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Impact of deer browsing on natural and artificial regeneration in floodplain forest

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A b s t r a c t . Deer are an important limiting factor for the growth of broadleaved trees in the forests of temperate zones. Their influence on vegetation was extensively studied in various forest types; however, data from floodplain forest is missing. The aim of this study was to confirm following hypothesis: The regeneration of the young tree stands in floodplain forest under high deer density is impossible without intensive protection by forestry management. Our hypothesis was confirmed only partially. Thanks to high production, the floodplain forest ecosystem is able to compensate for the lost biomass, so the browsing does not prevent the growth of natural tree regeneration. On the other hand, trees from artificial plantations are much more attractive for deer, their browsing is much more intensive, mainly during winter and regeneration is not possible without fencing.

Key words: browsing intensity, *Capreolus capreolus, Cervus elaphus*, nutrient content

Introduction

Floodplain forests of Southern Moravia (Czech Republic) are the residuum of unique biotopes. Despite considerable man-made changes these forests still have a landscape enhancement value and are important centres of biodiversity (K o v a ř í k o v á 1996). Vegetation associations, typical and exclusive to floodplain forests, provide food for relatively high number of ungulates (P r o k e š o v á et al. 2006).

High game density can negatively influence the management of this habitat, despite its high plant biomass. As in sub-mountain and mountain areas game density can also negatively influence the regeneration of commercial woody plants (oak, ash) that are planted on clear-cut plots. This is the reason why these plantations (highly attractive for game (D z i e c i o l o w s k i 1980)) are protected by fences, at least in the first years of their growth. Browsing in these artificial plantations and in the natural shrub layer can cause distinctive changes in vegetation associations' structure (G i l l 1992b, 2000, K i r b y 2001).

The damage intensity caused by ungulates to vegetation cover depends on several factors such as game density and structure of food sources (B e r g q u i s t 1998). Higher ungulate density increases browsing intensity and that negatively influences natural regeneration of vegetation (G i l l 2000). The analyses of roe deer and red deer diet in floodplain forest showed that woody plants are an important food source even in this type of biotope (B a r a n č e k o v á 2004, P r o k e š o v á 2004). High proportion of woody plants in both deer species' diet indicates that deer are an important factor influencing vegetation in floodplain forest.

Because vegetation production in floodplain forests is higher than in other biotopes of Central Europe (P e n k a et al. 1985), these could therefore support a higher number of

ungulates with relatively lower damage intensity to the shrub layer compared to other less productive biotopes. The damage intensity and plant species preference can be influenced by the plant shoot nutrients (Provenza et al. 1996, Tixier et al. 1997). A high volume of fibre and tannins decreases plant attractiveness to deer, on the contrary high level of well digestible proteins increases attractiveness of the plant as food source (Hobbs et al. 1983, Danell et al. 1994).

The aim of this study was to analyse browsing intensity caused by roe and red deer to the natural shrub layer and in artificial plantations with regard to floodplain forest regeneration. The damage intensity was studied in relation to game density, vegetation type and nutrient content. Since the damage intensity caused by game to floodplain forest stands has not yet been studied in detail, the results might help to improve rational deer management in this biotope.

Material and Methods

Study area

The study was carried out from 2001 to 2004 in the floodplain forest situated along the River Morava between villages Mikulčice and Tvrdonice (Czech Republic) (200–220 m above sea level). The study area (1041 ha) was a part of larger forest complex, which forms a 1 to 3 km wide and about 20 km long strip, along the River Morava (Barančeková 2004). The forest is managed with clear cutting especially of oak and ash trees. The cut areas are then planted with young woody plants of the cut species.

The forest stands of the study area consist of *Quercetum* and *Fraxineto-quercetum*. The eastern part of the studied area is surrounded by meadows reaching to the Morava River bank. Meadows also partly surround the north-western part and can be found inside the studied forest. The western part of the study area is surrounded by fields.

The study was carried out in two different habitats – natural shrub layer of the older forest stands and artificially planted unfenced areas. That way the usage of natural and artificial forest regeneration could be compared. The main tree species in forest were field maple (*Acer campestre*), oak (*Q. petrea*, *Q. robur*), European hornbeam (*Carpinus betulus*), narrow-leafed ash (*Fraxinus angustifolia*), black poplar (*Populus nigra*), white poplar (*Populus albus*), small-leaved lime (*Tilia cordata*) and European white elm (*Ulmus laevis*). The most abundant tree and shrub species were field maple (average cover (a. c.) 11.35 %), oak (a. c. 5.75 %), ash (a. c. 3.58 %) (Barančeková & Prokešová, unpublished data).

Methods

Nine monitoring plots (4×10 m) were laid out for monitoring of browsing intensity. Four plots were located in the artificial plantations (thereinafter artificial plantations – A) and five in natural shrub layer of the older forest stands (thereinafter shrub layer – N) (Fig. 1).

One thousand shoots were checked at each monitoring plot in March (winter browse) and in October (summer browse) in the years 2002 and 2003. In 2003 the shoots were divided into two height categories – up to 1 m and from 1 to 1.5 m. Using these two categories a proportion of browsing caused by roe and red deer was assessed. Browsing was recorded on all the tree species present in shrub layer of monitoring plots.

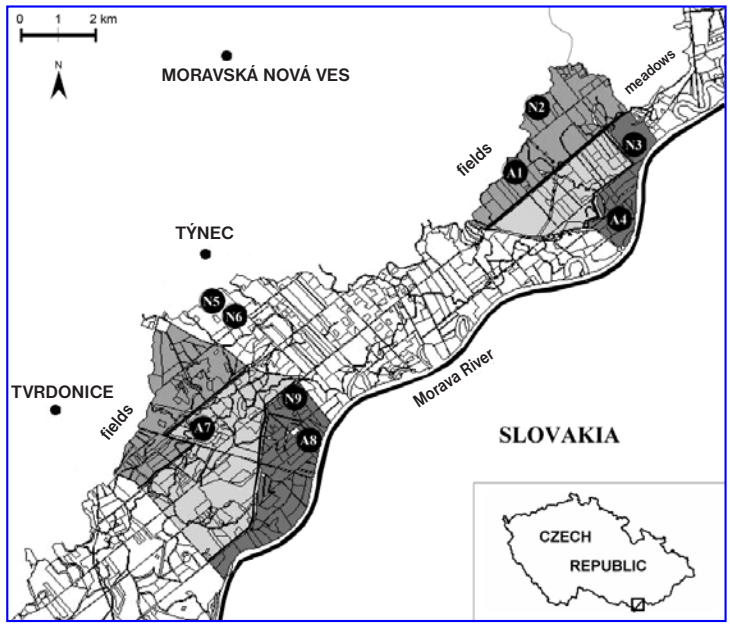


Fig. 1. Map of the study area with monitoring plots in artificial plantations (A) and natural growth (N).

Next, the interaction between browsing intensity and chosen vegetation variables (cover of tree layer (e3), shrub layer (e2), herb layer (e1)) was studied. Interaction between number of species present in single layer and browsing intensity, as well as interaction between densities of both deer species and browsing was also assessed. Data from vegetation mapping and data on the deer density (Prokešová et al. 2006) were used for these analyses. Furthermore, an assessment of browsing intensity on the three most abundant species in the shrub layer (field maple, oak, ash) was carried out.

To assess the preference for browsed species we used the formula for preference ratio (Malan & Van Wyk 1993): $PR = U_i / A_i$, where U_i is percentage utilization ($U_i = D_{ti} / D_{tt;}$ D_{ti} = number of damaged trees of species i within all sites sampled; D_{tt} = number of damaged trees of all species within all sites sampled) and A_i is percentage availability ($A_i = A_{ti} / A_{tt;}$ A_{ti} = number of available trees of species i within all sites sampled; A_{tt} = number of available trees of all species within all sites sampled).

Samples of tree species from the shrub layer were used to analyse the content of nitrogen (N), lipids (L) and fibre (F) with standard method (AOAC 1980). For data analyses (bivariate correlation using Pearson correlation coefficient r, χ^2 test) a statistical program SPSS version 11.5 for Windows was used.

Results

Browsing of shoots in the floodplain forest

The assumption about higher browsing intensity in artificial plantations in comparison to shrub layer was confirmed only partially. Browsing intensity was significantly higher in artificial plantations only during winter 2002 (χ^2 test, $p < 0.05$), through the rest of the study it was in both, artificial plantations and shrub layer, the same (Table 1).

Table 1. Shoot browsing intensity (%) in artificial plantations and in shrub layer (p-values in bold are statistically significant).

		winter	summer	p (winter / summer)
artificial plantations	2002	44.89	26.2	**0.027**
	2003	22.65	6.52	**0.003**
	p (2002 / 2003)	0.007	0.001	
shrub layer	2002	26.92	24.66	0.753
	2003	21.08	9.85	**0.043**
	p (2002 / 2003)	0.399	**0.012**	
all monitoring plots	2002	37.5	25.4	0.127
	2003	21.87	8.17	**0.012**
	p (2002 / 2003)	**0.043**	**0.003**	

Table 2. Browsing intensity (percentage of browsed shoots) on monitoring plots in artificial plantations (A) and in shrub layer (N) (p-values in bold are statistically significant).

Study plots	winter 2002	winter 2003	p	summer 2002	summer 2003	p
A 1	38.37	18.46	**0.008**	22.69	3.45	**0.001**
A 4	34.69	18.17	**0.023**	33.82	7.23	**0.001**
A 7	51.93	24.63	**0.002**	20.47	11.75	0.125
A 8	40.63	23.71	**0.035**	32.94	8.69	**0.001**
N 2	48.22	37.55	0.249	44.32	9.59	**0.001**
N 3	52.63	38.72	0.146	30.59	15.54	**0.027**
N 5	19.76	4.1	**0.001**	10.07	10.43	0.937
N 6	17.24	11.9	0.323	9.71	5.84	0.326
N 9	30.84	13.13	**0.008**	24.14	8.51	**0.006**

Shoots of woody plants in the shrub layer were generally browsed more in winter (29.66 %) than in summer (16.79 %), but this difference was on the verge of insignificance (χ^2 test, $p = 0.058$). Browsing intensity between summer and winter in the year 2003 was significantly different (χ^2 test, $p < 0.05$), but it did not differ in 2002 (Table 1).

In 2003 the winter and summer browsing intensity decreased in most of the artificial plantations and also in the shrub layer. The decrease in winter browsing was significant on four plots in artificial plantations and on two plots in the shrub layer. Summer browsing decreased significantly on three plots in artificial plantations as well as in shrub layer (Table 2).

Factors influencing browsing intensity

Game density

Analysis of the effect of deer density (roe and red deer) on total browsing intensity during winter showed a significant positive relation ($r = 0.978$; $p < 0.05$). This relation was, above all, influenced by the distribution of red deer in 2002 ($r = 0.712$; $p < 0.05$). Influence of roe deer density on total browsing intensity was not significant ($r = -0.094$; $p > 0.05$).

More detailed study of the relationship between deer density and browsing intensity of single woody plant species (field maple, oak, ash) showed a significant positive correlation between oak browsing intensity and red deer / deer (roe and red deer) density ($r = 0.951$;

Table 3. Relationship between density of ungulates and browsing of three most abundant tree species in shrub layer (Pearson correlation; * - significant at 0.05 level; ** - significant at 0.01 level).

	field maple	oak	ash
roe deer	**0.922****	-0.794	0.327
red deer	0.251	**0.951***	0.277
roe & red deer	0.787	**0.978***	0.446

Table 4. Relationship between browsing intensity on artificial plantations, shrub layer and all monitoring plots and vegetation factors (Pearson correlation; * - significant at 0.05 level; ** - significant at 0.01 level).

Vegetation variables	artificial plantations	shrub layer	all monitoring plots
tree layer (e3)	0.134	**0.861****	0.081
number of species in e3	0.174	-0.489	-0.18
shrub layer (e2)	0.035	-0.44	-0.098
number of species in e2	0.158	-0.065	0.022
Acer campestre	0.158	-0.254	-0.227
Quercus sp.	-0.144	-0.472	0.008
Fraxinus sp.	0.147	-0.07	0.057
Swida sanguinea	-	0.598	**0.409***
Crataegus sp.	0.109	0.417	0.21
herbaceous layer	0.195	0.24	0.148
Rubus spp.	-0.012	0.291	0.15

$p < 0.05$ / $r = 0.978$; $p < 0.05$) and between field maple browsing intensity and roe deer density ($r = 0.922$; $p < 0.01$). There was no other inter-dependence between deer density and shoot browsing (Table 3).

Vegetation factors

Most of the studied vegetation factors had no significant influence on browsing intensity (Table 4). A significant positive correlation was found between total browsing intensity and cover of blood-twig dogwood ($r = 0.409$; $p < 0.05$) and between the browsing intensity on the shrub layer and cover of the tree layer (e3) ($r = 0.861$; $p < 0.01$) (Table 4). The cover of shrub layer (e2) and cover of single tree species had no influence on browsing intensity ($p > 0.05$).

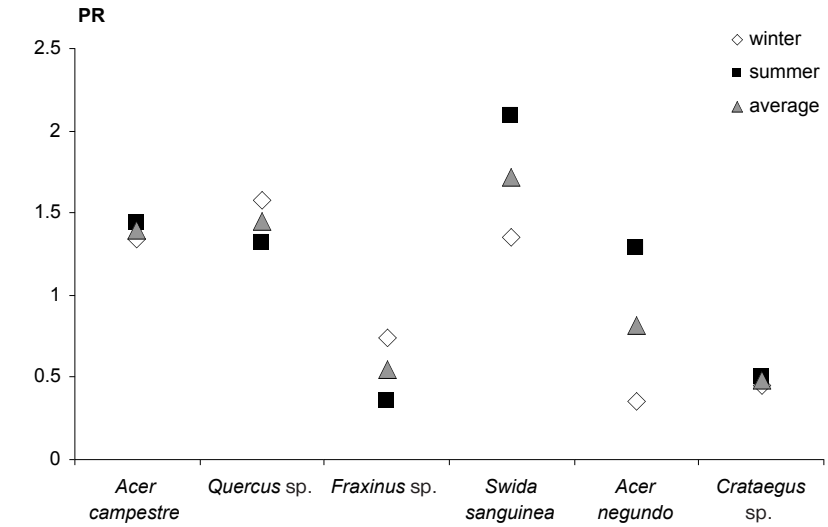
Roe deer browsing vs. red deer browsing

The shoots in the height category from 1 to 1.5 m were browsed more often (42.01 %) than those in the category up to 1 m (23.2 %) (χ^2 test, $p < 0.05$). Browsing intensity in both categories was higher in winter than in summer (Table 5). More shoots in the category 1 to 1.5 m were browsed in the artificial plantations than in the shrub layer, whereas the shoots up to 1 m were browsed more in the shrub layer compared to the artificial plantation (Table 5).

In the height up to 1 m blood-twig dogwood was the most browsed species and hawthorn was the least preferred species. During winter, the most preferred species was oak and the least preferred species was box elder. During summer, blood-twig dogwood was the most preferred and ash was the least preferred species (Fig. 2a).

Hawthorn was the least preferred species in the height from 1 to 1.5 m. During summer and winter this species was not browsed at all. During winter the most browsed species was blood-twig dogwood, and during summer the most browsed species was field maple (Fig. 2b).

a)



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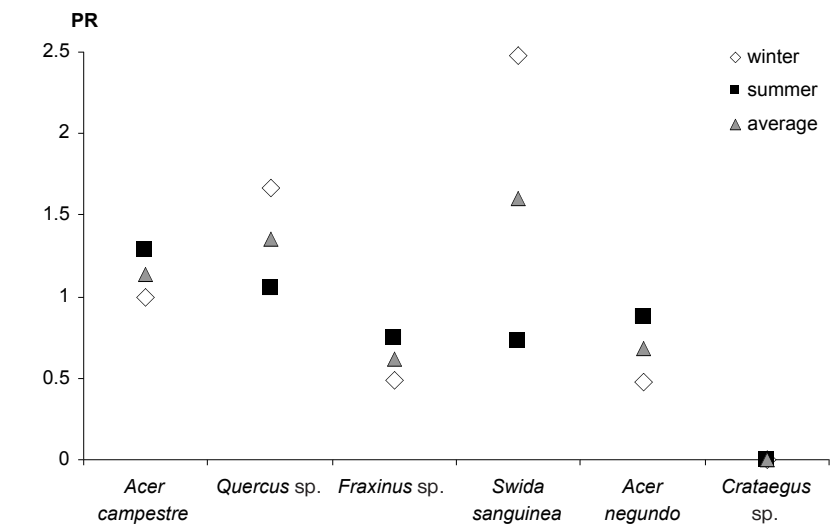

Fig. 2. Preference ratio (PR) of single species of woody-plants according to shoots browsing intensity in two high categories a) up to 1 m, b) from 1 to 1,5.

Preference ratio (PR)

Single woody plant species were browsed with different intensity and the preference of browsed woody plants expressed as preference ratio index (PR) was also different. The most preferred species was oak (PR = 1.57), which was simultaneously the second most abundant species on the monitoring plots. On the contrary, the least preferred woody plant was hawthorn

Table 5. Percentage of shoots browsed in two high categories (to 1 m; from 1 to 1.5 m) in artificial plantations, shrub layer and all monitoring plots (p-values in bold are statistically significant).

		to 1m	1–1.5m	p
artificial plantations	winter 03	50.73	76.66	**0.022**
	summer 03	7.3	4.87	0.486
	p	**0.001**	**0.001**	
shrub layer	winter 03	44.69	88.11	**0.001**
	summer 03	10.29	8.69	0.713
	p	**0.001**	**0.001**	
all monitoring plots	winter 03	39.05	81.05	**0.001**
	summer 03	9.14	5.99	0.418
	p	**0.001**	**0.001**	

(PR = 0.47), which was however more abundant than other more preferred species (Fig. 3).

Preference of woody plant species was different in both studied years as well as seasons (Table 6). Blood-twig dogwood was the most preferred species during winter, whereas oak was most preferred during summer (Fig. 2).

Nutrient content of woody plant species

The highest average level of all three analysed components (nitrogen, lipids and fibre) was found during vegetation period in the most browsed species – oak. At the same time, the nutrient content analyses showed that the least browsed species – ash – contained the lowest level of lipids and fibre (Fig. 4). Levels of single nutrient components differed in summer and winter periods. During winter, level of fibre increased significantly in field maple samples and a level of nitrogen decreased significantly in all species (ash, field maple, oak) (Fig. 4).

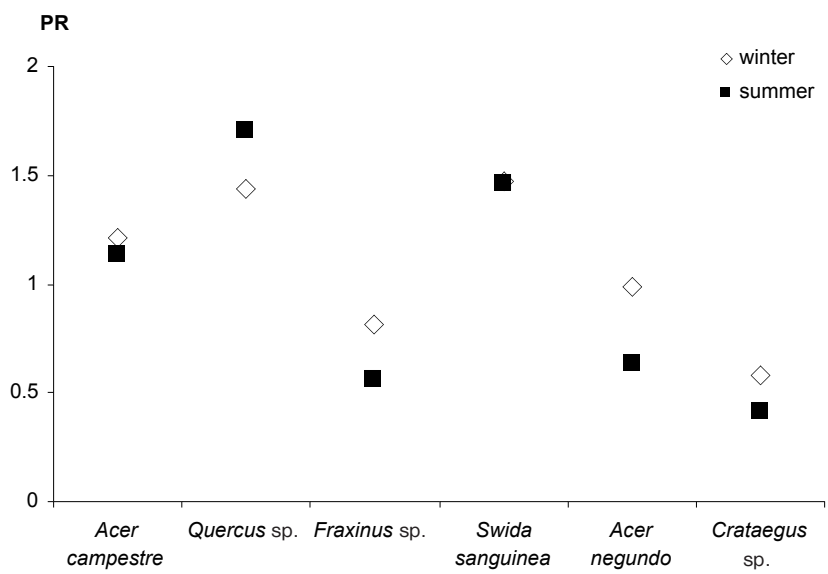

Fig. 3. Average values of preference ratio (PR) for single woody-plant species in floodplain forest during winter and summer.

Table 6. Preference ratio (PR) of six species of woody plants during the years 2002 and 2003.

	field maple	oak	ash	blood-twig dogwood	box elder	hawthorn
winter 2002	1.3367	1.4376	0.8243	1.4376	1.4376	-
summer 2002	1.0194	0.6396	0.7215	1.3228	0.3936	0.444
winter 2003	1.0804	1.4404	0.8088	1.5053	0.5373	0.5821
summer 2003	1.2506	2.766	0.4113	1.601	0.8646	0.3859

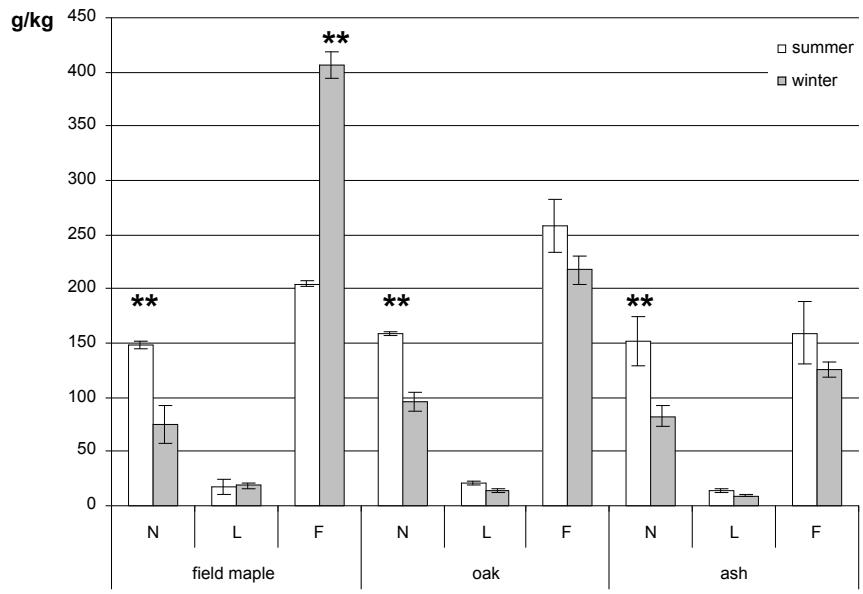

Fig. 4. Average volume of nitrogen (N), lipids (L) and fibre (F) in three tree species during summer period (growing season) (X.) and winter season (outside of the growing season) (III.) with standard deviation (** - difference significant at 0.01 level).

Discussion

Intensity of damage caused by ungulates to vegetation is dependent on a wide variety of factors, such as deer species, deer densities, plant species, and can cause various changes in vegetation structure and development (González Hernández & Silva-Pando 1996, Reimoser & Gossow 1996, Van Hees et al. 1996). However, human interference in the early stage of the tree growth also has a negative impact on vegetation structure by suppressing the "weed" tree species and favouring commercial species.

The damage caused to restoration of tree plantations by deer browsing is problem in many forest types, including floodplain forests. The leading shoots and leaves represent the fastest growing and the most nutritious parts of plants, and thereby they are very attractive food source for ungulates (Bryant & Kuropat 1980, Harper 1989). Browsing on vegetation in the floodplain forest was higher in winter period what is also in accordance with other authors (Rounds 1979, König & Baumann 1990, Homolka & Heroldová 2003, Ueda et al. 2003). However, the difference in browsing intensity

between summer and winter was significant only in 2003. Browsing intensity in the floodplain forest decreased in 2003 on the whole study area as well as on the monitoring plots. One of the reasons for different deer browsing intensity could be a difference in the length of snow cover, especially in the mountain regions (Homolka & Heroldová 2003). In this study, the duration of snow cover was similar in both years, so that could not influence the change of browsing intensity. Another possible factor that can influence browsing intensity is game density (Gill 1992a, Putman & Moore 1998). This factor can be considered the main reason for the decrease of browsing intensity in 2003 as the roe and red deer density on monitoring plots had a decreasing tendency during this period (Prokešová et al. 2006). However, the reason for this decrease was human disturbance due to timber harvest and not natural change of population density.

Browsing preference of deer species is influenced by their body size. Red deer most often browse shoots in the height of their shoulders (Renaud et al. 2001), which is for central European red deer 120–150 cm (Nečas 1959). Roe deer most often browse shoots at the height 70–100 cm (König & Baumann 1990). Hodge & Proper (1998) also recorded the most frequent browsing by roe deer at the height up to 1 m and by red deer up to 1.8 m. Consequently, roe deer were expected to favour shoots of height up to 1m, whereas red deer were expected to prefer shoots in the category from 1 to 1.5 m. We detected the highest browsing intensity in the height of 1 to 1.5 m. That indicates a higher impact of red deer on the floodplain forest compared to roe deer. This conclusion is in accordance with fact that woody plants represent a larger proportion of red deer diet compared to roe deer diet (Barančeková 2004, Prokešová 2004). Also red deer density in the forest was higher and their food requirements are higher than those of roe deer. Red deer prefer artificial plantations (Prokešová et al. 2006), where we detected the higher number of browsed shoots in the category from 1 to 1.5 m. On the contrary, roe deer density was the highest in the natural shrub layer of older forest stands (Prokešová et al. 2006), where the highest browsing intensity, in the category up to 1 m, was recorded.

Browsing ungulates often prefer some specific woody plants to others (König & Baumann 1990, Gill 1992a, Motta 1996, Chevallier-Redor et al. 2001). This preference can be influenced by abundance of tree species, or by their nutrient content (Westoby 1978, Duncan et al. 1994, Kitteredge 1995, Hartley et al. 1997, Čermák 1998). The most preferred species in the floodplain forest was oak, which was the second most abundant species in this biotope (5.75 %) and simultaneously the most abundant species in the artificial plantations. Ungulates, above all browsers which include roe deer, prefer plants with high nitrogen level and low fibre level (Hobbs et al. 1983, Danell et al. 1994). A high level of fibre was most likely the cause of relatively low browsing intensity of field maple, despite the fact that this tree species was the most abundant (11.35 %) in the floodplain forest. This agrees with the results of Tixier & Duncan (1997), who also found a negative correlation between high fibre level in food of roe deer and browsing. High preference for oak can be the result of its high abundance in the floodplain forest as well as of high nitrogen volume.

Our hypothesis of higher browsing intensity in the artificial plantation was partially confirmed as it was higher only during the year 2002. However, the reason for lower browsing intensity in second study season could be a decrease of deer density in monitored artificial plantations (Prokešová et al. 2006). High browsing intensity of shoots in the young artificial plantations of commercial tree species during 2002 indicates that a successful regeneration is impossible without fencing them. The higher attractiveness of

artificial plantations is in accordance with the results of Bergquist & Örlander (1997) and Reimoser & Gossow (1996).

The relationship between deer density and browsing intensity is, to some extent, influenced by habitat type and its carrying capacity. The carrying capacity of certain biotopes is in direct proportion to the number of animals using this biotope without being seriously affected (Langbein 1997). Vegetation production of the floodplain forest is higher than in other types of central European forest stands, thus the carrying capacity of this forest is high and provides a food supply to a relatively high number of ungulates, without serious damage to the forest vegetation.

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