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Variation of precipitation and its effect on phytomass production and consumption by livestock and large wild herbivores along an altitudinal gradient during a drought, South Gobi, Mongolia

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Abstract

The mountain ranges of southern Mongolia provide traditional pasture for livestock but also habitat for wildlife species, some of which are internationally rare and endangered (e.g. argali). Data from a 1-year field study show that the mountains receive higher precipitation than the surrounding semi-deserts and that this results in a gradient of phytomass production and therefore also in a gradient of forage availability.

Animal observations indicate that livestock generally outnumber large wild herbivores by a factor of 60 on the pediments and by a factor of 6 in the mountains. Moreover, during the drought in the summer of 2001 livestock intruded into argali and ibex habitat. This resulted in additional pressure on those animals through increased forage competition with livestock and increased frequency in anthropogenic disturbance.

Thus, while the use of the mountain steppes as reserves during drought is an opportunistic strategy employed by nomadic herders in a highly variable semi-arid ecosystem, it may interfere with nature conservation efforts for argali. Protection is especially needed during times of stress, while during years of abundant forage the potential for conflict is much lower. Furthermore, the problem may increase under changing climatic conditions.

Keywords: Wildlife:livestock competition; Land use conflicts; Communal grazing; Nomadic herders; Endangered species; Precipitation variability

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1. Introduction

Multiple use of rangeland for grazing livestock and the protection of (endangered) large mammals and resulting conflicts between both interests is a dilemma worldwide (see e.g. for Africa: de Leeuw et al., 2001; Stephens et al., 2001; Boone et al., 2002; Chanda et al., 2003; Moleele and Mainah, 2003. For North America: Fleischner, 1994; Treves et al., 2004. For Eurasia: Saberwal, 1996; Reading et al., 1999a; Rao et al., 2002. For South America: Baldi et al., 2001). The management of endangered species is an especially pressing issue all over Central Asia where many species of wild herbivores and predators have survived until today such as the argali (*Ovis ammon*), snow leopard (*Uncia uncia*), goitered gazelle (*Gazella subgutturosa*), bactrian camel (*Camelus bactrianus ferus*), asiatic wild ass (*Equus hemionus*) and saiga antelope (*Saiga tatarica*) (IUCN, 2004). Furthermore, a large proportion of the human population depends on livestock herding for their livelihoods (FAO, 2001). Most of the endangered animals are under pressure from growing human populations with their livestock, yet little is known about the biology of many of the species (Reading et al., 2005a, b), and even less about their dynamic interactions with livestock.

The question of the impact of livestock on wild herbivores is especially important in Mongolia where 83.9% of habitat is grassland (White et al., 2000), which serves as pasture for the livestock of semi-nomadic herders with 14% comprising protected areas (figure for 2003; EarthTrends, 2004). The area of protected reserves is planned to be more than doubled by 2030 (Chimed-Ochir, 1997 cited in Bedunah and Schmidt, 2004). As large livestock is free ranging and there are no fences excluding the animals from the protected areas (nor are such fences feasible or reasonable), the area of potential conflict between livestock production interests and nature conservation will increase sharply. Forage competition with livestock is, apart from poaching, the most important reason for the declining numbers of argali in Mongolia (Mallon et al., 1997; Reading et al., 1997), but also for other animals in the Trans-Himalaya (Mishra et al., 2002, 2004; Bagchi et al., 2004). Thus, there is an urgent need to assess the impact of livestock on large wild herbivores and to find solutions for the coexistence of both groups.

However, the knowledge about the actual regional dynamics in Mongolia is poor. Existing data are rare and are available on a very rough scale only (vegetation map with a scale of 1:1 500 000, from Lavrenko et al., 1979). Precipitation data as the key abiotic determinant for forage production are only available from a few meteorological stations which are mostly situated at lower elevations in the inter-montane basins and further disregard spatial variation, especially in the mountainous regions (Barthel, 1983). Data on the distribution of livestock are available only in annual intervals from within district boundaries but disregard the important inter-annual variations and migrations (e.g. National Statistical Office of Mongolia, 1996 and 2003). Without such information, regional patterns cannot be included in management plans for endangered species. Therefore, this study presents for the first time data on the annual dynamics of livestock and large wild herbivores, phytomass, and precipitation along an altitudinal gradient in the Gobi Gurvan Sayhan national park in southern Mongolia during a year of drought. In order to contribute to the understanding of the interactions between precipitation, phytomass productivity, and wildlife and livestock densities the data are discussed with respect to their relevance for the management of endangered animals in a heterogeneous landscape.

2. Study site

The Gobi Gurvan Saykhan National Park is situated in southern Mongolia (South-Gobi district, Ömnögov Aymag) and extends westwards from the district capital Dalandzadgad. It includes the southernmost outcrops of the Gobi Altay as well as vast areas of (semi-) desert. Covering some 21 700 km^2 it is among the largest national parks worldwide (Reading et al., 1999b). The park was established in 1993 in order to guarantee long-term sustainable use; protection of rare wildlife, (endemic) plant species, and special landscape features as well as the undisturbed development of the ecosystems (WWF, 1993; Reading et al., 1999b). The mountains of the Gobi Gurvan Saykhan range are of special interest to nature conservation as well as to the herders living in the region. The high altitudes belong to the core zone for protecting vegetation communities such as *Betula microphylla–Salix bebbiana* relic forests and *Kobresia myosuroides* mats, which are important for the preservation of biotic diversity (Miehe, 1996, 1998; Cermak and Opgenoorth, 2003; Wesche et al., 2005). They are also the habitat of scarce and endangered species such as argali (wild sheep, *O. ammon*), or snow leopard (*U. uncia*) (Finch, 1996; Reading et al., 1999b). On the other hand they are attractive to herders because they receive higher precipitation and therefore offer higher primary productivity in an otherwise semi-arid environment.

The region is semi-arid with a mean annual precipitation of 131 mm in Dalandzadgad, and high inter-annual variation (coefficient of variation = 36%). However, vegetation productivity is relatively high because 86% of the annual precipitation is concentrated in the summer, during the growing season (data Mongolian Meteorological Service, Retzer, 2004). The vegetation changes with altitude and precipitation from (semi-) desert steppes at lower elevations, to *Stipa gobica* steppes on the upper pediments, to dry mountain steppes dominated by *Agropyron cristatum* and *Stipa krylovii* at higher elevations (Wesche et al., 2005).

Although the mountain ranges are crucial components of the national park for the above reasons, data on the altitudinal distribution of precipitation are lacking as all meteorological stations are situated in the inner-montane basins. Similarly, no figures on the increased phytomass production in the mountains are available. Last but not least, seasonal altitudinal migration patterns of wildlife and livestock have not yet been studied.

The altitudinal transect presented here is situated on the southern slope of the Dund Saykhan mountain and stretches from ~2000 m to the summit region at ~2800 m (see Fig. 1).

Geomorphologically, the transect is split into two parts. The lower altitudes up to 2380 m are gently sloping pediment regions dissected by erosion gullies. The mountains are characterised by steep rocky slopes forming a very heterogeneous landscape of steep relief and pronounced differences in exposure. Plots for vegetation studies and climatic measurements were established at every ~200 vertical metres. All plots were situated in steppe vegetation, facing a southerly direction where possible.

3. Methods

3.1. Measurement of precipitation

Precipitation was measured using Hellmann rain gauges with 100 cm^2 catching area. They were installed some 50 cm above-ground on short posts, since longer posts would

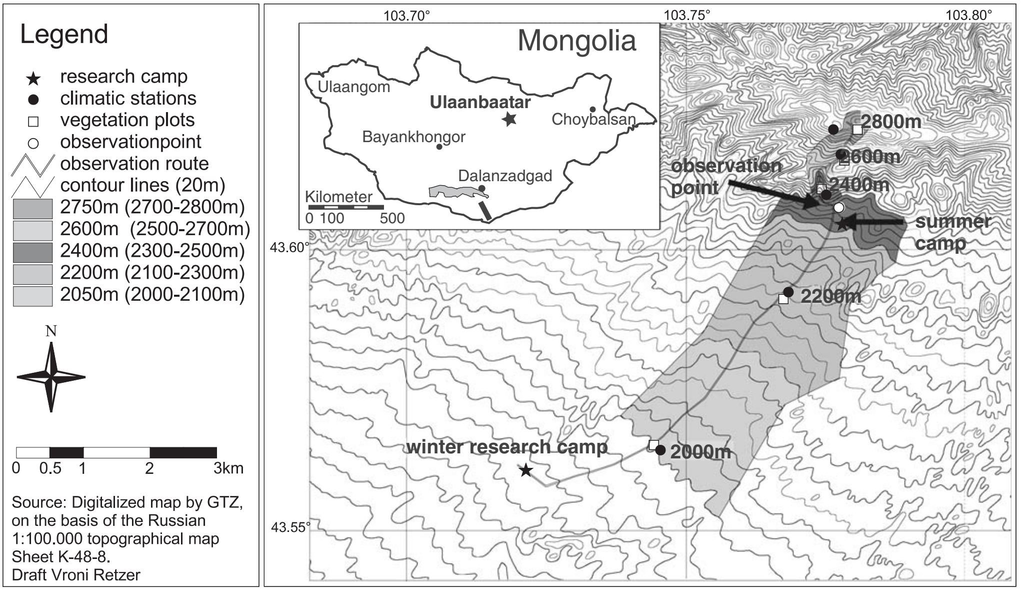

Fig. 1. Overview over the altitudinal transect: The locations of the research camps, climatic and vegetation plots, an outline of the animal observation area, and its altitudinal subdivisions, as well as the observation point and route are indicated. The inset indicates the location of the study area within Mongolia (arrow). The shape of the national park is outlined in gray.

have been destroyed by large livestock using them to scratch themselves. The gauges were emptied at monthly intervals starting in September 2000. Some oil was added into the gauges to prevent water from evaporating before collection. The amount of rain or snow was weighed, converted into millimeter precipitation and recorded. Although the Hellmann rain gauge has high error rates, especially during snowfall, it was nevertheless used since in a summer-rainfall region winter precipitation is low and of almost no subsequent importance to herbaceous vegetation growth (Walter and Breckle, 2004).

3.2. Vegetation data

All plots for the assessment of vegetation data were situated within grass-dominated steppe vegetation along the altitudinal transect and were accessible to all herbivores. Four 1 m^2 plots were marked as corners of a 1-ha plot on the pediments and of a 1/4-ha plot in the mountains. Vegetation cover was estimated directly in percent.

Standing crop on the plots was estimated using a double-sampling approach (Bonham, 1989; Catchpole and Wheeler, 1992). Within an exclosure experiment at 2350 m (data not presented here, see Retzer, 2004), phytomass was harvested by cutting with scissors at minimum height and length (~4 mm). Afterwards, phytomass was dried on a heating stove to constant weight. Unharvested standing crop on the plots (including all plots along the transect) was estimated using the parameters vegetation cover and height. Both parameters have been used successfully in a number of studies (Singh et al., 1975; Ward et al., 1998; Huennecke et al., 2001) and are recommended for pasture and herbaceous vegetation (Catchpole and Wheeler, 1992). For the most abundant plant species or taxonomic groups, maximum height of non-flowering shoots was measured with a ruler for 20 individuals per plot (or all if less than 20). Average height was calculated for each group and the group average was subsequently recorded as vegetation height for the whole plot. The 'most abundant species' differed along the transect due to changes in species cover: *Stipa*-species (= *S. krylovii* and to a lesser extent *S. gobica*) and *A. cristatum,* which dominate on the pediments, were replaced by *Koeleria altaica* and *Poa attenuata* in the mountains; within the *Allium*-genus the species changed from *A. polyrrhizum* on the pediments towards *A. eduardii* in the mountains.

Regression functions for cover and height—experimentally developed for the exclosure experiment at 2350 m on grazed and ungrazed plots (Retzer, 2004)—were used for the calculation of standing crop. As the functions changed tremendously with the onset of vegetation growth, two regression functions had to be used; one for winter (1) and one for the growing season after May 1st (2):

(1) standing crop $= 2.41 + 0.0095 \cdot \text{cover} \cdot \text{height}$ (Pearsons-$r^2 = 0.65$),
(2) standing crop $= 2.05 + 0.033 \cdot \text{cover} \cdot \text{height}$ (Pearsons-$r^2 = 0.74$).

Although extrapolation from one vegetation unit at 2350 m to different units between 2000 and 2800 m is a potential source of error, the computed results match the observations made during the investigation period and results of occasional test harvests very well. Therefore, the calculations seem to be a reasonable estimate of the distribution of phytomass along the altitudinal transect.

3.3. *Animal observations*

Animal densities were assessed by direct observation with binoculars. In order to get complete records for the whole transect, different approaches were combined: For the lower altitudes up to 2400 m, data from an observation hill near the summer site and from drives between the summer and winter camps were used.

Due to the more complicated relief, visual observation was more difficult in the mountains. There, notes on observed animals were taken each time when passing through the valley where the climatic transect and the vegetation plots were located. Records included altitude (above sea level, asl), number, and species of the observed animal(s), their distance and direction from a known position (such as observation point or other fixed points along the transect), as well as date and time of the observation. For the mixed flocks of sheep and goats separation of the two species was not possible. Therefore these herds were recorded as mixed herds of "shoat". A standard routine was applied to ensure the comparability of the results: First a 360° turn was made noting all sighted animals. Afterwards a second turn served to check whether animals had been missed.

Observations at the lower elevations were easier to realise and thus more numerous than those in the mountainous region. Calculations incorporated data from 128 observations from the observation hill, 54 from drives, and 28 from trips to the mountain. Moreover, the area observed decreased with increasing altitude and was much larger on the pediments than within the mountain range. Areas ranged from 617 ha (at 2000–2100 m) to 158 ha (at 2300–2400 m) on the pediment and from 17 to 30 ha for each 100-m-wide altitudinal belt within the mountain range. Thus, the data for the mountains are based on a considerably smaller observation area and on a lower number of observations. For these

Table 1
Overview of the standard Mongolian livestock equivalent Mongolian Sheep Unit (MSU) (Bedunah and Schmidt, 2000; Shurentuja et al., 2002)

Species	Camel	Horse	Cattle/ yak	Sheep	Goat	Shoat	Argali	Gazelle	Ibex
MSU	5	7	6	1	0.9	0.94	1.9	0.4	1.2

The factor used for "shoat" is derived from the proportion of goats and sheep (1.8/1) in the mixed herds of the herders in the vicinity of the study site (own interviews). The equivalents for large wild herbivores were calculated from average weight data (Data: National Statistical Office of Mongolia, 1996, 1998, for livestock weight, Huffman, 2003 for wildlife weight).

two reasons the observation data for the mountainous area are less reliable than those for the pediments. Thus species compositions are given only for the whole observation period, while for temporal dynamics the data were pooled for the mountain and for the pediments.

During the observation period a total of 210 observations were conducted. From these observations 1278 animal groups comprising 61 056 individuals were recorded. All information on animal observation was stored in a database and analysed within a GIS (ArcView 3.2, ESRI). The area observed was assessed and split along the contour lines. Animal type and number thereof from the various GIS layers were selected and merged with the altitudinal layers of the observation area in order to determine the number of livestock units within each altitude. Livestock numbers were converted to Mongolian Sheep Units (MSU, see Table 1) for better comparison of the grazing impact of the various species.

For the data on species composition all observations during the whole investigation period were analysed together. For the altitude labelled "2050 m" all observations between the 2000 and 2100 m contour lines were used; for "2200 m" all between 2100 and 2300 m, and so on. This approach was chosen to make the data comparable to precipitation and vegetation data. There is, however, one drawback for the altitudinal range around 2400 m: here, many more sightings from the pediments were grouped together with relatively few observations from inside the mountain range (see above). For this reason the altitude "2400 m" is much more representative of pediment conditions than of the mountain range and as such has to be kept in mind when interpreting the data.

4. Results and discussion

4.1. Precipitation

The South Gobi experienced an extreme drought during the summer of 2001: between May and September Dalandzadgad, the nearest weather station, received only 60% of the average precipitation (data: Mongolian Meteorological Service, Retzer, 2004). During this period of drought the data from the altitudinal transect demonstrate a substantial discrepancy in precipitation between the pediment and the mountain range (Fig. 2).

As expected, precipitation was similarly low during the winter months on all plots. However, the rainfall patterns of mountains and pediments differ markedly in summer. On the pediments (2000 and 2200 m), the summer rains failed completely from May to August and in September some 22–31 mm of rain was recorded.

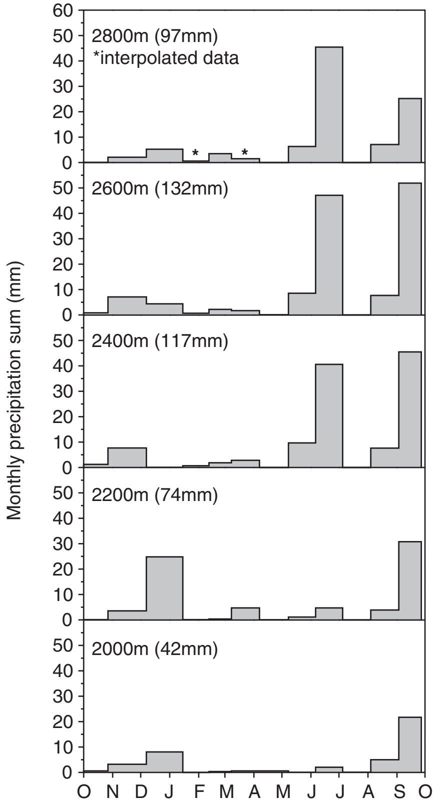

Fig. 2. Precipitation along the altitudinal transect during the investigation period from October 2000–October 2001. Missing data were interpolated using the data of previous and following months and data from the station at 2600 m.

At the mountainous stations (2400–2800 m) the rains set in May, and June brought some 40–46 mm, while July and August had no or very low precipitation. In September, up to 52 mm were recorded again. The pattern at the station at 2800 m differs slightly; although situated higher than the other two mountain stations, the annual precipitation is lower. This may be due to the particular topographic situation of this station. As the highest peak of the Dund Saykhan is at 2835 m, the area available for the placement of the gauge was limited. It was located relatively near to the ridge and was therefore exposed to high wind velocities. This may have been the cause for lower recorded precipitation there. Still, even this station showed considerably higher precipitation than on the pediment.

The measurements support the assumption of higher precipitation in the mountains as indicated by the vegetation (Miehe, 1996, 1998; von Wehrden and Wesche, 2002; Wesche et al., 2005). However, although precipitation in the mountains was higher than on the pediments in 2001, the failure of rain in July and August in a summer-rain region would suggest below-average precipitation for the mountains as well. As a conclusion, the drought of 2001 had a considerable effect along the whole transect, but less so in the mountains.

4.2. Vegetation

Fig. 3 shows the development of vegetation height, cover, and standing crop on the transect under grazing. Patterns of vegetation growth were closely related to the distribution of precipitation along the transect (see Fig. 2). Again, the distinct partitioning into a mountain and a pediment zone can be observed.

The pediment does not exhibit any substantial vegetation growth during the whole summer of 2001. Vegetation height remains below 20 mm during the whole summer; only a slight growth peak initiated by the late rains can be detected in September. The trend is more pronounced for vegetation cover: On both plots, vegetation diminishes resulting in only approximately 0.5% at 2000 m and less than 3% cover at 2200 m in September 2001. The estimated standing crop follows this development closely: Standing crop on the plots at 2000 and 2200 m varies between 21 and 43 kg ha^{-1}. These amounts are so low that they can barely be harvested by any large herbivore. The pediments incurred the worst effects of the drought with practically no phytomass being available for grazing livestock or wild herbivores during the whole growing season of 2001, and consequently for the following winter.

The situation is different in the mountains. Vegetation growth sets in with the first rains in May, and vegetation height reaches a maximum in June. The rains in June also lead to an increase in vegetation cover. However, both parameters diminish rapidly in the following months. Maximum standing crop is found in June with ~200 kg ha^{-1} at 2600 m and ~320 kg ha^{-1} at 2800 m. At these two altitudes standing crop decreases again as early as August. At 2400 m, however, the maximum of ~260 kg ha^{-1} is reached in August, but goes into decline afterwards. This rapid decrease in standing crop on all plots in the mountains indicates a relatively high grazing pressure in comparison to the available phytomass.

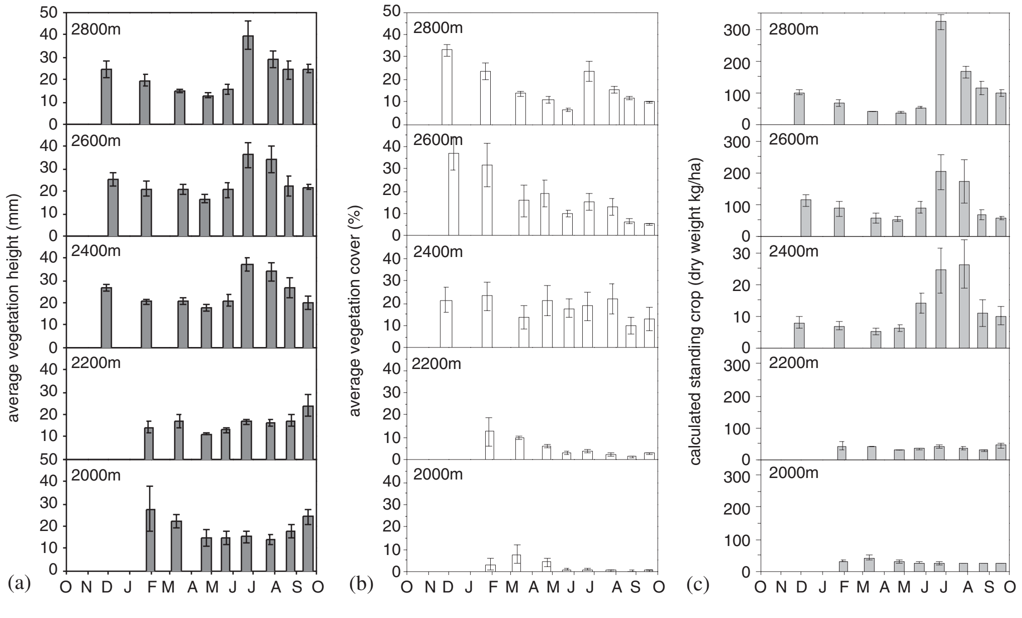

Fig. 3. Vegetation development along the altitudinal transect under grazing during the investigation period of October 2000–October 2001. (a) Vegetation height, (b) vegetation cover, and (c) estimated standing crop. Error bars indicate standard deviation.

In September 2001, at the end of the investigation period, standing crop on all plots in the mountains was approximately the same or even less than in November 2000. Thus, despite 2 more months of continuous grazing more phytomass was left 2 months after the end of the growing season in 2000 than directly at the end of growing season in September 2001. This indicates that the forage resources for herbivores were already depleted at this time and underlines the severity of the drought in the summer of 2001. This supports the idea that the mountains hold a reserve of phytomass for grazing herbivores, but cannot fully compensate for the failure in phytomass production at lower altitudes.

4.3. Distribution of large herbivores

The average distribution of large herbivores along the altitudinal transect during the investigation period shows a distinct altitudinal zonation (Fig. 4). The data basis

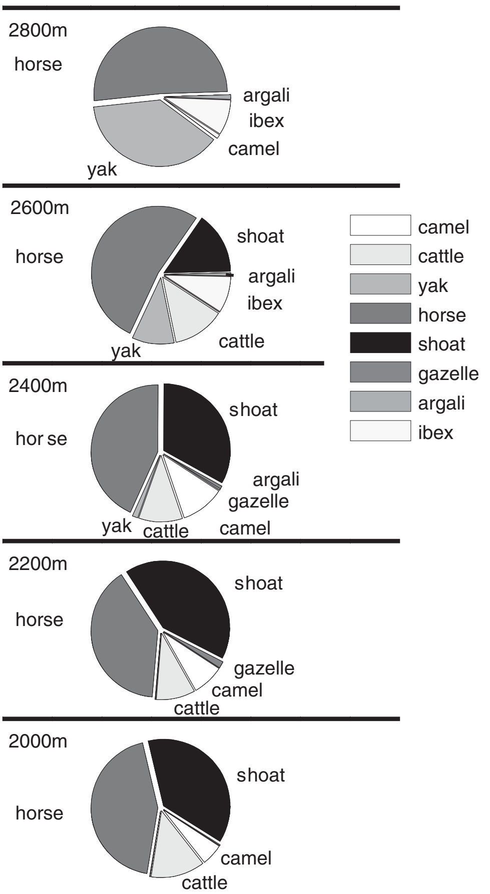

Fig. 4. Average species composition of livestock and wild herbivores along the altitudinal transect during the investigation period. Proportions are given in Mongolian livestock units, Mongolian Sheep Unit (MSU).

are livestock densities given in livestock units (MSU, see Table 1) as such represents the consumption of the different species more closely than that of simple livestock numbers.

In the distribution of large herbivores the difference between pediments and mountains is evident although the transition appears to be more gradual than the pattern observed from precipitation and vegetation. Data have to be interpreted with some caution, due to the higher number of observations performed on the pediment compared to that in the mountains which were pooled for the altitude of "2400 m". Thus, this altitude basically represents the situation on the upper pediment, and not that of the mountains.

Horses are dominant along the whole transect (Fig. 4). They are the only species which does not show a clear preference for any altitude. They account for up to 52% of the grazing pressure in the mountains and more than 40% on the pediments. The other livestock species are more restricted. Cattle, as well as small livestock, are mostly found on the pediments. They occasionally also climb into the mountains up to 2600 m, but never to the summit region (2750 m). While the proportion of cattle remains constant at about 10% from 2050 up to 2600 m, shoats seem to be confined more to the pediments, with a share of 33–41% there and only 15% at 2600 m.

Camels and yaks are restricted to desert steppe and mountain habitats, respectively (see also Lensch et al., 1996; Bazargur, 1998; Taishin et al., 1999). While camels are confined to the lower elevations, yaks occur only in the summit regions. Camels constitute 5–11% of the grazing herbivores on the pediment and are only rarely observed in the mountains. Yaks on the other hand prefer the high mountains and comprise 10% at 2600 m, and more than 30% at the summit region. They are occasionally seen at lower altitudes, especially in autumn and winter.

The distribution of wild herbivores is also very distinctive. Gazelles are only observed on the pediments and in low densities of 1–2% on average with the centre of distribution being around 2200 m. Wild sheep (argali) and ibex (*Capra sibirica*) have a similar distribution centred in the mountains. Argali account for 1% and the more numerous ibex for 10%. The rare and endangered argali use the mountains as habitat during summer, but descend to the upper pediments in winter (see also Huffman, 2003). Ibex on the other hand have only been observed in the mountains. This habitat distribution is typical: ibex generally prefer the more rugged terrain within the mountains while argali are fonder of hillier terrain (Reading et al., 1997, 1999b; Hess, 1988; Amgalanbaatar and Reading, 2000).

Although the comparison of observations of wild herbivores with livestock is expected to be biased by the larger flight distance of wild animals, the records for wild herbivores seem to be reliable as can be judged from dung observations next to the vegetation plots. Therefore, it is safe to state that livestock accounts for the main share of the grazing impact encountered along the whole transect. The figures show that the impact of livestock is generally much higher than that of wild herbivores. It is about 60 times larger on the pediments and about 6 times larger in the mountains. Even when taking the likely underestimation of wild animals into account, livestock outnumber large wild herbivores considerably. Large wild herbivores' densities in the mountains are higher than on the pediments by a factor of 24, but livestock densities are also 2.3 times higher in the mountainous area.

4.4. Comparison of livestock and wild herbivore densities

During the whole investigation period animal densities were constantly lower on the pediments than in the mountains (Fig. 5). This may not be a usual pattern and may be related to the untypically dry conditions when more forage was available in the mountains.

On the pediments, livestock densities were relatively high during winter, which can be explained by the fact that the winter camps of many herders are located around 1900 m. When herders start moving towards their summer sites from the middle of March onwards, some flocks of sheep and goats are probably driven out of vision. Livestock densities on the pediment remained low during summer and even diminished at the end of summer. This is paralleled by the lack of forage on the pediments which forces livestock and herders to seek better pasture on the northern side of the Dund Saykhan in the mountains, or by migrating further away. The main share of wild animals on the pediments comprises migrating gazelle herds which moved through the area in spring. Argali were observed occasionally at the upper end of the pediment during winter.

In the mountains, herbivore densities decreased in winter compared to the autumn of 2001. This is probably due to the higher snow cover inside the mountain range which made the area less accessible. Herbivore densities increased again in February reducing the remaining phytomass further (see Fig. 3c). After a sharp drop, especially in March, the livestock densities increased constantly until July, reaching 1.5 MSU ha^{-1} when herders moved their herds towards and into the mountain range. In August, livestock densities dropped to about 0.2 MSU ha^{-1}, when herders moved their animals to grazing grounds far away due to the lack of forage and equally bad prospects for the following winter. The distribution of livestock can be explained by the herders' migration strategies and phytomass availability, but the dynamics of wild herbivores need more thorough investigation to allow for proper interpretation.

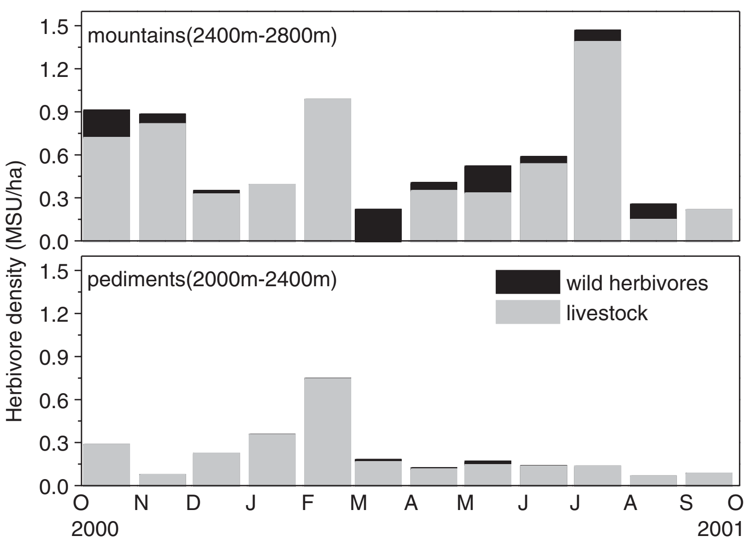

Fig. 5. Densities of wild animals (black) and livestock (gray) during the investigation period from October 2000–October 2001 within the mountains and on the pediments.

4.5. Relevance of findings for conservation planning

The data presented here illustrate a classic dilemma between nature conservation and human needs: Herders, as well as argali and ibex, need the limited resources of the high altitude environment especially during times of stress: The mountains are forage resources which can be exploited by livestock during times of drought, but on the other hand are habitat for the endangered argali. Besides the forage scarcity during drought, which hits wild and domestic herbivores alike, the influx of the livestock into the mountains during drought has more negative aspects for large wild herbivores:

- Forage competition with livestock becomes more severe than under normal conditions.
- The competition for water may be intensified as during drought conditions some herders move to springs which are otherwise used only infrequently by them and are normally exclusively available to wildlife (own observation and interviews).
- Wildlife is likely to be disturbed more frequently by herders searching for and herding their livestock in the mountains. A higher disturbance frequency in turn leads to a loss of calories during flights and reduces the time spent on forage consumption, thus further diminishing the nutritional situation of the wild herbivores.
- The proximity of herders to the animals and sightings during the herding of livestock may lead to a higher poaching rate, and
- to increased predation by domestic guard dogs (Reading et al., 2005a).

This poses a current threat to the populations in the Gobi Gurvan Saykhan as forage competition with domestic sheep and poaching are regarded as being the major reasons for the decreasing numbers of argali (Valdez, 1988; Reading et al., 1999c). Data on forage competition between ibex and livestock are much rarer, possibly because they are not endangered and live in even more rugged terrain that is less suitable for livestock (Amgalanbaatar and Reading, 2000). Competition between introduced livestock species and native large wild herbivores of similar sizes has been shown in different grassland regions around the world (Voeten and Prins, 1999; Campos-Arceiz et al., 2004), and has also been suggested to cause local extinction by competitive exclusion (Mishra et al., 2002).

The effect of livestock and herders intruding into the mountains on the large predators such as snow leopard, wolf, and lynx has not yet been investigated. Therefore, also the possible indirect effects on wild herbivores cannot be assessed in this study. It is conceivable that the presence of larger numbers of livestock in the mountains reduces the pressure on wild herbivores because the predators can switch to livestock as prey. On the other hand, the predators may also be disturbed by the presence of humans and change their diurnal rhythms thus increasing pressure on wild herbivores. However, until such indirect effects are investigated further, all these feedback mechanisms remain speculative.

As the mountainous areas of the Gobi Gurvan Saykhan are situated in a matrix of semi-desert, the habitat of argali and ibex resemble isolated islands, and are therefore particularly vulnerable (Primack, 1995). In the Gobi Gurvan Saykhan, Mongolian argali reach their south-eastern most point of distribution along the Gobi Altay (Anonymous, 1990). Until now the status of these populations cannot be assessed with any certainty. Genetic findings of relatively low spatial variance, but high within-population variance indicate a fair amount of genetic exchange along the Gobi Altay—at least until recently (Tserenbataa et al., 2004). For ibex no such data are available. Without further research on the population biology of argali—especially on the exchange between different populations and possibilities of re-establishment after local extinction—no further conclusions can be drawn. However, as these populations live at the distributional limit of the (sub)species they deserve special attention as warning indicators of far-reaching changes.

There is no easy way to mediate the conflict. An efficient management strategy of the populations which could support local conservation efforts and offer income alternatives such as the hunting fees paid by foreign trophy hunters is still lacking, but if established may be a helpful tool (Amgalanbaatar and Reading, 2000). The only recommendation on a local scale is to educate the herders about the situation in order to raise awareness and to encourage early migration in years of drought. This could be done by supplying information on regions with better pasture conditions, giving assistance for transport, and finally, providing supplementary fodder to those still unable to move. In the long term, and on a larger scale, better management strategies for large livestock numbers are needed. A functioning market for animal products is necessary to encourage the sale of surplus livestock during good times in anticipation of the next adverse situation (drought). Consequently, when forage is scarce, fewer animals would have to share the remaining fodder and grazing competition with wildlife would be reduced. Furthermore the herders could sell their livestock when the prices are better and thus make up for the reduced number of animals.

5. Conclusions

Although livestock and wildlife have coexisted in the area since the arrival of livestock thousands of years ago (Fernandez-Gimenez, 1999), the survival of the argali in the Gobi Gurvan Saykhan mountains is not at all secure in a changing economic and climatic environment. Periods of increased livestock numbers, such as that observed in the late 1990s (National Statistical Office of Mongolia, 1996, 2003), may very well intensify forage competition and disturbance by humans. However, livestock numbers are not likely to increase further as they are largely controlled by the variability of the precipitation regime (Retzer and Reudenbach, 2005). Additionally, climate change can make the dry steppe ecosystems more vulnerable to grazing, making adaptations in grazing management necessary (Christensen et al., 2004). Furthermore, the climatic pattern may be about to change from frequent oscillations between dry and wet years to multi-year dry and wet periods of which the 3-year drought from 2001–2003 is just one example (data Mongolian Meteorological Service, Retzer, 2004; Retzer and Reudenbach, 2005). If this trend continues, it will directly affect the populations of wildlife as the population's chances to recover from a multi-year drought are much smaller than from a single-year drought (Illius et al., 1998; Oba, 2001; Patterson and Power, 2002). Metapopulations may be especially sensitive to these changes, as has already been shown for mountain sheep in California (Epps et al., 2004). For these reasons the interactions between livestock, wildlife, and possible climatic changes have to be observed carefully in the future.

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