



## Short communication

## Comparison of vegetation changes along grazing gradients with different numbers of livestock

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## ARTICLE INFO

## Article history:

Received 13 July 2008

Received in revised form

5 January 2009

Accepted 11 January 2009

Available online 15 February 2009

## Keywords:

Grazing intensity

Mongolia

Plant functional type

Rangeland ecology

Semi-arid

## ABSTRACT

The objective of this study was to clarify whether the changes in percent cover of plant functional types (i.e., life forms and growth forms) along a grazing gradient reflect the livestock number, which would reinforce the reliability of using a grazing gradient design and improve the management of rangeland. We selected two livestock camps that for many years have had different numbers of livestock, with approximately six times more sheep-equivalents at site 1 than at site 2. Vegetation was sampled in 10 quadrats on five transects along the grazing gradient at each site. In each quadrat, we recorded percent cover of each plant species. Our findings suggested that vegetation changes along the grazing gradient under different livestock numbers were characterized by changes in the cover of life forms: perennial species were replaced by annual species near the camps (10–50 m). However, we did not find growth form change that reflected the difference in the number of livestock.

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## 1. Introduction

Heavy grazing causes significant changes in vegetation. The vegetation degradation process is generally characterized by changes in plant functional types, that is, by changes in life forms such as an increase in the abundance of annual species with a concomitant decrease in perennial species (McIntyre and Lavorel, 2001; Pakeman, 2004; Diaz et al., 2007), and several studies have also reported this to be the case in Mongolia (Fernandez-Gimenez and Allen-Diaz, 1999, 2001; Sasaki et al., 2005, 2007). Moreover, studies of the steppes of Inner Mongolia, northeastern China, and North America reported a change in growth form: the original dominant caespitose grasses were being replaced by rhizomatous grasses due to the change from moderate or low-level to heavy grazing (Mack and Thompson, 1982; Milchunas et al., 1988; Xie and Wittig, 2003).

To facilitate the management of arid and semi-arid ecosystems for both biological conservation and sustainable use, understanding the response of vegetation to different grazing intensities is critical.

According to Fernandez-Gimenez and Allen-Diaz (2001), grazing gradients provide a way to observe vegetation changes under different grazing intensities in areas where it is not possible to manipulate livestock densities of free-ranging grazers. Previous studies used the distance from a source of water (Fernandez-Gimenez and Allen-Diaz, 1999, 2001; Sasaki et al., 2005) or from a livestock camp (Whalley et al., 1978; Rogers and Whalley, 1989; Riginos and Hoffman, 2003; Sasaki et al., 2007) to assess the impact of grazing on rangeland structure and function, while controlling the background environmental factors.

In studies of grazing gradients, the number of livestock should be one critical factor affecting the patterns of vegetation responses to the variation in relative grazing intensity (Sasaki et al., 2008). Most previous studies using the grazing gradient approach assumed that the plant community differs according to the grazing intensity along the gradient, and a few such studies investigated the effects of the period of grazing along the gradient (Adler et al., 2004; Nangula and Oba, 2004) and the effects of livestock number over a relatively short period of grazing (Dorrough et al., 2004). If the grazing gradient does differ with the number of livestock, however, it remains unclear how vegetation would change along the grazing gradient. Therefore, in this study we attempted to clarify the influence of livestock number on changes in vegetation, thus reinforcing the reliability of studies using a grazing gradient design and improving the management of rangeland. The objective of this study was to clarify whether the changes in the cover of

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plant functional types—that is, life form (annual vs. perennial) and growth form (caespitose vs. rhizomatous)—along a grazing gradient reflect the livestock number.

## 2. Materials and methods

### 2.1. Study area

The study area is located in the Hustai National Park (HNP), Mongolia (47°46′–48°N, 105°54′–56°E, mean elevation 1378 m a.s.l.). Based on the data from the HNP climatic station, from 1999 to 2005 the mean seasonal temperatures were approximately 13 °C from April to September and –12 °C from October to March, and the mean annual precipitation was approximately 232 mm (CV, 31%). HNP is surrounded by a buffer zone, where the number of livestock has been controlled and managed, and the HNP has records of the number of livestock grazing in the area.

We selected two livestock camps that had long-term differences in the number of livestock but approximately the same seasonal use and environmental conditions. These camps are used by herders during the winter and spring to gather their livestock together at night. Both sites are located on the eastern side of a mountain and have a slight slope (2–5%). Based on soil analysis (pipette method 3A1: USDA-NRCS, 1996), the soil texture at both sites was loamy sand and the soil type was classified as “dark chestnut” (according to HNP documents).

These two camps had records of the number of livestock for every year from 1977 to 2006, and the number of livestock before 1977 was more or less the same as during these years. These numbers were reported by owners of the livestock camps, who said these same camps had been used for at least a few hundred years. In this study, we use the number of livestock as an indication of grazing intensity, because grazing gradients are representative of cumulative grazing intensity (Adler and Hall, 2005).

The livestock were mainly sheep and goats. The sheep-equivalent coefficients used by the National Statistical Office of Mongolia are 7.0, 5.0, 6.0, 1.0, and 0.9 for horse, camel, cattle, sheep, and goat, respectively. The mean annual number of livestock at each study site from 1977 to 2006 was as follows: site 1, horse  $23 \pm 1$ , camel  $1 \pm 0$ , cattle  $22 \pm 2$ , sheep  $200 \pm 32$ , and goat  $472 \pm 34$ , for a sheep-equivalent of  $923 \pm 62$ ; site 2, horse  $9 \pm 1$ , camel  $0 \pm 0$ , cattle  $1 \pm 1$ , sheep  $24 \pm 3$ , and goat  $46 \pm 14$ , for a sheep-equivalent of  $139 \pm 19$ . Thus, site 1 has had a larger number of livestock than site 2 over the long term.

### 2.2. Sampling design

A vegetation survey was performed in early August 2007. The grazing gradient was set parallel to the contour lines from each camp to minimize the effects of topography. We set five survey transects perpendicular to the gradient at 10, 50, 100, 200, and 500 m from the camps. Vegetation was sampled in 10 quadrats ( $1 \times 1$  m) established at intervals of 1 m along each transect. In each quadrat, we recorded cover (%) for each species. Our sampling procedures were determined *a priori* based on previous work in Mongolian rangelands (Fernandez-Gimenez and Allen-Diaz, 1999, 2001; Sasaki et al., 2005, 2007). In those studies, transects were set 500–2000 m outward from camps, but our study sites included concave slopes at distances between 500 and 1000 m from the camps. Therefore, we considered 10–500 m transects as the most representative. There were no features other than the camps, such as wells, that affected animal movement.

### 2.3. Data analysis

We analyzed whether the changes in the cover of plant functional types, with a focus on life forms and growth forms, along a grazing gradient are related to the livestock number. Data for each gradient were subjected to detrended correspondence analysis (DCA; Hill, 1979) using values for plant cover. We examined the correlations between the DCA axes and distances from camps using Pearson's correlation coefficients. All species were classified by life form (perennial grasses, perennial forbs, annual forbs, shrubs), and the dominant species of perennial grasses were classified by growth form (caespitose or rhizomatous). These classifications were based on Jigjidsuren and Johnson (2003), Grubov (2001), and information provided by Mongolian botanists. We calculated the ratio of each life form along the gradient from each site, using relative values for plant cover. Dominant species were determined based on the relative values of each species at each transect. The differences in life form and growth form were considered fixed effects in an ANOVA. When site  $\times$  distance interactions were statistically significant, the two-way ANOVA was followed by post-hoc contrasts using *t*-tests with Bonferroni corrections for the within-distance comparisons. Before performing these analyses, all dependent variances were assessed for normality of distribution and heterogeneity of variances. We used  $\ln(y + 1)$  transformation where needed (Sokal and Rohlf, 1995). The level of significance was  $P < 0.05$ .

## 3. Results

There was a negative correlation between DCA axis 1 and the distance from camp ( $r = -0.68$ ,  $P < 0.001$ ), and this axis represented the vegetation differences with increasing distance from the camps.

The cover values of perennial species were different between sites (Table 2), and the value at site 2 was higher than that at site 1 (Fig. 1). These cover values increased with increasing the distance from the camps at both sites. The cover values of annual forbs (mostly *Chenopodium album*) were significantly higher at site 1 (higher grazing intensity) than at site 2 at the 10-m transects (Fig. 1). Thus, the pattern of life forms was a high value of annual forbs cover within 10 m of the camp at site 1 and a high value of perennial species far from the camps at site 2.

The values of caespitose grasses (mostly *Stipa krylovii*) were higher at site 1 than at site 2. At 200 m from the camps, *S. krylovii* was the dominant species at both sites (Table 1). The values of rhizomatous grasses (mostly *Leymus chinensis*) were significantly higher at site 2 than at site 1 (Fig. 1). In addition, the cover of rhizomatous grasses at the 50-m transects was significantly greater than at other transects at site 1 and significantly greater at site 2 than at site 1.

## 4. Discussion

Despite the limitation of small sample size, our findings suggest that vegetation changes along the grazing gradient at sites with different numbers of livestock (Fig. 1) were characterized by changes in the cover of various life forms, from annual forbs to perennial species, close to the camps (10–50 m). Although we did not find changes in growth form from rhizomatous to caespitose grasses according to the difference in livestock number, the lower value of rhizomatous grasses at site 1 than site 2 may indicate the stronger grazing intensity at site 1.

DCA axis 1 indicated differences in the vegetation at each transect along each grazing gradient (Fig. 1), with more annual forbs near the camps and more perennial species far from the camps at both sites.

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