Belg. J. Zool., 143(2) : 95-105 July 2013

Selective use of forest habitat by Biłgoraj horses

Daniel Klich[1,*] & Magdalena Grudzień[1]

[1] The John Paul II Catholic University of Lublin, Chair of Applied Ecology, Konstantynów str. 1H, 20-708 Lublin, Poland.
[*] Corresponding author: Daniel Klich, e-mail: klich@kul.pl

ABSTRACT. Primitive horses are quite often kept in nature reserves with access to the forest, which they sometimes penetrate to use the vegetation. Horses, as grazers, use specific foraging and anti-predator strategies that differ from typical browsers. The aim of the study was to assess the factors influencing the pattern of forest use by Bilgoraj horses. We hypothesized that the essential factors influencing their pattern of foraging are: browse abundance, distance to pasture, and openness of the habitat. Data were collected at the Biłgoraj Horse-Breeding Centre near Janów Lubelski, Poland. The horses browsed significantly more on woody vegetation in parts of the forest more exposed to sunlight and more abundant in browse material (especially containing preferred species). Distance to the main pasture had a significant effect upon browsing intensity only when an interaction with the abundance of preferred browse was considered.

KEY WORDS: Biłgoraj horse, browse, forest, habitat openness

INTRODUCTION

Grazing by horses is increasingly becoming the preferred mode of natural maintenance of meadows that are no longer under agricultural practices. It controls the growth of woody vegetation in grassland communities as it helps in the delay or even prevention of the processes of secondary succession (Borkowski, 2002). Due to their adaptability primitive races of horses are preferred for such tasks. These horses are kept in reserves with access to the forest, which they occasionally penetrate to forage on its vegetation (Jaworski, 2003; Stachurska et al., 2006). There have been no prior studies on patterns of habitat use in forests. However, there were a number of studies focusing on grazers in relation to grassy environments (e.g. Coughenour, 1991; Bailey et al., 1996; Edouard et al., 2009), woody species succession on meadows (Green & Kauffman, 1995; Carmel & Kadmon, 1999), and their impact on forest undergrowth, and the growth of tree seedlings (van Uytvanck & Hoffmann, 2009; Wassie et al., 2009; Törn at al., 2010; Bobiec et al., 2011). Some studies also considered the issue of bark stripping by grazers (Kuiters et al., 2006; Klich, 2009). Although woody vegetation constitutes a marginal percentage in the diet of horses (Cosyns et al., 2001), high density of animals, which is common in reserve conditions, may lead to a significant impact on tree stands (Jorritsma et al., 1999). Better knowledge regarding the factors influencing decisions by horses regarding their foraging patterns would be useful in the management of free ranging animals and could help to minimize damage to forest stands.

Both wild (King, 2002) and domestic horses (Jorritsma et al., 1999; Cosyns et al., 2001; Kuiters et al., 2006) use the forest habitat to a limited degree. Horses do not enter forests only to search for food (Cosyns et al., 2001; Kuiters et al., 2006). Other motivations play a role such as seeking protection against insects and high temperatures, as well as looking for substrates to rub against (Jezierski & Jaworski, 1995; King, 2002). The foraging pattern of horses in a forest results from both the specific structure of patches of woody vegetation and their specific foraging strategy. There is a lack of knowledge regarding the criteria the horses use when feeding upon woody vegetation. Further, it is not clear whether abundance of browse and browse preference play a role. Following optimal foraging theory, one would expect horses – being bulk feeders – to graze upon taller vegetation to take in more food with minimized energy costs (Edouard et al., 2009). Horses require higher amounts of food than do ruminants, since they are hindgut fermenters, digesting food more rapidly but relatively less efficiently (Illius & Gordon, 1992). Quite opposite to this expectation, some evidence indicates that horses tend to graze on lower vegetation (Fleurance et al., 2001; Lamoot et al., 2005) and have a strategy of maintaining parts of the meadow in good quality by permanent grazing just like other grazers (Bakker et al., 1983; Fleurance et al., 2001). Although horses are able to utilize low quality herbage (Gudmundsson & Dyrmundsson, 1994; Chodkiewicz & Stypiński, 2011), their selection of food of better quality based on digestibility of energy aligns with optimal foraging theory. Given the diversity of species in grassland communities, even within an individual patch there will be spatial diversity of food quality resulting in selectivity of the grazers (Searle & Shipley, 2010). With regard to browse material, the quality may differ strongly between tree species, individual trees, and even within a tree (Suomella & Ayres, 1995; Touré et al., 1998). This difference in quality seems to affect foraging by browsers, but apparently grazers use woody vegetation much more homogenously (Searle & Shipley, 2010). As grazers, horses are less selective with regard to browse quality relative to browsers such as red deer (van Wieren, 1996). On the other hand, horses have a lower ability to detoxify plant secondary compounds than do browsers (McNab, 2002). There is even some evidence for browse selectivity in horses (Skiwski & Klich, 2012). Polish konik in the Eastern Carpathians tend to browse on woody vegetation characteristic of more open parts of the forest (Skiwski & Klich, 2012). Massive abundance of browse in the forest habitat affects the amount of light available to lower parts of the forest. In some cases, the presence of undergrowth also fundamentally changes the light conditions (Conway et al., 1997). Those changes may be connected with lower lateral visibility (due to the density of twigs) or just limit the amount of sunlight reaching the ground vegetation. Horses are typical open-environment species. This is an anti-predator strategy allowing them to scan their surroundings for any predator. Horses in captivity show a high plasticity to artificial conditions while retaining most of their natural reactions including the anti-predator behaviour (Hansen et al., 2001; Estevez et al., 2007). The possibility of an unexpected attack makes ungulates vulnerable to predators, resulting in avoidance of forest habitats by some species (Pépin et al., 1996), and a quicker flight reaction in highly risky habitats (LaGory, 1987; Taraborelli et al., 2012). Moreover, horses need a relatively long time to adapt to the dark when moving between extreme light conditions (Hanngi & Ingersoll, 2009). The distance to pasture is another factor relating to the use of forest habitat by horses. Horses spend more than half of the day grazing on pasture (Duncan, 1992; Fleurance et al., 2001). Their food choice is based upon quality of the grassy vegetation, a factor that also determines their level of woody vegetation use (Cosyns et al., 2001). Horses were found to engage in debarking of trees and shrubs of preferred species, and foraging was much more intense along the edge of a tree stand and at solitary trees or shrubs in meadows (Klich, 2009). There have been similar findings for other ungulate species underlining the influence of spatial distribution of vegetation upon foraging behaviour within substitute habitats (Clarke et al., 1995; Hester & Baillie, 1998). From optimal foraging theory, a meadow as a main feeding site, may optimally fulfill the requirements of horses regarding food and safety. When foraging in woodlands, horses expend energy for translocation and spend more time in a less open and thus more risky environment. On the other hand, there is some evidence that for typical forest ungulates, which perceive open areas as risky, the distance to the forest edge is a factor that determines the level of meadow use (e.g. Aulak & Babińska-Werka, 1990). Foraging and anti-predator strategies may represent antagonistic needs and motivations in individuals, in both the wild and captivity. Although there are other mechanisms mitigating this antagonism (e.g. CLARK & DUKAS, 1994), the predation risk usually reduces the foraging efficiency (BROWN, 1999; HOWERY & DELIBERTO, 2004; GUILLEMAIN et al., 2007). We expect that in forests, which for horses are a non-standard habitat, horses adapt their foraging strategy and anti-predator strategy. This study set out to assess the factors influencing forest use pattern of Biłgoraj horses, a race very closely related to Polish koniks. We hypothesize that three factors have an influence on forest habitat use by horses: (a) the abundance of browse; (b) the distance to the pasture; and (c) the light conditions that represent the openness of habitat. Locations that are safe (opened and close to pasture), and have an abundance of attractive food sites, should be then used by horses more frequently and for a longer time. By contrast, any inconvenience related to the habitat structure or any factor causing a decrease of food quality should shorten the time spent there by horses for grazing. We tested three factors that could influence the horses' choice in selecting particular plots for feeding:

1. The abundance of browse – represented by two variables: (a) Preferred browse – total number of twigs of preferred woody species (in each plot); we expected this variable to reflect the strength of tendency in choice of patch selection. (b) Other browse –total number of other twigs available within each plot (randomly taken and not preferred),
2. Distance to the pasture – represented by each plot distance to forest edge,
3. Openness of the habitat – represented by Trans Total value in each plot.

MATERIALS AND METHODS

Data was collected in Szklarnia Village, Biłgoraj Horse-Breeding Centre near Janów Lubelski in the East of Poland between September 5 and 10, 2011. Horses in the breeding center were kept in various conditions. Stallions were stabled with daily access to pastures, while mares and yearlings were free ranging in enclosures. Depending on the season, the group of mares with yearlings had access to meadows during spring, meadows with hay provided ad libitum during winter, and meadows with access to forest during summer and autumn. In the summer-autumn enclosure, the meadow was bordered directly by a forest patch about 100 m wide and 600 m long. Two habitats were distinguished within this forest: fresh mixed coniferous forest and alder swamp forest. Both habitats were spatially mixed and horses were interchangeably using them. Two months after the release of 20 horses into a summer-autumn enclosure, eight parallel transects in 50 m intervals were delimited within the forest habitat. Maximal transect length was 100 m but depended on the accessibility of the area for horses. For instance, transects were shorter if they reached the fence of the enclosure. Consequently, transect length varied from 30 m to 100 m. Along the transects, 5 m x 2 m plots were defined at 10 m intervals, starting from the edge of the forest. The total number of plots equalled 72. However, three plots were excluded from further analyses because of low accessibility for horses. This was due to felled trees or high level of water. Within each plot that was browsed by horses, the remaining twigs of trees and shrubs that were up to 2 m above the ground were counted, and categorized by tree or shrub species.

Based on the number of browsed and not consumed twigs, the Jacobs' selectivity index was calculated for all tree and shrub species to quantify the preference of horses for each species (JACOBS, 1974). The statistical significance of the Jacobs' selectivity index was verified by chi square test, comparing the number of twigs browsed and not consumed for each plant species separately (df = 1). To quantify the openness of the habitat, a photo was taken in the center of each plot with a fish-eye lens, directed vertically upwards at 1 m above the ground. Pictures were elaborated with Gap Light Analyzer. We used Trans Total value, which represented the amount of direct and diffused solar radiation passing through the canopy and topographic mask (FRAZER et al., 1999). The Trans Total value represented the visual openness of the forest site at the height of one meter.

Statistical analyses using Statistica 9.0 software were performed to identify the factors that could influence the selective use of forest by horses. The dependent variable representing the browsing behaviour of the horses was the number of browsed twigs within each plot. Plots with less than 20 twigs of preferred browse or other browse were excluded from the analyses as it was assumed that low amounts of available browse would not be sufficiently attractive for horses. Out of 72 delimited plots along the transects, data from 49 plots were compared (after excluding plots with less than 20 twigs of preferred browse or other browse, and low accessibility for horses). In order to assess the influence of each factor upon foraging pattern of horses in the forest and to take mutual interactions and nonlinear relationships into consideration, we used a Response Surface Regression model in GRM (General Regression Models).

RESULTS

A total number of 29,777 browsed and not browsed twigs from 22 tree and shrub species were registered within all plots (Tab. 1). The highest number of twigs belonged to *Frangula alnus*, *Salix sp.*, *Abies alba* and *Alnus glutinosa*. Horses mainly browsed on *Frangula alnus* and *Abies alba*. According to the Jacobs' selectivity index, horses preferred six tree species, mainly deciduous and one coniferous – *Abies alba*. Among shrubs, horses preferred *Frangula alnus*, *Rubus sp.* and *Crataegus sp.* Other analyzed species were avoided by horses. In the case of *Padus avium*, the negative value was close to zero, and an intake of its browse should be regarded as random. Two other avoided species, *Populus tremula* and *Rosa canina*, were present in very low amounts and consequently the Jacobs' index did not show their real preference status.

When both habitats in this study – i.e. fresh mixed coniferous forest and alder swamp forest – were treated separately, we found that the preference towards browse in both habitats was limited by site openness or exposure (Fig. 1). The horses preferred *Tilia cordata* in the fresh coniferous forest and avoided it in the alder swamp forest, where that species was only available in one plot with limited openness. In the case of many other tree or shrub species, the direction of the preference of horses for them changed after excluding plots with low degree of openness.

Among all 49 analyzed plots, horses browsed unevenly. Two of the three tested factors had a significant independent influence on foraging pattern of horses (Tab. 2). There also occurred significant interactions among variables; in all cases preferred browse abundance (PB) interacted with all other variables. E.g. distance to the pasture (DP) interacted with PB, and had then a significant influence on foraging pattern of horses. Although, there are no statistically significant correlations among variables, a specific trend between them is apparent (Fig. 2). The amount of preferred browse tends to increase together with increasing distance to the pasture. This interaction reflects a mutual relationship between PB and DP, so the sole significant influence of DP on foraging pattern of horses was not found.

The interaction between habitat openness (OH) and the amount of preferred browse (PB) increased the joint role of both variables in the horses' feeding choices. However, no relationship between the variables was found. The third example of such interaction is one between preferred browse (PB) and other browse (OB). This interaction is a result of priorities in the feeding behaviour of horses, as they first search for preferred food and then tend to use mostly the available composition of browse.

Total abundance of browse as well as preferred browse and other browse determined most of the spatial decisions, but the fraction of available preferred browse was most important. This contribution was also shown in the significant

TABLE 1

Browse intake and its preference by Biłgoraj horses (Jacobs' index) and statistical significance (Chi-square test with Yates' correction), * as a percentage of all browsed twigs or all twigs available.

	Number of browsed twigs		Number of available twigs		Jacobs' Index	Chi square	p
	N	[%]*	N	[%]*			
Species							
Trees							
Abies alba	765	0.216	2922	0.098	0.433	444	0
Acer platanoides	2	0.001	36	0.001	-0.364	0.66	0.416
Alnus glutinosa	84	0.024	3309	0.111	-0.675	264.05	0
Betula pendula	137	0.039	746	0.025	0.22	22.11	0
Betula pubescens	61	0.017	236	0.008	0.373	29.81	0
Carpinus betulus	25	0.007	478	0.016	-0.394	16.69	0
Malus sylvestris	41	0.012	199	0.007	0.27	9.87	0.002
Fagus sylvatica	107	0.03	1700	0.057	-0.321	44.28	0
Padus avium	153	0.043	1419	0.048	-0.052	1.34	0.247
Padus serotina	4	0.001	69	0.002	-0.346	1.54	0.214
Picea abies	39	0.011	723	0.024	-0.382	24.45	0
Pinus sylvestris	33	0.009	410	0.014	-0.196	4.48	0.034
Populus tremula	0	0	4	0	-1	0.01	0.904
Quercus robur	173	0.049	489	0.016	0.509	168.71	0
Salix sp.	223	0.063	5285	0.177	-0.526	300.96	0
Sorbus aucuparia	128	0.036	578	0.019	0.308	41.7	0
Tilia cordata	7	0.002	37	0.001	0.228	0.79	0.374
Shrubs							
Corylus avellana	33	0.009	1133	0.038	-0.616	76.72	0
Crataegus sp.	57	0.016	305	0.01	0.224	9.48	0.002
Euonymus europaeus	0	0	107	0.004	-1	11.69	0.001
Frangula alnus	1124	0.317	7988	0.268	0.117	37.48	0
Rosa canina	0	0	3	0	-1	0.11	0.735
Rubus sp.	351	0.099	1601	0.054	0.318	116.56	0

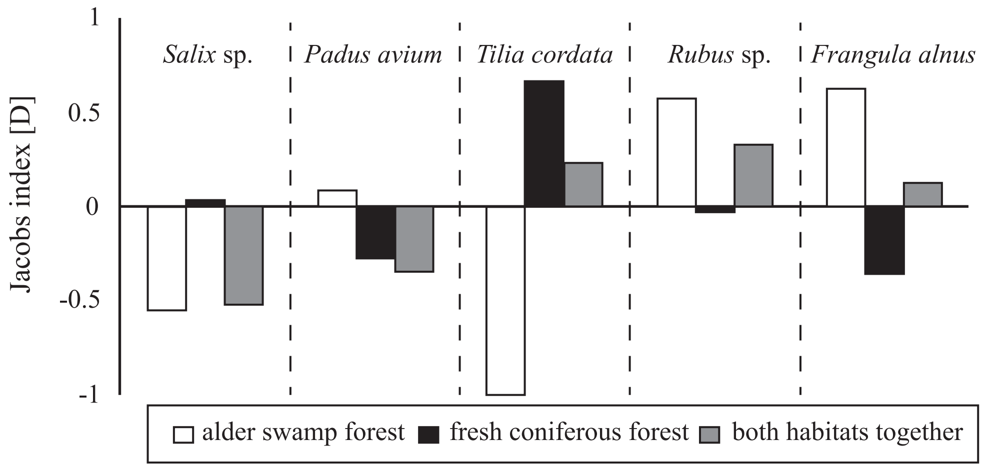

Fig. 1. – Jacobs' index in both studied forest habitats.

TABLE 2

Statistical summary of Response Surface Regression model using: distance to the pasture (DP), openness of the habitat (OH), preferred browse (PB), other browse (OB) to predict the frequency of browsing by horses (number of browsed twigs within each plot); $R^2 = 0.94$, R^2 (adjusted) = 0. 915, p = 0.000 for whole model.

variables	Beta (β)	Standard error (β)	t	R^2	p
DP	-0.084	0.051	- 1.62	0.333	0.113
DP^2	-0.036	0.066	- 0.58	0.597	0.565
OH	0.35	0.067	5.21	0.609	0.000
OH^2	0,021	0.051	0.62	0.346	0.539
PB	0.537	0.085	6.29	0.758	0.000
PB^2	0.137	0.078	4.2	0.714	0.000
OB	0.427	0.097	4.41	0.812	0.000
OB^2	-0.051	0.15	-1.15	0.922	0.259
DP*OH	-0.044	0.058	- 0.81	0.483	0.421
DP*PB	-0.189	0.06	- 2.52	0.516	0.016
OH*PB	0.399	0.079	4.17	0.721	0.000
DP*OB	0.014	0.089	0.27	0.776	0.787
OH*OB	-0.005	0.054	-0.06	0.399	0.949
PB*OB	0,384	0.06	3.68	0.513	0.001

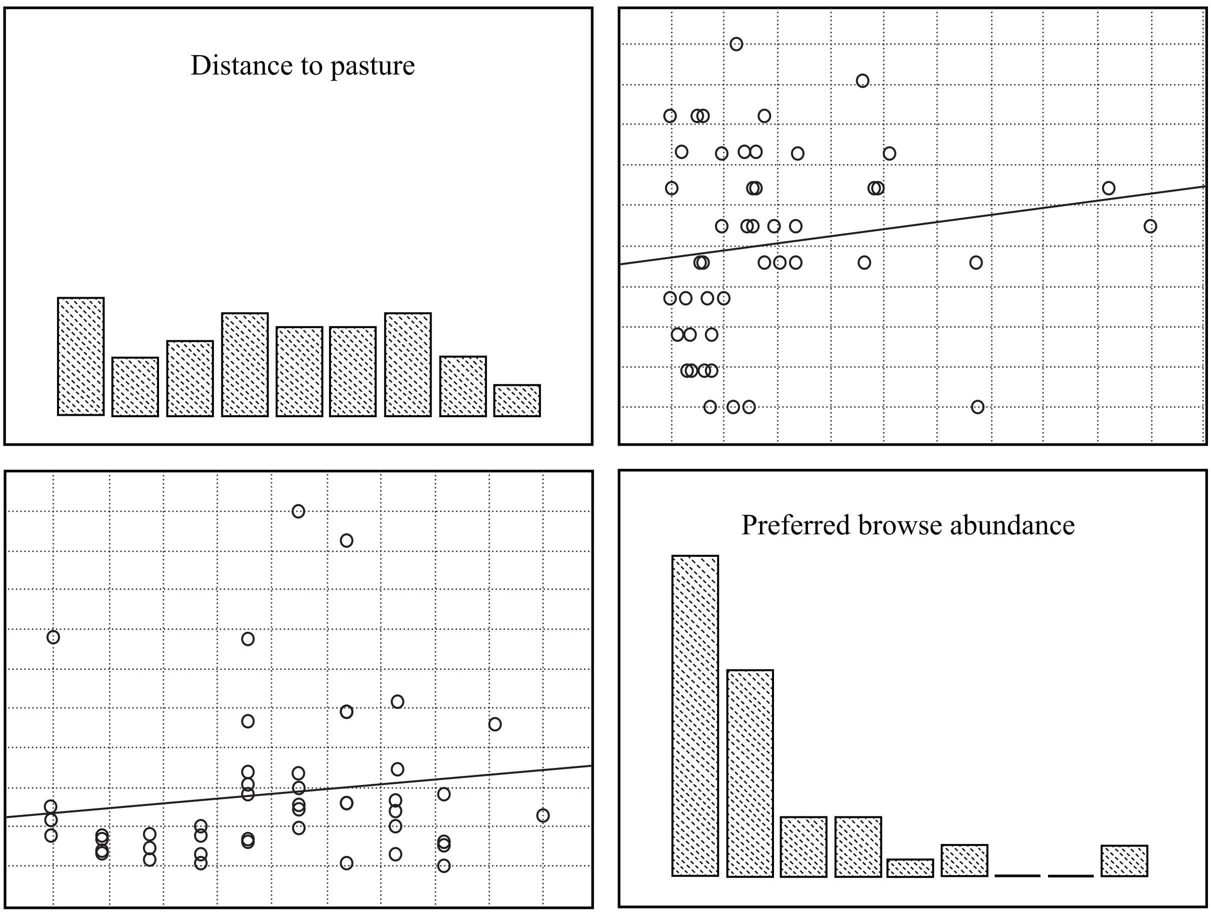

Fig. 2. – The scatter plot matrix of independent variables: distance to pasture and preferred browse abundance.

interactions of preferred browse with habitat openness and with presence of other woody species. This suggests that horses were actively looking for preferred woody species in open habitat and that they foraged more intensively in sites with a higher abundance of preferred species. Although the distance to the main pasture was not significant as a factor determining the spatial use of the forest habitat, this variable in combination with preferred browse, did show a negative influence on foraging intensity. The correlation between both parameters was low but their interaction caused the variable "distance to the pasture" to become significant in the model due to the high correlation between the parameter "preferred browse" and the dependent variable "number of browsed twigs". Although sole DP influence on foraging pattern was not statistically important, such interaction among variables caused an obvious tendency of horses to search for preferred twigs closer to pasture.

DISCUSSION

Although the Jacobs' index revealed a distinct preference of horses for almost half of the available tree and shrub species, the results showed that horses exhibit a dietary spectrum and food preferences dependent on local conditions. Konik horses, which are closely related to Bilgoraj horses, always showed a preference for *Rosa canina* and *Prunus spinosa*, and *Fagus sylvatica* and *Salix sp.* in conditions of high density of horses in the Bieszczady Mountains (SKIWSKI & KLICH, 2012). *Betula sp.*, which was preferred in our study, was highly avoided there. The differences are probably not due to differences between races of horses but to environmental factors. Konik horses showed a high plasticity in woody and meadow vegetation (VAN WIEREN, 1996; CHODKIEWICZ & STYPIŃSKI, 2011; SKIWSKI & KLICH, 2012). In other analyses, koniks were actively looking for *Betula sp.*, and they also avoided *Salix sp.* and *Alnus sp.*, as in our study (BORKOWSKI, 1997). The data indicate a wide dietary spectrum in Polish konik as well as Biłgoraj horses. Although both races show high preferences towards some woody species, they can also browse on many other species of second order of preference.

The results indicate that browse consumption of Biłgoraj horses is considerably dependent on site openness since they significantly preferred exposed sites. Where shrubs were abundant in the nature reserves in Belgium, Koniks used mainly shrubs, and their use of the forest habitat was only marginal (HOFFMANN, 2002). Leaves and twigs exposed to sunlight contain more proteins, but also higher amount of tannins and other secondary plant metabolites (HARTLEY et al., 1997; KAROLEWSKI et al., 2011). These limit the nutritive value of plant tissues (DUNCAN & POPPI, 2010), but higher biomass and regeneration may induce ungulates to browse in forest gaps exposed to the light (KUIJPER et al., 2009). According to these findings horses seem to follow a similar behaviour, particularly since they can feed on lower quality food (GUDMUNDSSON & DYRMUNDSSON, 1994; CHODKIEWICZ & STYPIŃSKI, 2011) relative to donkeys (COSYNS et al., 2001) and compensate for lower energy intake by consuming higher quantities of food (ILLIUS & GORDON, 1992; CLAUSS et al., 2010). Openness of habitat increases its importance for foraging behavior because of interaction with PB, which suggests an active search for preferred twigs by horses in more open parts of forest habitat.

The analysis of results has shown that, apart from habitat openness, horses are guided by the abundance of preferred woody species. Looking for patches of preferred browse, they choose a feeding station and forage there for a longer time. At these feeding stations they will indulge in bulk feeding with low selectivity, specific for grazer type feeding. This results in consumption of a high amount of twigs from other woody species normally randomly taken or even avoided. In consequence, horses attracted to a patch of preferred woody species also consume twigs of other species once there. Probably, the presence of PB in particular parts of the forest plays the initial role in choice, then the total abundance of food (usually connected with habitat openness) is the factor that decides whether the animal will remain within the selected site. In this regard, the interaction among variables that may strengthen or diminish the attractiveness of a given habitat patch is important.

This foraging strategy overlaps with the antipredator strategy. Open sites in the forest offer better visibility, allowing for more time for retreat from or defense against eventual predators. For large herbivores living in grasslands, defense in such places would only imply flight (e.g. FitzGibbon & Lazarus, 1995). Although horses notice small stimuli better on overcast days than on sunny days (Saslow, 1999), and maintain good visibility in the dim light, they require a relatively long time to adapt to the dark when moving from bright light conditions (Hanggi & Ingersoll, 2009). This explains their tendency to avoid dark parts of the forest. Individuals that have lower energy demands due to reduced energy loss and a well-balanced food base, which is usually the case in captivity, have no reason to take risks and will probably tend to shift their foraging from risky to safe microhabitats (Brown, 1999). The choice of more safe habitats results in foraging in open sites of the forest, higher amounts of food intake, occasionally also including not-preferred woody species. Further, monocotyledonous vegetation, which constitutes the main food base for horses, occurs mostly in parts of the forest exposed to sunlight (e.g. Vospernik & Reimoser, 2008). Thus, the use of open forest makes possible the use of abundant and fast recovering browse while allowing access of sunlight to the ground vegetation thereby promoting the growth of graminoids.

According to the results we obtained, browsing intensity depended on distance to the main feeding ground (pasture), but this relationship was only significant when considered as an interaction with PB. This can possibly be explained by the spatial distribution of the plots in different light conditions. Plots in the alder swamp forest were mostly much darker than those in fresh mixed coniferous forest, or than plots situated at the edge of the forest. Horses first had to cross the alder forest in order to reach the more open coniferous stand. The width of a strip of alder swamp forest varied along particular transects and this could have caused a trend towards higher abundance of PB with increasing distance to pasture. Moreover, transects often ended near the forest road where the degree of openness was very high and where the site was abundant with graminoids. Horses could spend a little more time in these places grazing and browsing, treating this area as a “supplementary pasture”. This aspect could explain the weak significance of the factor “distance to the pasture” on the overall foraging pattern of horses, which was modified by specific local conditions. Therefore, we determined that horses were looking for preferred browse closer to the pasture, and the amount of PB was the main variable influencing their choice in the pattern of forest use.

CONCLUSIONS

We found a tendency of Biłgoraj horses to search for feeding sites abundant in browse (especially preferred species), more exposed to sunlight and close to the pasture. Using more open sites ensures their sense of security, gives access to fast-recovering browse, and stimulates the development of monocotyledonous species. They also follow a foraging strategy of maintaining good quality forage in selected patches. They forage on high amounts of food in open, quickly recovering sites. This suggests that in spite of some selectivity towards available food resources, their preference is more oriented towards patches in specific conditions (openness and browse abundance) than to singular woody species. Such selectivity has already been shown in grazers in grassy environments (Searle & Shipley, 2010). We speculate that the more open are the available sites in the forest, the greater would be their penetration by horses and the longer would be the time spent there. Such pattern of habitat use would lead to uneven forest growth, and may stimulate changes in undergrowth and ground flora towards shrub reduction and massive occurrence of grasses. Such process indeed occurred in the areas of Roztoczański National Park where Polish koniks roam, specifically in the more exposed tree stands (Wlizło & Szwed, 2007).

ACKNOWLEDGEMENTS

Authors would like to thank the administration of Lasy Janowskie Landscape Park for this research opportunity. We also thank Prof. Perzanowski, Dr. Cosyns and Dr. Vervaecke for insightful feedback and advice.

REFERENCES

Aulak W & Babińska-Werka J (1990). Use of agricultural habitat by roe deer inhabiting a small forest area. Acta Theriologica, 35(1-2):121-127.

Bailey DW, Gross JE, Laca EA, Rittenhouse LR, Coughenour MB, Swift DM & Sims PL (1996). Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management, 49(5):386-400.

Bakker JP, de Leeuw J & van Wieren SE (1983). Micro-patterns in grassland vegetation created and sustained by sheep-grazing. Vegetatio, 55(3): 153-161.

Bobiec A, Kuijper DPJ, Niklasson M, Romankiewicz A & Solecka K (2011). Oak (*Quercus robur* L.) regeneration in early successional woodlands grazed by wild ungulates in the absence of livestock. Forest Ecology and Management, 262(5):780-790.

Bokdam J, van Braeckel A, Werpachowski C & Znaniecka M (eds). (2002). Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz (PL), Goniadz.

Borkowski M (1997). Koniki polskie w czynnej ochronie przyrody. In: Sokólska J (ed), Hodowla zachowawcza i użytkowa konika polskiego. Materiały sympozjum w Supraślu (13.06.1997) w ramach II spotkań z Naturą i Sztuką, Supraśl: 39-46.

Borkowski M (2002). Limiting bush encroachment at Biebrza marsh by Konik/Tarpan grazing. In: Bokdam J, van Braeckel A, Werpachowski C & Znaniecka M (eds), Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz (PL), Goniadz:96-98.

Brown JS (1999). Vigilance, patch use and habitat selection: foraging under predation risk. Evolutionary Ecology Research, 1:49-71.

Carmel Y & Kadmon R (1999). Effects of grazing and topography on long-term vegetation changes in a Mediterranean ecosystem in Israel. Plant Ecology, 145(2):243-254.

Chodkiewicz A & Stypiński P (2011). Preferencje pokarmowe koników polskich wypasanych w Biebrzańskim Parku Narodowym. Woda-Środowisko-Obszary Wiejskie, 11(2):33-42.

Clarke JL, Welch D & Gordon IJ (1995). The influence of vegetation pattern on the grazing of heather moorland by red deer and sheep. I. The location of animals on grass/heather mosaic. Journal of Applied Ecology, 32(1):166-176.

Clauss M, Kaiser T & Hummel J (2010). The morphophysiological adaptations of browsing and grazing mammals. In: Gordon IJ *&* Prins HHT (eds), The Ecology of Browsing and Grazing. Springer-Verlag, Berlin, Heidelberg:47-88.

Conway DW, Parker AJ & Parker KC (1997). Understory light regime, shrub layer and sand pine (*PInus clausa*) regeneration in four scrub stands. American Midland Naturalist, 138(1):84-96.

Cosyns E, Degezelle T, Demeulenaere E & Hoffmann M (2001). Feeding ecology of Konik horses and donkeys in Belgian coastal dunes and its implications for nature management. Belgian Journal of Zoology, 131(Supplement 2):111-118.

Coughenour MB (1991). Spatial components of plant-herbivore interactions in pastoral, ranching, and native ungulate ecosystems. Journal of Range Management, 44(6):530-542.

Duncan AJ & Poppi DP (2010). Nutritional ecology of grazing and browsing ruminants. In: Gordon IJ *&* Prins HHT (eds), The Ecology of Browsing and Grazing, Springer-Verlag, Berlin, Heidelberg: 89-116.

Duncan P (1992). Horses and grasses. The nutritional ecology of equids and their impact on the Camargue. Springer-Verlag, New York.

Edouard N, Fleurance G, Dumont B, Baumont R & Duncan P (2009). Does sward height affect feeding patch choice and voluntary intake in horses? Applied Animal Behaviour Science, 119(3-4):219-228.

Esteves I, Andersen I-L & Nævdal E (2007). Group size, density and social dynamics in farm animals. Applied Animal Behaviour Science, 103(3-4):185-204.

FitzGibbon CD & Lazarus J (1995). Antipredator behaviour of Serengeti ungulates: Individual differences and population consequences. In: Sinclair ARE & Arcese P (eds), Serengeti II: Dynamics, management and conservation of an ecosystem, University of Chicago Press, Chicago: 274-*296.*

Fleurance G, Duncan P & Mallevaud B (2001). Daily intake and the selection of feeding sites by horses in heterogeneous wet grasslands. Animation Resources, 50(2):149-156.

Frazer GW, Canham CD & Lertzman KP (1999). Gap Light Analyzer (GLA), Version 2.0: Imaging software to extract canopy structure and gap light transmission indices from true-colour fisheye photographs, users manual and program documentation. Copyright © 1999: Simon Fraser University, Burnaby, British Columbia, and the Institute of Ecosystem Studies, Millbrook, New York.

Green DM & Kauffman JB (1995). Succession and livestock grazing in a north-eastern Oregon riparian ecosystem. Journal of Range Management, 48(4):307-313.

Gudmundsson O & Dyrmundsson O (1994). Horse grazing under cold and wet conditions: a review. Livestock Production Science, 40:57-63.

Guillemain M, Arzel C, Legegneux P, Elmberg J, Fritz H, Lepley M, Pin C, Arnaud A & Massez G (2007). Predation risk constrains the plasticity of foraging behaviour in teals, Anas crecca: a flyway-level circumannual approach. Animal Behaviour, 73(5):845-854.

Hanggi EB & Ingersoll JF (2009). Stimulus discrimination by horses under scotopic conditions. Behavioural Processes, 82(1):45-50.

Hansen I, Christensen F, Hansen HS, Braastad B & Bakken M (2001). Variation in behavioural responses of ewes towards predator-related stimuli. Applied Animal Behaviour Science, 70(3):227-237.

Hartley SE, Iason GR, Duncan AJ & Hitchcock D (1997). Feeding behaviour of red deer (*Cervus elaphus*) offered Sitka spruce saplings (Picea sitchensis) grown under different light and nutrient regimes. Functional Ecology, 11:348-357.

Hester AJ & Baillie GJ (1998). Spatial and temporal patterns of heather use by sheep and red deer within natural heather/grass mosaics. Journal of Applied Ecology, 35(5):772-784.

Hoffmann M (2002). Experiences with grazing in Flemish nature reserves (N. Belgium). In: Bokdam J, van Braeckel A, Werpachowski C & Znaniecka M (eds), Grazing as a conservation management tool in peatland. Report of a Workshop held 22-26 April 2002 in Goniadz (PL), Goniadz: 49-53.

Howery LD & DeLiberto TJ (2004). Indirect effects of carnivores on livestock foraging behavior and production. Sheep & Goat Research Journal, 19:53-57.

Illius AW & Gordon IJ (1992). Modelling the nutritional ecology of ungulate herbivores: Evolution of body size and competitive interactions. Oecologia, 89(3):428-434.

Jacobs J (1974). Quantitative measurement of food selection. A modification of the forage ratio and Ivlev's Electivity Index. Oecologia, 14:413-417.

Jaworski Z (2003). Ocena warunków etologiczno-hodowlanych koników polskich utrzymywanych w systemie rezerwatowym. Wydawnictwo UWM, Olsztyn.

Jezierski T & Jaworski Z (1995). Reakcje obronne przed owadami u koników w warunkach pastwiska i rezerwatu leśnego. In: Jaczewski Z, Żurkowski M & Jaworski Z (eds), Biologia i hodowla zachowawcza konika polskiego. Materiały z ogólnopolskiej konferencji naukowej Popielno 18-19 maja 1995 r, Stacja Badawcza Rolnictwa Ekologicznego i Hodowli Zachowawczej PAN w Popielnie, Popielno:29-34.

Jorritsma ITM, van Hees AFM & Mohren GMJ (1999). Forest development in relation to ungulate grazing: a modeling approach. Forest Ecology and Management, 120:23-34.

Karolewski P, Jagodziński A & Grzebyta J (2011). Influence of tree age, needle age and location in the crown on the phenolic compounds content in needles of young Scots pines, Sylwan, 155(12):797-807.

King SRB (2002). Home range and habitat use of free-ranging Przewalski Horses at Hustai National Park, Mongolia. Applied Animal Behaviour Science, 78(2-4):103-113.

Klich D (2009). Analiza uszkodzeń kory spowodowanych przez konika polskiego w warunkach zagrodowych w Bieszczadach. Roczniki Bieszczadzkie, 17:307-317.

Kuijper DPJ, Cromsigt JPGM, Churski M, Adam B, Jędrzejewska B & Jędrzejewski W (2009). Do ungulates preferentially feed in forest gaps in European temperate forest? Forest Ecology and Management, 258:1528-1535.

Kuiters AT, van der Sluijs LAM & Wytema GA (2006). Selective bark-stripping of beech, *Fagus silvatica*, by free-ranging horses. Forest Ecology and Management, 222:1-8.

LaGory KE (1987). The influence of habitat and group characteristics on the alarm and flight response of white-tailed deer. Animal Behaviour, 35(1):20-25.

Lamoot I, Meert C & Hoffmann M (2005). Habitat use of ponies and cattle foraging together in a coastal dune area. Biological Conservation, 122(4):523-536.

McNab BK (2002). The physiological ecology of vertebrates: a view from energetics. Cornell University Press, New York.

Pépin D, Lamerenx F, Chadelaud H & Recarte J-M (1996). Human-related disturbance risk and distance to cover affect use of montane pastures by Pyrenean chamois. Applied Animal Behaviour Science, 46(3-4):217-228.

Saslow CA (1999). Factors affecting stimulus visibility for horses. Applied Animal Behaviour Science, 61(4):273-284.

Searle KR & Shipley LA (2010). The Comparative Feeding Behaviour of Large Browsing and Grazing Herbivores. In: Gordon IJ *&* Prins HHT (eds), The Ecology of Browsing and Grazing. Springer-Verlag, Berlin, Heidelberg:117-148.

Skiwski M & Klich D (2012). Spring and summer browsing by Polish konik in enclosures and free ranging conditions in the Bieszczady Mts, 156(10):792-800.

Stachurska A, Pięta M, Jaworski Z, Ussing AP & Pluta M (2006). Factors that influence coat hair length in primitive horses *(Equus caballus)*. Journal of Food, Agriculture and Environment, 4(1):215-219.

Suomella J & Ayres MP (1994). Within-tree and among-tree variation in leaf characteristics of mountain birch and its implications for herbivory. Oikos, 70(2):2112-222.

Taraborelli P, Gregorio P, Moreno P, Novaro A & Carmanchahi P (2012). Cooperative vigilance: the guanaco's (Lama guanicoe) key antipredator mechanism. Behavioural Processes, 91(1):82-89.

Touré SF, Michalet-Doreau B, Traoré E, Friot D & Richard D (1998). Occurrence of digestive interactions in tree forage-based diets for sheep. Animal Feed Science and Technology, 74(1):63-78.

Törn A, Siikamäki P & Tolvanen A (2010). Can horse riding induce the introduction and establishment of alien plant species through endozoochory and gap creation? Plant Ecology, 208(2):235-244.

van Uytvanck J & Hoffmann M (2009). Impact of grazing management with large herbivores on forest ground flora and bramble understorey. Acta Oecologica, 35(4):523-532.

van Wieren SE (1996). Do large herbivores select a diet that maximizes short-term energy intake rate? Forest Ecology and Management, 88:149-156.

Vospernik S & Reimoser S (2008). Modelling changes in roe deer habitat in response to forest management. Forest Ecology and Management, 255:530-545.

Wassie A, Sterck FJ, Teketay D & Bongers F (2009). Effects of livestock exclusion on tree regeneration in church forests of Ethiopia. Forest Ecology and Management, 257(3):765-772.

Wlizło B & Szwed W (2007). Roślinność Ostoi Konika Polskiego w Roztoczańskim Parku Narodowym. Prace Katedry Przyrodniczych Podstaw Leśnictwa Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu, 2:1-117.

Received: October 10th, 2012

Accepted: August 6th, 2013

Branch editor: Eens Marcel