Activity time budget patterns of sheep and goats co-grazing on semi-natural species-rich dry grassland

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ABSTRACT: Activity time budget patterns and grazing response to sward and environmental conditions were investigated for paddocks of sheep and goats co-grazing for conservation purposes on a semi-natural species-rich dry grassland community endangered by shrub and tall perennial plant encroachment in a protected nature reserve in South Moravia (Czech Republic). Grazing was conducted by a rotational stocking system for 14 weeks in late grazing season in 2008 with 60 dry ewes and 20 goats. Twelve ewes and four goats were observed; grazing, ruminating, idling and other activities (salt licking, social interactions, walking), along with topographical position in the paddock were recorded at 5-minute intervals within 14 hours of daylight. Sheep and goats did not differ in their principal activity time budgets, such as the average total daylight time spent grazing (sheep: 8.57 h, goats: 8.59 h), ruminating (sheep: 1.42 h, goats: 1.44 h), or idling (sheep: 3.23 h, goats: 3.18 h), the duration of bouts of each activity, or the number of bouts of grazing and ruminating. There was no pattern in activity time budgets indicating dynamics in progressing season, nor was there a response to daily average temperature or to paddock size. Sheep and goats showed similar responses to groundcover of particular plant functional types. The animals showed a positive trend in response of total daylight grazing time to grass available biomass and a negative response of total daylight grazing time to herbaceous biomass for both sheep and goats. The total daylight grazing time was independent of availability of woody plants. Goats devoted more time (1.51 h) to other activities than sheep (1.34 h), especially to social interactions and salt licking. On the other hand, sheep spent proportionally more time walking. Both sheep and goats showed similar patterns in spatial use of paddocks on hill slopes, spending the most time in the middle part and the least time in the lower part of paddocks.

Keywords: animal behaviour; activity pattern; small ruminant; mixed pasture; semi-natural grassland

Co-grazing of different ruminant species has been practised for multiple purposes. It is, primarily, a tool for increasing carrying capacity and pasture production (Glimp, 1985). Various findings for animal performance in terms of live-weight gains have been reported: none (Norton et al., 1990), or more likely for sheep than cattle (Abaye et al., 1994; Walker, 1994; Kitessa and Nicol, 2001) or goats (Radcliffe et al., 1991; Animut et al., 2005b) grazing simultaneously on the same pasture. Other advantages of multi-species grazing systems involving cattle and sheep include improved spatial use of pasture (Forbes and Hodgson, 1985), nematode parasite control (Waller, 2006), and potentially lower losses to predation in some areas (Hulet et al., 1987).

Benefits of mixed grazing of sheep and goats lie mainly in management and improvement of vegetation conditions (Walker, 1994) and, consequently, in enhancing plant and animal biodiversity (El Aich and Waterhouse, 1999). Goats play an important role in controlling the development of woody plant species, which may in turn enhance

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the herbaceous cover (Celaya et al., 2007). On the other hand, the expansion of perennial tall grasses or weeds and invasive herbaceous species presents another risk for natural vegetation ecosystems with high species richness. Since sheep have the ability to graze on herbaceous plants that are often toxic to cattle (Hejcman et al., 2008), the co-grazing of sheep and goats is complementary and provides a very efficient tool for the management of dry grasslands (Dostálek and Frantík, 2008).

Sheep and goat behaviour in relation to foraging and diet selection has been widely investigated (Gurung et al., 1994; Hadjigeorgiou et al., 2003; Animut et al., 2005b reviewed by Papachristou et al., 2005). Diurnal patterns in time spent grazing or on other activities were particularly related to seasonal dynamics of forage availability and quality in tropical environments (Kronberg and Malechek, 1997; Ouédraogo-Koné et al., 2006; Sanon et al., 2007) or to different management systems, either on highly productive ryegrass/white clover swards (Penning et al., 1997) or on grass/forb pastures at different stocking rates (Animut et al., 2005a) and with or without food supplement (Animut et al., 2007). Complex behaviour of co-grazing sheep and goats in conservation grazing systems that are not focused on an outcome for animal production has not been investigated. Since the diet composition of sheep and goats may differ in proportions of grass, forbs, and woody plants, differences in activity patterns and grazing strategies between them could be expected.

We investigated, therefore, the activity patterns and strategies of sheep and goats co-grazing for conservation purposes on a semi-natural species-rich dry grassland community endangered by shrub and tall perennial plant encroachment in a protected nature reserve in South Moravia (Czech Republic). The aims of the study were to investigate (1) differences in particular activities and time budgets between dry ewes and goats, (2) grazing response of dry ewes and goats to sward and environmental conditions, and (3) spatial distribution of dry ewes and goats over paddocks in relation to topography.

MATERIAL AND METHODS

Study site

The study was carried out on species-rich steppe dry grassland in the core of the "Tabulová, Růžový vrch and Kočičí kámen" National Nature Reserve (48°50'N, 16°38'E), 40 km south of Brno, Czech Republic. The total area of the reserve is 109.06 ha, with altitude ranging 350–445 m a.s.l. The locality receives annual rainfall of 571 mm and has an annual mean temperature of 9.6°C. There are two soil types present: rendzina and chernozem. The grazing area is species-rich dry grassland with a mosaic of vegetation: *Festucion valesiacae* (dominated by *Carex humilis* and *Aster linosyris*) on the southward slope of the hill, *Cirsio-Brachypodion pinnati* (dominated by *Bromus erectus* and *Brachypodium pinnatum*) on the lower slopes, and *Berberidion* dominated by scrubs *Crataegus monogyna, Prunus mahaleb*, and *P. spinosa*, which indicate abandoned pastures in the area (Chytrý et al., 2001).

Design of the experiment and investigated animals

The experiment was conducted late in the grazing season, from August 7th until September 28th, 2008. There were 14 paddocks in the study area, ranging 0.33–0.74 ha with varying terrain topography and slopes (Table 1, Figure 1). Each paddock was grazed by the animals for 3–6 days. The herd of grazing animals consisted of 60 ewes and 20 goats of different breeds. 20% of the animals, namely twelve ewes (breeds: 1 East Friesian, 1 Improved Valachian, 1 Cigaya, 2 Romney Marsh, 1 Merinolandschaf, 1 Sumava) and four goats (breeds: 2 White Shorthair, 1 Alpine, 1 Brown Shorthair × White Shorthair), were selected for observation and individually marked for identification. Before the start of the experiment, the animals were in a rotational stocking system on similar sward and under similar grazing management conditions.

Data collection

A plant species composition survey had been performed one day before animal behaviour data were collected in each paddock. All plant species were recorded and a visual estimate of the percentage cover of individual species in all height classes was made separately, according to the seven-degree Braun-Blanquet scale (Mueller-Dombois and Ellenberger, 1974). The nomenclature used for plant species identification followed Kubát et al. (2002).

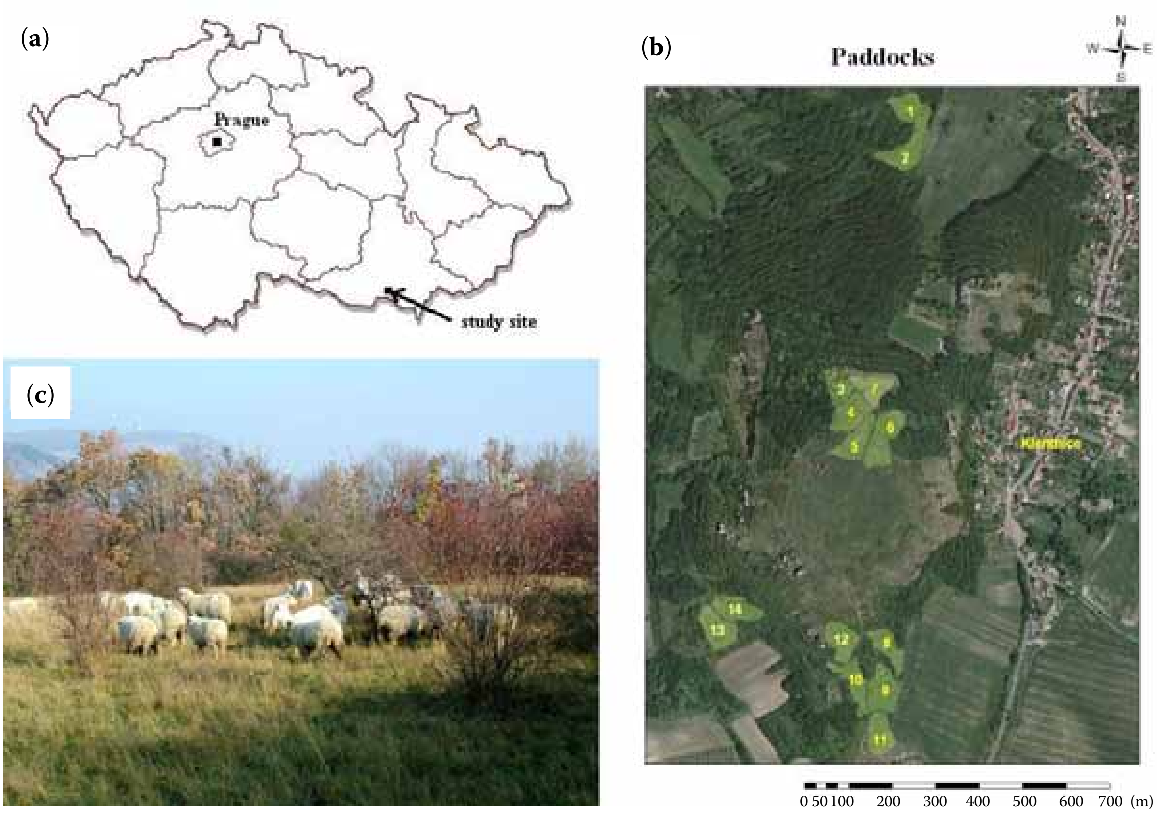

Figure 1. Location of the study site in the Czech Republic (**a**), distribution of paddocks over the area (**b**), sheep and goats co-grazing dry grassland (**c**)

With respect to animal grazing competence and the availability of the sward to animals, the following three relevant plant functional types were determined: grasses, forbs, and shrubs. The tree layer (> 3 m) was not available to animals as a food resource.

Behavioural pattern data on marked animals were always collected on the second day after the animals were moved to the paddock, for all fourteen paddocks. Direct observation of each marked animal was performed by scan-sampling at 5-minute intervals from 6:00 a.m. to 8:00 p.m. A total of 169 records per animal in one observation day were carried out. The principal activities of sheep and goats were grazing, ruminating, and idling; other behaviour included drinking, salt licking, comfort behaviour, social interaction, walking, and excretion. Grazing was defined as direct forage intake, including biting, chewing, and ingestion. Ruminating was defined as chewing the cud in a lying or standing position. Idling involved lying or standing without any activity. Air temperature was recorded at 1-hour intervals. Each paddock was divided horizontally on three levels: upper, middle, and lower slope (slopes for each paddock are given in Table 1). The position of the animals in the paddock was recorded with each behaviour record.

Data analyses

To investigate the activity time budget pattern, we used three indicators: total time spent on a particular activity during daylight (14 h), activity bout (defined as an uninterrupted sequence of a particular activity (Lehner, 1996)), and bout frequency for each activity (number of bouts within 14 h of observation). For repeated (within-subject) measures, the General Linear Models (GLM) Procedures were used. The behavioural variables were total daylight time spent grazing, ruminating, idling, and other activities, and bout duration and bout frequency for grazing, ruminating, idling, and other activities. The difference between sheep and goats and the effect of paddock (categorical predictors) were investigated. To reveal significant differences between tested effects, all the analyses were followed by Tukey's HSD post hoc test.

Proportions of time spent by goats and sheep on each particular activity – walking, drinking,

Table 1. Environmental characteristics and total cover of plant functional types in each paddock

Paddock	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Area (ha)	0.52	0.56	0.33	0.54	0.50	0.74	0.44	0.42	0.65	0.50	0.49	0.48	0.56	0.49
Slope (%)	15.9	24	14.5	14.6	11	12.4	16.2	10.6	8.3	12.8	15.9	28.7	20.3	19.3
Daily temperature (°C)	24	20	21	22	24	20	20	13	15	14	9	11	12	12
Cover of plant functional types (%)														
Grass	86	75	78	88	89	58	78	40	45	40	71	50	85	49
Forbs	23	14	1	6	4	27	9	19	12	15	14	9	9	11
Shrubs < 1 m tall	10	3	13	8	5	15	13	38	46	46	13	40	5	35
Shrubs 1–3 m tall	24	25	15	19	29	39	24	30	41	18	10	45	15	54
Trees	5	0	65	0	2.5	2.6	0	2.5	5	2.5	7.5	2.5	2.5	2.5

salt licking, comfort behaviour, and social interactions – and at particular positions in the paddock (upper, middle, and lower) were tested by goodness-of-fit tests using contingency tables. The response of the total daily grazing time of dry ewes and goats to cover of particular plant functional types and to environmental conditions such as average daily temperature and paddock area were tested by linear regression. All behaviour data were analyzed using the STATISTICA 9.1 package (StatSoft, Tulsa, USA).

RESULTS

A total of 140 plant species were recorded in the area of fourteen established paddocks. The dominant species included *Arrhenatherum elatius*, *Brachypodium pinnatum*, *Bromus erectus*, *Centaurea scabiosa*, *Fragaria viridis*, *Scabiosa ochroleuca*, *Prunus mahaleb*, *Rosa canina*, and *Crataegus monogyna*. The total proportion of plant species within functional types over the whole grazing area was: grasses 18%, forbs 68%, shrubs 6%, and trees 8%. However, grasses and shrubs constituted the most available biomass in the sward (Table 1).

The complete results for the activity time budget pattern are given in Table 2. Sheep and goats did not differ in their principal activity time budgets, such as average total daylight time spent grazing, ruminating or idling, the duration of bouts of each activity, or the number of grazing and ruminating bouts. However, there was a difference in the number of idling bouts: sheep had a higher rate of idling bouts than goats ($F_{(1.196)}$ = 5.09, P = 0.025). Sheep and goats differed in their ruminating time spent in lying or standing positions (χ^2 = 4.68, df = 1, P = 0.031). Sheep spent 48.3% of ruminating time lying and 51.7% standing (n = 2491), while goats ruminated 52.6% lying and 47.4% standing (n = 865). On the other hand, the animals spent their idling time in similar proportions (χ^2 = 0.34, df = 1, P = 0.55); sheep rested 49.1% lying and 50.9% standing (n = 7606), while goats 48.4%lying and 51.7% standing (n = 2460).

Sheep and goats also differed in total time daily devoted to other activities ($F_{(1.196)}$ = 23.16, P < 0.001). Goats spent longer time on other activities than sheep and differed also in the proportional occurrence of each "other activity" (χ^2 = 21.97, df = 4, P < 0.001), namely, goats spent more time

Table 2. Activity time budgets of co-grazing goats and sheep during 14 h of daylight

	Goats		Sheep	
	mean	S.E.	mean	S.E.
Total daylight time (h)				
Grazing	8.59[a]	6.0	8.57[a]	3.1
Ruminating	1.44[a]	2.7	1.42[a]	1.7
Idling	3.18[a]	3.7	3.23[a]	2.8
Other activities	1.51[a]	3.3	1.34[b]	2.0
Behaviour sequence (h)				
Grazing bout	1.43[a]	2.8	1.39[a]	1.7
Ruminating bout	0.18[a]	0.5	0.18[a]	0.3
Idling bout	0.22[a]	0.7	0.21[a]	0.4
Number of bouts				
Grazing	5.2[a]	0.15	5.4[a]	0.09
Ruminating	4.3[a]	0.12	4.3[a]	0.08
Idling	6.2[a]	0.19	6.6[b]	0.11

[a,b]significant differences (P < 0.05) between goats and sheep

Table 3. Proportion of time (%) spent on each activity (χ^2 = 21.97, df = 4, $P < 0.001$)

	Goats	Sheep
Walking	36.5[a]	40.8[b]
Drinking	11.3[a]	12.9[a]
Comfort	20.5[a]	21.4[a]
Social interactions	17.8[a]	14.8[b]
Salt licking	13.9[a]	10.1[b]
Activities in total	100	100
Number of records	1187	3044

[a,b]significant differences ($P < 0.05$) between goats and sheep

Table 4. Proportion of time (%) spent by goats and sheep in upper, middle, and lower parts of the paddocks (χ^2 = 11.85, df = 2, $P = 0.003$)

	Goats	Sheep
Upper part	39.3[a]	37.3[b]
Middle part	45.0[a]	46.5[b]
Lower part	15.7[a]	16.2[a]
Activities in total	100	100
Number of records	9464	28392

[a,b]significant differences ($P < 0.05$) between goats and sheep

on social interactions and salt licking, while sheep spent more time walking (Table 3).

Both sheep and goats showed similar patterns in spatial use of paddocks on hill slopes, spending the most time in the middle part and the least time in the lower part of the paddock (Table 4). There was, however, a significant difference between sheep and goats regarding the time spent in the upper and middle parts of the paddock. The upper part was used more by goats than sheep, whereas the middle part was used more by sheep than goats (χ^2 = 11.85, df = 2, $P = 0.003$).

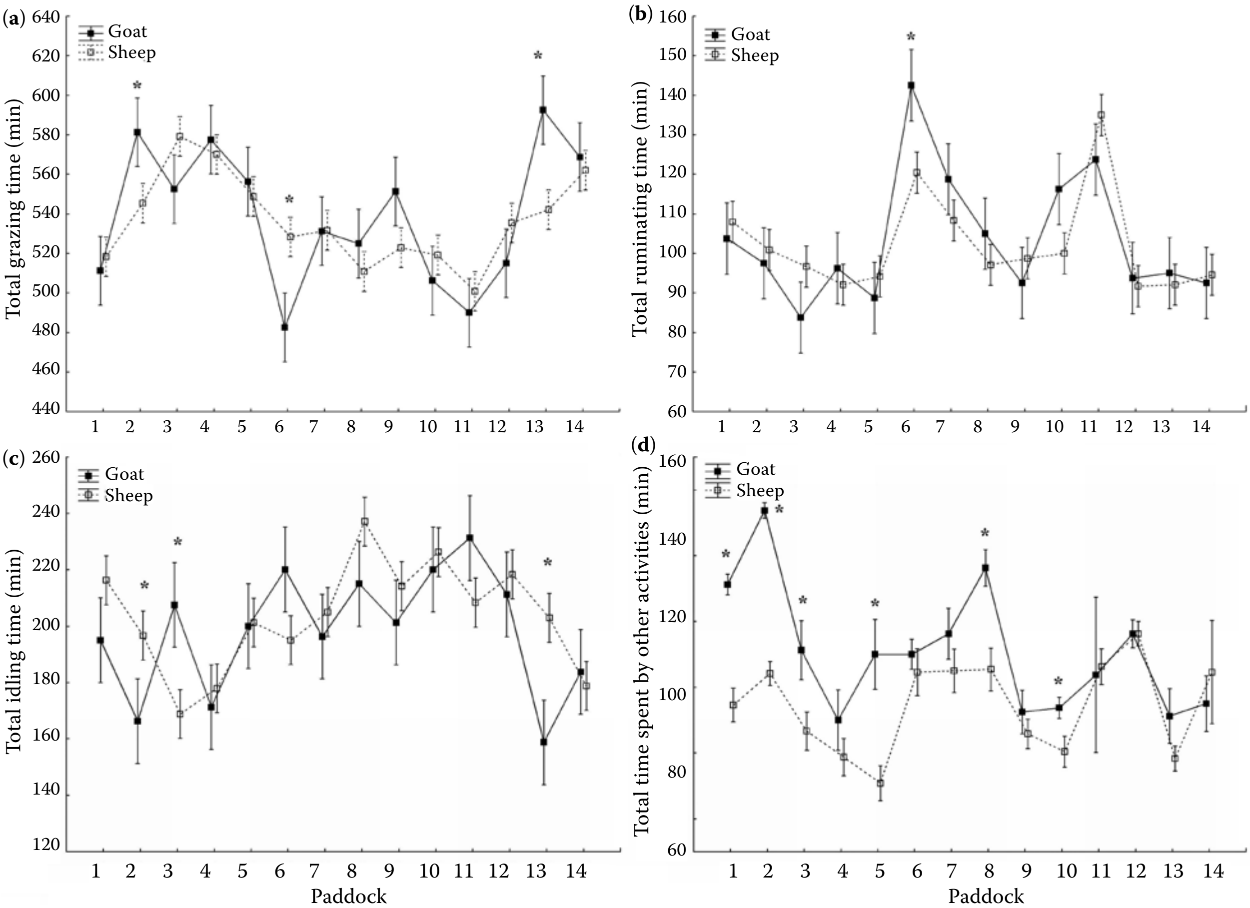

Figure 2. Total daylight time spent grazing (**a**), ruminating (**b**), idling (**c**), and on other activities (**d**)

*significant differences between sheep and goats at a given paddock at $P < 0.05$

vertical bars represent standard error of the mean

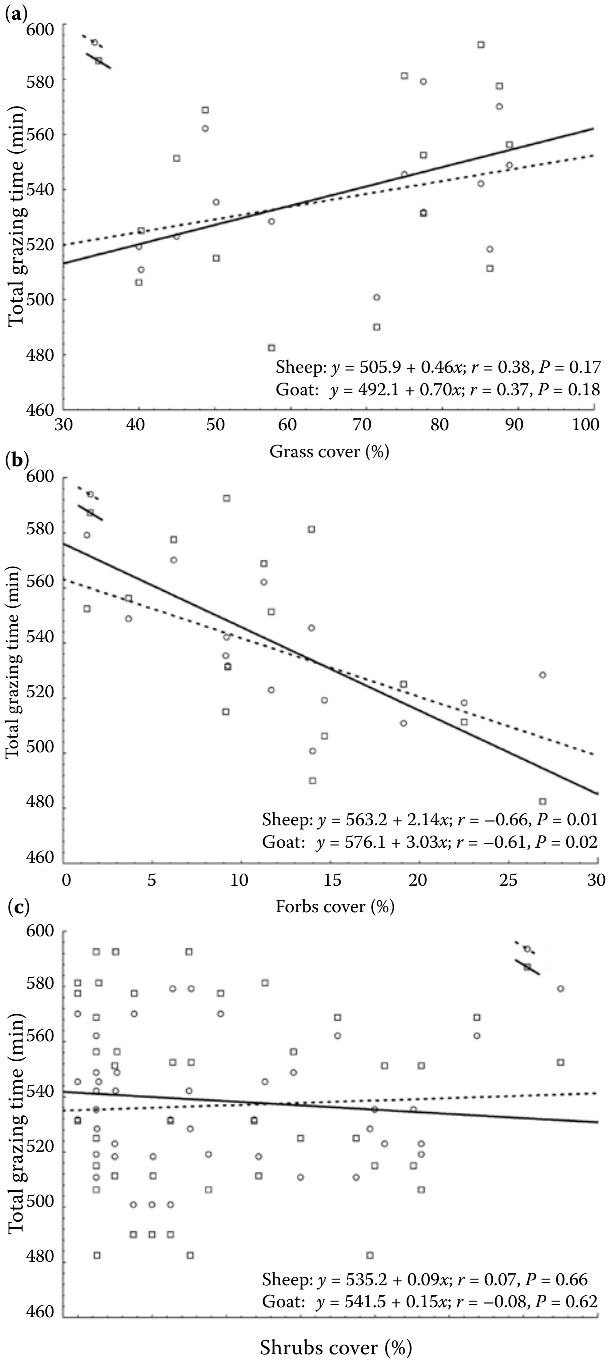

Figure 3. Response of total daylight grazing time of sheep and goats to cover of plant functional types: grasses (**a**), forbs (**b**), shrubs (**c**)

The activity daytime budgets were different among paddocks (for all activities $P < 0.001$) but similar for sheep and goats, with the exception of paddocks 2, 3, 6, and 13 (Figure 2). There was, however, no behavioural pattern indicating the progressing season. There was no relationship between total time spent on particular activities and average daily temperature (for all analyses $P > 0.05$ and $r^2 < 0.05$) or area of the paddock (for all analyses $P > 0.05$ and $r^2 < 0.02$).

Sheep and goats showed similar responses to cover of particular plant functional types. Total grazing time for both sheep and goats was positively correlated to grass cover and negatively correlated to forbs cover in paddocks, while there was no relation to shrub cover (Figure 3).

DISCUSSION

The total daylight grazing, ruminating, and idling times for sheep and goats on dry grassland plant communities were similar and corresponded more or less to activity times recorded on other types of pastures (Kronberg and Malechek, 1997; Animut et al., 2005a, 2007). No difference was found in activity bout patterns between sheep and goats, although sheep with a higher portion of grass and forbs in their diet (Hejcmanová, unpublished data) could have longer grazing bouts with a lower rate during the day in contrast to browse foraging patterns assuming shorter and more frequent bouts (Hofmann, 1989). Similarity in complete grazing patterns (total grazing times, bout duration, and number of bouts) for sheep and goats, implying also similarity in their ruminating and idling patterns, suggests that co-grazing sheep and goats on species-rich sward had similar daily biorhythm. Their behaviour differed only in some paddocks. Conspicuously lower total daily grazing time for goats and their higher ruminating and idling in paddock 6, and this not only in comparison to sheep but also in comparison to other paddocks in general, indicate that goats responded thereby to the sward offering the highest proportion of forbs and high proportion of shrubs. In paddocks 2 and 13 goats showed the highest total grazing time, without any remarkable change in ruminating times, but at the expense of resting. Additionally, with a relatively high proportion of other activities, this indicates that activities were not driven only by diet offer with high proportion of grasses in these paddocks, but also by other factors, namely by slopes. Slopes may serve as a sort of environment enrichment and thus enhance more active exploitation of paddocks' space.

Domestic herbivores prefer species-rich swards as they can obtain greater benefit through enhanced daily nutrient intake (Wang et al., 2010). Different plant functional types represent forage of different nutritional value and act complementarily in animal diet selection. The available biomass of grasses, forbs, or woody plants thus influences the voluntary forage intake. The negative response of total daylight grazing time, one of elements determining daily forage intake (Forbes, 1988), to herbaceous biomass may indicate that animals are able to satisfy their food requirements in shorter time, for instance via larger bite size on forbs in comparison to grasses. The total daylight grazing time was independent of the availability of woody plants. Penning et al. (1997) reported opposite relations of total daylight grazing time for sheep and goats and suggested that total grazing time is determined not only by availability but also by animal preferences for, and exploitation of, particular diet items. These relationships are more pronounced on heterogeneous species-rich than on homogeneous low-species swards (Baumont et al., 2000; Dumont et al., 2005).

There were no other factors affecting grazing or other behaviour patterns. There was a lack of seasonal dynamics in grazing patterns, most likely due to starting grazing late in vegetation season when plants in the sward were already in late phenological stages, since the vegetation was not previously grazed (Kleinebecker et al., 2011). There was no effect of paddock size on behaviour pattern. Indeed, the areas of particular paddocks did not differ enough to significantly alter the stocking rate among paddocks, hence there was no effect of paddock area on activity pattern. Average daily temperature also had no effect on total daily time spent on particular activities, although higher temperatures affect daily activity patterns, including foraging times, in other herbivores, for instance antelopes (Owen-Smith, 1998) or cattle (Hejcmanová et al., 2009).

The difference between sheep and goat behaviour was manifested particularly in other activities, as similarly reported, but without more detail, by Kronberg and Malechek (1997). For instance, goats used licks containing salt and micro-elements (Na, Mg, Ca, Zn, Se, Mn, Fe, Co) more frequently than sheep. This suggests that goats ingested a lower quality diet than sheep, hence they had higher need for nutrients or micro-elements, which help animals to cope with lower palatability of forage or plant toxins (Provenza et al., 2003).

Walking of animals over the pasture area has been considered in many studies as a determinant of energy expenditure (Lin et al., 2011) or as an indicator of spatio-temporal use of pasture (Gipson et al., 2003; Schlecht et al., 2006). It is not, however, possible to make any generalizations, either due to inconsistent values for sheep and goats or due to different methods used for measuring (Animut and Goetsch, 2008). In our case, goats spent less time walking than sheep, probably because they perceived browse plants as a discrete food resource (a "patch"), and animals do not walk away from a shrub or tree until they deplete it and they readily perceive another item nearby. On the other hand, grasses and forbs are continuously distributed food resources over the paddock and sheep are prepared to walk towards their preferred forage (Dumont et al., 1998).

Goats displayed more social interactions than sheep, despite sheep maintaining visual and body contact with companions and generally having closer inter-individual distances (Arnold and Dudzinski, 1978; Bøe et al., 2006; Andersen and Bøe, 2007). The high rate of social interactions among goats probably reflects evolutionary adaptation to competition for access to food resources, namely browse plants which might be more scattered than grass and forbs. This could be particularly apparent when animals are herded in a limited area of enclosed paddock.

The spatial use of paddocks by animals may be influenced by the distribution of forage resources (Gipson et al., 2003; Schlecht et al., 2006) or by resting or watering places (Andersen and Bøe, 2007; Jørgensen et al., 2011); however, in hilly areas, spatial use is related to anti-predator strategy (Carr et al., 2007). Goats and sheep spent more time in the upper and/or in the middle part of paddocks on slopes, but were rarely on the lower part, as similarly reported by Hejcman et al. (2008). Being on the upper part of the slope may help detect potential oncoming predators more easily and facilitate escape.

We can conclude that behaviour of sheep and goats co-grazing on dry species-rich grassland for conservation purposes may not vary in their principal activities. They are however responsive to plant functional types available in the sward and to other environmental factors on pasture which should be taken into account for effective grazing along with respect to animals' natural behaviour.

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