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Red deer in the floodplain forest: the browse specialist?

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A b s t r a c t . The diet composition of red deer (*Cervus elaphus* L.) was studied from October 2001 to November 2002 in the floodplain forest along the Morava River by the microscopic analysis of 310 red deer pellets. The shoots of broadleaved trees formed the main component of red deer diet throughout the year, 71 % of volume on the average. The trophic diversity was the highest at the end of summer and in autumn, when red deer consumed in more fruits, forbs, grasses and also the crops on fields near the forest, e.g. maize. The majority of the diet originated from the forest, whereas fields were visited only at the end of summer and in autumn. Additional feeding during winter does not play an important role in the diet of red deer. The analysis of feeding behaviour showed that in the floodplain forest red deer were browse specialists in all seasons of the year. Other food sources were less important.

Key words: *Cervus elaphus*, diet, woodland, Czech Republic

Introduction

Despite their small area (approximately 1.25 % of all forest stands in the Czech Republic), floodplain forests form a unique habitat with high primary production and biodiversity (P e n k a et al. 1985). The last residues of floodplain forests along the Morava and Dyje Rivers are surrounded by intensively cultivated agricultural areas, which are accessible for deer feeding. They offer to herbivore species a wide variety of feeding sources.

Red deer have a substantial impact on forest vegetation and play a significant role in functioning of forest habitats (G i l l 2000). The diet composition of red deer differs between individual forest types in relation to food supply (D z i ę c i o ł o w s k i 1969, 1970, K o s s a k 1976), competition with other herbivore species (G e b e r t V e r h e y d e n - T i x i e r 2001) and population density (A b r a m s 1980, L a t h a m 1999). In the Czech Republic research on the feeding ecology of red deer has been carried out in coniferous and mixed forests in the Krkonoše Mts (F i š e r & L o c h m a n 1969), the Krušné hory Mts (H e r o l d o v á 1993), the Beskydy Mts (H o m o l k a 1995), the Jeseníky Mts (H o m o l k a & H e r o l d o v á 2001), and also in upland mixed forests (the Drahanská vrchovina Uplands; H o m o l k a 1990). Data are still lacking from floodplain forests except for a short note by L o c h m a n (1985). The lack of data on diet from this habitat type is also apparent in other countries in Central and Western Europe. In contrast, the diet of red deer has been extensively studied in other forest types e.g., in the coniferous mountain forests of Poland (D z i ę c i o ł o w s k i 1970), in Białowieża primeval forest (G ę b c z y ń s k a 1980), in the mixed forests in Hungary (M á t r a i & K a b a i 1989), in British pine-oak forests (H e a r n e y & J e n n i n g s 1983), in mixed-coniferous forests of Scotland (M i t c h e l l et al. 1977, L a t h a m et al. 1999), in coniferous forests of Denmark (J e n s e n 1968).

Red deer consume items of both high and low nutritional value. They are able to digest the plants with a high crude fibre content (H o f m a n n 1989). In areas with good food supply, broadleaved trees and forbs dominate red deer diet during the growing season. In spring and autumn the proportion of grasses increases and their content is also high in winter. In areas of restricted food supply, grasses dominate in red deer diet throughout the year. If conifers are present, needles can form more than one third of the diet volume during winter (M á t r a i & K a b a i 1989). In areas where fields are situated near the forest, crops can form a very important part of the diet (J e n s e n 1968, L o c h m a n 1985). Individual habitat conditions therefore strongly influence the diet composition of red deer.

The aim of the study was to obtain basic data on feeding ecology of red deer in floodplain forest. Such data may help to identify the role of red deer in this habitat and provide a basis for other studies of interactions of red deer with floodplain forest vegetation as well as with the syntopic population of roe deer. In this study, the following hypotheses were tested:

– broadleaved trees and forbs will dominate the diet of red deer through the growing season;
– grasses will dominate the diet in spring and in autumn, whereas the proportion of the grasses and woody plants will be equal in winter;
– crops will form an important part of red deer diet as an available easily palatable and energy-rich feeding source;
– the composition of the diet will be different between subplots of the study area depending on their distance from meadows and fields.

Study Area

The research was carried out from November 2001 to October 2002 in south-eastern part of the Czech Republic near the border with Slovakia. The study area of 1 041 ha in size is situated in altitude 200–220 m above see level (Fig. 1). The average daily temperature is 10 °C and the annual precipitation is 500–600 mm.

Prevailing habitat is the commercial managed forest. The tree associations are classified mainly as unions *Querceto-Fraxinetum* and *Ulmeto-Fraxinetum*. The dominant canopy tree species are oak (*Quercus robur, Q. petrea*), ash (*Fraxinus excelsior, F. lanceolatus*) and field maple (*Acer campestre*). Less abundant but regularly occurring are other tree species: poplar (*Populus* spp.), box elder (*Acer negundo*), elm (*Ulmus laevis*), common alder (*Alnus glutinosa*), black walnut (*Juglans nigra*) and lime (*Tilia* spp.).

The shrubby vegetation is well developed and diversified. Except for the previously mentioned tree species there is blackthorn (*Prunus spinosa*), blood-twig dogwood (*Swida sanguinea*), hawthorn (*Crataegus* spp.), spindle (*Euonymus* sp.), willow (*Salix* spp.), elder (*Sambucus nigra*) and rose (*Rosa* spp.). Shrubs are formed by artificial plantations of seedlings (mainly ash and oak) and also in some sites by naturally regenerating stands.

The herb layer is also well developed and uniform with a marked dominance of several species, such as *Rubus* spp., *Galium* spp., *Urtica dioica* and the invasive *Aster novi-belgii*. The families of abundant species are: Lamiaceae, Asteraceae and Ranunculaceae. There are also sedges (*Carex* spp.) and grasses (*Poa* sp., *Calamagrostis* sp., *Phalaroides* sp.). Larger meadows are situated along the eastern (the bank of the Morava River) and north-western

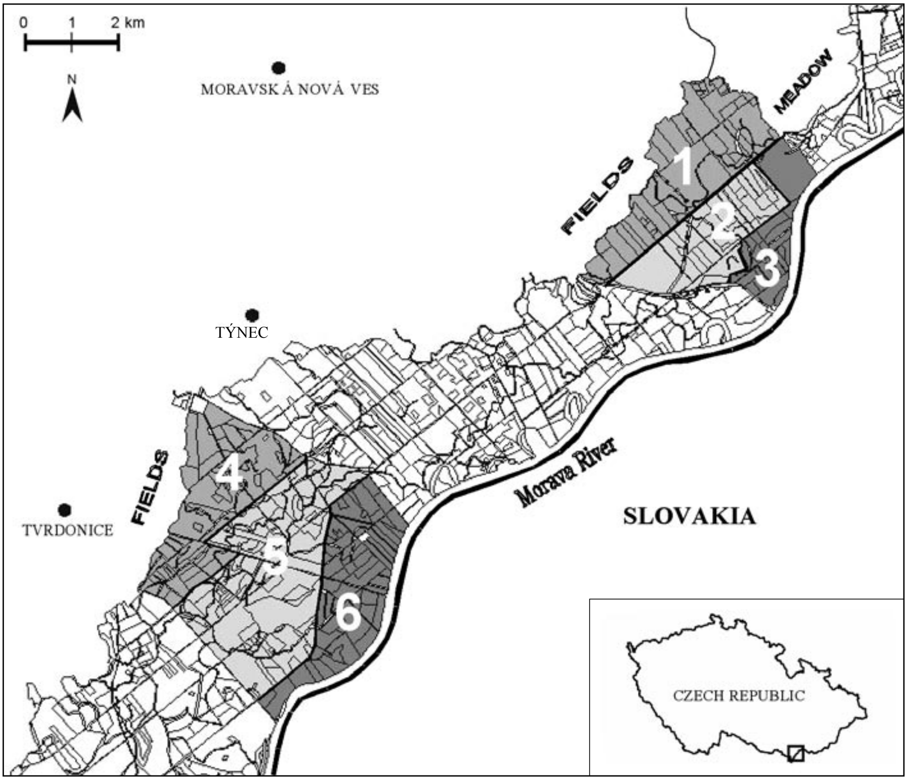

Fig. 1. GIS map of the forest with two study sub-areas, each divided into three subplots. The subplots are coloured in grey scale and marked with numbers from 1 to 6 (The original digital map is provided by The Forests of the Czech Republic, Forest Enterprise.).

edge of the forest, small meadows also are found inside the forest (the size of meadows is 133 ha, approximately 12.8 % of the whole area). Crop fields are situated along western edge of the forest (maize, rape, lucerne, winter cereals).

From the beginning of October to the end of March game species are additionally fed on cereals (maize, barley and wheat), mangel, apples and hay. On average 5.2 individuals.km^{-2} were harvested in the study area annually during the last five years (Forests of the Czech Republic, pers. comm.). Our unpublished data (based on re-counting of winter pellet groups on monitoring plots) show that the density of red deer is 12.8 individuals.km^{-2}. Roe deer are present in this area, their feeding ecology being studied simultaneously (B a r a n č e k o v á 2004).

The study area was divided to test for potential differences in diet composition and the influence of alternative feeding sources (adjacent fields and meadows). Two sub-areas, northern and southern, were chosen in the floodplain forest. Each one was then divided into three subplots: eastern (along the Morava River, meadows), central (central part of the forest) and western (in vicinity of fields), so that the research was made of six subplots (Fig. 1).

Material and Methods

The droppings of red deer were regularly collected each month over the course of the year. In total, 310 pellets (each one from a different pellet group) were processed by microscopic analysis (at 50–100x magnification) to establish diet composition. The surface of the cover slide (18 x 18 mm) was taken as 100 %, so that each visual field was approximately 2 %. During the analysis the surface of field covered by each fragment of individual items was assessed, so it was possible to establish the quantitative composition of diet (percentage of volume % v). Individual components were classified at the family or the genus level if possible. If this was not possible, items were referred to main feeding groups such as woody plants or fruits. The samples were grouped to two-month periods, because this division described the changes in diet composition optimally from the point of view of natural development of vegetation. For statistical processing and testing of potential differences in the diet composition between periods and subplots, the food components were linked together to seven feeding categories (broadleaved trees = woody plants, grasses, grains, fruits, forbs, bramble and unidentified fragments).

Microscopic analysis of faecal sample composition may overestimate some items (browse, grasses) and underestimate others (fruits, forbs) compared to macroscopic analysis of stomach contents (Dzięciołowski 1970, Anthony & Smith 1974). The possible deficiencies of microscopic analysis are eliminated by collecting many samples from different seasons of the year. Moreover, I used the method of Homolka & Heroldová (1992), who compared the results from pellet and stomach analysis and concluded that the results were not significantly different. In addition, the index of importance was calculated for individual items, I = (% v + % f)/2, where % f is the relative frequency %f = 100 x f/Σf (Obrtel & Holišová 1974). The index overestimates well-digestible items occurring in the pellets frequently but in small quantity (e.g. fruits and forbs). On the other hand woody plants or grasses are underestimated.

The trophic diversity was expressed by Shannon – Weaver's index $H' = -\Sigma x_i \times \ln x_i$, where x_i is % v of i^{th} component in the diet of species and index of equitability $J' = H'/\ln S$, where S is the number of components.

The data were arc-sin transformed (Sokal & Rohlf 1981). General comparisons of percentage volume of feeding components between seasons and subplots of the study area were made using analysis of variance (ANOVA) in program SPSS. Post-hoc Bonferonni test was used to detect differences between individual seasons/subplots. The relationships between food components were assessed on the basis of mutual correlation using Pearson correlation coefficient.

Results

The diet composition of red deer did not differ between six subplots of the study area (ANOVA, $p>0.05$ all comparisons). The difference in the volume of feeding categories between northern and southern sub-area and also between eastern, western and central one was not significant except volume of grains (seeds of grain crops from fields and also from additional feeding) in August–September and October–November. The grains formed the higher proportion in subplots near the river ($p<0.01$). Consequently, samples from individual subplots were grouped together and further analysed.

Woody plants (leaves, buds, bark, and wood) were most frequent in the diet and comprised 71 % of volume overall (Table 1). The fragments belonged to several tree species, with leaves from oak and blood-twig dogwood identified.

The proportion of woody plants in red deer diet changed in the course of the year ($p<0.001$, Fig. 2). The highest volume of woody plants was found in April–May ($p<0.01$)

Table 1. Feeding components identified in red deer diet in the floodplain forest, their percentage of volume (%v), relative frequency (%f) and importance index (I) together with the values of the trophic diversity (H`) and equitability (J`) for each study period.

ITEMS	Dec.–Jan.			Feb.–March			April–May			June–July			Aug.–Sept.			Oct.–Nov.		
	%v	%f	I	%v	%f	I	%v	%f	I	%v	%f	I	%v	%f	I	%v	%f	I
woody plants (leaves, buds, bark)	78	20	49	76	19	47	85	15	50	80	19	50	49	16	33	53	17	35
fruits (from woody plants)	1.1	8.4	4.7	1.4	12	6.4	1.6	12	6.7	1.1	10	5.8	4.6	14	9.1	4.4	13	8.5
grasses (green parts of plants)	15	19	17	14	19	17	10	15	13	13	19	16	30	16	23	18	17	17
grains (seeds of grain crops)	1.8	6.7	4.2	1	7.6	4.3	1.1	1.4	1.3	1.6	6.7	4.1	11	13	12	18	15	17
Cerastium sp.	0.1	0.6	0.3	-	-	-	0.1	3.6	1.8	0	1.3	0.7	-	-	-	-	-	-
Cirsium arvense	-	-	-	-	-	-	0	0.4	0.2	-	-	-	-	-	-	-	-	-
Galium spp.	-	-	-	+	0.3	0.2	0.2	5.4	2.8	0.1	2.1	1.1	0	1.2	0.6	+	0.6	0.3
Rubus sp.	2	7.1	4.6	4.9	8.2	6.5	0.1	3.3	1.7	0	1.3	0.7	0.1	2.1	1.1	4.4	5.1	4.8
Solidago gigantea	+	0.3	0.2	0	0.6	0.3	0	1.1	0.6	0	0.7	0.3	-	-	-	-	-	-
Symphytum sp.	+	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Urtica spp.	+	0.3	0.2	0.5	1.8	1.2	0.1	3.6	1.8	0	1	0.5	0	1.5	0.7	0.1	1.1	0.6
Verbascum sp.	0	1.2	0.6	+	0.3	0.2	+	0.7	0.4	0.1	2.4	1.2	+	0.3	0.1	0	3.4	1.7
Asteraceae	0.3	7.1	3.7	0.5	8.8	4.6	0.4	5.4	2.9	0	1.7	0.9	0.1	0.9	0.5	0	1.7	0.9
Brassicaceae	-	-	-	-	-	-	0	1.1	0.5	-	-	-	-	-	-	0	1.1	0.6
Fabaceae	-	-	-	0	0.6	0.3	0.3	8.9	4.6	0.4	5.7	3	0.3	5	2.6	0.2	6.3	3.2
Lamiaceae	0.2	7.4	3.8	0.5	12	6.3	0.2	6.1	3.1	0	2.7	1.4	0	2.1	1	0.1	1.7	0.9
Ranunculaceae	0	1.5	0.8	0	1.5	0.8	0.1	4.6	2.4	0	2	1	0	2.1	1	0.1	0.7	0.4
forbs (unidentified)	0.6	7.8	4.2	0.1	3	1.6	0.3	4.6	2.5	1.4	11	6.4	2.2	9.4	5.8	0.4	9.1	4.7
seeds of forbs	-	-	-	-	-	-	0	0.4	0.2	0.2	1	0.6	0.8	6.2	3.5	0.7	5.1	2.9
unidentified fragments	1.9	12	7	1.3	6.1	3.7	0.6	7.9	4.2	1.4	11	6.2	1.5	11	6.2	0.5	2.9	1.7
H`(J`)	0.812 (0.300)			0.889 (0.328)			0.639 (0.217)			0.743 (0.262)			1.319 (0.487)			1.349 (0.487)		

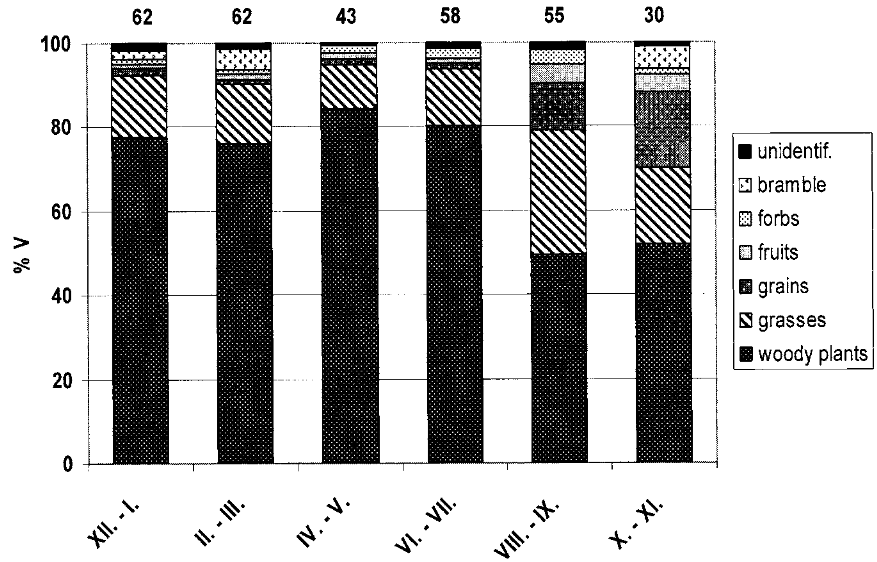

Fig. 2. Diet composition of red deer in each two-month period in the floodplain forest.

with a decrease towards the end of summer and in autumn (Fig. 3A). However, the shoots of broadleaved trees were most important in all seasons of the year. The red deer consumed woody plants in a quantity typical of a browse specialist.

Grasses (green parts of the plants) were the second most important component in the diet throughout the year (17 % of volume on the average, Fig. 2). Their volume in the diet did not differ between seasons except for a significant increase in August and September ($p<0.001$, Fig. 3B). It was not possible to identify grasses specifically but, based on the anatomical structures of tissues, the majority was formed by wild species, the occurrence of cereals being negligible.

The volume of grains was low through most of the year (Fig. 2). They formed 1–2 % of diet except in August–September and October–November, when they significantly increased to 11 and 18 % respectively ($p<0.001$, Fig. 3C). Field crops play a significant role for red deer only at this time.

At the end of summer and in autumn a similar increase in the volume of fruit items in the diet was found ($p<0.001$, Fig. 3D). Horse – chestnuts and sclerenchyma from stones of different drupe types (e.g. haw and sloe) were identified. In the period August–September the content of forbs also increased (mainly Fabaceae and the seeds of forbs) in the diet ($p<0.001$, Fig. 3E). Both items (fruits and forbs) occurred in small volume (Fig. 2) but with high frequency in the diet, what resulted in relatively high indexes of importance (Table 1). Bramble was consumed by red deer occasionally during winter (Fig. 2, Fig. 3F).

In total, 20 items were identified in the diet of red deer. The trophic diversity was higher during August–September and October–November compared with other periods ($p_{1,2}<0.001$). During both periods the diet did not contain higher number of components, but the items were more equally consumed (highest values of equitability).

A negative correlation (using Pearson correlation coefficient r) was used to show the substitution of broadleaved trees by other feeding components through the year. Negative correlation was significant between the volume of woody plants and volume of grasses (the highest value of r), grains, fruits and forbs (Table 2). The proportion of other feeding items in the diet was not consistent and independent of the volume of others.

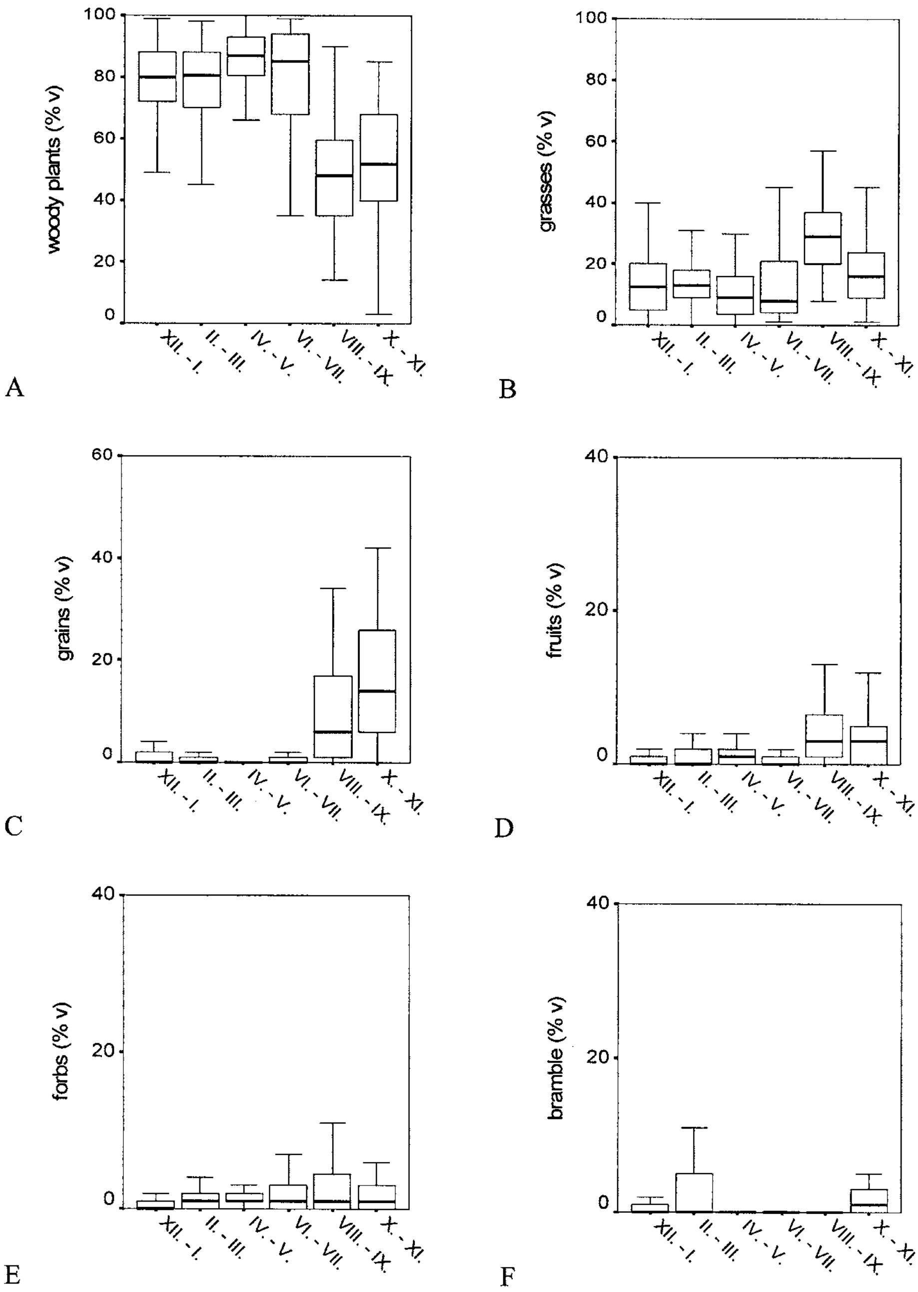

Fig. 3A-F. The proportion (% v) of six main feeding categories in the diet of red deer, together with median and quartiles within each feeding category in the course of one year in the floodplain forest.

Table 2. Correlation between volume of individual feeding components in red deer diet in the floodplain forest (the numbers are the exact values of Pearson correlation coefficient r; r** means the significance p<0.01, "-r" means negative correlation between two components).

Items	woody plants	grasses	grains	fruits	forbs	bramble
woody plants	1	**-0.730****	**-0.618****	**-0.357****	**-0.229****	**-0.303****
grasses	-0.730**	1	**0.175****	**0.120****	NS	NS
grains	-0.618**	0.175**	1	**0.206****	NS	NS
fruits	-0.357**	0.120**	0.206**	1	**0.242****	NS
forbs	-0.229**	NS	NS	0.242**	1	NS
bramble	-0.303**	NS	NS	NS	NS	1

Discussion

The diet composition of red deer in the floodplain forest was characterised by an unusually high content of browse and low content of forbs and grasses. It is not consistent with the foraging strategy proposed by H o f m a n n (1989), who characterised the red deer as an intermediate feeder with a tendency to grazing. The red deer appears as a typical browser despite an abundance of grasses in forest meadows, in corridors and on the bank of the river. It is interesting that the volume of broadleaved trees in red deer diet was higher than that in roe deer, where the broadleaved trees formed only 56 % by volume on average (B a r a n č e k o v á 2004). Apparently, red deer preferred items with higher nutrition volume compared to the nutrition volume of grasses throughout the year. The high proportion of shoots of woody plants in winter as well as in summer indicates that this component is sufficiently rich in nutrition (P a d a j g a 1984) and is not a limited food resource. The cover of shrub layer is 35 % on the average (unpublished data) and forms an important part of the food supply in the floodplain forest.

The results of this study are similar to those obtained by macroscopic analysis of stomach contents from a site close to my study area (L o c h m a n 1985). Woody plants were also the most important part of red deer diet and formed 62 % by volume, grasses forming 36 %. As in my study forbs had only a small importance in red deer diet in the floodplain forest in spite of their abundance.

In habitats where the abundance of browsed tree species was considered relatively high woody plants formed from 40 % (vegetation period) to 90 % (winter) of red deer diet, e.g. in mixed forests of Poland (D z i ę c i o ł o w s k i 1967, 1970, J a m r o z y 1980) and Hungary (M á t r a i & K a b a i 1989) or in Drahanská vrchovina Uplands of Czech Republic (H o m o l k a 1990). In habitats where the browsed woody plants were missing or less abundant (e.g. the Island of Rhum, the Scotish Highlands, alpine meadows on the tops of mountains), grasses occurred in high quantity and made up 50 to 90 % of diet volume (M i t c h e l l et al. 1977, H e r o l d o v á 1993, L a t h a m et al. 1999, H o m o l k a & H e r o l d o v á 2001). Eventually, woody plants were substituted for other components abundantly occurring in an individual area, e.g. by bramble (*Rubus* spp.), ferns or by *Vaccinium myrtillus* (F i š e r & L o c h m a n 1969, G ę b c z y ń s k a 1980, H o m o l k a 1995). It is evident that diet composition is influenced by food supply.

Woody plants were not replaced by field crops in our study area as much as expected, even though they were available on fields along the whole western edge of the forest. Crops such as mangel or wheat may form an important component in red deer diet (J e n s e n

1968, Putman & Moore 1998). In the study area the fields were visited by animals only occasionally. Of greatest importance were the nutritious grains of maize in August–September and October–November periods. The presence of other field crops (rape, wheat) was not detected in droppings. The low attractiveness of field crops for red deer during the growing season was reported also by Szemethy et al. (2003) in deciduous forests of Hungary.

Identifying grains in pellets is easy and their presence there can be used as a marker for the spatial activity of red deer, providing information on the use of fields for foraging. But the closeness of fields did not result in a significant increase in volume of crops in the pellets ($p>0.05$). In contrast more grains were detected in pellets found near the river, the greatest distance from the fields. Based on my observations, the grains originated from fields to which red deer moved at night. During the day they kept far away from villages, where they found better shelter (dense vegetation in plantations). Generally, red deer have a wide spatial activity. Their home range changes between seasons (the lowest is during the winter and the highest is through the rut) and decreases in areas with good food supply (Clutton – Brock 1982, Koubek & Hrabě 1996). In the floodplain forest the red deer had a wider spatial activity, as we expected based on unlimited feeding sources.

It is interesting that additional feeding during the winter had little influence on both red deer and roe deer diet (Barančeková 2004). It may be due to the composition of food provided or by its limited extent.

In the floodplain forest this herbivore species preferred woody plants over other natural food. This may represent a potential threat for the natural regeneration of forest stands. The floodplain forest is a commercial managed forest, with regeneration based on artificial planting. The planted seedlings are more nutritious, as a consequence of their exposure to sun in open stands, which makes them more attractive to browsing deer (Miller et al. 1982, Partl et al. 2002). High costs to protect planted seedlings against deer browsing are incurred to allow the natural regeneration of forests. We are currently assessing the impact of red deer on woody stands.

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