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THE IMPORTANCE OF CULTIVATED PLANTS IN THE DIET OF RED AND ROE DEER AND MOUFLON

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Abstract

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The botanical composition of red and roe deer and mouflon diet was studied in the mosaic landscape in Drahanská vrchovina highlands, Czech Republic. We focused on the proportion and quality of agricultural crops and natural forest plants and estimated quality of the herbivore diet. Diet quality was monitored by the near infrared reflectance spectroscopy on the basis of nutritional quality of diet items. Red deer, roe deer and mouflon ingested all cultivated plants growing close to forest. However, the proportion of cultivated plants varied between seasons and herbivore species. The peak of crops consumption occurred in summer – when cereals spikes were ripe. The average proportion of corn for red deer was 40%. Cultivated plants were well accessible for herbivores in the study area and during vegetation period formed an important part of their diet, but the importance of cultivated plants for herbivores was lower compared with natural food resources present in forests during vegetation period. Although the main natural food sources had lower nutritional value, they formed the main part of herbivore diet in the study area. The availability of cultivated plants increases the quality of food supply during the growing season, but for herbivores the natural food sources are crucial, forming the main part of their diet both in summer and in winter. Wildlife management should reckon with feeding preferences of herbivores.

Keywords: agricultural crops, deer, diet quality, diet composition

INTRODUCTION

In the current landscape of Central Europe, where large predators are missing, the numbers of large herbivores are influenced mainly by hunting and by the food accessible throughout the year. The quantity and the quality of food resources differ substantially in individual habitats and change often during the year. It is the winter that is usually considered to be the most difficult season for large herbivores due to the shortage of quality food and due to the increased demands for energy spent on thermoregulation and movement (Kamler and Homolka, 2011; Mysterud *et al*., 2000; Cornelis *et al*., 1999). The requirements of herbivores are increased by the snow cover causing the movement more difficult and the food less accessible. Although the number of populations is normally decreased in winter, their survival also depends on the nourishment conditions during the preceding growing season, when herbivores produce energy reserves (Katona *et al*., 2014). Low availability of high quality food supply during the growing season could have the same influence on herbivores survival as extreme winters. Arnold *et al*. (2004) found that red deer, similar to many other northern ungulates, shows large seasonal fluctuations of metabolic rate, as indicated by heart rate, with a 60% reduction during the winter nadir compared with the summer peak. Mechanism of energy conservation associated with peripheral cooling extensively lowers energy expenditure during winter and herbivores are able to successfully occupy also localities with severe winter conditions. The carrying capacity of environment for herbivores

is therefore significantly limited by the accessibility and quality of food during the growing season. When evaluating the growing season the following is essential: the start of the vegetation period, its duration and the nutritional value of the food in the second half of the vegetation period, when animals produce fat reserves.

Large herbivores are able to migrate to distant places to search for better food resources and to change flexibly the composition of the ingesta (Teitelbaum *et al*., 2015; Thirgood, 1995; Szemethy *et al*., 2003a; Matrai *et al*., 2004). The food and habitat preference depend not only on the quality of food resources, but also on their quantity and accessibility, on the risks of disturbance and other factors. The habitat, food and survival strategy selection become more complicated in agricultural and cultivated lands than under natural conditions, because the agriculture significantly influences the food and cover availability in the environment and the quality and accessibility of food resources vary greatly during the year. There is a considerable lack of exact data about the behaviour of herbivores in such conditions and about the significance of food resources outside the forest and the results of partial studies are very different. Matrai *et al*. (2004), Brinkman *et al*. (2005) conclude that movements of large herbivores have been well documented in forest dominated habitats; however, little information related to deer movements exists in intensively cultivated areas. Detailed region-specific empirical information is needed for effective management of deer populations.

Attention is paid to causes of migration of large herbivores into agricultural areas. Szemethy *et al*. (2003b) studied seasonal home range shift of red deer between agricultural and forested areas in Hungary and did not confirm better nutritional quality in agricultural area as the main cause of massive migration of the animals into fields. Deer diet was dominated by browsing in the forest (65–85%), whilst in agricultural fields wood species were as important as grasses (26–44% and 39–55%, respectively). Consumption of cultivated plants was low (under 10%) in the agricultural area and nutritive quality of the diet was lower at the agricultural site than in the forest. Johnson *et al*. (2001) examined the foraging behaviour of woodland caribou. Caribou in both forest and alpine environments selected sites where the biomass of particular lichen species was the greatest and snow depth the least, but did not select those species with the highest nutritional value. In this case a trade-off between forage abundance and accessibility at the scale of the landscape was found. Kjosvedt *et al*. (1998) studied the quality of main agricultural plants. Osborn, Jenks (1998) noticed that white-tailed deer density was twice higher in the areas with the access to agricultural land, suggesting that these fields are important feeding sites. Use of the agriculture areas by free living herbivores could be influenced by more factors, mainly by the palatability of the cultivated plants, the food available in the forest, the snow cover that disappears faster from open areas, the feeding specialisation of herbivore species and its space activity, the intensity of human activities in the field and forest (e.g. field and forest work, proximity of houses and tourism, hunting) and by the cover available in both environments (Dai *et al*., 2007; Welch *et al*., 1990; Thirgood, 1995; Matrai *et al*., 2004).

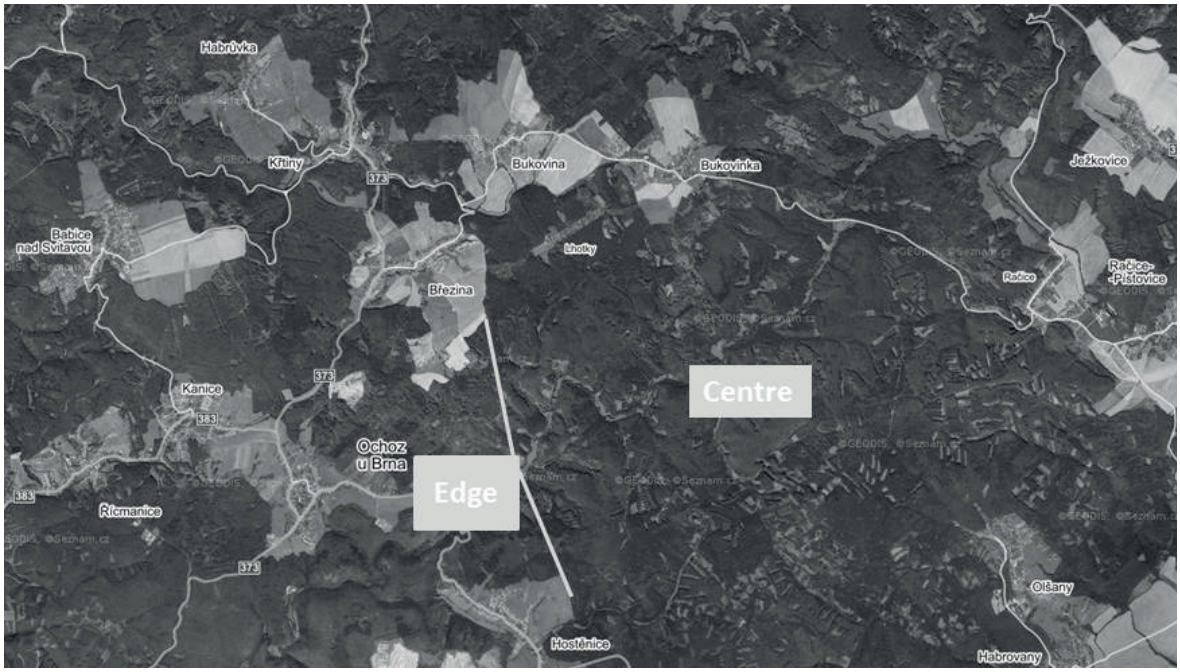
Herbivore species with small home area use fields – if located close by – on the forest edge. Animals living in the centre of large forests do not go to feed in the fields. Typical species representing such behaviour is roe deer, except for roe deer living in large field (Zejda, 1978; Zejda *et al*., 1985; Zejda and Bauerová, 1985). On the other hand species with large space activity (red deer) migrate to places with high quality food resources covering considerable distance and staying there for longer periods, e.g. seasonal migration when maize is ripening. Or they move every night to places with highly attractive food resources located more than one kilometre away (Kamler and Homolka, 2011; Koubek and Hrabě, 1996).

In this study we analyse the foraging behaviour of red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and mouflon (*Ovis musimon*) in complex of woods and in neighbouring fields with cultivated plants. We tested the following hypotheses: 1. quantity and quality of food resources are higher in the field than in the forest, 2. animals living on the edge of woods complex have higher diet quality.

Study Area

Our study area was the southern part of the Drahanská vrchovina Highlands, approximately 10km NE of Brno between Hostěnice, Bukovinka and Račice (49.26N, 16.80E). This forested area is approximately a circle of 10km in diameter. The elevation varies from 340 to 500 m in the area. On the boundary of this forest there are villages, meadows and fields. The annual mean air temperature in the region attains 6–8 °C, the annual total precipitation from 530 to 620mm and continuous snow cover lasts there for 46–67 days on average.

The relief of the study area is rather varied. In its center there is a low east-west ridge 425–500 m above sea level. This ridge emits numerous lateral and subdividing branches, mutually separated by deep valleys with permanent or periodical streams. Almost entire study area is limited by the valleys of the Říčka and Hostěnický potok streams, formed by the steep c1iffs of the surrounding ridges and flatlands. The relative height of these cliffs is up to 100 m. The original woodland was oak-hornbeam woods, acidophilous oak woods and partly beech woods with *Luzula* sp., in the stream valleys lowland forests and alder stands. At present the study area is covered predominantly by coniferous forests (i.e. stands in which conifers make up over 75%), occupying 53% of its area. Mixed (coniferous and broadleaved) stands make up 26% and broad-



1: *Map of the study area*

leaved 21% of the total area. The dominant tree species include *Picea abies* (42%), *Fagus sylvatica* (25%), *Larix decidua* (10%), *Pinus sylvestris* (7%), *Quercus spp.* and *Carpinus betulus* (6% each). Other woody plant species occur in negligible amounts. All these stands are c1assified as productive, with standard management using a 100–120-year cutting cyc1e. The coniferous stands are harvested by c1ear cutting and reforested by Norway spruce with an admixture of larch. The broadleaved stands are harvested by shelterwood felling, utilizing natural regeneration, chiefly of beech. The forest consists of a mosaic of areas covered by stands of different ages and species composition. The food supply for large herbivores was mapped in detail in Homolka and Heroldová (1990). Spruce monocultures cover over 50% of the area but in the shrub layer is high quantity of other food sources. The biomass of woody plant sprouts (0–150 cm level) averaged 166 kg.ha^{-1} dry weight in summer and 58 kg.ha^{-1} dry weight in winter. Most of the logged areas are rapidly grown over by grasses of the genus *Calamagrostis* which predominate. The herb layer in older tree stands depends on the habitat type and the amount of light that penetrates through the canopy of tree crowns. Some of the herb layer types are dominated by *Calamagrostis spp.* as in the case of those covering the clearings. Others are dominated by *Senecio ovatus* or *Oxalis acetosella*. Especially in rather moist habitat types the herb layer may be dominated by ferns. In broadleaved stands the herb layer is dominated by *Poa nemoralis* and *Luzula spp.*, in some types also *Impatiens parviflora*. We monitored the occurence of agricultural plants in the herbivore diet and the quality of important food sources for herbivores. We collected samples of plants and faeces in four seasons (spring – May, summer – July, autumn – September and winter – February). Samples of the herbivore faeces and the vegetation were collected during the study focused on the impact of herbivores on the forest vegetation from 2003 to 2011, minimally 2 km from the forest edge (locality "forest centre") and on fields and neighbouring forest (locality "forest edge"; see Fig. 1).

MATERIALS AND METHODS

Botanical Composition of the Deer Diet

We determined the botanical composition of the red and roe deer diet by the microscopic analysis of their faeces. From the faecal samples collected, one pellet was removed and used to prepare a microscopic slide. The representation of various food components was estimated on the basis of their relative coverage in the microscopic field. For the purpose of the evaluation of the overall character of the diet, the components were pooled to form primary forage classes: grasses, *Rubus* spp., browse, needles, forbs, seeds and others (see Kamler and Homolka, 2011).

Generalized linear models were used for evaluation of dynamics in ruminant diets in relation to species, locality and season of a year. One-Way ANOVA was used to analyze individual factors. Numbers in compared samples differed and therefore we chose Scheffe post hoc test for multiple comparison. All analyses were done in SPSS ver. 11.0.

Quality of the Deer Diet

Diet quality of red and roe deer was monitored by the near infrared reflectance spectroscopy (NIRS) from their faeces. We developed calibration equation that reflects the relationship between the content of dietary metabolizable energy (ME) in the diet and NIR spectral information. ME content in deer diet was determined from vegetation samples we collected from both agricultural plants and natural diet resources during the first stage of our research. Only samples of those plants whose share in the diet was over 1% were collected. We picked those parts of plants that the deer usually browse (simulation of browsing) and we took at least 5 samples of each species. At the same time we collected samples of fresh faeces. From each species we obtained minimally 10 samples. The samples of vegetation and faeces were dried in a ventilated drying chamber at 60 °C to constant weight. We did not mention the possible differences in the quality of diet components between years and localities because of high variability of the content of analyzed nutrients during vegetative stages, locality etc. Our developed calibration model reflect the diet quality (content of ME in the diet) and shows possible differences.

For the purpose of ME calculation we assessed the content of Kjeldahl nitrogen, crude protein, fat, fibre, nitrogen free extract (NFE) and ash in the vegetation samples. On the basis of these data we calculated the content of ME (Sommer *et al.*, 1994). For the content of dietary energy we used the Axelsson's regression equation to assess the content of digestible organic matter and the regression equation according to Hewitt (2011) to calculate the content of digestible nitrogen compounds. We calculated the content of nutrients in all main individual plants and their content in the diet was calculated according to Westoby (1974) or Popovic *et al.* (2009). This procedure is completely described in Kamler and Homolka (2005). ME was used as the main criterion of the diet quality because of high importance of energy content for wild ruminants. Selection of the diet higher in energy but lower in protein was proved by using experimental food to feed free living white-tailed deer in Canada. In this experiment nitrogen levels ranged from 1.8 to 2.6% and deer were able to discriminate among experimental food and preferred the food higher in digestible energy and the food lower in nitrogen for each given level of digestible energy (Monteith *et al.*, 2014). Changeable reliability of faecal nitrogen and other easy indicators of diet quality was proved in our previous study (Kamler and Homolka, 2005).

NIRS measurements were carried out using a producer Nicolet Antaris, a near infrared reflectance spectrophotometer in the 9860–4100 cm^{-1} wavelengths range, with 50 scans being collected from each sample. The spectra produced by the spectrometer represent overall chemical and physical properties of a sample. Chemical information appears at a specific location in the spectrum. Physical properties of a sample, such as particle size, are eliminated by mathematical corrections. Data were analysed using TQ Analyst software. Partial least square regression (PLS) was chosen as a method of computing the calibration equation quantifying the relationship between NIR absorption and reference values (Smolinski *et al.*, 2003). PLS is recognized as a very powerful tool for developing models from spectroscopic data (Shenk and Westerhaus, 1991) and is preferred in the studies analysing biological materials (Kleinebecker *et al.*, 2011; Xiccato *et al.*, 1999). For validation of our equation we used standard error of cross validation (SECV). SECV is used to estimate the error of prediction for unknown samples by simulating the prediction process by leaving part of a data set out, developing the calibration model on the rest of a data matrix and making predictions for samples left out. This process is repeated several times so that each sample is left out once.

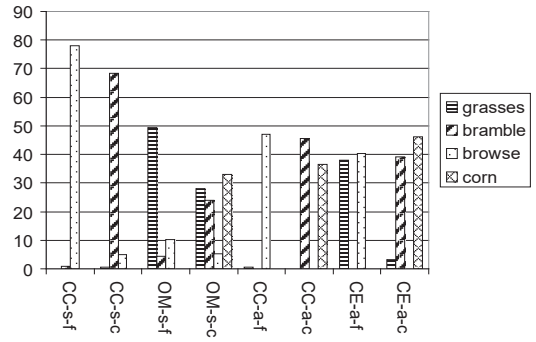
RESULTS

Agricultural and Forest Items in the Red and Roe Deer and Mouflon Diet

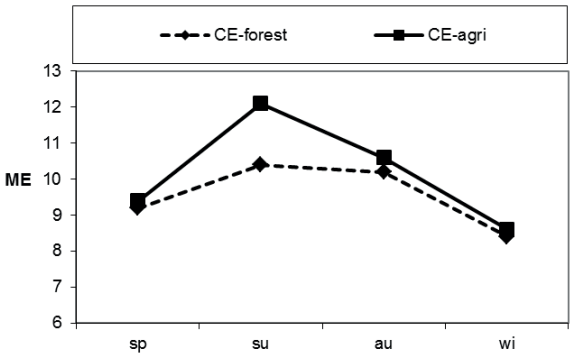
Spring wheat, winter wheat and maize were sown in the monitored areas near the complex of woods. Red deer, roe deer and mouflon ingested all cultivated plants; however, not equally during the seasons. In winter the food resources on fields were of lower quality and quantity and often covered with snow. The use of cultivated plants by herbivores was therefore negligible and we analysed the botanical composition of herbivore diet only during the vegetation period.

In spring, the proportion of agricultural plants was significant also in roe deer ingesta, a browser that does not basically ingest grasses. All species intensively used green cereals at the beginning of the vegetation. After development of the natural food sources, all species switched to the forest plants (90% of the total ingesta in summer).

The summer – when cereals spikes ripen – is a significant season concerning the ingesting of cultivated plants. Some samples contained up to 90% of ripening cereals; the average for red deer was 40% (Fig. 2). We found no significant difference between the content of cereal grain in animals living in the centre of the woods complex and those living at its edge ($p > 0.05$). Animals could migrate to such an important food resource for a distance of more than 5 km. We found that ingesting cereal grains in this period increased significantly the quality of the game diet. In some places, where attractive plants were growing near the woods complex, the numbers of animals increased at the forest edge. This period of intensive feeding of cereals lasted till the harvest. Individuals grazing in the fields ingested food of much higher quality than individuals feeding only on natural food resources. This difference was most



2: *The content of main items (% of the volume) in the red (CE) and roe (CC) deer and mouflon (OM) diet in Drahanská vrchovina highlands in summer (s) and autumn (a) in the centre of forest complex (c) and at the forest edge near agricultural fields (f)*



3: *The content of metabolizable energy (ME, MJ/kg) of the red deer (CE) diet consisting only of forest plants (forest) and the mixed diet containing both forest plants and crops (agri) in four seasons (sp, su, au, wi) in the locality Drahanská Vrchovina highlands*

significant in red deer, an intermediate feeder that is the most flexible species when choosing its diet (Fig. 3).

Cereals in the cultivated areas were accessible only till the harvest and since then animals ingested only natural food. In autumn – till the beginning of the snowfall – red deer grazed also on the green winter crops – without a significant effect on the diet composition, though.

All monitored species depended mainly on natural food resources in forests and the accessibility and quality of the food resources determined the nutritional conditions of herbivores. The availability of cultivated plants increases the quality of ingesta during the growing season. There is no food left after harvest, but produced fat reserves help animals to survive crucial winters. Similarly, in spring the green food is accessible sooner for animals at the edge of woods complex.

Quality of Main Diet Resources

In the summer, the agricultural crops had higher nutritional quality than the natural food resources in the forest environment. In spring the quality of crops was similar to that of forest plants, but at the beginning of the vegetation period the available biomass of crops was higher than the biomass of new leaves and grasses in the forest. Main nutritional characteristics of the main food components are shown in Tab. I.

DISCUSSION

In the monitored environments large herbivores intensively ingested cultivated plants mainly in the period when cereals were ripening and the cereal grains made up approximately 40% of their diet on average. This relates to the high nutritional energy of cereal grains compared to the natural diet. Animals whose diet consists of more than 50% of cereals ingested food of double quality compared with animals remaining only in the forest environment. Lashley *et al.* (2015) compared the quality of natural food and cultivated plants. In the underbrush of natural broad-leaved forest the quality of preferred plant species was similar to the average quality of cultivated plants and the game does not need to feed in the fields during the growing season. On the contrary our results show that ripening cereals increase significantly the quality of the diet.

In winter animals grazed mainly in forests. Red deer ingested cultivated plants the most and migrated further behind the forest edge. Roe deer

I: *Content of nitrogen (N-g/kg), fiber (F-g/kg), nitrogen free extract (NFE-g/kg) and metabolizable energy (ME-kJ/kg) in the main components of herbivore diet*

Forage	season	NS	F	NFE	ME
Winter wheat	spring	326	132	363	9.4
Winter wheat	summer	136	30	798	13.8
Oats	summer	109	113,6	681	11.6
Maize	summer	106	24	772	12.5
Norway spruce	spring	105	299	524	7.6
Bramble	spring	130	177	632	10.6
Bramble	summer	135	300	481	9.07
European beech	spring	70	425	475	7.8
European beech	summer	127	252	571	9.9
Raspberry	summer	160	264	497	9.5
Common oak	spring	157	257	506	9.6

ingested cultivated plants to a lesser extent and mouflon ingested only natural diet. On the contrary Barančeková (2004) found that during the growing season the diet of roe deer consisted mainly of cultivated plants, namely alfalfa and sugar beet. Roe deer inhabiting field environment ingested mainly food left in the field after the harvest or alfalfa and winter crops (Muska, 2007) and formed large groups near these food resources. Mouflon in our locality did not use plants from the fields despite it is considered to be a species which causes significant damages. In our case mouflons preferred habitats in the centre of the forest probably due to human disturbances.

We confirmed the high quality of agricultural crops in summer and their high consumption by wild herbivores. Szemethy *et al.* (2003b) conversely found out that cultivated plants were not dominant red deer diet components and their presence in the diet was rather negligible. It their study a fundamental part of red deer population migrated into agricultural area, but animals both in the forest and in the field consumed mostly browse. This case could be explained by the low quality of crops in the time of animal migration due to disturbance in the forest and shows high plasticity in the food selection of red deer. Changes in the diet composition of red deer following phenological stages of vegetation were reported by Jiang *et al.* (2006). Adaptation to varying feeding conditions throughout the seasons or years was also confirmed by Dumont *et al.* (2005). In our study the comparison of diet qualities between agricultural and forest habitats supports the hypothesis on nutritive benefits of agricultural environments.

For the measurement of the food quality we used the content of metabolizable energy as the main criterion. Selection of the diet higher in energy but lower in protein was proved by using experimental foods (Monteith *et al.*, 2014). In the most dietary components there is a good correlation between the content of energy and protein (nitrogen) but using nitrogen content as direct indicator of diet quality is questionable (Kamler and Homolka, 2005). In similar study Kjosvedt *et al.* (1998) measured the total energy digestibility of total dry matter and several minerals.

Szemethy *et al.* (2003b) used the content of crude protein and crude fiber for evaluation of the diet quality. They did not measure digestive energy content because of its significant difficulties and unreliability for free-ranging animals. They evaluated low quality of food supply in fields on the basis of low protein content in agricultural diet items. However, comparison of diet quality on the basis of protein content is problematic.

Our study demonstrates the high quality of agricultural crops in summer. Large herbivores preferred field crops to natural food resources. Wildlife management should reckon with feeding preferences of herbivores.

CONCLUSION

Cultivated plants were intensively ingested by large herbivores in the study area. The cereal grains formed approximately 40% of their diet during summer and their nutritional value was higher than the natural food supply. Our results demonstrate the high quality and high attractiveness of agricultural crops in summer for large herbivores.

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