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Forage competition between livestock and Mongolian Pika (*Ochotona pallasi*) in Southern Mongolian mountain steppes

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Drought

Summary

Nomadic pastoralism is the most suitable form of land use in the semi-arid grasslands of the world and from a pastoralist point of view wild herbivores are considered forage competitors to livestock. Although small mammals are abundant in steppe ecosystems forage competition between small mammals and livestock has rarely been quantified. This study presents the results of an exclosure experiment investigating forage competition between the Mongolian Pika (*Ochotona pallasi*) and livestock in the *Stipa–Allium*-steppes of the Gobi Gurvan Saykhan, southern Mongolia. Available forage in the area consists primarily of *Stipa krylovii*, *Agropyron cristatum*, and *Allium polyrrhizum* (representing 80% of available phytomass), all of which are regarded as desirable forage plants. In the drought year of 2001 however, species heights indicated that *Allium* is avoided by pika and livestock alike while *Stipa* and *Agropyron* are intensely browsed.

Pika and livestock populate the same habitat and browse the same limited forage species, leading to the conclusion that both herbivore groups compete for forage. Due to their smaller body size, pika are able to bite down the vegetation to a lower level and thereby consume more of the available forage, giving them a competitive advantage over the livestock.

Zusammenfassung

In den semi-ariden Steppengebieten der Erde ist nomadische Weidenutzung die angepaßte traditionelle Landnutzungsform. Aus Sicht der Viehhirten sind wilde Herbivore Futterkonkurrenten für das Weidevieh. Obwohl Kleinsäuger in Steppen-Ökosysteme häufig große Dichten erreichen, wurde die Futterkonkurrenz zwischen Kleinsäugern und Weidetieren bislang nur selten quantifiziert. Die vorliegende Studie

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untersucht die Futterkonkurrenz zwischen dem Mongolischen Pfeifhasen (*Ochotona pallasi*) und dem Weidevieh in den *Stipa–Allium*-Steppen des Gobi Gurvan Saykhan (südliche Mongolei). Die Hauptweidearten sind *Stipa krylovii, Agropyron cristatum* und *Allium polyrrhizum*, die zusammen etwa 80% der verfügbaren Phytomasse ausmachen. All diese Arten gelten als wünschenswerte Futterpflanzen. Messungen der Pflanzenhöhen zeigen, dass in dem Dürrejahr 2001 *Allium* sowohl von Pfeifhasen wie Weidevieh gemieden wird, wohingegen *Stipa* und *Agropyron* intensiv beweidet werden.

Pfeifhasen und Weidevieh nutzen die *Stipa–Allium*-Steppen ganzjährig und beweiden dieselben durch die Dürre begrenzten Futterressourcen. Daher stehen im Untersuchungsjahr beide Herbivorengruppen in Futterkonkurrenz zueinander. Aufgrund ihrer geringeren Körpergröße können Pfeifhasen die Vegetation auf ein niedrigeres Niveau abweiden als das Weidevieh. Sie erreichen so einen größeren Prozentsatz der verfügbaren Phytomasse, und besitzen daher einen Konkurrenzvorteil gegenüber dem Weidevieh.

Introduction

Grasslands cover approximately 40% of the earth's terrestrial surface, and semi-arid grasslands account for some 28% of these grasslands (White, Murray, & Rohweder, 2000). Semi-arid grasslands have been shaped over millennia by grazing of large herbivores and soil-digging small mammals such as pocket gophers, prairie dogs, or pika (Bond & Keeley, 2005; Kinlaw, 1999; Whitford & Kay, 1999).

Since most grassland regions are unsuitable for non-irrigated agriculture due to low and erratic rainfall, the dominant land-use is (semi-)nomadic pastoralism (Scholz, 1995). Thus, competition for forage between wild herbivores and livestock is of general importance in most semi-arid areas and numerous studies have investigated and often demonstrated forage competition between large wild herbivores and livestock (e.g. Bagchi, Mishra, & Bhatnagar, 2004; Mishra, Van Wieren, Ketner, Heitkonig, & Prins, 2004; Voeten & Prins, 1999). As wild ungulates have been drastically reduced in numbers, currently the focus of eradication programs is on small mammals (see the overview for North America by Fagerstone & Ramey, 1996 or Samjaa, Zöphel, & Peterson, 2000; Zhang, Zhang, & Liu, 2003 for examples from Asia). However, studies on competition between small mammals and livestock are scarce and often solely focus on dietary overlap (Krueger, 1986; Mellado, Olvera, Quero, & Mendoza, 2005). One reason may be that, although forage competition is widely assumed whenever animals graze the same area, it is far less simple to provide scientifically sound evidence for it: Even in times of general forage shortage herbivores can partition resources with respect to habitat use and/or forage selection and therefore may not compete directly (see also Madhusudan, 2004). In order to establish forage competition three criteria have to be fulfilled: (1) overlap of habitat use, (2) overlap of forage selection, and (3) forage scarcity (resource limitation; Begon, Harper, & Townsend, 1996; van der Wal, Kunst, & Drent, 1998).

In Mongolia the impact of small mammals and forage competition are of special relevance because almost 75% of its area is used for semi-nomadic pastoralism, which contributes heavily to the gross domestic product (~17% in 2004, National Statistical Office of Mongolia, 2005). Following privatisation of state herds during the political transformation in the 1990s, livestock numbers increased to an temporary all-time high of 33.5 million heads (National Statistical Office of Mongolia, 2005), while the breakdown of industry, administration, and state farms forced many people to return to livestock rearing (so-called "new nomads", Müller, 1995).

Some small mammals are known to benefit from high grazing impact and concerns have been raised that they may additionally impair pasture: In the steppes of central Mongolia and China the Brandt's vole (*Microtus brandti*) seems to benefit from overgrazing. Apart from forage competition, its negative reputation relates especially to its potential for massive population outbreaks and its habit of 'devastating the landscape' by constantly digging new burrows (Samjaa et al., 2000; Zhang, Zhang et al., 2003; Zhang, Pech et al., 2003). This initiates a vegetation succession cycle which only gradually regenerates to 'natural' steppe vegetation (Samjaa et al., 2000). For these reasons, the Brandts' vole is classified as a pest and major eradication programs are targeting the species (Davis, Leirs, Pech, Zhang, & Stenseth, 2004).

In the eastern Mongolian steppe, the Daurian pika (*Ochotona daurica*) is sometimes regarded as a pest due to forage competition with livestock (Zhang, Zhang et al., 2003; Zhang, Pech et al., 2003), although other authors debate this (Guriceva, 1985). Furthermore, it has been proposed that pika's density increases with grazing impact (Guriceva, 1985; Zhong, Zhou, & Sun, 1985).This proposal conflicts with a recent study showing that their density actually decreases with grazing impact (Komonen, Komonen, & Otgonsuren, 2003). Such differences have resulted in varying opinions on their pest status: While many authors regard the Daurican pika as a pest (Zhang, Zhang et al., 2003; Zhang, Pech et al., 2003), others perceive them as being neutral, with respect to livestock dynamics, and suggest that they may play a role as a keystone species (Komonen et al., 2003).

Such examples have raised concerns that the most abundant small mammal in the Gobi Gurvan Saykhan national park – the Mongolian Pika (*Ochotona pallasi*) – may also become a pest under increasingly intense livestock grazing. Thus forage competition between livestock and pika was addressed by the following questions: (1) Do both groups overlap in forage use? (2) Does the availability of forage actually limit herbivore numbers? And (3) If so, how intense is the competition?

Materials and methods

Study area

The Gobi Gurvan Saykhan national park, established in 1993, is situated in southern Mongolia and includes the southernmost outcrops of the Gobi Altay as well as vast areas of (semi-) desert. Covering more than 27,000 km^2, it is among the largest national parks worldwide (Reading, Johnstad, Batjargal, Amgalanbaatar, & Mix, 1999). The region is semi-arid with a mean annual precipitation of 131 mm in Dalanzadgad (Aymag capital, ~80 km south-east of the investigation area) with a high inter-annual variation (coefficient of variation = 37%). However, vegetation productivity is relatively high because precipitation is concentrated in the growing season (86%, data Mongolian Meteorological Service, Retzer, 2004). The zonal vegetation changes along a gradient of increasing altitude and precipitation, from (semi-) desert steppes in the lower elevations to *Stipa gobica* steppes in the upper pediments, and to dry mountain steppes dominated by *Agropyron cristatum* and *Stipa krylovii* at higher elevations (Wesche, Miehe, & Miehe, 2005). The exclosures (see below) are located within the *Stipa–Allium* type of mountain steppe on the south-facing upper pediments of the "Dund Saykhan" mountain at about 2300 m asl.

Virtually, all suitable area within the park is used as pasture for 200,000 heads of livestock managed by more than 1100 pastoralists. Only the western areas are sparsely populated due to a lack of water (Bedunah & Schmidt, 2000). The livestock mix includes all six species typically found in Mongolia: camels, horses, cattle, yak, sheep, and goat. Species composition changes with altitude, but sheep and goat are by far the most numerous animals, followed by horses, camel, cattle and yak. Livestock composition changes seasonally and responds to altitudinal phytomass availability (Retzer, Nadrowski, & Miehe, 2006). Mongolian Pika (*O. pallasi,* family Ochotonidae, order Lagomorpha) are herbivorous, burrowing small mammals (~200 g/adult), diurnal and active in winter (Smith, Formozov, Hoffmann, Zheng, & Erbajeva, 1990). They are the most abundant small mammals in the mountains (Retzer & Nadrowski, 2002).

Data collection

To study phytomass consumption by pika and livestock, an exclosure experiment was set up consisting of four different treatments: (1) access for livestock and pika – no fencing, (2) access for livestock only – low, narrow wire fence, (3) access for pika only – high, wide wire fence, and (4) non-grazing – combination of the two wires. Each treatment (size ~3 × 3 m) was replicated four times on different pediments (except for the first harvest in September/October 2001). Sampling started in October 2000 and took place every 4–6 weeks on one 1 m^2 plot within each treatment and replication. Standing crop (SC) was estimated using a double-sampling technique (Bonham, 1989): At each sampling date phytomass was harvested on half of the plots by clipping standing biomass at minimum height (~4 mm) and dried on a stove to constant weight. Plots harvested once were not sampled again. Vegetation cover was estimated directly as percent. Vegetation height was calculated as the average height of the three most abundant taxonomic groups: *Allium* spp. (= *A. polyrrhizum* and to a lesser extent *A. prostratum*), *Stipa* spp. (= *S. krylovii* and to a lesser extent *S. gobica*), and *Agropyron cristatum*. Heights were measured with a ruler for 20 individuals (or all if less than 20). SC on the non-harvested plots was then calculated using the parameters vegetation cover and height. This approach was recommended for pasture and herbaceous vegetation (Catchpole & Wheeler, 1992) and worked well in a number of other studies (Guevara, Gonnet, & Estevez, 2002; Huennecke, Clason, & Muldavin, 2001; Paton, Nunez-Trujillo, Diaz, & Munoz, 1999).

Due to substantial year-to-year differences between regression equations, SC had to be analysed separately for the dormant period before May 1, 2001 (Eq. (1)), and for the growing season 2001 (Eq. (2); see also Johnson, Johnson, & West, 1988):

$$SC = 2.41 + 0.0095 \times \text{cover} \times \text{height} \quad (\text{Pearson's } r^2 = 0.65), \tag{1}$$

$$SC = 2.05 + 0.033 \times \text{cover} \times \text{height} \quad (\text{Pearson's } r^2 = 0.74). \tag{2}$$

Pika managed to invade some of the non-grazing plots during the summer of 2001. Therefore, the values for the invaded plots were corrected by applying growth rates obtained from undisturbed plots.

The same method is used to estimate phytomass for *Allium*, *Stipa*, and *Agropyron* using multiple regressions:

$$SC(\textit{Allium}) = -0.13 + 0.6685 \times \text{cover} + 0.0392 \times \text{height} \quad (\text{Pearson's } r^2 = 0.75), \tag{3}$$

$$SC(\textit{Stipa}) = -1.10 + 0.8722 \times \text{cover} + 0.0522 \times \text{height} \quad (\text{Pearson's } r^2 = 0.79), \tag{4}$$

$$SC(\textit{Agropyron}) = -1.07 + 0.5377 \times \text{cover} + 0.1368 \times \text{height} \quad (\text{Pearson's } r^2 = 0.69). \tag{5}$$

However, as species height and phytomass are correlated (Pearson's $r^2 = 0.60$ for *Allium*, $r^2 = 0.44$ for *Stipa*, and $r^2 = 0.48$ for *Agropyron*), and height measurements exist for all species at all dates – while phytomass has to be estimated using the double sampling approach – species height can be used as a proxy for phytomass. All statistical analyses were carried out with both data sets and lead to the same results.

Calculation of productivity and consumption

For the calculation of consumption the paired-plot method is used (Bonham, 1989). Growth or consumption is calculated separately for each replicate as the differences from one date to the next (missing values are replaced with the mean). Above-ground net primary productivity (ANPP) is calculated by summing up the average of all positive increments on the non-grazing treatment (ORNL DAAC, 2002; Singh, Lauenroth, & Steinhorst, 1975). Consumption is calculated by comparing SC on an area exposed to grazing to that on a reference treatment protected from grazing (non-grazing). However, consumption has to be calculated separately for periods of vegetation growth and non-growth conditions:

Growth conditions: Intake during the growing season is determined by subtracting ANPP on the grazed area from ANPP on non-grazing plots (Pucheta, Cabido, Diaz, & Funes, 1998). This assumes that plant growth is similar on all treatments and neglects possible trampling effects under grazing (see exemplarily Eq. (6) for pika):

$$C(\text{pika}) = SC(n2) - SC(n1) + [SC(p1) - SC(p2)]. \tag{6}$$

Consumption (C) is calculated analogously for livestock and pika & livestock. With $SC(n1)$ being SC on the non-grazing treatment at date 1, $SC(n2)$ SC on the pika only treatment at date 2, $SC(p1)$ SC on the non-grazing treatment at date 1, and $SC(p2)$ SC on the pika only treatment at date 2.

Non-growth conditions: During non-growth conditions plant decay has to be considered additionally. A constant decay rate is assumed on all plots (see also Wiegert & Evans, 1964). Thus, the observed decay on the treatment non-grazing is proportionally subtracted from SC on the other treatments (Eq. (7) for pika):

$$C(\text{pika}) = \left(1 - \frac{SC(n1) - SC(n2)}{SC(n1)}\right) \times SC(p1) - SC(p2). \tag{7}$$

Consumption is calculated analogously for both herbivore groups. Total consumption during the investigation year is finally calculated by summing up all positive increments of consumption.

Livestock density

Livestock densities were estimated by regular direct observation using binoculars from an elevated hill and during trips along the pediment. The following parameters were recorded: date and time, number and species of each group of animals, their distance and direction from the observation point. Numbers of goats and sheep were pooled as 'shoats' because differentiating the species in the mixed herds was impossible. For better comparability, animal densities were converted into stocking units: the "Mongolian Sheep Unit" (MSU). 1 MSU is equivalent to an intake of 365 kg of dry forage per year (~1 kg/day). One horse is equivalent to 7 MSU, one cattle or yak to 6 MSU, one camel to 5 MSU, one sheep to 1 MSU, and one goat to 0.9 MSU, respectively (Bedunah & Schmidt, 2000). For shoats an average MSU of 0.94 was used, according to the proportion of sheep and goats (1:1.78) in the herds of the neighbouring pastoralists. Livestock observation data were analysed using Arc View 3.2 ESRI (2000). Furthermore, livestock numbers were obtained from interviews with herders.

Body condition scoring and livestock numbers

Body condition scoring is used to estimate livestock's nutritional condition by feeling the level of fat and muscle deposition over and around the vertebra of the loin region (Thompson & Meyer, 1994). From November 2000 until September 2001 body condition of ten adult female sheep from one experienced herder near the research station was estimated regularly.

Data analysis

Prior to analysis, distribution of data and variances were visually inspected using histograms and normal probability plots (Quinn & Keough, 2003). As the assumptions of normality and homogeneity of variances could be met, parametric tests were applied. Treatment effects on heights and phytomass of *Allium*, *Stipa*, and *Agropyron* and on total phytomass were examined using a repeated measure ANOVA with months as inner subject factors and blocks (exclosure) and treatments as between subject factors. For analysis of species heights per block means were used. Tukey-corrected post hoc tests were used to test differences between the grazing treatments. These analyses were conducted for the growing season only (five sampling dates), as this is the time of grazing impact. Analyses were performed using Statistica 6.1 (StatSoft Inc., 2003).

Results

Overlap of habitat

The pastures of the upper pediments are grazed by livestock year round (Fig. 1). Large wild herbivores are clearly outnumbered by domestic livestock – the combined density (in terms of MSU) of wild sheep, ibex, and gazelles is only about 2% that of livestock, and therefore neglected in the following analyses. Livestock composition varies seasonally according to the migration patterns of the herders. In winter, sheep and goat cannot reach the upper pediments because the winter

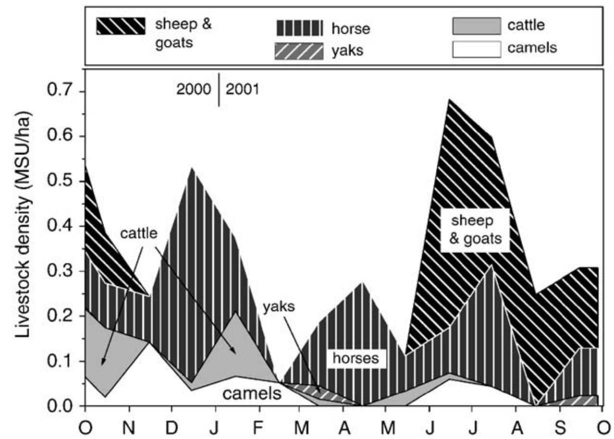

Figure 1. Livestock densities (MSU/ha) in the surroundings of the exclosure experiment from October 2000 to October 2001. Livestock composition is subject to seasonal variation depending on the migration patterns of the herders.

camps are located some 8 km down the pediments, while herds have a grazing radius of some 3 km around the camp to which they return every night. As larger livestock species are free ranging, they graze in the mountains during the entire year. Pika are also present year round as they do not hibernate and are active in winter (personal observation; see also Smith et al., 1990). Results from a mark-recapture experiment show that pika densities on the pediments vary between approximately 30 individuals/ha in winter and 70 individuals/ha during the reproduction period in summer (Nadrowski, Retzer, & Miehe, 2002). Thus, pika and livestock use the upper pediments for grazing during all seasons.

Overlap of forage resources

The vegetation of the *Stipa–Allium* steppes is dominated by three perennial species: *S. krylovii*, *Allium polyrrhizum*, and *A. cristatum*. These species accounted for a large share of the total vegetation cover (e.g. more than 80% in September), and of available phytomass (78%) during the summer of 2001. According to interviews with herders, all of them are palatable for livestock, though *Allium* is not a favourite.

Stipa and *Agropyron* heights generally decline in the following order: non-grazing – livestock only – pika only – pika & livestock (Fig. 2). Differences between the pika only and pika & livestock treatments are smaller than those between any of the other treatments. In September of 2001 – at

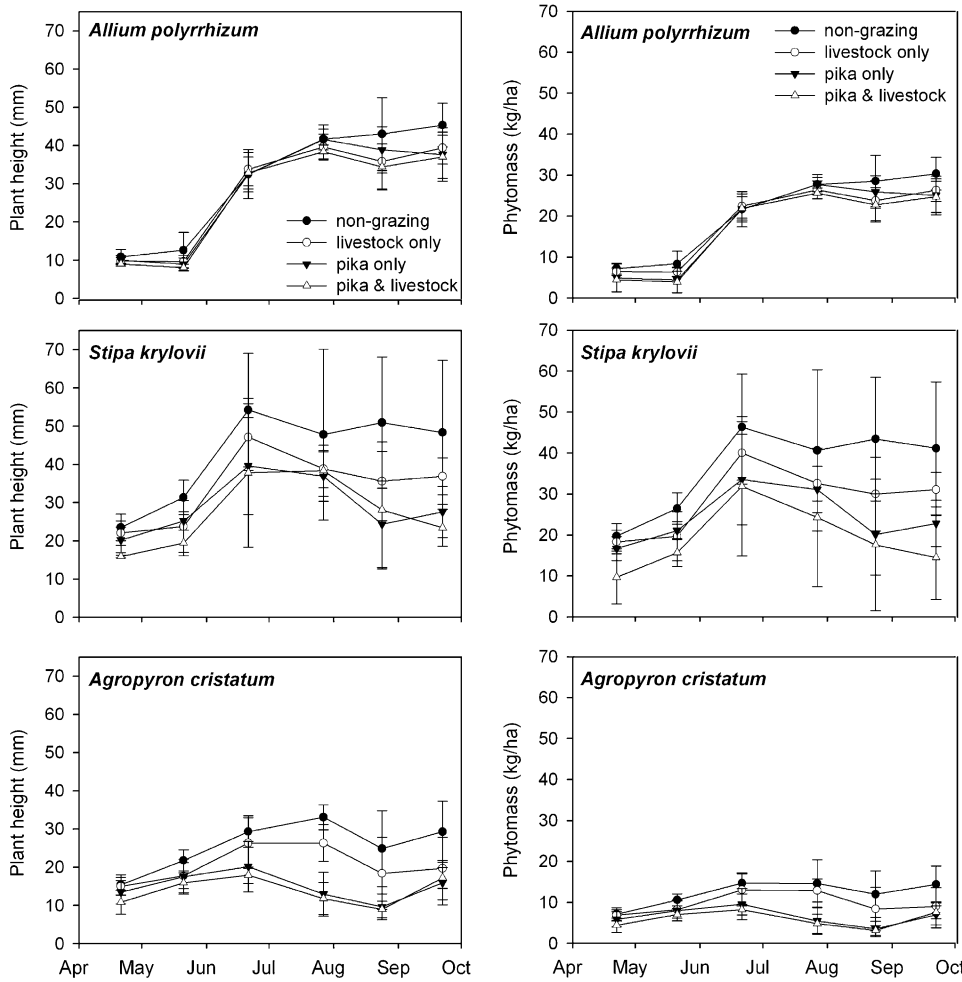

Figure 2. Average plant height (left) and phytomass (right) of the three most important plant species/groups (*Stipa krylovii*, *Allium polyrrhizum*, and *Agropyron cristatum*) during the grazing season of 2001 ($n = 4$). Error bars indicate standard deviation.

the end of the summer – the non-grazing treatment exhibits the greatest heights (mean = 52 mm for *Stipa* and 32 mm for *Agropyron*), with the livestock only treatment producing intermediate (mean = 38 mm for *Stipa* and 22 mm for *Agropyron*), and the pika only and pika & livestock treatments the lowest heights (mean = 28 mm and 24 mm for *Stipa* and 16 and 18 mm for *Agropyron*, respectively). *Allium* heights are very similar among the various treatments except in August and September when the non-grazing treatment has slightly greater heights than the grazed treatments. The same is true for species phytomass (see Fig. 2).

Though *Allium* heights are slightly lower on the grazed treatments (Fig. 2), differences are small and repeated measures ANOVA reveal no significant treatment effect for *Allium* (Table 1). This is in contrast to the two other species, *Stipa* and *Agropyron*. Here, the repeated measures ANOVA indicates a significant treatment effect ($p < 0.05$, Table 1). Tukey-corrected post hoc tests show the same pattern for both species: the non-grazing and livestock only treatments differ from the pika only and pika & livestock treatments ($p < 0.05$, data not shown). Thus, the grazing of pika causes the difference.

Although a significant grazing effect of the single species cannot be established due to large variations between the exclosures, total phytomass data do suggest a significant effect. Tukey-corrected post hoc comparisons of a repeated measures ANOVA using total phytomass data shows significant differences between all treatments except between pika only and pika & livestock treatments (Table 2). This indicates that both herbivore groups feed on the available phytomass and therefore forage resources overlap.

Table 1. Results of a repeated measures ANOVA (month as inner subject factor, block and treatment as between subject factors and interaction terms are shown) for the average heights of *Allium polyrrhizum*, *Stipa krylovii* and *Agropyron cristatum* on the different grazing treatments

	Allium polyrrhizum					*Stipa krylovii*					*Agropyron cristatum*				
	SS	df	MS	F	p	SS	Df	MS	F	p	SS	df	MS	F	p
Month	551.81	3	183.94	9.648	**<0.001**	3365.71	4	841.43	13.0739	**<0.001**	557.37	4	139.34	9.9935	**<0.001**
Block (exclosure)	445.12	3	148.37	5.035	**0.026**	2368.15	3	789.38	4.6587	**0.036**	828.98	3	276.33	4.6228	**0.032**
Treatment	209.45	3	69.82	2.369	0.138	3688.05	3	1229.35	7.2553	**0.011**	2088.49	3	696.16	11.6463	**0.002**
Month × block	218.13	9	24.24	1.271	0.297	1155.09	12	96.26	1.4956	0.177	246.73	12	20.56	1.4746	0.179
Month × treatment	174.24	9	19.36	1.015	0.453	842.10	12	70.18	1.0904	0.400	429.08	12	35.76	2.5644	**0.014**

Significant differences with $p<0.05$ are given in bold.

Table 2. Results from Tukey-corrected post hoc tests of a repeated measures ANOVA for the total phytomass on the different grazing treatments

Treatments	Livestock only	Pika only	Pika & livestock
Non-grazing	**0.0015**	**0.0002**	**0.0002**
Livestock only		**0.0358**	**0.0095**
Pika only			0.8011

Significant differences with $p<0.05$ are given in bold.

Forage scarcity

The previous sections demonstrate that pika and livestock utilise the same forage resources. However, this only leads to forage competition when resource supply is lower than actual demand. The body condition of animals is a good indicator for their nutritional status. It shows a strong seasonality: herbivores are maximally nourished at the end of the grazing season and subsequently fat reserves decline throughout winter until fresh forage becomes available in spring. At the end of September 2001 body condition scores were only slightly above average, which is even lower than in January of 2001 after three winter months with low forage supply (Fig. 3). This indicates that the sheep were undernourished and thus may have had difficulties surviving the following winter.

Indeed, livestock numbers decreased drastically from 2000 to 2002 (Table 3). On average, herders lost more than one quarter of their livestock with larger animals (horses, cattle) experiencing the greatest losses. Although forage scarcity for pika is much more difficult to investigate, population data indicate that pika also suffered from population decline following the drought of 2001 (Nadrowski, pers. comm.). Thus, forage scarcity was severe in the summer of 2001, causing subsequent forage competition between pika and livestock.

Intensity of forage competition

Fig. 4 shows the phytomass dynamic on the different treatments during the investigation period. All treatments exhibit strong seasonal variations similar to the variation in body condition (see Fig. 3). The effects of the grazing treatments are significant throughout the growing season (univariate results of repeated measures ANOVA $p<0.05$). Impact of pika is greater than that of livestock as can be seen by the similar development of the pika only and pika & livestock treatments. The livestock only treatment is intermediate. This visual impression is also confirmed by the overall budget of forage intake for the different treatments (Table 4): Pika consumed about 20% more phytomass than livestock.

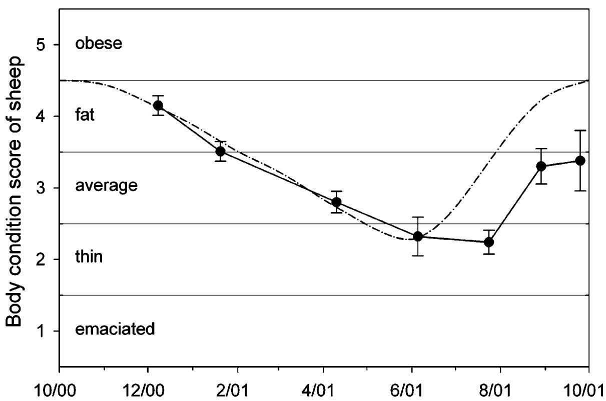

Figure 3. Average body condition of ten sheep in the vicinity of the exclosure experiment. Error bars indicate standard deviation. The dotted line shows the theoretical development in a year with sufficient forage to replenish fat reserves before winter (own draught after descriptions from herders).

Table 3. Livestock losses of herders in the vicinity of the research camp from 2000 to 2002 in per cent

Herder	Sheep (%)	Goat (%)	Horses (%)	Cattle (%)
Otshir+Zündajusch	−25	−16	−47	−67
Ajusch	−35	−13	−87	−100
Budee	−16	−21	−74	−50
Mean	−25	−16	−69	−72

Discussion

Forage selection

According to Jigjidsuren and Johnson (2003) all three major species in the exclosure experiment are "palatable to livestock throughout the year" and even are regarded as highly nutritious (*Agropyron, Stipa*) or rich in protein (*Allium*, "all types of livestock readily eat it"), respectively. *A. polyrrhizum* is used as supplementary forage for young and sick small livestock during late winter and spring (Yamasaki & Ishida, 2004). Herders in the vicinity of the research camp also claim that the onion is utilised by almost all livestock species (own interviews). Some of them also state that *Allium* has to be consumed in a forage mix because it can cause sickness when fed without a sufficient fraction of other species. This is in accordance with findings from Fernandez-Gimenez (2000) where herders also ranked *A. polyrrhizum* and *Stipa* spp. as the most desirable pasture plants, closely followed by *A. cristatum*.

However, the data on vegetation height (Fig. 2) show that grazing reduces heights of *Allium* proportionally less than those of *Stipa* and *Agropyron*. Whereas pika only and pika & livestock

Table 4. Forage consumption on the treatments livestock only, pika only, and pika & livestock in relation to phytomass production during the grazing season 2001 (May–October 2001)

Consumption	Phytomass (kg/ha)	Percentage (%)
Livestock only	122±6	68
Pika only	162±4	90
Pika & livestock	164±4	91
Production	180±3	100

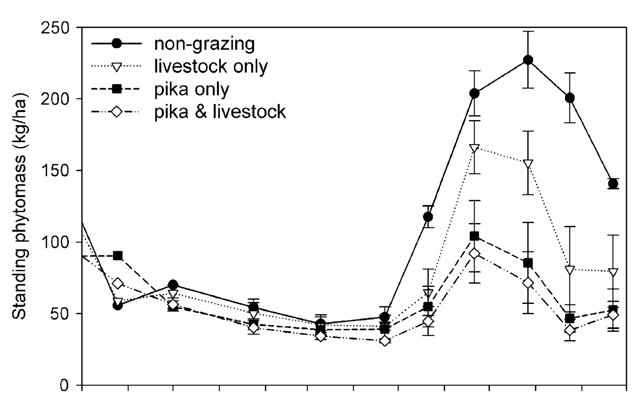

Figure 4. Standing phytomass on the different grazing treatments of the exclosure experiment from October 2000 to 2001 ($n = 4$). Error bars indicate standard error for the replicates.

treatments have significant impacts on the heights of the latter two species, they do not reduce *Allium* height. Furthermore, the factor block explains a higher proportion of the variance in a factorial ANOVA for *Allium* than treatment does, while the opposite is true for *Stipa* and *Agropyron*. Thus effects associated with the position of the exclosures, such as abiotic soil conditions, have a stronger influence on *Allium* height than grazing has. In addition, height of *Allium* is greater on all grazing treatments than that of *Stipa* or *Agropyron*. This implies that neither pika nor livestock make full use of the fodder resource offered by the onions. Therefore, *Allium polyrrhizum* is clearly not a preferred forage plant. On the contrary, even during a year of drought animals explicitly select against it. A possible explanation of this result which stands in contrast to the above-cited literature may be the season of consumption: *Allium* is said to be preferably consumed by livestock in autumn when it is dried and has lost most of its aromatic sulphurous compounds (Fernandez-Gimenez, 2000). An indicator for this may be the increasing difference between *Allium* height on the non-grazing treatment and all grazed treatments at the end of the growing season (Fig. 2).

Forage competition with livestock

Forage competition was evident, and forage consumption by pika was approximately 20% higher than by livestock (Table 4). However, this cannot be directly converted into a hypothetical 20% higher livestock number in the absence of pika, as the proportions of consumption fluctuate from year to year (Wesche & Retzer, 2005). Furthermore, the pika's habitat is restricted to mountainous regions of the Gobi Gurvan Saykhan (less than 17% of the park is higher than 2000 m, pers. comm. H. von Wehrden), whereas domestic animals utilise a larger range of habitats. Finally, livestock numbers are additionally limited by other factors such as water availability. Thus, the overall effect of competition on livestock numbers is very likely to be small.

Although dietary overlap or forage competition with livestock is a major reason to regard small mammals as pests, this cannot be the sole motivation. Small mammals considered pests have more negative impacts on the pastures such as destruction by digging and subsequent succession of less palatable species (Samjaa et al., 2000; Zielinski, 1982). The Mongolian Pika does not exert such negative impacts; instead it may be regarded as an ecosystem engineer due to the improved nutrient availability and plant growth associated with its burrows (see Wesche et al., 2005). Furthermore, the argument that small mammals compete for forage with livestock is always an anthropo(-zoo)genic point of view as small mammals are in return affected by grazing livestock (e.g. Eccard, Walther, & Milton, 2000; Hayward, Heske, & Painter, 1997).

Implications of forage competition – competitive superiority of pika?

In 2001, pika consumed larger amounts of the available phytomass than livestock and therefore can be regarded as competitively superior (Table 4). This is in accordance with findings from simulation experiments which state that ruminants "of smaller body size are competitively superior to larger ones due to allometric relationships of bite size and metabolic requirements to body size" (Clutton-Brock & Harvey, 1983), and that "large grazers can facilitate food availability for smaller species but with the latter being competitively dominant" (Farnsworth, Focardi, & Beecham, 2002). Pika have smaller mouths and thus can graze vegetation to a lower level than livestock. This is confirmed by the heights of *Stipa* and *Agropyron*, which are grazed by both herbivore groups (Fig. 2). Plant heights in the pika & livestock treatment are not significantly different from those in the pika only treatment, but are significantly lower than in the livestock only treatment. This indicates that pika manage to graze both species to a lower level than livestock. Furthermore, pika have the additional advantage of being present virtually all the time while livestock merely pass along a certain spot every other day. However, the local superiority of pika is balanced by the much higher mobility of livestock (see Retzer & Reudenbach, 2005). Therefore, pikas' immobility turns into a disadvantage in dry years when pika have to cope with whatever small amount of phytomass is available. Possible leftovers from the previous year's hay harvest may mitigate the effect of drought on pika populations somewhat, but data on this are still lacking, and it seems improbable that such supplies last through two subsequent dry years.

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