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ASSESSMENT OF THE IMPACT OF DEER ON THE DIVERSITY OF YOUNG TREES IN FOREST ECOSYSTEMS IN SELECTED LOCALITIES OF THE CZECH REPUBLIC

JÁN MERGANIČ[1,3*], RADEK RUSS[2], JANA BERANOVÁ[2], KATARÍNA MERGANIČOVÁ[1]

[1] Forest Research, Inventory and Monitoring – FORIM, Huta 14, 962 34 Železná Breznica, Slovakia; e-mail: j.merganic@forim.sk
[2] Institute of Forest Ecosystem Research, Ltd. – IFER, Areál 1. Jílovské a.s. 1544, 254 01 Jílové u Prahy, Czech Republic; e-mail: jana.beranova@ifer.cz, Russ@ifer.cz
[3] Czech University of Life Sciences in Prague, Faculty of Forestry, Wildlife and Wood Sciences, Department of Forest Management, Kamýcká 129, 165 21 Praha 6 – Suchdol, Czech Republic

Abstract

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The presented paper analyses deer impact on tree species and height diversity of young trees in three localities of the Czech Republic. The selected localities consisted of one fenced part, where deer has been excluded for a long time; and an unfenced part with free access to deer. The data were collected within the framework of the statistical forest inventory based on systematic sampling of the inventoried area. Tree species and height diversity were quantified using ten diversity indices. The analysis revealed that excessive deer densities pose a threat both to tree species and height diversity of young trees. Higher negative deer impact on tree species diversity can be expected on acidic sites, while height diversity is more sensitive to deer influence on fertile sites. However, if deer densities are low and do not reach the carrying capacity of the site, deer presence has no effect on tree species and height diversity of young trees.

Key words: deer impact, tree species diversity, height diversity, diversity indices, fencing

Introduction

The impact of deer on forest ecosystems has long been considered (Putman, 1986; Gill, 1992a, b; Gill, Beardall, 2001; Rooney, 2001; Côté et al., 2004). Deer affects not only vegetation, but also other animal groups, invertebrates, soil, nutrient cycling, etc., while the effects may

* Corresponding author

be both direct and indirect (Putman, 1986; Rooney, 2001; Rooney, Waller, 2003), as well as positive and negative (Putman, 1986; Reimoser et al., 1999; Gill, Beardall, 2001; Crête et al., 2001; White et al., 2004). To state if and how deer presence influences a particular element of woodland biodiversity depends on deer density, species-specific and site-specific factors, and on the relationship between deer and the examined element (e.g. competition, predation) (Putman, 1986; Stewart, 2001; White et al., 2004). However, in general excessive deer densities usually exert an adverse overall effect on biodiversity (Putman, 1986; Rooney, 2001; Côté et al., 2004; White et al., 2004; Carson et al., 2005), although some plants, invertebrates and animals may benefit from it (White et al., 2004).

Forest regeneration representing the future forest stand is most vulnerable to damage caused by deer when considering the tree layer of the ecosystem (Potvin et al., 2003). In general, three major types of direct damage can occur: browsing, bark stripping, and fraying trees with antlers (Gill, 1992a, b; Motta, 1996). Although all these effects are classified as damage to a particular tree, considering the forest stand as a unit they do not always have to have a negative influence on its tree species diversity. The overall impact is related to many different factors, e.g. to timing and intensity of damage, to tree species composition of the understorey, to what species is affected by deer, to the susceptibility of the tree species to damage etc. (Putman, 1986; Gill, 1992a; Reimoser et al., 1999; Côté et al., 2004). If e.g. deer reduces the proportion of the most abundant tree species in understorey/regeneration, this can increase tree species diversity (Helle, Aspi, 1983; Gill, 1992b), while damaging rare and vulnerable tree species can cause species loss from the ecosystem (Martin, Daufresne, 1999).

Furthermore, damage by deer has an influence on the forest structure (Putman, 1986; Gill, Beardall, 2001; Rooney, 2001; Rooney, Waller, 2003; Côté et al., 2004). When deer densities are sufficiently great, the vertical habitat complexity of forest ecosystems may be reduced (Rooney, 2001). On the other hand, below a certain threshold of deer density no damage occurs and very little effect either on species composition or on woodland structure is apparent (Gill, 1992a).

As Rooney (2001) pointed out on an example in North America, in the pre-settlement period deer densities were low and regulated by weather, predators, and forest structure and composition. Human induced changes to natural woodlands brought imbalances in these relationships. Hence, it is now difficult to know what level of deer density can be expected in a sustainable forest ecosystem for any particular conditions. To obtain such information, long-term exclosure experiments have been established to study the response of forest ecosystems to deer exclusion (e.g. Eiberle, 1967; Leibundgut, 1974; Ertl, 1989; König, Baumann, 1990; Pollanschütz, 1992; König, 1997; Nomiya et al., 2003; Von Oheimb et al., 2003; Stone et al., 2004; etc.). Although such studies do not provide us with the information about the desired status of the forest because deer naturally belong to forest ecosystems, they can support objective judgements of deer impact (Reimoser et al., 1999).

In the presented paper we examined an indirect influence of deer presence on young trees in the forest understorey using the data from long-term exclosures. The analysis consisted of two partial goals:

(1) to evaluate how deer influences tree species and height diversity of young trees, which is in accordance with Reimoser et al. (1999), who suggested that total tree density, species composition, and height structure are the main indicators of deer impact on forest regeneration,

(2)and to assess how site fertility affects deer impact on diversity of young trees, if at all.

Tree species and height diversity of young trees was quantified using ten most common diversity indices in order to analyse and present the reaction of each of them, which can in future help a scientist to select the most appropriate index for a particular task.

Material and methods

Site description

Within the presented work the data from three different forest regions of the Czech Republic were used: Brdská vrchovina (locality Svätá Anna), Středočeská pahorkatina (locality Libeř), and Jihomoravské úvaly (locality Ranšpurk and Cahnov). All localities consist of one fenced (control) and one unfenced part with free access to animals.

The fenced part of Svätá Anna has a size of 47.46 ha (fenced since 1970's) while the unfenced part covers 25.13 ha. Regarding the site characteristics, 60% of the experiment area is represented by acidic edaphic series (acidic oak beech forests) (UHÚL, 2001). The locality is situated at an elevation of 491 m a.s.l. , has an average annual temperature of 7.7° and a mean annual precipitation of 571 mm. Coniferous tree species, namely Norway spruce (*Picea abies* Karst.), Scots pine (*Pinus sylvestris* L.), silver fir (*Abies alba* Mill.), and European larch (*Larix decidua* Mill.), make up approximately 70% of species composition. The amount of broadleaved species, from which the most common are oak (*Quercus* sp.) and hornbeam (*Carpinus betulus* L.), is in the fenced part 10% higher than outside the exclosure. There are several deer species present in the locality: red deer (*Cervus elaphus* L.), fallow deer (*Dama dama* L.), white tailed deer (*Odocoileus virginianus* Bodd.), and roe deer (*Capreolus capreolus* L.). Deer densities in the unfenced part have consistently exceeded the carrying capacity (by a factor of 3) for over a long time (Fig. 1).

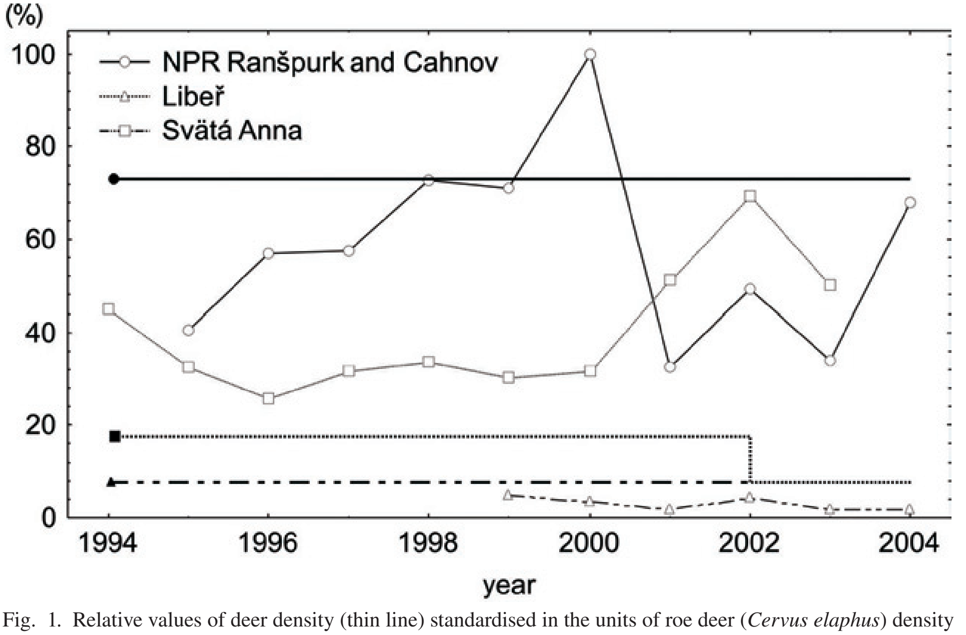

Fig. 1. Relative values of deer density (thin line) standardised in the units of roe deer (*Cervus elaphus*) density per 1,000ha and their carrying capacity (heavy line) in the examined localities.

The exclosure of the locality Libeř covers 28.74 ha (fenced since 1970's). The unfenced part has an area of 18.64 ha. Acidic edaphic series (acidic oak beech forest) prevail in this locality (UHÚL, 2001). The locality is situated at an elevation of 408 m a.s.l., has an average annual temperature of 8.1° and a mean annual precipitation of 614 mm. The main tree species are Norway spruce, and Scots pine. Oak and hornbeam are the most common broadleaves. In the exclosure, the proportion of broadleaved species is higher by about 10% than in the unfenced part. Within the locality, only roe deer occurs from deer species, whereby in the long term its densities have never reached the carrying capacity of the locality (Fig. 1).

The last locality consists of the two state nature reserves Ranšpurk (fenced since 1983) and Cahnov (represents unfenced control site). Both reserves are hardwood floodplains (elm hardwood floodplain) (UHÚL, 1999). The locality is situated at an elevation of 165 m a.s.l., and has a mean annual temperature of 9.7° and an average annual precipitation of 527 mm. There are only broadleaved species present in the reserves, whereby field maple (*Acer campestre* L.), narrow-leaved ash (*Fraxinus angustifolia* W a h l e n b.), hornbeam, and oak are the dominant species there. The locality is characterised by the presence of roe deer, fallow deer, and red deer. In the long term, deer densities have fluctuated around the carrying capacity of the locality, usually being below it (Fig. 1).

Material

In all three localities, the data were collected within the framework of the statistical forest inventory. As a sampling design systematic sampling was applied, i.e. the sample plots each of size 500 m^2 were established in a regular net over the inventoried area. In the locality Svätá Anna in total 69 sample plots were established, out of which 39 plots were located in the fenced area and 32 plots in the unfenced part. In Libeř 25 plots were situated in the fenced part and 24 plots in the unfenced part. In the last evaluated locality 23 and 22 sample plots were established in the reserves Ranšpurk and Cahnov, respectively.

From the total of 50 variables assessed during the inventory, we used the information about site, parent stand, species composition, frequency and height configuration of young trees in the understorey, i.e. of the trees with a minimum height of 10 cm and a maximum diameter at breast height of 6.9 cm. Within the sample plots, the young trees were assessed by stratified sub-sampling on three circle sub-plots, each with a radius of 2m (i.e. area 12.57 m^2).

Quantification of tree species and height diversity of young trees

Tree species and height diversity of young trees in the understorey was quantified using diversity indices. From the great number of existing indices we selected those that are considered by the majority of authors (e.g. Ludwig, Reynolds, 1988; Krebs, 1989) as the most suitable for numerical assessment of diversity in examined populations. These indices can be divided into three groups:

- indices of species richness describing community diversity on the base of number of species

$$N0 = S \qquad \text{(Hill, 1973) [1]}$$

$$R1 = (S\text{-}1)/\ln(N) \qquad \text{(Margalef, 1958) [2]}$$

$$R2 = S/\sqrt{N} \qquad \text{(Menhinick, 1964) [3]}$$

- indices of species heterogeneity combining species richness and evenness

$$\lambda = 1 - \sum_{i=1}^{S} w_i^2 \qquad \text{(Simpson, 1949) [4]}$$

$$H' = -\sum_{i=1}^{S} (w_i \ln(w_i)) \qquad \text{(Shannon, Weaver, 1949) [5]}$$

$$N1 = e^{H'} \qquad \text{(Hill, 1973) [6]}$$

$$N2 = 1/\lambda \quad \text{(Hill, 1973) [7]}$$

- indices of species evenness that quantify the equitability of species in community

$$E1 = H'/ln(S) \quad \text{(Pielou, 1975, 1977) [8]}$$

$$E3 = (e^{H'}-1)/(S-1) \quad \text{(Heip, 1974) [9]}$$

$$E5 = ((1/\lambda)-1)/(e^{H'}-1) \quad \text{(Hill, 1973) [10]}$$

where *S* is the number of tree species or height classes; *N* is the number of individuals; and w_i is the relative abundance of tree species or height class *i*.

Species heterogeneity and species evenness indices were calculated using the species or height class proportion determined from the number of individuals. Considering the interpretation of the above-mentioned indices, higher values always indicate higher diversity.

Statistical analysis of deer impact on diversity of young trees in understorey

The analysis of deer impact on diversity of young trees is based on simple or hierarchical analysis of variance. The examined factors were deer presence (fenced and unfenced part) and site fertility described by integrated edaphic series (acidic versus fertile sites). The Tukey test was used to test the significance of the differences between the levels of the particular factor.

For correct interpretation of the obtained results the homogeneity of the experiment must be ensured. However, in long-term experiments such as the one presented here, it is difficult to meet this requirement, because of the problems to maintain the conditions at the starting level (Gill, Beardall, 2001), and hence, to exclude the influence of side factors. Therefore, prior to analysis the homogeneity of the conditions inside and outside the exclosures was tested using the principles of contingency tables, analysis of variance, and regression analysis.

Results

Examining homogeneity of site and stand conditions inside and outside exclosures

The homogeneity test examined seven potential factors that can affect the interpretation of the results: slope, type of terrain, aspect, edaphic series as a parameter integrating site conditions, age of the parent stand, stand closure, and the proportion of the side light. According to the results of the homogeneity test, no significant differences in site and stand conditions between the fenced and the unfenced part of the locality Svätá Anna were detected.

In Libeř significant differences between the fenced and the unfenced part were found in the edaphic series and stand closure, while the exclosure consists of more fertile sites, and its forest stands are characteristic of lower closure. Due to these facts, more detailed analyses were made to examine the relationship between stand closure and the values of tree species and height diversity for the fenced and the unfenced part and the acidic and fertile edaphic series separately. In the acidic edaphic series outside the exclosure significant relationship was detected between closure and the indices *S, R1, H´,* λ*, N1* and *N2*. The situation was similar in the case of height diversity indices, where the homogeneity test detected significant relationship between closure and all indices except *R2*. In the next step, the values of the significant indices were corrected for the influence of closure, i.e. new values of the indices were obtained from the regression for the average value of stand closure in the fenced part. Further analyses were performed with these corrected values. To eliminate the differences between the edaphic series, indices were compared only within one edaphic series.

The test of the last locality comprising the Nature Reserves Ranšpurk and Cahnov revealed the identity between them. Overall, after the correction of the data in Libeř we can state that the homogeneity between the compared parts of the localities is assured.

Deer impact on tree species diversity of young trees

In the first examined locality Svätá Anna, the ratio between the broadleaved and coniferous tree species in species composition of young trees is balanced, whereby in the exclosure broadleaved species and in the unfenced part coniferous species slightly prevail. Young trees in the fenced part are mainly silver fir, Norway spruce, oak, and hornbeam, but there is also a considerable amount (approx. 10%) of fast-growing broadleaves. In the unfenced part, spruce, and hornbeam are the most common species among the young trees. The factor "fence" was detected as a significant factor influencing tree species diversity of young trees, while the factor "edaphic series" was not proven to have a significant influence in this locality (Table 1). It means that significant differences were found between the fenced and the unfenced part, but not between the acidic and fertile edaphic series within a certain part (Fig. 2). Significant deer impact was found for nine out of ten diversity indices (Table 1). As shown in Fig. 2, higher values of indices were obtained for the fenced part in all three components of diversity (richness, heterogeneity, evenness). In the acidic edaphic series, significant differences between the fenced and the unfenced part were detected in all examined cases, while in the fertile edaphic series this was found only for *H´* and λ. Considering the sensitivity of indices to deer impact, *R1*, λ and *E5* were the most sensitive indices from the groups of species richness, heterogeneity, and evenness, respectively.

In the case of Libeř, among young trees broadleaved species prevail both in the fenced and the unfenced part, although in the exclosure their proportion is by about 10% higher. Species composition of young trees consists mainly of Norway spruce, oak, hornbeam and fast-growing broadleaves (silver birch – *Betula verrucosa* Ehrh., wild cherry – *Cerasus avium* (L.) Moench., European aspen – *Populus tremula* L., rowan – *Sorbus aucuparia* L., black alder – *Alnus glutinosa* Gaertn.).

Regarding tree species diversity, it was necessary to evaluate deer impact separately for each edaphic series using the corrected values as described in section 3.1. Analysis of variance did not detect a significant influence of the factor "fence", and hence of deer presence, on any of the examined diversity indices. Fig. 2 presents that in the acidic edaphic series higher tree species diversity was observed in the unfenced part. In contrast, the results for the fertile edaphic series show an opposite trend, since all indices except *S* and *R1* indicate higher diversity in the exclosure. The most sensitive indices were *E3* and *N2* regardless of the edaphic series.

T a b l e 1. Hierarchic (Svätá Anna) and simple (Ranšpurk and Cahnov) analysis of variance examining the influence of the factor "fence" (i.e. deer impact) and the factor "integrated edaphic series" on the values of tree species diversity.

Diversity index	Factor	Locality			
		Svätá Anna *p*		State Nature Reserves Ranšpurk and Cahnov *p*	
S	fence	0.0006	***	0.0731	
	edaphic series*fence	0.6178			
R1	fence	0.0002	***	0.7652	
	edaphic series*fence	0.7281			
R2	fence	0.1002		0.0054	**
	edaphic series*fence	0.1703			
H´	fence	0.0000	***	0.9197	
	edaphic series*fence	0.2971			
	fence	0.0000	***	0.9030	
	edaphic series*fence	0.1693			
N1	fence	0.0001	***	0.8232	
	edaphic series*fence	0.5533			
N2	fence	0.0001	***	0.5518	
	edaphic series*fence	0.5699			
E1	fence	0.0000	***	0.5285	
	edaphic series*fence	0.1524			
E3	fence	0.0001	***	0.2974	
	edaphic series*fence	0.1684			
E5	fence	0.0000	***	0.3230	
	edaphic series*fence	0.1488			

Note: Significance level: ***p <0.001=99.9%, **p <0.01=99% and *p <0.05=95%; grey part indicates fields where the analysis was not possible

In Ranšpurk and Cahnov species composition of the young trees is very similar to that of the parent stand, while field maple highly prevails. Narrow-leaved ash, and hornbeam are also frequent among the young trees. This last locality is characteristic of only one edaphic series present in both reserves Ranšpurk and Cahnov. Hence, within the analysis only the influence of the factor "fence" was tested. As shown in Table 1, the only significant differ-

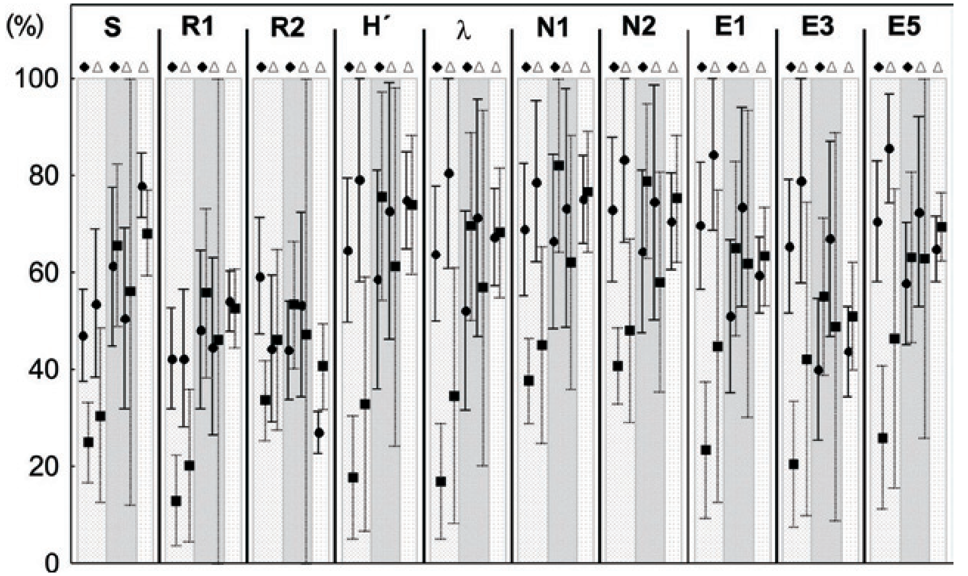

Fig. 2. Relative values of tree species diversity of young trees in the fenced and the unfenced part of each examined locality described by diversity indices *S - E5*.
(Legend: Arithmetic mean: ● – fenced part, ■ – unfenced part; Interval, inside which the real mean should occur with probability 95% ($t_{\alpha/2}$ standard error of mean): – fenced part, – unfenced part; Integrated edaphic series: ◆ – acidic, △ – fertile; Locality: – Svätá Anna, – Libeř, – State Nature Reserves Ranšpurk and Cahnov)

ence between the fenced and the unfenced part was found for *R2*. In seven out of ten cases, higher values of diversity indices were calculated for the unfenced part (Fig. 2). The most sensitive indices to deer impact were *R2* and *S*.

Deer impact on height diversity of young trees

In Svätá Anna, a significant influence of deer was detected for all indices except *R2* (Table 2). The factor "edaphic series" had a significant effect only on *N1*, although *S*, *R1*, *H´* and *N2* were close to critical value $p = 0.05$ (Table 2). As presented in Fig. 3, higher average values of the majority of indices were observed in the fenced part regardless the edaphic series. The analysis revealed significant differences between the fenced and the unfenced part only in the fertile edaphic series in the case of *S*, *R1*, *H´*, λ, *N1* and *N2*. The most sensitive indices were *S*, *H´* and *E1* representing richness, heterogeneity, and evenness, respectively.

In Libeř, the analysis did not detect any significant impact of deer on height diversity of young trees. According to the results shown in Fig. 3, in the acidic edaphic series higher

T a b l e 2. Hierarchic (Svätá Anna) and simple (Ranšpurk and Cahnov) analysis of variance examining the influence of the factor "fence" (i.e. deer impact) and the factor "integrated edaphic series" on the values of height diversity of young trees.

Diversity index	Factor	Locality			
		Svätá Anna *p*		State Nature Reserves Ranšpurk a Cahnov *p*	
S	fence	0.0053	**	0.0000	***
	edaphic series*fence	0.0641			
R1	fence	0.0121	*	0.0000	***
	edaphic series*fence	0.0740			
R2	fence	0.9750		0.0804	
	edaphic series*fence	0.3149			
H´	fence	0.0043	**	0.0000	***
	edaphic series*fence	0.0551			
	fence	0.0072	**	0.0000	***
	edaphic series*fence	0.1216			
N1	fence	0.0110	*	0.0000	***
	edaphic series*fence	0.0355	*		
N2	fence	0.0321	*	0.0000	***
	edaphic series*fence	0.0514			
E1	fence	0.0139	*	0.0000	***
	edaphic series*fence	0.2829			
E3	fence	0.0283	*	0.0003	***
	edaphic series*fence	0.3487			
E5	fence	0.0252	*	0.0000	***
	edaphic series*fence	0.3029			

Note: Significance level: ***p <0.001=99.9%, **p <0.01=99% and *p <0.05=95%; grey part indicates fields where the analysis was not possible

height diversity in the exclosure was obtained only from two indices *S* and *R1*. When examining the fertile edaphic series, the values of *R2, H´*, λ, *N1, N2* and *E3* suggest that the fenced part has higher height diversity of young trees (Fig. 3). The most sensitive indices in the acidic and fertile part were *S* and *N2*, respectively.

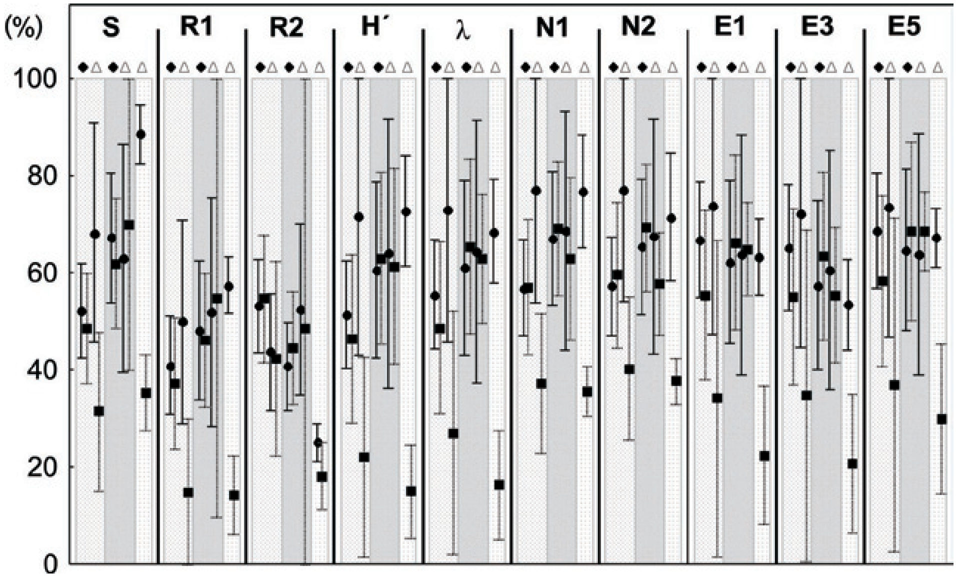

Fig. 3. Relative values of height diversity of young trees in the fenced and the unfenced part of each examined locality described by diversity indices *S* - *E5*.
(Legend: Arithmetic mean: ● – fenced part, ■ – unfenced part; Interval, inside which the real mean should occur with probability 95% ($t_{\alpha/2}$ standard error of mean): 12 – fenced part, 13 – unfenced part; Integrated edaphic series: ◆ – acidic, △ – fertile; Locality: – Svätá Anna, – Libeř, – State Nature Reserves Ranšpurk and Cahnov)

The analysis of the last locality consisting of the two reserves Ranšpurk and Cahnov revealed a significant deer impact on height diversity of young trees in all cases except *R2*, which is close to the critical value (Table 2). Fig. 3 documents that all indices exhibited higher values of height diversity in the fenced part Ranšpurk. Regarding the sensitivity of indices, the results coincided with those obtained for Svätá Anna, i.e. the most sensitive indices were *S*, *H´* and *E1*.

Discussion

From the three examined localities, locality Svätá Anna was found to be influenced by deer the most. This locality has been under intense pressure due to the excessive deer density for the last ten years (Fig. 1), which has affected both the tree species and height diversity of young trees. The influence of deer was apparent in all components of tree species diversity, i.e. in richness, heterogeneity, and evenness, while the values of all the calculated indices were higher in the exclosure (Table 1, Fig. 2).

The analysis showed that due to high deer pressure the risk of the loss in tree species diversity is higher on the acidic sites, whereas the height diversity of young trees is more threatened on the fertile sites (Fig. 2). Considering tree species diversity, fertile sites provide suitable conditions for more tree species (Barnes et al., 1998), and hence, deer selection does not have such profound effects on tree species richness as on acidic sites (Fig. 2). Côté et al. (2004) also reported that deer impact is larger in low-productivity habitats.

On the other hand, fertile sites are characteristic by denser and more diverse ground vegetation (Barnes et al., 1998). Therefore, such sites are more attractive to deer, also because of the higher nutrient content of the plants from the fertile sites (Gill, 1992a). If deer density is too high, as it is in Svätá Anna, where the average deer density during the last ten years was 3 times higher than its carrying capacity, the height diversity of young trees is more affected on fertile sites (Fig. 3).

In addition, excessive deer pressure usually leads to a reduction in palatable plant species and the spread of unpalatable ones or those tolerant to deer damage, mainly ferns and graminoids (Kirby, 2001; Rooney, 2001; Carson et al., 2005). This shift in plant composition may inhibit tree regeneration (Kirby, 1990; Kirby, 2001; Côté et al., 2004). Selective feeding of deer is also documented by the values of *E1-E5* that are significantly lower in the unfenced part regardless of site fertility (Fig. 2). Similar findings were observed in the evaluation of the height diversity of young trees (Fig. 3), because most browsing by deer usually occurs at an intermediate level between ground and full reach (Gill, 1992a; Ellenberg et al., 2001; Côté et al., 2004).

Locality Libeř is the opposite example to Svätá Anna, as here deer densities have always been far below the carrying capacity (Fig. 1). Therefore, the analysis of the deer impact on forest ecosystem could hardly detect any significant influence of deer. In several cases (e.g. index *S*), a higher diversity was found in the unfenced part. Similar results were reported also for ground vegetation by Rambo and Faeth (1999), Von Oheimb et al. (2003), Stone et al. (2004), etc. Helle and Aspi (1983) showed that moderately grazed areas by reindeer had the highest species richness, since this grazing pressure created space for the plants, which would be in ungrazed areas out-competed (Putman, 1986). Higher diversity of the unfenced part may also be caused by management practices, as e.g. Reimoser and Gossow (1996) documented that ungulates impact depends on the applied silvicultural system. Although the management analysis detected that the same management prescription was to be applied in both fenced and unfenced parts of the locality Libeř, according to the information obtained from the forest enterprise the forest stands inside the exclosure were in reality left to natural development until the 1990s, while in the unfenced part clear-cutting, shelterwood and selection systems were applied. This fact can explain the obtained results, because the usual management practices are aimed at maintaining a certain species composition, which does not have to coincide with the natural status. Hence, tree species diversity can be higher in the unfenced managed part than inside the exclosure, because intermediate frequencies of disturbance increase species diversity when compared with no or very low disturbance frequencies (Barnes et al., 1998). In addition, clear-cutting can also lead to increased tree species diversity through promoting pioneer tree species (Barnes et al., 1998; Brokaw, Lent, 1999).

The State Nature Reserves Ranšpurk and Cahnov represent the locality in which the silvicultural human influence can be excluded. Nonetheless, the only significant difference in tree species diversity between the fenced part Ranšpurk and the unfenced part Cahnov was detected for the index *R2* (Table 1, Fig. 2). In addition, although in general Ranšpurk has a higher species richness than Cahnov, *R2* indicates the opposite. This is due to the character of the index, as it accounts for the size of population and is sensitive to a wide range of individuals' frequencies. It was the frequency of young trees that caused the opposite reaction of *R2* as expected, since in the unfenced part Cahnov the frequency of young trees is only half their frequency in Ranšpurk. Interestingly, a higher tree species heterogeneity and evenness was also observed in the unfenced Cahnov (Fig. 2). This may be explained by the fact that in Ranšpurk, where higher species richness was detected, new tree species can occur thanks to deer exclusion, but their proportion in species composition is small.

Considering height diversity of young trees, the results of the analysis revealed significantly higher height diversity in the exclosure Ranšpurk than in Cahnov (Table 2, Fig. 3). This corresponds with other works, which reported a simplified vertical structure of forest stands as a result of deer impact (e.g. Gill, 2000; Rooney, 2001).

Conclusion

While assessing deer impact on forest ecosystems, it should not be forgotten that deer have always been a considerable component of their natural biodiversity. Therefore, within the sustainable forest management the efforts should focus on keeping deer densities at sensible levels, which depend on site-specific and species-specific conditions. The results of our analysis support this statement, since only excessive deer densities pose a threat to tree species and height diversity of young trees. Higher negative deer impact on tree species diversity can be expected on acidic sites, while height diversity is more sensitive to deer influence on fertile sites. With low deer densities that do not reach the carrying capacity of the site, no significant effect of deer presence on tree species and height diversity of young trees has been detected.

Translated by the authors

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