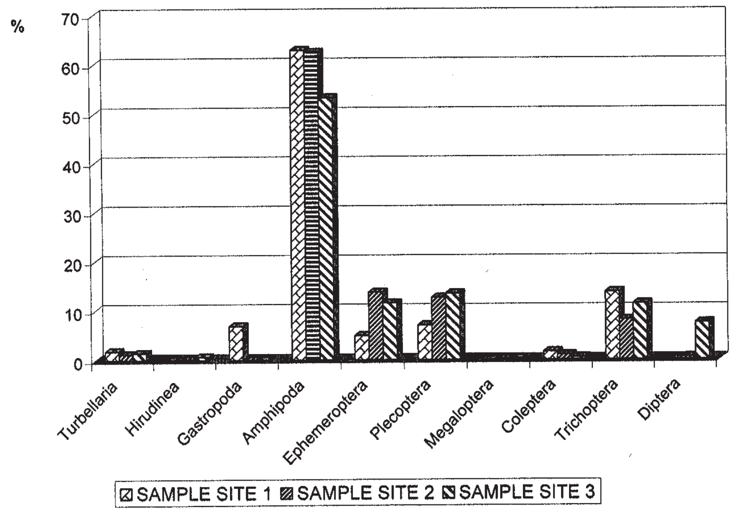

Fig. 2. Relative abundance of systematic groups in the macrozoobenthos in 1998

The species-specific and rate-specific widespread representatives of the macrozoobenthos also included Trichoptera. In the water samples were dominant above all the species *Potamophylax nigricornis*, *Hydropsyche angustipennis*, *Hydropsyche pellucida*, *Rhyacophila dorsalis*. Their presence in Hostiansky potok was also confirmed by Krno (1992, 1993).

The representation of animals of other systematic groups in waters of observed section of Hostiansky potok was lower, evaluated as rare and random. The lowest rate and abundance was ascertained for Megaloptera. The finding of two individuals of the species *Sialis lutaria* in the year 1998 in the second sampling site is considered extraordinary because during the previous term the occurrence of this species was not recorded.

The number of the individuals and species and the number of the systematic groups in 1998 was slightly higher compared to the year 1997. The lowest values of the listed indicators were ascertained for the 1st sampling site (Table 1).

Water saprobity in the monitored segment of Hostiansky potok was evaluated through the saprobity index calculated using the modified Pantle-Bruck's index (Zelinka and Marvan, 1996, 1997 – extract from Losos, 1992). The structure of macrozoobenthos in all three sampling sites documented only a low water pollution. In the year 1997 moved the values of the calculated saprobity index from 0.7040 (1st sampling site, October) to 1.4475 (3rd sampling site, April). The 1st sampling site was approved for almost all the year (February, March, April, June, July, August, September, October, November and December) to be an oligosaprobic zone, according to the STN 75 7221 with water of the 1st surface water cleanness class (very clean water). In the sampling sites 2 and 3 there were also oligosaprobic zones, in terms the benthos saprobity index belonging to the 1st or 2nd surface water quality class (very clean water and clean water). In the year 1998, the values of saprobity index were moving within from 0.7034 (3rd sampling site, October) to 1.5923 (3rd sampling site, August). On the basis of the calculated values of saprobity index we can say that similar to the preceding year, also over the most part of this year, water in the observed segment of Hostiansky potok indicated an oligosaprobic zone equivalent to the 2nd class of surface water quality, with exception of two months, when the water could even be classified as belonging to the 1st cleaness-class of surface water quality. Compared to the year 1997, the quality of the water was lower because over most of the year, the ascertained values of the saprobity index indicated the 2nd class of the water cleanness, i.e. clean water. Clean oligosaprobic water in the sampling sites in the upper part of the Hostiansky potok stream was also ascertained by Deván (1993) – on the basis of Ephemeroptera coenoses occurrence and by Krno (1989) – on the basis of occurrence of Plecoptera, Figs 3, 4.

Table 1. Numbers of individuals, species and systematic groups in years 1997 and 1998

Sampling site	Year	Number of individuals	Number of species	Number of systematic groups
1	1997	1,214	31	7
	1998	1,336	29	7
2	1997	1,462	29	8
	1998	1,502	32	9
3	1997	1,492	30	6
	1998	1,528	34	9

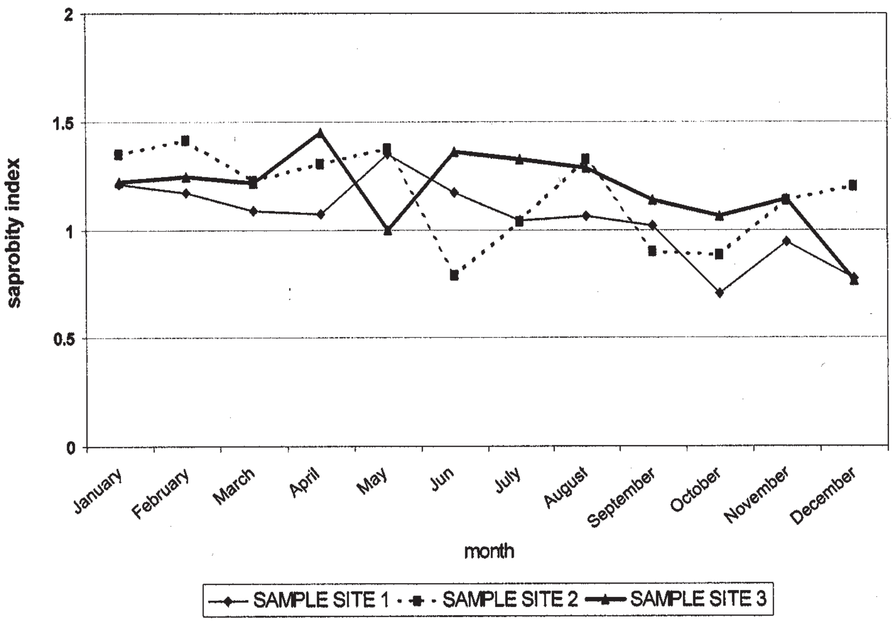

Fig. 3. Saprobiological characteristic of the Hostiansky potok stream in 1997

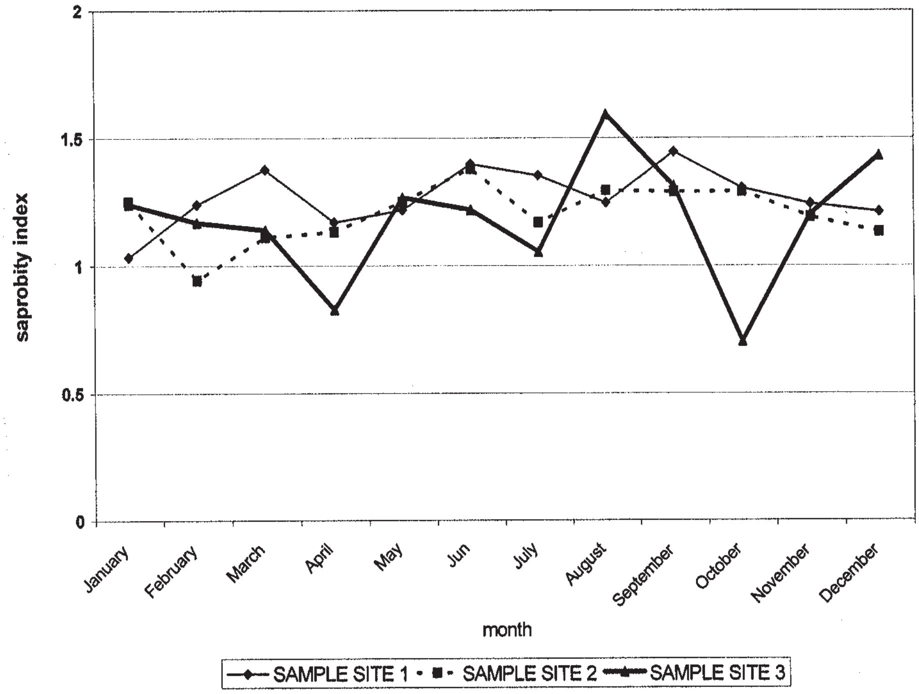

Fig. 4. Saprobiological characteristic of the Hostiansky potok stream in 1998

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Biologické hodnotenie kvality vody vodného toku Hostiansky potok v pohorí Tríbeč

Súhrn

Práca uvádza hodnotenie kvality povrchovej vody metódou stanovenia stupňa saprobity. V rokoch 1997 a 1998 sa na 3 odberových miestach vodného toku Hostiansky potok celkovo odobralo 72 vzoriek vody, v ktorých sa nachádzalo 8534 bentických živočíchov. Determinovaných 62 druhov makrozoobentosu sa zaradilo do 10 systematických skupín, z ktorých sa vo vodách sledovaného úseku Hostianskeho potoka takmer pravidelne vyskytovali zástupcovia systematických skupín Amphipoda,Plecoptera, Ephemeroptera a Trichoptera. Z výsledkov saprobiologického hodnotenia kvality vody sledovaného úseku vodného toku vyplýva, že voda si počas obidvoch rokov udržiavala približne rovnakú kvalitu. Hodnoty sapróbnych indexov sa pohybovali v rozpätí od 0,7034 do 1,5923, preto podľa STN 75 7221 bola voda Hostianskeho potoka pretekajúca lesným ekosystémom zaradená do I. až II. triedy, t. j. hodnotená ako veľmi čistá až čistá, zodpovedajúca pásmu oligosaprobity.

Production of the aboveground dendromass of European chestnut (*Castanea sativa* Mill.) in relation to leaf area index and climatic conditions

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Abstract

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The work deals with the above-ground dendromass formation and its relationship to both leaf area index (LAI) and climatic conditions in different stand types of European chestnut (*Castanea sativa* Mill.) at the series of PRP Lefantovce (Forest administration Nitrianska Streda, Forest enterprise Topoľčianky, Slovak Republic) tended during 25 years by moderate crown thinning with frequency of 5 years. The highest mean periodical increment per leaf area unit (g dm^{-2} $year^{-1}$) was observed in all stand types during years 1977–1981 and 1982–1986. It was found out that production of above-ground dendromass of European chestnut stands is in close correlation with LAI, with admixture of woody-plant species in stands, their tending (thinning) and climatic conditions. Rainfalls showed to be the limiting factor (not less than 500 mm per year).

Key words

leaf area index, climatic conditions, production of above-ground dendromass

Introduction

Dry matter production by plants is dependent on their leaf area index, expressed by the surface area of leaf blades per unit area of the ground, and on the net assimilation yield. The leaf area index and net assimilation rate are dependent on the environment and also on the developmental phase and density (spacing) of trees in the population (Tokár 1989a, b, 1997). High production can only be reached if maximum leaf surface area has been reached in the most favourable vegetation period (Oszlányi, 1985; Walter, 1964, sec. Vyskot et al. 1971).

Build-up of aboveground dendromass in various stand types of young European chestnut (*Castanea sativa* Mill.) trees in Slovakia is being surveyed by Tokár (1980, 1987, 1998). In this work we evaluate dry matter production of aboveground dendromass in dependence on the leaf area index for various stand types of European chestnut tended by applying moderate thinning from above.

Materials and methods

The experiment was carried out in the years 1976, 1981, 1986, 1991, 1996 and 2001 in the experimental area Horné Lefantovce (Forest Enterprise Topoľčianky, Forest Commission Nitrianska Streda, south-western Slovakia) in the following types of forest stands: a pure stand of *Castanea sativa* Mill., mixed stands of *Castanea sativa* Mill. with *Tilia cordata* Mill. and *Castanea sativa* Mill. with *Pinus sylvestris* L. In 1976 was the age of European chestnut tress 13 years, and the age of the admixed woody species was 14 years. In the years 1976, 1981, 1986, 1991, 1996, 2001, moderate crown-thinning treatments were applied to the stands, aimed at positive selection (Tokár, 1989a, 1993, 1998).

Permanent research plots (PRP) are part of Castanetarium Horné Lefantovce (14.38 hectares) that belongs to the 3rd forest vegetation tier (fvt) and group of forest types (gft) Fagetum pauper inferiora, the soil type is Luvisol, at altitude of 220 m (Tokár and Kukla 2005).

The stands were established by row planting with one-year-old European chestnut seedlings of Lefantovce provenance and with two-year-old little linden seedlings also from Lefantovce. The distance between the rows was 1 m and the spacing between the seedlings in a row was also 1 m. The stands were even-aged and homogeneous. In 1976, a series of 6 partial permanent research plots (PRP-s) was established with the aim to evaluate the structure, development, production and quality of stands affected by moderate crown thinning with positive selection and 5-year frequency, especially with regard to changes in qualitative and quantitative parameters of the stands. All trees on the PRP-s were numbered. At the end of each of the growing seasons 1976, 1981, 1986, 1991, 1996, 2001, there were undertaken inventories comprising dendrometric measurements, assessment of sociological structure and stem and crown quality.

At the same time, following the long-term thinning plan, moderate crown-thinning interventions with positive selection (quality thinning in the sense of Schädelin) aimed at tending of prospective trees were undertaken. Their influence was assessed corresponding to the stand type, based on volume and mass production, stem and crown quality as well as development of the prospective trees. The inventory results can be found in Tokár (1980, 1985, 1987, 1989a, 1990, 1993, 1998).

Values of photosynthesis in the active surface area of leaves and aboveground dendromass were determined using the destructive method of sample trees. The sample tree selection was performed in such a way as to comply best with the fact that between the basal area and weight of trees (their dendromass) there exists a direct dependence which can be best-fitted with a 2^{nd}-degree parabola (Tokár,1989a, b). The number of sample trees was determined by stratified selection corresponding to the basal area values in the particular tree classes, with an error of 10% (Šmelko, 1988). In young stands (less than 20 years), with relatively high diameter variability, there were selected by 30 sample trees of each species. In older stands with more homogeneous diameter values, there were selected by 15 sample trees (Tokár, 1984, 1985, 1989a, b, 1990, 1993, 1998).

Leaf area index was determined as follows: First we directly, using a photoplanimeter EIJKELKAMP, measured leaf area values on three representative samples (3 x 100 leaves) collected from all sample trees. From these values we calculated conversion coefficients (fresh weight of leaves in kg/fresh leaf area in m^2), which were subsequently used for leaf area calculation for all the sample trees. The Burger formula according to which 1 g of fresh needles has a surface area of 55 cm^2 (Polster, 1950, cf. Steinhűbel, 1973) was used for determining the phosynthetically active surface of needles in Scotch pine. Calculated leaf area values were correlated with DBH values. The fitting function was a 2^{nd} degree parabola. Then the fitted values were multiplied by tree numbers in particular diameter intervals, and the values of active leaf area (leaf area index – LAI – in ha ha^{-1}) were obtained. Finally, the correlation relationship between LAI and tree age was fitted with a 2^{nd} degree parabola (see figures and tables).

DBH, tree height, length and width of crown were measured on all sample trees. Weight of stem, branches (living and dead), annual shoots and leaves were determined using a scale KAMOR with a capacity of 50 kg and an accuracy of 0.01 kg. From three sample trees representing tree classes, representative samples were taken from each third of the stem, branches and twigs (annual shoots and leaves) and dried at 105 °C in order to determine the percentage of dry matter.

The calculated values of individual components of the aboveground dendromass were correlated with DBH and the correlation was fitted by a parabola of the 2^{nd} degree, (Tokár, 1989b). The values of aboveground dendromass stock on the individual PRP-s were obtained by multiplication of the fitted values by tree numbers in particular diameter intervals corresponding to the diameter structure of the stands. These values were used for calculation of mean periodical increments in the aboveground dendromass expressed per stand area unit and per leaf area unit. In this way, we have obtained comparable standards (equivalents) for evaluation of the influence of different silvicultural measures (thinning) and stand composition on the final production and for comparison between tended and untended stands (control PRP-s).

Climatic date (average annual temperatures and annual rainfall) were used from the publications of Slovak University of Agriculture in Nitra (Špánik et al., 1995, 2002).

Results

Leaf area index (LAI)

Since the beginning of the thinning experiment, together with thinning impact on volume and weight production of aboveground dendromass, also leaf area index was examined (Table 1). At the experiment establishment in 1976 (stand age 13 years) the highest LAI was found in the European chestnut stand mixed with little linden (5.85 ha ha^{-1}). In 2001 (25 years after the first thinning) was the highest LAI found on the control plot – European chestnut stand mixed with Scotch pine (11.61 ha ha^{-1}).

Table 1. Experimentally obtained leaf area index (LAI) for various stand types of European chestnut (*Castanea sativa* Mill.) on the PRP series Lefantovce over the years 1976–2001

PRP	Woody species	1976		1981		1986		1991		1996		2001	
		Age (years)	LAI (ha ha^{-1})	Age (years)	LAI (ha ha^{-1})	Age (years)	LAI (ha ha^{-1})	Age (years)	LAI (ha ha^{-1})	Age (years)	LAI (ha ha^{-1})	Age (years)	LAI (ha ha^{-1})
I (check)	*Castanea sativa* Mill.	13	2.02	18	2.12	23	2.93	28	3.96	33	4.50	38	5.38
II	*Castanea sativa* Mill.	13	2.09	18	2.36	23	3.56	28	3.95	33	3.87	38	4.52
VII (check)	*Castanea sativa* Mill.	13	1.92	18	1.89	23	2.42	28	2.65	33	2.80	38	2.70
	Tilia cordata Mill.	14	3.84	19	0.75	24	5.00	29	2.92	34	3.52	39	4.05
	Total	13	5.76	18	2.64	23	7.42	28	5.57	33	6.32	38	6.75
VIII	*Castanea sativa* Mill.	13	1.87	18	1.67	23	2.71	28	2.80	33	2.96	38	3.34
	Tilia cordata Mill.	14	3.98	19	0.48	24	3.46	29	1.69	34	2.00	39	2.34
	Total	13	5.85	18	2.15	23	6.17	28	4.49	33	4.96	38	5.68
IX (check)	*Castanea sativa* Mill.	13	1.70	18	1.72	23	2.90	28	2.00	33	2.90	38	3.32
	Pinus sylvestris L.	14	1.38	19	1.92	24	2.15	29	6.93	34	6.13	39	8.29
	Total	13	3.08	18	3.64	23	5.05	28	9.93	33	9.03	38	11.61
X	*Castanea sativa* Mill.	13	1.64	18	1.39	23	2.63	28	2.06	33	2.05	38	2.72
	Pinus sylvestris L.	14	1.52	19	1.77	24	1.94	29	3.91	34	5.66	39	5.94
	Total	13	3.16	18	3.16	23	4.57	28	5.97	33	7.71	38	8.66

Aboveground dendromass stock

In 2001 (stand age 38 years) we found the highest aboveground wood mass stock (229.02 t ha^{-1}) in the untended stand of European chestnut mixed with Scotch pine (Table 2). Comparing the stock values, we can see that the values in the tended European chestnut monoculture and the tended European chestnut stands mixed with Scotch pine were lower compared to the corresponding untended control stands by 12.36% and 20.06%, respectively. On the other hand, the tended chestnut stand mixed with little linden had production value higher by 34.18% compared to the control, the cause of which is most probably in favourable allelopathic and ecological conditions created for the chestnut trees by the systematically applied tending (thinning) interventions.

Mean periodical increment in aboveground dendromass

Over the period of the stand development, the PRPs were subjected to six thinning interventions. The results of surveys undertaken and evaluated at 5-year intervals allowed us to determine mean periodical increments per growing area (t ha year^{-1}) and per leaf area (g dm^{-2} year^{-1}).

In the European chestnut monocultures, the highest periodical increment per growing area (Table 3) was found in two periods (1977–1981 and 1997–2001) and reached the values of 8.69 t ha^{-1} year (PRP II) and 6.53 t ha^{-1} year^{-1} (PRP I), respectively.

Also in the mixed stands (Table 3) we identified two periods of mean periodical increment culmination per growing area unit (1982–1986 and 1997–2001). In the European chestnut stand mixed with little linden it reached a value of 9.08 t ha^{-1} year^{-1} and in the chestnut stand mixed with Scotch pine it was 12.15 t ha^{-1} year $^{-1}$. In 1982–1986 was the highest mean periodical increment in chestnut trees (8.32 t ha^{-1} year^{-1}) observed in the stand mixed with Scotch pine (PRP X) and in 1997–2001 was the highest value (5.94 t ha^{-1} year^{-1}) found in the tended European chestnut stand mixed with little linden (PRP VIII).

The highest values of mean periodical increment per leaf area unit (Table 4) were in all the stand types found in the years 1977–1981. In general, during the whole development, the tended stands had higher increments compared to the untended ones. The highest value (6.38 g dm^{-2} year^{-1}) was found in the tended European chestnut stand mixed with little linden (PRP VIII), with the chestnut trees share 4.61 g dm^{-2} year^{-1} (72.25%).

An important ecological factor which takes part in reaching a maximal increment of aboveground dendromass dry matter per leaf area unit (g dm^{-2} year^{-1}) is a mean annual sum of rainfalls (Fig. 1). It should not be lower than 500 mm what also meteorological data from period 1977–1981 prove (mean annual temperature 9.5 °C, mean annual sum of rainfalls 538.2 mm).

Table 2. Aboveground dendromass proportion in dry mass of various stand types of European chestnut (*Castanea sativa* Mill.) trees on the PRP series Lefantovce

PRP	Woody species	Aboveground dendromass (t ha^{-1})					
		1976	1981	1986	1991	1996	2001
		Age of stands (years)					
		13	18	23	28	33	38
I (check)	*Castanea sativa* Mill.	37.32	74.18	83.97	114.78	141.56	174.19
II	*Castanea sativa* Mill.	41.37	84.81	102.63	116.28	121.37	151.57
VII (check)	*Castanea sativa* Mill.	33.09	50.62	81.19	77.97	87.50	88.37
	Tilia cordata Milá.	19.75	28.13	42.97	60.75	74.30	93.97
	Total	52.84	78.75	124.16	138.72	161.80	182.34
VIII	*Castanea sativa* Mill.	39.96	75.48	91.00	88.15	99.70	129.39
	Tilia cordata Mill.	16.23	20.49	31.06	38.14	48.04	60.67
	Total	53.19	95.97	122.06	126.29	147.74	190.06
IX (check)	*Castanea sativa* Mill.	19.56	52.07	91.16	89.19	90.14	104.78
	Pinus sylvestris L.	18.94	27.68	32.05	44.88	78.16	124.24
	Total	38.50	79.75	123.21	134.07	168.30	229.02
	Castanea sativa Mill.	19.69	46.35	87.94	63.89	69.19	95.12
X	*Pinus sylvestris* L.	20.34	23.62	26.20	50.58	70.04	72.66
	Total	40.03	69.97	114.14	114.47	139.23	167.78

Table 3. Mean periodical increment in aboveground dendromass per growing area unit in the mixed stands of European chestnut (*Castanea sativa* Mill.) trees on the PRP series Lefantovce

PRP	Woody species	Mean periodical increment (t ha^{-1} year^{-1})					
		1966–1976	1977–1981	1982–1986	1987–1991	1992–1996	1997–2001
I (check)	*Castanea sativa* Mill.	2.87	7.37	1.96	6.16	5.36	6.53
II	*Castanea sativa* Mill.	3.18	8.69	3.56	2.73	1.02	6.04
VII (check)	*Castanea sativa* Mill.	2.54	3.51	6.11	0.64	1.91	0.17
	Tilia cordata Mill.	1.41	1.68	2.97	3.56	2.71	3.93
	Total	3.95	5.19	9.08	4.20	4.62	4.10
VIII	*Castanea sativa* Mill.	2.84	7.70	3.10	0.57	2.31	5.94
	Tilia cordata Mill.	1.16	0.85	2.11	1.42	1.98	2.53
	Total	4.00	8.55	5.21	1.99	4.29	8.47
IX (check)	*Castanea sativa* Mill.	1.50	6.50	7.82	0.39	0.19	2.93
	Pinus sylvestris L.	1.35	1.75	0.87	2.57	6.66	9.22
	Total	2.85	8.25	8.69	2.96	6.85	12.15
X	*Castanea sativa* Mill.	1.51	5.33	8.32	0.81	1.06	5.19
	Pinus sylvestris L.	1.45	0.66	0.52	4.88	3.89	0.52
	Total	2.96	5.99	8.84	5.69	4.95	5.71

Table 4. Mean periodical increment in aboveground dendromass per leaf-area unit in the mixed stands of European chestnut (*Castanea sativa* Mill.) trees on the PRP series Lefantovce

PRP	Woody species	Mean periodical increment (t ha^{-1} year^{-1})					
		1966–1976	1977–1981	1982–1986	1987–1991	1992–1996	1997–2001
I (check)	*Castanea sativa* Mill.	1.42	3.48	0.67	1.55	1.19	1.21
II	*Castanea sativa* Mill.	1.52	3.68	1.00	0.69	0.26	1.34
VII (check)	*Castanea sativa* Mill.	1.32	1.86	2.52	0.24	0.68	0.06
	Tilia cordata Mill.	0.37	2.24	0.59	1.22	0.77	0.97
	Total	1.69	4.10	3.11	1.46	1.45	1.03
VIII	*Castanea sativa* Mill.	1.52	4.61	1.14	0.20	0.78	0.56
	Tilia cordata Mill.	0.29	1.77	0.61	0.84	0.99	1.08
	Total	1.81	6.38	1.75	1.02	1.77	1.64
IX (check)	*Castanea sativa* Mill.	0.88	3.78	2.70	0.13	0.06	0.88
	Pinus sylvestris L.	0.98	0.09	0.40	0.37	1.09	1.11
	Total	1.86	3.87	3.10	0.50	1.15	1.99
X	*Castanea sativa* Mill.	0.92	3.83	3.16	0.39	0.52	1.91
	Pinus sylvestris L.	0.95	0.37	0.27	1.25	0.69	0.09
	Total	1.87	4.20	3.43	1.64	1.21	2.00

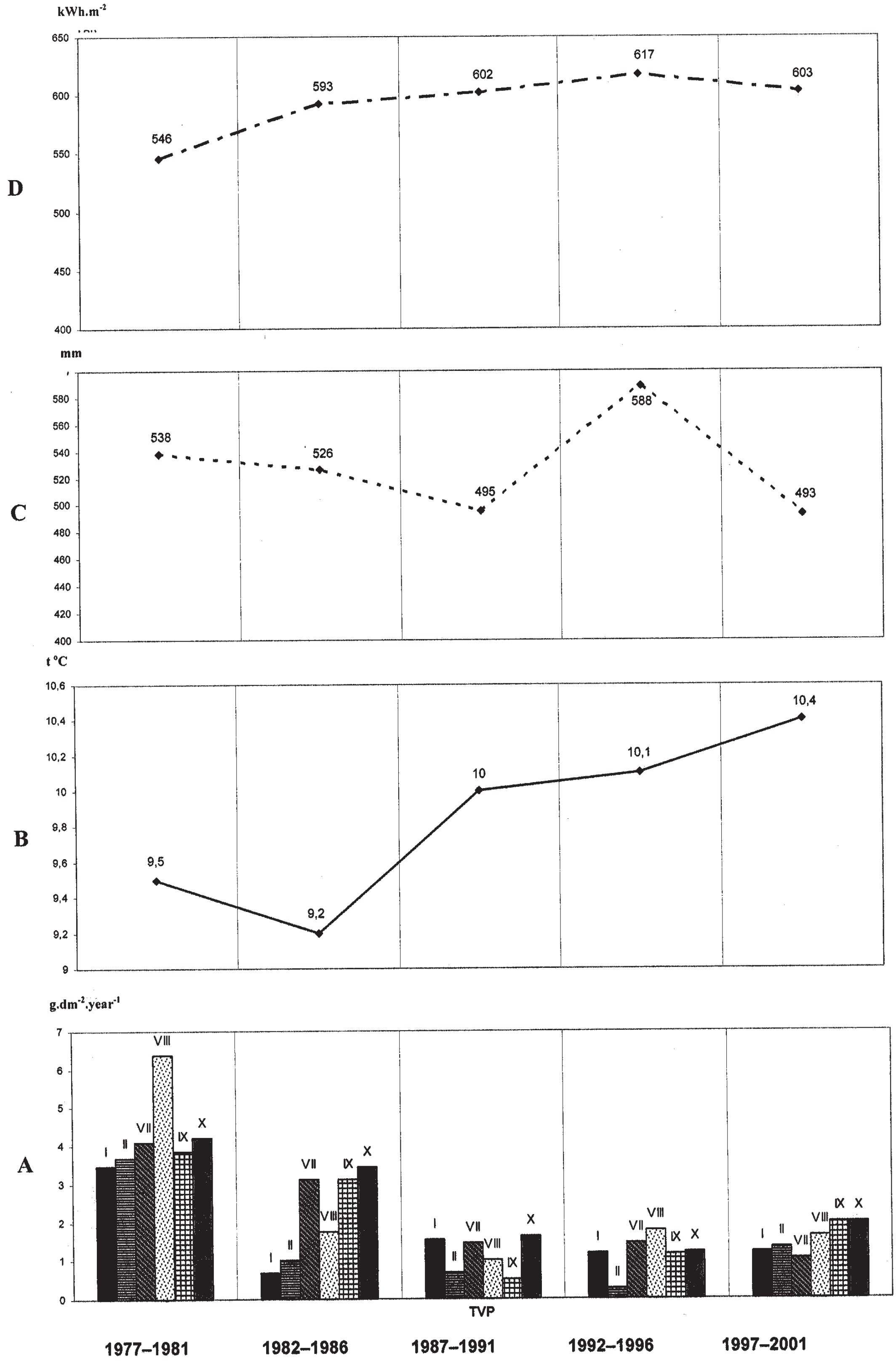

Fig. 1. Dendromass production per leaf area unit (g dm^{-2} year^{-1}) and climatic characteristics for period 1977–2001 at the series of PRP Horné Lefantovce
A Mean periodical increment (g dm^{-2} year^{-1}), B Average annual temperature (t °C), C Annual rainfall (mm), D Photosyntetically active radiation (GFAR kWh m^{-2}), I – X Permanent Research Plots (PRP)

From the results we can draw the important conclusion that the aboveground wood mass production in European chestnut stands is closely correlated with leaf area of tree crowns, which is itself dependent on the stand composition (other species admixture) and the applied silvicultural measures (thinning) and climatic conditions.

Discussion

Assimilatory surface of crown is one of the factors determining the production vigour of the woody plant. Tokár (1980, 1984, 1985, 1987, 1989, 1995, 1998) reports that the photosynthetic activities of woody plants not only depend on ecological conditions in the growing area (soil fertility, stand type, allelopatic relations) and climate history in the year, but also, to a considerable extent, on genetic and physiological conditions of the species. Reaching high production requires reaching maximum leaf surface area in the most favourable vegetation period (Walter, 1964, sec. Vyskot et al., 1971). The worse are the site conditions, the bigger amount of assimilatory organs is necessary for the creation of the same amount of woody matter (Assmann, 1968; Tokár , 1989; Vyskot et al., 1971).

There has been confirmed the hypothesis proposed by Tokár (1980, 1987, 1998) about higher production of aboveground dendromass in the stands of European chestnut mixed with little linden and stands of European chestnut mixed with Scotch pine. The higher production values in these stands are censed by favourable ecological conditions that are governing in these stands.

The annual dry biomass production per leaf area unit was the subject studied by Walter (1964), sec. Vyskot et al., 1971. For the European chestnut, the author gives a value of 1.15 g dm^{-2} $year^{-1}$. As show our results, the values of this variable are dependent on several ecological and silvicultural parameters (stand type, tree species, silvicultural measures, climate history in the current year). Optimum conditions for reaching the maximum production in the chestnut trees occurred in 1977–1981 in the tended stand of European chestnut mixed with little linden, when mean annual temperature was 9.5 °C and mean annual sum of rainfalls 538.2 mm. It is in accord with the results of Tokár (2004) obtained in thinning experiments of pure chestnut stands at locality Žirany.

Conclusions

The work evaluates creation of aboveground dendromass in relation to leaf area index (LAI) in various types of European chestnut (*Castanea sativa* Mill.) stands tended for 25 years by moderate crown thinning with positive selection, applied at 5-year intervals, on the PRP series Lefantovce (Slovak Republic).

In the course of stand development, the values of LAI and dendromass production (growing stock, increments) are varying, corresponding to various ecological conditions and silvicultural measures.

The highest value of LAI in 1976 (stand age 13years) was found in the European chestnut stand mixed with little linden (5.85 ha ha^{-1}). In 2001 (stand age 38 years) was the highest value found in the untended stand mixed with Scotch pine (11.61 ha ha^{-1}). In this stand type we have also found the highest aboveground dendromass stock 229.02 t ha^{-1}.

The highest mean periodical increment per growing area unit (9.08 t ha^{-1} $year^{-1}$) was found in 1982–1986 in the untended chestnut stand mixed with small-leaved linden and in 1997–2001 in the untended chestnut stand mixed with Scotch pine (12.15 t ha^{-1} $year^{-1}$).

The highest mean periodical increment per leaf area unit (6.38 g dm^{-2} $year^{-1}$) in 1977–1981 was found in the tended European chestnut stand mixed with small leaved linden, with the chestnut trees share by 4.61 g dm^{-2} $year^{-1}$ (72.26%). Limiting factors of reaching this increment is mean annual sum of rainfalls (not less than 500 mm).

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Produkcia nadzemnej dendromasy porastov gaštana jedlého (*Castanea sativa* Mill.) vo vzťahu k indexu listovej plochy a ku klimatickým podmienkam

Súhrn

Práca zhodnocuje tvorbu sušiny nadzemnej dendromasy a jej vzťah k listovej ploche korún (LAI) a klimatickým podmienkam rôznych typov porastov gaštana jedlého (*Castanea sativa* Mill.) vychovávaných 25 rokov miernymi úrovňovými prebierkami, pozitívnym výberom a intervalom opakovania 5 rokov na sérii TVP Horné Lefantovce (Lesná správa Nitrianska Streda, Lesný závod Topoľčianky).

Najvyšší LAI sa zistil pri založení pokusu v r. 1976 (vek porastov 13 rokov) v zmiešanom poraste gaštana jedlého s lipou malolistou (5,85 ha ha^{-1}), v r. 2001 (vek porastov 38 rokov) v zmiešanom poraste gaštana jedlého s borovicou lesnou (11,61 ha ha^{-1}).

V r. 2001 najvyššiu zásobu nadzemnej dendromasy (229,02 t ha^{-1}) dosiahol zmiešaný nevychovávaný porast gaštana jedlého s borovicou lesnou. Z vychovávaných porastov vyššiu zásobu nadzemnej dendromasy dosiahol len zmiešaný porast gaštana jedlého s lipou malolistou (190,06 t ha^{-1}).

V priemernom periodickom prírastku na jednotku rastovej plochy (t ha-1 rok^{-1}) sa dosiahli maximálne hodnoty v období rokov 1977–1981 a 1982–1986. Najvyššia hodnota sa dosiahla v zmiešanom nevychovávanom poraste gaštana jedlého s lipou malolistou v období r. 1982–1986 (9,08 t ha^{-1} rok^{-1}).

Podobné výsledky sa dosiahli aj pri priemernom periodickom prírastku na jednotku listovej plochy (g dm^{-2} rok^{-1}), kde sa najvyššie hodnoty dosiahli takisto v období r. 1977–1981 a 1982–1986. Najvyššiu hodnotu (6,38 g dm^{-2} rok^{-1}) dosiahol zmiešaný vychovávaný porast gaštana jedlého s lipou malolistou v r. 1977–1981.

Ukázalo sa, že produkcia nadzemnej dendromasy porastov gaštana jedlého je v tesnom vzťahu k LAI, zmiešaniu drevín, ich fytotechnike (prebierkam) a klimatickým podmienkam. Limitujúcim faktorom sú priemerné ročné zrážky za zhodnocovacie obdobie (nie menšie ako 500 mm za rok).

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Ecologically allowable populations of hoofed game in the District Stropkov

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Abstract

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Hoofed game is a very important component of forest biocoenoses. Our research objects were forest ecosystems in NE Slovakia. We evaluated the current stocks of game, on the background of the standardised winter stocks (SWS), and the numbers of the killed (shot) animals. The aim of this work was the game management with focus on the hoofed game and a proposal of measures for lowering the damage to the ecosystems caused by the hoofed game in the concerned area over the years 1997–2002. To date, there have been certified 11 hunting grounds in the territory of the District Stropkov. The average area of a ground is 3,140 ha. For the whole district, they have been determined, according to the valid standards, the following stocks for red deer – 300 animals and 208 animals roe deer. The present stocks of red deer in the District Stropkov need to be concerned as underestimated, do not corresponding to the current possibilities and the carrying capacity of the hunting grounds. Comparing the standardised game stocks with the current state in spring, we obtain a figure of 56% only. On the other hand, it has been recognised that the present amount of the red deer in the district is too low. If the present SGS were taken as a base for the management of the red deer in the district in the future, it would mean a tendency to further decline of the present, evidently low SGS in the future, in many hunting grounds with only a very low number of animals left for survival.

Key words

Stropkov, hoofed game, hunting area, spring game stocks, planned structure

Introduction

Forest is an immense, high-differentiated complex of living organisms – a biocoenosis or a forest ecosystem. These organisms are mutually dependent, and each of them has a specified role in the frame of the whole ecosystem. In terms of their relations to forest woody plants, the organisms can be beneficial, injurious or indifferent.

For this reason, it is important to ensure and maintain an appropriate coexistence of forest and wildlife that can be reached by application of various measures in the forest and game management. The fact that the success cannot be reached by application of one single measure only is frequently neglected in the practice (Hell, 2001).

Slovakia comprises 41.6% ground plane, whose area is 49,034 km^2. Slovakia with its forest cover belongs to the European countries with the highest percentage of forestland. Topography and climate conditions have provided a background for formation of a number of different forest ecosystems – from floodplain to high-mountain forests (Řéh, 1999).

A very important component of a forest biocoenosis consists of vertebrate animals. Some of them cause severe damage to forest, primarily because their food demands. The red deer participates by the highest percentage on the damage caused by the hoofed game. The red deer influences the development and structure of forest communities, beginning with the regeneration up to about one half of the rotation period. In dependence on the intensity of game influence on the forest, the adverse effects can reach very different grades. The major part in this process is browsing of young woody plants and bark stripping. The other damage (crushing, knocking out, seed feed, dragging) is only of local importance – connected with high game stocks (Forst, 1996).

The activity of wildlife in a forest need not be negative only. A positive phenomenon is, for example, grazing of undesirable vegetation (raspberries, blackberries, willows, grasses…) that could restraint the appropriate development of the target species. In general, however, the negative working of wildlife on development of the ecosystem is decisive. It is important to ensure and maintain an appropriate coexistence of the wildlife and the forest, which can be in the forest management provided by a whole complex of measures: individual, mechanical and chemical protection, restoration methods applied on forest stands and the appropriate measures realised in game keeping and hunting: maintaining the winter stocks of game corresponding to the bearing capacity (determined by the standard) of the given ecosystem and by the game management (Belina, 1997).

The aim of this work was to evaluate the natural conditions and the actual state of forest management in a model area situated in the administration District Stropkov in north-eastern Slovakia. We have assessed the game management with focus on the hoofed game and elaborated a proposal of measures for lowering the damage to the ecosystems caused by the hoofed game over the area.

Material and methods

The research objects were forest ecosystems in NE Slovakia. We evaluated the current stocks of game, issuing from the standardised winter stocks (SWS) and the numbers of the killed (shot) animals. The data were collected from catalogues of regional wildlife management presentations, from hunting reports (Ministry of Agriculture SR) 1-01 Annual Report on spring stocks of wildlife to May 31, and from reports on hunting grounds and the wildlife hunting. The damage was evaluated fulfilling the data into the L 115 – Report on damage caused to forest stands by the wildlife.

The study area in the District Stropkov comprises 34,535 ha, from which the total hunting area takes 33,419 ha. The detailed data (to year 2002) about the hunting area and about the particular hunting grounds are summarised in Table 1.

Table 1. Total hunting area and hunting grounds in the District Stropkov

Number	Hunting ground	Area of ground in ha					Quality class	Hunting zone
		Agricultural land	Forest land	Water bodies	Other plots	Total		
1	Ferdaska – Vyš. Olšava	1,368	1,413	14	192	2,987	III	J-XXVII 3
2	Sakalov – Lomné	1,078	1,257	437	121	2,893	III	J-XXVII 3
3	Dubinka – Mrázovce	1,040	1,483	316	150	2,989	III	J-XXVII 1
4	Hrun – Breznica	2,490	2,925	84	268	5,767	III	J-XXVII 1
5	Kančov Potok – Stropkov	1,171	673	46	176	2,066	IV	J-XXVII 1, J-XXVI 2
6	Maleník – Vojtovce	1,588	1,309	29	226	3,152	III	J-XXVII 1, J-XXVI 2
7	Diľ – Havaj	1,159	2,367	22	126	3,674	IV	J-XXVI 2, J-XXVII 1
8	Kamjana – Miková	791	1,624	29	121	2,565	IV	J-XXVI 2, J-XXVII 2
9	Dolina – Olšavka	1,770	1,211	37	276	3,294	III	J-XXVI 2, J-XXVII 1
10	Vysoká Hora – Chotča	1,312	1,201	49	268	2,830	III	J-XXVI 2, J-XXVII 1
11	Ondava – Duplín	1,269	827	53	169	2,318	IV	J-XXVI 2, J-XXVII 3

To date, 11 hunting grounds have been certified in the territory of the District Stropkov. The average area of a ground is 3,140 ha, the largest is the hunting association (HA) Hrun with an area of 5,767 ha, the smallest is HA Kančov Potok with 2,066 ha. The forest cover percentage of the grounds is 47%. For the whole district, they have been determined by norms the following stocks:

- Red deer – 300 (that means 9 animals per 1,000 ha of the hunting area): 123 bulls, 117 hinds and 60 kids.
- Roe deer – 208 (6 animals per 1,000 ha of the hunting area), 82 roe-bucks, 79 does and 47 kids.

The hunting grounds have in general been assigned to the third quality class for the red deer: seven grounds with the total area of 23,912 ha (69%) belong to the third class, two grounds with the area of 8,557 ha (25%) to the fourth class, one ground, 2,066 ha (6%) has been assigned to the fifth class.

Allocation of hunting zones in the District Stropkov

The boundaries of the hunting zones encroaching the district territory have been determined by the Decree No. 91/1997 Body of law about the hunting zones and about the qualitative classification of hunting grounds.

The district territory is encroached by two red deer zones (Fig. 1):

1. J XXVI zone Nízke Beskydy Mts.
   The hunting zone consists of two sub-zones: Vyšný Mirošov and Habura. It is situated in the boundary territory between Slovakia and Poland, from Becherov (west) to Palota (east). The northern boundary of the zone follows the state boundary, the southern crosses the Nízke Beskydy Mts. and proceeds to Bardejov – Svidník – Stropkov – Havaj – Krásny Brod and Medzilaborce. The boundary between the sub-zones is represented by the state motorway Svidník – Ladomírová – Krajná Poľana – Vyšný Komárnik. The hunting zone encroaches the area of four administration districts: Bardejov, Svidník, Stropkov, Medzilaborce. The zone comprises: HA Díl', HA Kamjana, HA Dolina, HA Vysoká Hora, HA Ondava.
2. J XXVII zone Humenné
   The zone consists of three sub-zones: Stropkov, Hrubov and Ondava hunting zones. It encroaches the territory of five administration districts: Svidník, Stropkov, Vranov nad Topľou, Medzilaborce and Humenné. The northern boundary follows the line Svidník – Stropkov – Havaj – Krásny Brod. The eastern boundary is coincident with the Laborec River crossing the villages Krásny Brod – Radvaň – Koškovce – Humenné. The southern boundary runs across Humenné – Brestov – Nižná Sitnica – Žablín – Slovenská Kajňa – Detrik – Matiaška – Hanušovce. The western boundary crosses Hanušovce – Giraltovce – Okrúhle – Rovné. The boundary between the sub-zones follows the Ondava River and the state motorway Havaj – Varechovce – Oľka – Nižná Sitnica. The zone encompasses hunting associations HA Sakalov, HA Dubinka, HA Hrun, HA Kančov Potok, HA Maleník.

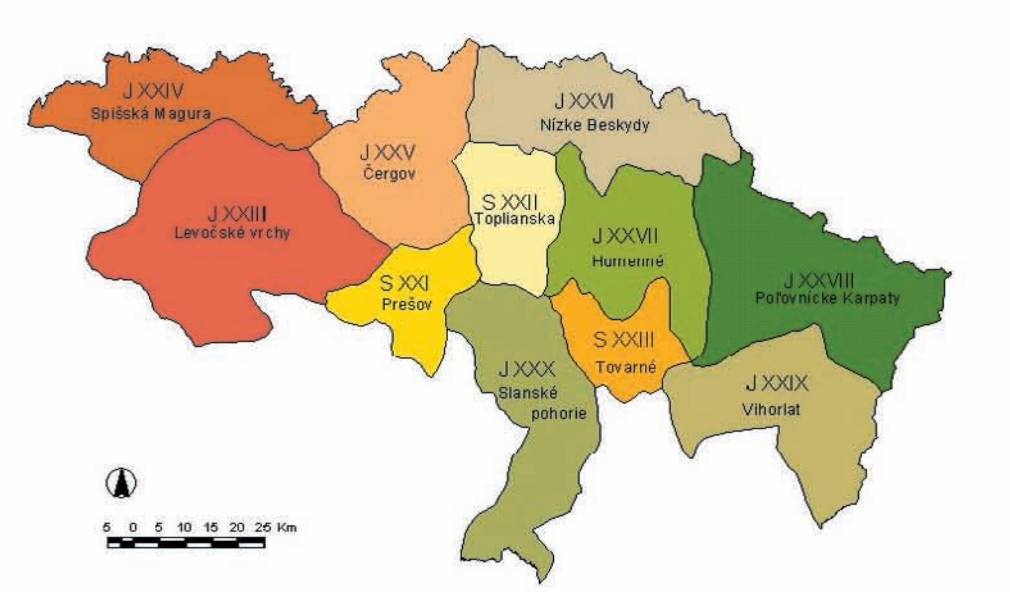

Fig. 1. Current arrangement of hunting zones in NE Slovakia, according to the Decree of Ministry of Agriculture SR No. 91/1997 Body of law

Results and discussion

Standardised game stocks (SGS) Present SGS of hoofed game

The present standardised stocks of hoofed game in the District Stropkov had in general been scheduled in years 1990–1995, that means before it has been applied the Decree of the Ministry of Agriculture No. 91/1997 – dealing with hunting zones and qualitative classification of hunting grounds and mitigating the impact of previous severe methods used in quality assessment.

The survey of the current standardised stocks of hoofed game – red deer is summarised in Table 2. For the whole administration district there has been stated a total number of 300 animals. The lowest density of the standardised game stocks (SGS) is in HA Dubinka – three animals per 1,000 ha of the hunting area.

The highest but closer to real state have been scheduled the standardised game stocks of red deer in the hunting grounds Vysoká Hora – 10 animals per 1,000 ha of the hunting area and in the HA Dolina – 14 animals per 1,000 ha of the forest. Major part of the hunting grounds has been classified to the third quality class.

The present stocks of red deer in the district Stropkov need to be assessed as underestimated, do not corresponding to the current possibilities and the carrying capacity of the hunting grounds. A standardised total value of 300 animals only represents eight animals per 1,000 ha of the hunting area what is a low number for an appropriate game management. Comparing the standardised game stocks with the current state in spring, we obtain a figure of 56% only. On the other hand, there has been recognised that the present amount of the red deer in the district is too low. If the present SGS were taken as a base for the management of the red deer in the district in the future, it would mean a tendency to further decline the present, evidently low, SGS in the future, leaving in many hunting grounds to survive minimum animals only.

SGS of the roe deer in the District Stropkov have been stated to 208 animals (Table 3) what means an average density of six animals per 1,000 ha of the hunting area. The lowest SGS of the roe deer have been determined in the HA Hrun Breznica – three animals per 1,000 ha of the hunting area.

The highest and, simultaneously, somewhat closer to the real state are the SGS of the roe deer in the grounds HA Ferdaska – Vyšná Olšava – 12 animals per 1,000 ha of the hunting area.

In spite of less favourable natural conditions in the northern part of the district and of the occurrence of predators, the current numbers are too low, not consistent with the reality. On the other hand, the current stocks of the roe deer are reported with such number as 14 animals per 1,000 ha of the hunting area. It follows that it is not desired to keep "artificially" the roe deer numbers low as prescribed by the standards when the natural conditions allow higher real states. Moreover, in the case of roe deer, no serious damage to forest ecosystems is to be expected.

Table 2. Stocks and kill numbers of red deer in the District Stropkov in 2002

Hunting ground	Standardised game stocks (ps)	Spring game stocks (ps)	Planned shooting (ps)	Kill number (ps)	Quality Class
Ferdaska – Vyš. Olšava	36	54	12	11	III
Sakalov – Lomné	27	50	9	7	III
Dubinka – Mrázovce	19	49	12	11	III
Hrun – Breznica	25	64	12	11	III
Kančov Potok –Stropkov	8	15	6	5	IV
Maleník – Vojtovce	38	54	10	10	III
Diľ – Havaj	39	74	12	12	IV
Kamjana – Miková	15	20	5	5	IV
Dolina – Olšavka	45	60	9	8	III
Vysoká Hora – Chotča	38	73	9	9	III
Ondava – Duplín	10	23	8	9	IV
Total	300	536	104	98	–

Table 3. Stocks and kill numbers of roe deer in District Stropkov in 2002

Hunting ground	Standardised game stocks (ps)	Spring game stocks (ps)	Planned shooting (ps)	Kill number (ps)	Quality Class
Ferdaska – Vyš. Olšava	36	59	15	14	III
Sakalov – Lomné	28	52	17	17	III
Dubinka – Mrázovce	20	52	12	12	III
Hrun – Breznica	16	50	14	14	III
Kančov potok –Stropkov	10	49	18	18	IV
Maleník – Vojtovce	17	52	15	15	III
Diľ – Havaj	22	49	13	13	IV
Kamjana – Miková	10	10	0	0	IV
Dolina – Olšavka	20	33	8	7	III
Vysoká Hora – Chotča	17	61	9	9	III
Ondava – Duplín	12	27	11	11	IV
Total	208	494	132	130	–

Stock numbers and kill numbers
Red deer

Up to the earliest 90s of the last century, the numbers of red deer in the district Stropkov were very high; sometimes exceeding the surplus what was reflected on damage to forest stands. The distinct reduction performed in 1990–1995, together with a considerable fragmentation of the hunting grounds escaped from the control and, together with poaching, caused a severe decline in the stocks of red deer, in many grounds to the minimum, and a complete destroy of its social structure. A specific situation was in 1993 that can be labelled as a year of transformation when one half of the old hunting grounds were still functioning (it was the last year of validity of their rental contracts) and, on the other hand, there were recognised one half of new grounds in virtue of new property relations to the soil. The causes between the hunters were on the cutting edge, and the situation was reflected on the game. As a result, in 1993 there was recorded the highest kill number of red deer in the district history.

Since 1996, measures directed to stabilisation and increasing of the total numbers of the red deer were accepted in the adjacent district Vranov nad Topľou. The measures meant general limiting of the hunting activities and minimisation of the allowed numbers in hind hunting, with the aim to increase the increment and the total numbers of the red deer population (Lehocký and Špilár, 1992). In the other districts, no special measures aimed to stabilisation of the declining red deer management were applied, with exception of the directives issued by the Ministry of Agriculture since 1998 and valid for the whole SR territory. This fact is necessary to take into consideration for further evaluation of the game management in the discussed district.

SGS of the red deer in the whole district in 1997–2002 ranged between 362–566 animals (Fig. 2), the average was 489 animals. The density was 14 animals per 1,000 ha of the hunting area or 30 animals per 1,000 ha of the forest. The highest numbers of red deer were recorded in the HA Vysoká Hora – Chotča: the average number of the stock over 1997–2002 was 53 animals what means 19 animals per 1,000 ha of the hunting area and 44 animals per 1,000 ha of the forest. Somewhat lower were the numbers in the HA Maleník: 16 animals per 1,000 ha of the hunting area and 9 animals per 1,000 ha of the forest. The lowest were SGS numbers in the HA Kančov Potok: seven animals per 1,000 ha of the hunting area or three animals per 1,000 ha of the forest.

In summary, the present stock values of the red deer and the values of its population density are low throughout the whole district, and they do not correspond to the actual carrying capacity of the forest ecosystems. However, there is a question whether the figures on the paper correspond to the real state, whether the documented spring stocks are true, whether the data reported from some references are not overestimated and whether a duplicity in spring census within two adjacent grounds is avoided. That is why it is possible to expect a moderate increase in the stocks in the near future.

The total hunting number has been set in average 98 red deer animals for the whole hunting zone what means three animals per 1,000 ha of the hunting area. The most animals were hunted in the HA Díľ – Havaj, in average four per 1,000 ha of the hunting area, the lowest kill numbers, representing two animals per 1,000 ha only were in the HA Kamjana – Miková.

In years 1997–2002, there were a 40% decline in both the planned and actual shooting of the red deer, mainly thanks to the nation-wide applied directives and measures issued by the Ministry of Agriculture since 1998, with the purpose to restore the red deer management endangered by the decline. In spite of the fact that in the last four years were the scheduled shooting numbers lowered, as required by the just discussed measures, at present maintain the actual numbers still lower than the planned ones. The data about the planned and actual kill are summarised in Table 4.

The planned structure of red deer hunting in 1997 was the following: 198 animals in total (Table 4), from which there were 69 deers, 76 hinds and 53 kids (Fig. 4). The realised kill numbers were: 178 animals (89.9% from the planned number) in total (Fig. 3); 53 deers (76.8%), 72 hinds (94.7%) and 53 kids (100%).

The kill numbers planned for the year 1998 were already lower: 128 animals in total (by 70 animals less compared to the preceding year), from which there were planned 41 deers, 42 hinds and 45 kids (Fig. 4). The realised kill numbers were: total 122 (95.3 % of the planned, Fig. 3) animals, 36 deers (87.8%), 41 hinds (97.6%) and 45 kids (100%).

The planned structure of red deer hunting in 1999 was: 100 animals in total (Table 8), from which there were 30 deers, 34 hinds and 36 kids (Table 8). The planned kill numbers were realised exactly (each item by 100%, Fig. 3).

The planned structure of red deer hunting in 2000 was the following: 92 animals in total (Table 8), from which there were 32 deers, 33 hinds and 27 kids (Fig. 4). The realised kill numbers were: 84 animals (91.3% from the planned number) in total (Fig. 3); 31 deers (96.8%), 28 hinds (84.8%) and 26 kids (96.3%).

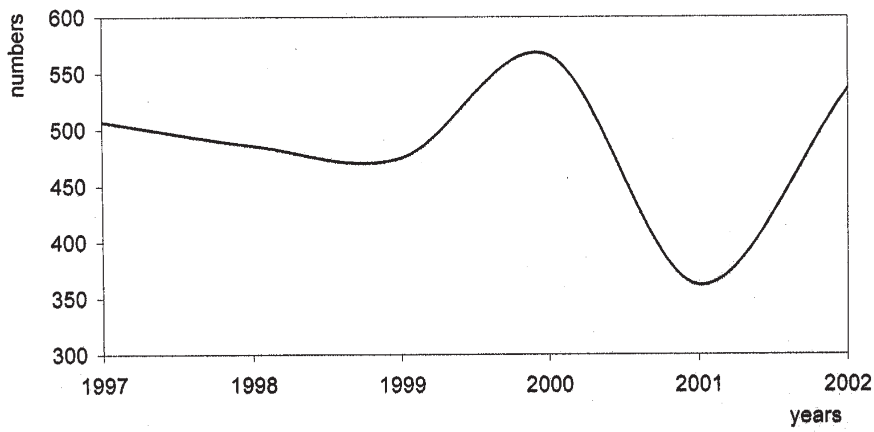

Fig. 2. Spring stocks of red deer in the District Stropkov in 1997–2002

Table 4. Structure of red deer shooting in the District Stropkov in 1997–2002

Year	1997	1998	1999	2000	2001	2002
Deers planned	69	41	30	32	36	37
(ps) realised	53	36	30	31	25	33
Hinds planned	76	42	34	33	23	33
(ps) realised	72	41	34	28	22	31
Kids planned	53	45	36	27	36	34
(ps) realised	53	45	36	26	36	34
Kill planned	198	128	100	92	95	104
Realised in total	178	122	100	84	83	98

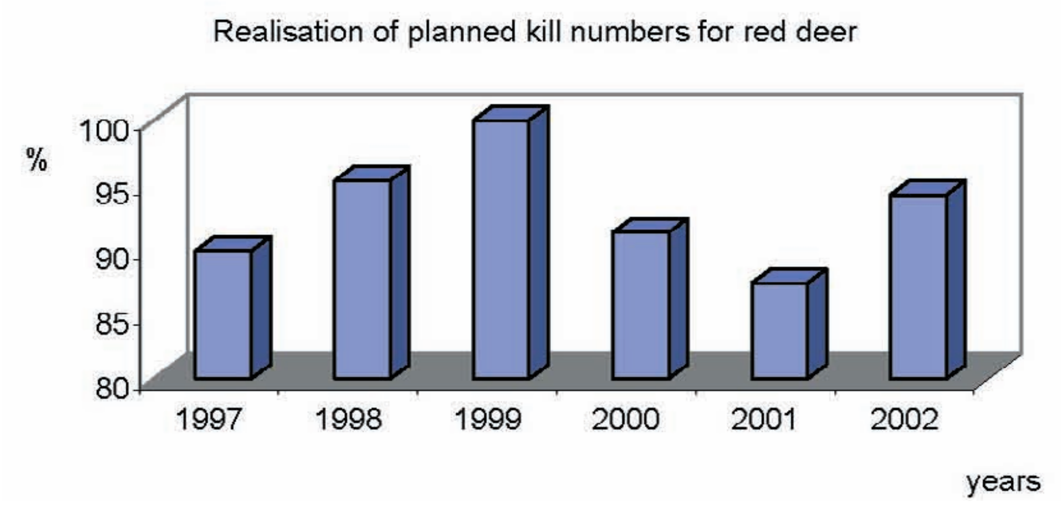

Fig. 3. Planned and realised (in %) numbers of killed red deer in the District Stropkov in 1997–2002

The planned structure of red deer hunting in 2001 was: 95 animals in total (Table 4), from which there were 36 deers, 23 hinds and 36 kids (Fig. 4). The realised kill numbers were: 83 animals (87.4% from the planned number) in total (Fig. 3); 25 deers (69.4%), 22 hinds (95.6%) and 36 kids (100%).

The planned structure of red deer hunting in 2002 was the following: 104 animals in total, from which there were 37 deers, 33 hinds and 34 kids (Fig. 4). The realised kill numbers (Table 8) were: 98 animals (94.2% from the planned number) in total; 33 deers (89.2%), 31 hinds (94%) and 34 kids (100%).

In average were the kills planned in 1997–2002 realised by 93%. The biggest difference was in deers – the numbers stated for hinds and kids were approached closely (by 94% and 99%, respectively, Fig. 5).

It is necessary to point out the low numbers and density of the red deer animals, primarily the hinds even when compared to the reported spring game stocks (SGS). The best, 100%, correspondence to the plan has

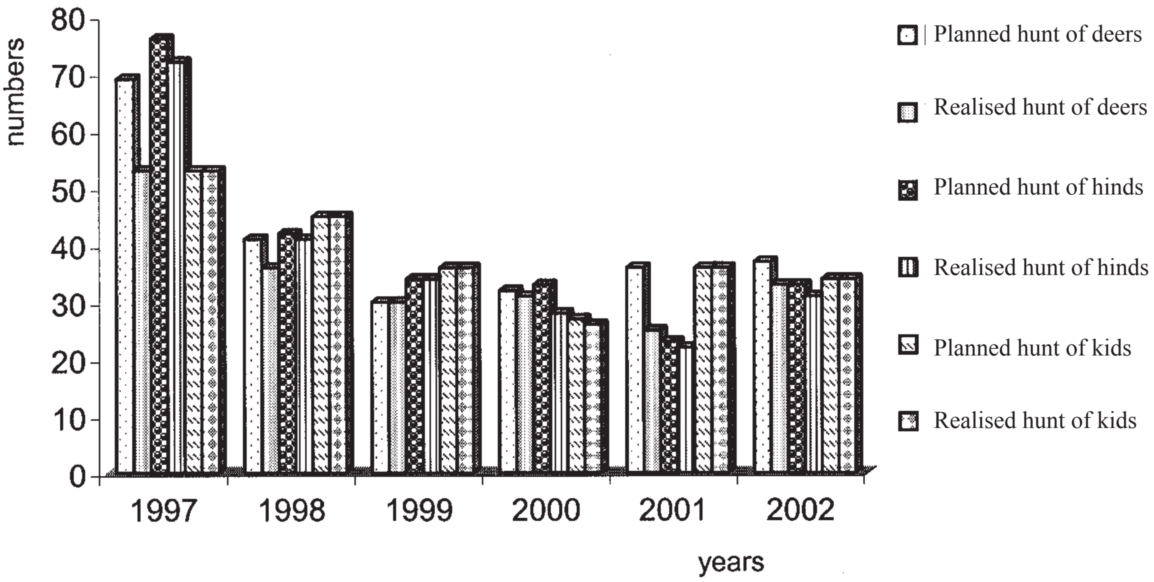

Fig. 4. Structure of red deer hunting in the District Stropkov

been recorded in the HA Vysoká Hora, with the core of the red deer population in the District Stropkov.

According to the scheduled structure of red deer hunting, in the last years is noticeably preferred hunting of deers before hinds. An optimum structure requires to maintain the rate 34–36% for deers and hinds and 30–32% for kids. Preferred shooting of bulls and protection of hinds was also reflected on the structure of spring game stocks. While the numbers recorded in 1998 were nearly close (40% of deers and 41% of hinds), in 2002 was observed a dominance of hinds (40% compared to 37% for deers). The rate of kids has been stabilised at a level of 23%. Optimum is considered the following structure of spring game stocks: 38–40% deers, 38–40% hinds and 20–22% kids (Garaj, 1999).

The reported structure of spring game stocks does not fully correspond to the situation in the hunting grounds. Nevertheless, it is necessary to increase the current numbers of red deer animals. However, this aim cannot be reached by several-year protection of hinds in expense of deers. Such a method could promote the unfavourable social structure of the population by an overall rejuvenation with prevailing females and a distinct lack of male animals in all age categories. In the District Stropkov, it is necessary to increase the current numbers in both hinds and deers, and at the same time, to establish and maintain equalised their sexual and age structure.

Roe deer

The actual density of roe deer is, among others, influenced by appropriateness of the biotopes that means by environmental conditions and the carrying capacity of the hunting grounds. The roe deer has especially favourable conditions mainly in the southern, less forested part of the district, with agricultural land at altitudes up to 300 m a.s.l. The conditions in the north – central forested part of the hunting zone are in general less favourable, but also here, in scarce-forested valleys, there exist roe deer micropopulations of a considerable quality.

The spring game stocks of roe deer reported in the last six years range between 317–494 animals (Fig. 6). The mean density of roe dear over the whole district is 14 animals per 1,000 ha of the hunting area what is practically equal to the red deer density. The highest spring stocks in 1997–2002 were recorded in the HA Kančov Potok and HA Ferdaska – 49 and 59 animals, respectively, representing 28 and 33 animals per 1,000 ha of the hunting area. In the other HA is the density according to the reported spring game stocks only 12–13 animals per 1,000 ha of the hunting area. The planned and actual kill numbers are listed in Table 5.

The structure of roe deer hunting in 1997 was the following: planned 203 animals in total, from which there were 72 roe-bucks, 77 roe-does and 54 kids (Fig. 8). The realised kill numbers were (Table 9): 197 animals (97% from the planned number) in total, 68 roe-bucks (94.4%), 76 roe-does (98.7%) and 53 kids (98.1%).

The structure of roe deer hunting in 1998 was the following: planned 219 animals in total (Table 9), from which there were 77 roe-bucks, 69 roe-does and 73 kids (Fig. 8). The realised kill numbers were (Fig. 7): 210 animals (95.9% from the planned number) in total, 69 roe-bucks (89.6%), 68 roe-does (98.5%) and 73 kids (100%).

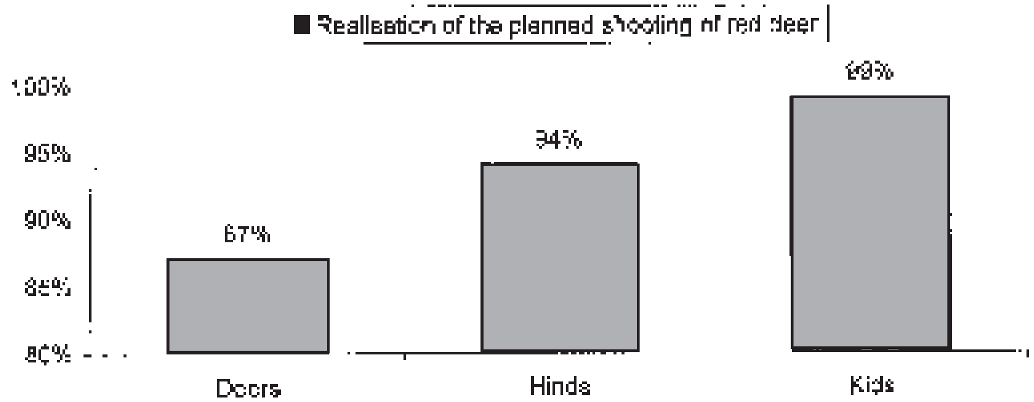

Fig. 5. Realisation of the planned shooting in average numbers for the period 1997–2002

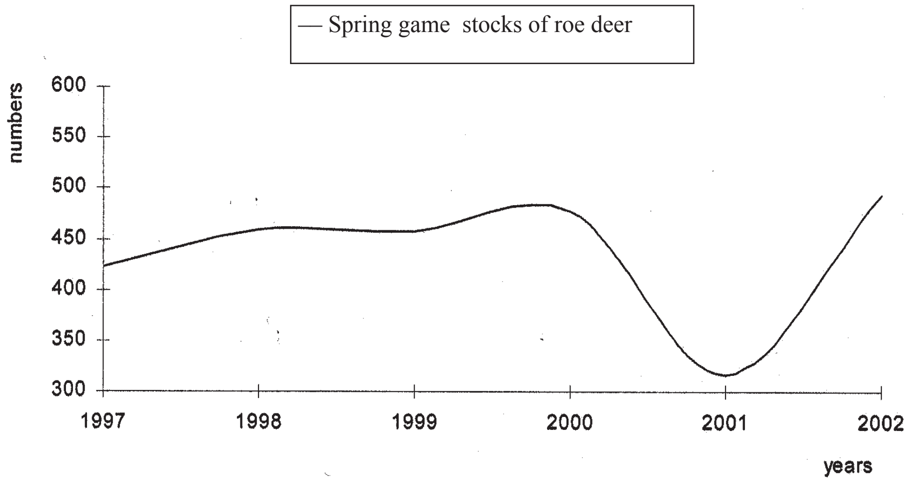

Fig. 6. Spring game stocks of roe deer in the District Stropkov in 1997–2002

Table 5. Structure of hunting of roe deer in the District Stropkov in 1997–2002

Year	1997	1998	1999	2000	2001	2002
Roe-buck planned	72	77	59	24	35	49
(ps) actual	68	69	59	23	35	47
Roe-doe planned	77	69	56	22	31	42
(ps) actual	76	68	55	22	29	42
Roe kids planned	54	73	55	16	31	41
(ps) actual	53	73	56	16	31	41
Kill planned	203	219	170	62	97	132
Realised in total	197	210	170	61	95	130

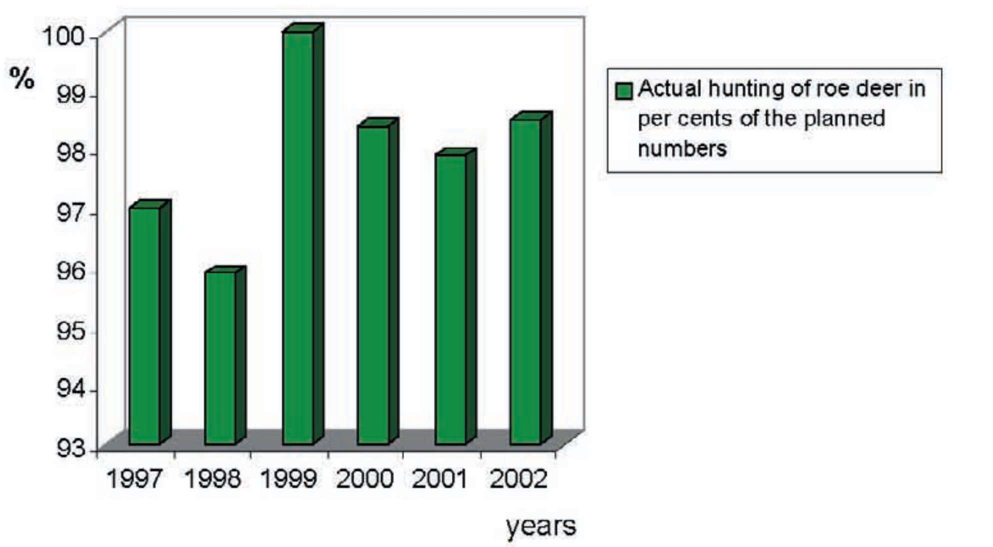

Fig. 7. Realisation of the planned shooting of roe deer in the District Stropkov in 1997–2002

The structure of roe deer hunting in 1999 was the following: planned 170 animals in total, from which there were 59 roe-bucks, 56 roe-does and 55 kids (Fig. 8). The realised kill numbers were: 170 animals (100 % from the planned number) in total, 59 roe-bucks (100%), 56 roe-does (100%) and 55 kids (100%).

The structure of roe deer hunting in 2000 was the following: planned were only 62 animals in total, which was by 108 less than in the preceding year. From this number there were 24 roe-bucks, 22 roe-does and 16 kids. The realised kill numbers were (Fig. 7): 61 animals (98.4% from the planned number) in total, 23 roe-bucks (95.8%), 22 roe-does (100%) and 16 kids (100%).

The structure of roe deer hunting in 2001 was the following: planned kill of 97 animals in total, from which there were 35 roe-bucks, 31 roe-does and 31 kids (Table 5). The realised kill numbers were: 95 animals (97.9 % from the planned number) in total, 35 roe-bucks (100%), 29 roe-does (93.5 %) and 31 kids (100%).

The structure of roe deer hunting in 2002 was the following: planned 132 animals in total (Table 5), from which there were 49 roe-bucks, 42 roe-does and 41 kids. The realised kill numbers were (Fig. 7): 130 animals (98.5% from the planned number) in total, 47 roe-bucks (95.9%), 42 roe-does (100%) and 41 kids (100%).

The mean total bag of roe deer in the district over the discussed period is about 140 animals what, similar to the case of red deer, represents four animals per 1,000 ha of the hunting area.

A higher kill was, after conversion to the whole hunting ground area, in the HA Kančov Potok (8 animals per 1,000 ha of the hunting ground). Both the planned and realised hunting of roe deer in 2000 recorded a decrease by more than 40% compared to 1999, which was caused by the Directive of the Ministry of Agriculture SR allowing the actual shooting rates not higher than the actual increments in the standardised game stocks. In the whole District Stropkov was the shooting plan for years 1997–2002 realised by 98%. The shooting of roe-bucks was realised by 96%, roe-does by 94% and kids by 99% (Fig. 9).

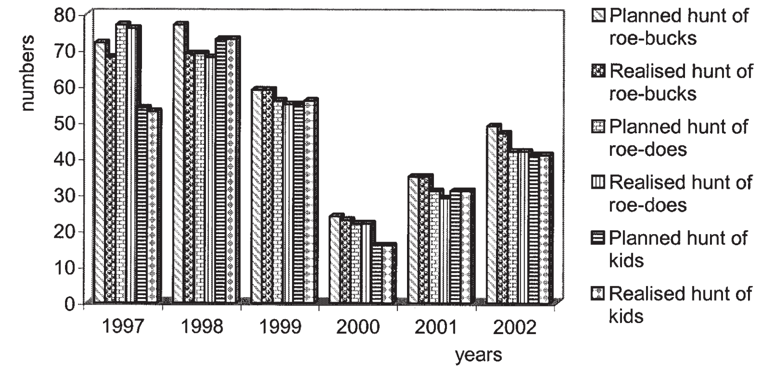

Fig. 8. Hunting of roe deer in the District Stropkov

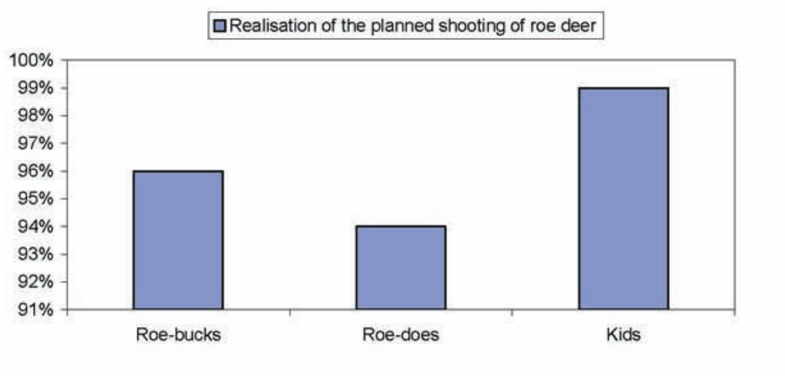

Fig. 9. Realisation of the planned shooting in average numbers for the period 1997–2002

The highest, practically 100% realisation of the planned shootings was in the HA Díľ. In hunting, roebucks are preferred to roe-does.

Conclusions

The purpose of this paper was to provide a review about stocks, shooting numbers, and game management quality of hoofed game in forest ecosystems of the model territory Stropkov.

We evaluated game stocks over the whole district territory. By our opinion, they should turn more realistic in the future (to increase standardised game stocks). However, this aim cannot be reached by several-year protection of hinds in expense of bulls. Such a method could promote the unfavourable social structure of the hoofed game. It is necessary to maintain a favourable rate between the sexes ensuring an appropriate age and sexual structure of the populations. The current numbers of hoofed game in the District Stropkov are: 536 red deer animals and 494 roe deer animals. No serious damage to woody plants has been reported, only some local injuries. We propose to establish ecologically supportable game stocks (turn the current standardised stocks to more corresponding to reality) and to provide the game management keeping with the following rules:

- To maintain the numbers of the game at the level of tolerable (standardised) stocks
- To maintain an appropriate sexual and age structure
- To increase the carrying capacity of the hunting grounds (provided with meadows, game fields, browsing plots, fruit-bearing woody plants and shelter possibilities)
- To feed the game with high-quality feedstuff
- To ensure sufficient numbers of suitable, appropriately spaced feeding sites in such a way as to avoid game concentration in proximity of stands endangered by browsing
- To ensure enough calm in the hunting grounds for the game diurnal activities (grazing, moving) and for the repose.

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Ekologicky únosné stavy raticovej zveri v okrese Stropkov

Súhrn

V práci sa zaoberáme sledovaním a zhodnocovaním prírodných a lesohospodárskych pomerov modelového územia severovýchodného Slovenska okresu Stropkov. Posudzujeme manažment poľovníctva so zameraním na raticovú zver a vypracovávame návrh opatrení na zmiernenie škôd spôsobených raticovou zverou. Hodnotili sme kmeňové stavy zveri, pričom sa vychádzalo z normovaných kmeňových stavov (NKS) a výšky odstrelu. Údaje sme čerpali z katalógov trofejí z okresných chovateľských prehliadok, poľovníckych výkazov Poľov (MP SR) 1-01 Ročný výkaz o jarnom kmeňovom stave zveri k 31. 03., a o revíri, stave a love zveri. Na zhodnotenie rozsahu škôd nám slúžili tlačivá L 115 Hlásenie škôd spôsobených zverou na lesných porastoch. Celková výmera je na území okresu Stropkov 34 535 ha, pričom celková poľovná plocha je na výmere 33 419 ha. Prehľad o výmere poľovnej plochy a poľovných revírov do roku 2002 nám dáva tabuľka č. 1. V súčasnosti je na území okresu Stropkov uznaných 11 poľovných revírov. Priemerná výmera revíru je 3 140 ha. Revír s najväčšou výmerou je PZ Hrun s výmerou 5 767 ha. Najmenšiu výmeru má PZ Kančov Potok 2 066 ha. Prehľad o súčasných normovaných kmeňových stavoch raticovej zveri jelenej nám dáva tabuľka č. 2. a srnčej tabuľka č. 3. Pre celý okres sú v súčasnosti stanovené normované kmeňové stavy (NKS) jelenej zveri 300 kusov, čo predstavuje hustotu len 8 kusov na 1 000 hektárov poľovnej plochy. Najnižšia hustota normovaných kmeňových stavov jelenej zveri vo vyjadrení na 1 000 ha je

v PZ Dubinka a to 3 kusy na 1 000 ha celej poľovnej plochy. NKS srnčej zveri v okrese Stropkov sú stanovené v celkovej výške 208 jedincov tabuľka č. 3. Predstavuje to priemernú hustotu NKS na 1 000 ha poľovnej plochy len 6 kusov srnčej zveri. Najnižšie NKS srnčej zveri na 1 000 ha sú stanovené v PZ Hrun Breznica, a to 3 kusy na 1000 ha poľovnej plochy. Poľovné revíry sú zaradené prevažne do III. akostnej triedy. Celkove je súčasná početnosť raticovej zveri a jej populačná hustota v okrese nízka a nezodpovedajúca podmienkam a úživnosti prostredia. V štruktúre lovu zveri je v ostatných rokoch výraznejšie uprednostňovaný lov samčej zveri na úkor samičej. Súčasná početnosť zveri v okrese je 536 kusov jelenej zveri a 494 kusov srnčej zveri. Škody nie sú vykazované, naberajú len lokálny charakter.

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In the papers, it is necessary to use SI symbols. Non-integer numbers should be provided with a decimal point, (e.g. 1.7), not a comma (1.7), the thousands (with exception of years) are separated with a comma: 5,600. The variables in mathematical formulae and expressions should be written in italics, the symbols for functions and constants in the normal font, the matrices in bold capitals, the vectors in bold small letters. Latin names of genera, species, sub-species and varieties are written in *italics*, the name of the author of the description (or his abbreviation) normally: e.g. *Lymantria dispar* (Linnaeus, 1758), *Lymantria dispar* (L.), *Abies cephalonica* Loud. var. graeca (Fraas) Liu. The names of cultivars are written normally, e.g. *Olea europea* L. cv. Chalkidikis. All the tables and figures must be referred to in the text: Table 1, Tables 2–4, Figs 2–4. The authors are asked to indicate placing of the tables and figures on the text margins.

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Book

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Dissertation

Chromová, L. 2002: *Pôdne a vegetačné zmeny lesných spoločenstiev okolia obce Brusno (Veporské vrchy)* [Changes in soils and vegetation of forest communities of the Brusno village (the Veporské Mts.)]. PhD thesis. Bratislava: Comenius University, Faculty of Natural Sciences. 122 p.

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