

Short communication

Marmot disturbances in a Mongolian steppe vegetation

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Abstract

We conducted a study in Mongolia on the *Stipa* steppe, which is the main habitat for the Siberian marmot (*Marmota sibirica*). The marmots create mounds that differ greatly in vegetation cover. Three types of mounds were distinguished, depending on the species dominating the vegetation on the mounds: an *Artemisia* type of mound, *Leymus* type and a *Stipa* type. It is hypothesized that the three types of mound represent a series of succession.

The activities of the marmots lead to enhanced forage quality on the *Artemisia* and *Leymus* types of mound, as indicated by increased nitrogen concentrations in the on-mound vegetation.

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The burrowing activities and grazing of rodents can have significant effects on plant species abundance and community structure, as was shown for kangaroo rats which play a key role in the maintenance of desert grasslands (Brown and Heske, 1990; Heske et al., 1993; Fields et al., 1999), and for the prairie dogs in the North American grasslands (Coppock et al., 1983; Archer et al., 1987; Detling, 1998). These animals have a great impact on the landscape by creating mounds and altering vegetation structure and composition (Whitford and Kay, 1999).

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In the forest steppe region of Mongolia, the typical *Stipa* steppe is one of the main habitats of the Siberian marmot (*Marmota sibirica*) (Gunin et al., 1999). The marmots are large herbivorous rodents that burrow and live colonially and graze mainly on grasses and herbs. Our study was conducted on the *Stipa* steppe at Hustai National Park, located at 100 km west of Ulaan Baatar, Mongolia (47°50'N, 106°00'E). The vegetation of the *Stipa* steppe is made up of a rich variety of grasses and herbs and dominated by the bunchgrass *Stipa krylovii* (Hilbig, 1995; Wallis de Vries et al., 1996). In the park live several small rodent species, such as the long tailed souslik (*Citellus undulates*), the grey—and the striped hamster (*Cricetulus migratorius* and *barabensis*), and the bigger Siberian marmot (*M. sibirica*) that is very abundant. The overall marmot density in the national park was 1.16 marmots per ha in 1998, which is normal for most of the steppe in Mongolia (Takhi reintroduction centre, 1998). In the areas where the study was conducted the density was higher and reached a level of 3.85 marmots per ha, and 6.37 marmots per colony. Colonies appeared to occur somewhat aggregated. We examined the relation between marmot mounds and the species composition, species cover, diversity, plant biomass and soil- and plant-N-concentrations of the local vegetation.

Three types of mounds were distinguished: a type in which the vegetation on the mounds was dominated by *Artemisia adamsii*, a type in which the mounds were dominated by *Leymus chinensis* (*Elymus chinensis*, Grubov, 2001), and a type in which the mounds were dominated by *S. krylovii*. In the summers of 2002 and 2003, three marmot mounds of each type of mound were selected randomly and two plots were established on each mound with an additional two plots in the common steppe vegetation 3 m away from the mound.

The on-mound location was characterized by an entrance of a marmot hole with a small patch of bare soil around the entrance, and a surrounding vegetation which was distinct from the normal steppe vegetation in that it showed clear signs of disturbance by the activities of the animal. Marmot dung in front of the entrance indicated that the mound was still in use by marmots. All selected mounds were inhabited.

The off-mound location consisted of the normal steppe vegetation, without burrows of marmots.

In August 2002 and 2003, measurements of species frequency and species cover were performed in two plots in the vegetation of the on-mound location and two plots in the off-mound location of the selected mound.

In the plots a 0.5×1 m grid divided into 10×10 cm sections was laid on the vegetation, and the occurrences of all species in each of the sections was recorded, giving the species frequencies (max. 50). For all species with a cover of $\geq 1\%$ in the entire plot, we visually estimated their percentages cover in each plot.

Species richness is calculated as the number of species that occur within one plot.

The above-ground biomass was sampled by clipping two strips of 50×50 cm in each of the on-mound and off-mound plots. The vegetation was clipped at ground level and dried in an oven at 70 °C for 48 h and weighed.

To determine soil characteristics one soil core per strip with a diameter of 2.8 cm and 7 cm deep was taken. Belowground plant parts were removed and the soil was oven dried at 70 °C for 48 h.

Total organic nitrogen, phosphorus and potassium concentrations in the above-ground biomass was determined after kjeldahl digestion using a continuous flow analyzer (SKALAR, Breda, Netherlands).

A two-way analysis of variance (ANOVA) was used to analyze the effects and the interactions between factors ‘type of mound’ (*Artemisia*, *Leymus*, *Stipa*, $df = 2$) and ‘sampling location’ (on-mound, off-mound, $df = 1$). With a one-way ANOVA the significance of the effect of ‘sampling location’ was tested for the three types of mound separately and in the same way the effect of ‘type of mound’ was tested for on-mound and off-mound separately. A Bonferroni correction was applied to correct for multiple comparisons.

In order to classify the vegetation of the on- and off-mound plots of the three types of mound, we performed a two-way indicator species analysis (Hill, 1979; Jongman et al., 1995). Default cut levels (0, 2, 5, 10, 29) were used.

We performed a correspondence analysis (CA) with species frequency data of 2002 and 2003 (Jongman et al., 1995), to analyze the effect of disturbance by marmots on the overall composition of the on- and off-mound vegetation of the different types of mounds, using the statistical package MVSP 3.0 (Kovach Computing Services, Anglesey, UK). The correlation coefficients between the concentrations of N and P in the vegetation and soil (Nveg, Pveg, Nsoil, Psoil) and the first and second ordination axis were calculated to evaluate which factors may explain these axes.

Clear differences in cover of different species were found between the on- and off-mound vegetation of the *Artemisia* and the *Leymus* type of mounds in 2002 and 2003, but not for the *Stipa* type of mound (Fig. 1). The three name-giving species each dominated the on-mound vegetation of each of the three types of mounds, respectively, but *Stipa krylovii* dominated the off-mound vegetation of all the three types of mounds.

There were several species (*Astragalus brevifolius*, *Bupleurum bicaule*, *Allium bidentatum*, *Haplophylum dauricum*), which were present in the on-mound vegetation of the *Stipa* type of mound and the off-mound of all three types of mounds, while they were absent or had a lower frequency on the *Artemisia* and the *Leymus* types of mound (Table 1). Therefore, species richness was highest in the on-mound vegetation of the *Stipa* type of mound and also relatively high in the off-mound vegetation of all the types of mound, while the species richness in the on-mound vegetation of the *Artemisia* type of mound and of the *Leymus* type of mound was much lower (Table 1).

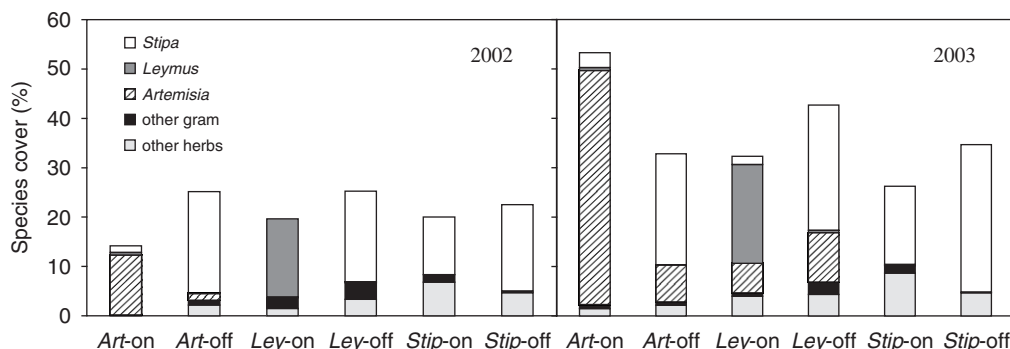


Fig. 1. Species cover on the different types of marmot mounds (*Artemisia*-, *Leymus*- and *Stipa*-type) on the mounds and off the mounds in 2002 and 2003.

Table 1

Species frequencies and species richness for the different types of marmot mounds, on the mounds and off the mounds, for the years 2002 and 2003 ($n = 12$)

	Frequency					
	Art type	Ley type	Stip type	Art off-mound	Ley off-mound	Stip off-mound
Graminoids						
<i>Stipa krylovii</i>	4.7	3.3	23.1	27.8	26.5	28.3
<i>Leymus chinensis</i>	3.5	31.2	0.8	1.3	2.5	.
<i>Poa attenuata</i>	.	0.2	0.2	0.4	3.3	0.6
<i>Agropyron cristatum</i>	.	3.3	7.0	0.6	3.5	4.6
<i>Cleistogenes squarrosa</i>	0.4	0.2	1.1	1.3	3.9	0.7
<i>Koeleria macrantha</i>	.	0.2	4.1	2.0	2.8	2.3
<i>Stipa sibirica</i>	.	.	1.4	.	.	1.1
<i>Carex duriuscula</i>	5.8	4.5	8.5	4.9	13.4	7.1
Forbs						
<i>Artemisia adamsii</i>	33.3	4.3	.	11.0	3.2	0.2
<i>Thermopsis dahurica</i>	.	0.1	.	.	0.1	.
<i>Caragana pygmaea</i>	.	0.9	2.3	1.7	1.1	0.8
<i>Astragalus brevifolius</i>	0.1	.	1.7	5.7	3.6	6.7
<i>Oxytropis myriophylla</i>	0.1	.	.	.	.	.
<i>Artemisia frigida</i>	.	1.1	8.5	3.8	4.2	10.2
<i>Potentilla acaulis</i>	.	.	2.3	.	0.1	3.3
<i>Potentilla bifurca</i>	.	1.0	11.6	0.8	3.5	0.8
<i>Cymbaria dahurica</i>	2.4	0.3	1.7	1.9	2.7	1.6
<i>Ptilotrichum canescens</i>	2.0	.	0.5	0.3	0.8	0.6
<i>Goniolimon speciosum</i>	.	0.1	0.1	.	0.3	.
<i>Bupleurum bicaule</i>	.	.	0.8	0.4	0.1	0.4
<i>Pulsatilla bungeana</i>	.	.	.	.	0.3	.
<i>Saussurea salicifolia</i>	0.1	.	0.3	.	0.3	0.8
<i>Haplophyllum dauricum</i>	0.1	.	0.3	0.8	0.7	1.0
<i>Androsace incana</i>	.	.	0.1	.	.	.
<i>Allium bidentatum</i>	.	0.1	0.8	2.4	0.5	5.3
<i>Iris trigida</i>	.	.	0.9	.	0.3	1.1
<i>Veronica incana</i>	.	0.4	.	.	2.3	.
<i>Heteropappus biennis</i>	0.1	2.4	2.9	0.3	1.5	2.5
<i>Amblynotus rupestris</i>	.	1.6	1.9	0.1	0.3	5.6
<i>Chenopodium album</i>	1.9	1.4	3.6	1.5	3.7	3.9
<i>Bupleurum scorzonifolium</i>	.	.	0.7	.	0.6	0.5
<i>Stellera chamaejasme</i>	.	.	.	.	0.4	.
<i>Potentilla conferta</i>	0.3	0.1	0.3	.	0.8	0.6
<i>Orostachis malacophylla</i>	.	.	1.6	.	.	4.9
<i>Potentilla multifida</i>	.	1.7	0.2	.	0.6	0.3
<i>Sibbaldianthe adpressa</i>	0.6	0.4	.	0.8	0.5	.
<i>Arenaria capillaries</i>	.	.	.	0.5	0.4	.
<i>Potentilla tanacetifolia</i>	0.1	.	.	.	.	.
<i>Allium spec</i>	.	.	0.5	.	.	0.6
<i>Cirsium esculentum</i>	.	.	.	.	0.1	.
<i>Ephedra sinica</i>	.	.	.	.	.	0.1
Species richness	4.5	6.2	10.9	8.3	10.3	11.3

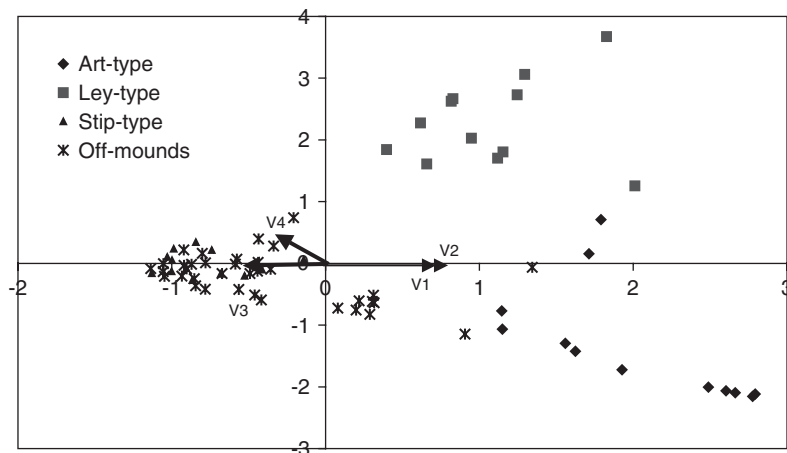


Fig. 2. Scores of a correspondence analysis (CA) of the on- and off-mound sites of the *Artemisia*-, *Leymus*- and *Stipa*-types of mounds. v1 = vector of N-concentration in the vegetation (0.68; -0.04); v2 = vector of P-concentration in the vegetation (0.78; 0.00); v3 = vector of N-concentration in the soil (-0.56; 0.05); v4 = vector of P-concentration in the soil (-0.31; 0.37).

A Twinspan classification (not shown) reproduced the division in the three types of on-mound vegetation, and included all off-mound plots with the *Stipa* on-mound vegetation into one large vegetation unit. In the first subdivision of the *Stipa* vegetation the on- and off-mound vegetations were distinguished, with *Astragalus brevifolius*, *Saussurea salicifolia* and *Allium bidentatum* positively discriminating the off-mound vegetation from the on-mound vegetation.

The CA confirms the Twinspan classification (Fig. 2): the on-mound *Artemisia* and *Leymus* plots are clearly separated from the *Stipa* plots and the off-mound plots along the first axis, while the second axis separates the *Artemisia* and *Leymus* on-mound plots. The first axis explains 15.7% of the variation; the second axis explains 13.1%.

The N- and P-concentrations in the on-mound vegetation of the *Artemisia* and *Leymus* type of mounds were significantly higher than in the off-mound vegetation (Fig. 3). This explains the significant effect of sampling location and type of mound on the nitrogen and phosphorus concentration in the vegetation. In this respect the *Stipa* type of mound differed from the other two types of mounds, as there were no on- and off-mound differences in N- and P-concentration of the vegetation.

The great difference in species cover and composition that exists between mounds dominated by *Artemisia adamsii* or *Leymus chinensis* and their surrounding off-mound vegetation probably results from disturbance. The *Stipa* type of mound seems to be less disturbed, because the vegetation on these mounds is similar to its surrounding vegetation. This could be the result of less burrowing, or because the initial creation of the mound was longer ago and the vegetation had already recuperated from the disturbances. Visual inspection, e.g. around the entrance of the burrow, suggested the latter.

Disturbance by marmots decreases species richness as it was found that species richness was highest in the surrounding *Stipa* vegetation and on the *Stipa* dominated mounds, while it was much lower on the more disturbed *Artemisia* and *Leymus* dominated mounds.

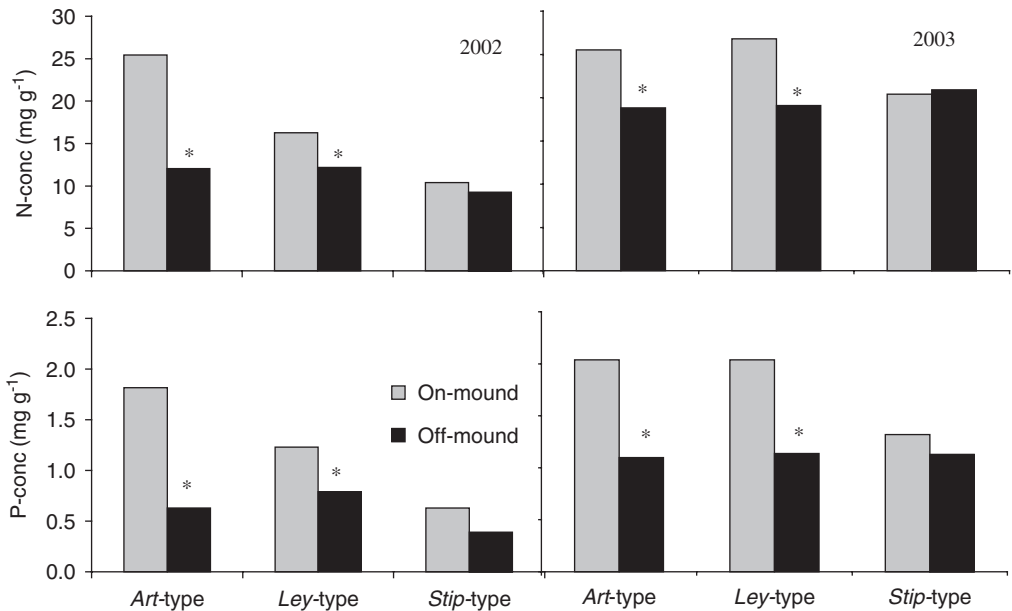


Fig. 3. N- and P-concentrations in the vegetation of the different types of marmot mounds (*Artemisia*-, *Leymus*- and *Stipa*-type) on the mounds and off the mounds in 2002 and 2003. *Indicate a significant difference between the on- and off-mound location $p < 0.05$.

We hypothesize that the different types of mounds represent a series of succession, considering the growth habit of the species dominating the different types of mounds.

When a mound is created by burrowing marmots, the mound initially consists of bare soil. This can be easiest colonized by *Artemisia adamsii*, a perennial forb, generally occurring in the steppe vegetation. It produces many, easily dispersed seeds that establish well in degraded vegetation and bare soil (Yankai and Shunji, 1990; Hilbig, 1995). The perennial grasses *Leymus chinensis* and *Stipa krylovii* do produce seeds, but under the relatively dry conditions seedlings are not commonly found and do not establish well (Min et al., 1990; Wang et al. 2001, *Leymus chinensis* = *Aneurolepidium chinensis*). For both species, vegetative growth is by far their most common way of site colonization. *Leymus* shows a fast lateral spread by forming rhizomes (Min et al., 1990; Wang et al., 2001; Jigjidsuren and Johnson, 2003; Van Staaldin and Anten, 2005). *Stipa*, however, is a caespitose grass with a much slower lateral spread (Grubov, 2001; Van Staaldin and Anten, 2005). It does not make long rhizomes but it relatively slowly increases its bunch size by growing more tillers. *Stipa* bunches can break up as parts of the bunch die off (Van Staaldin et al., submitted for publication). Given these growth habits of the species it is suggested that new, bare mounds are first colonized by *Artemisia*, then invaded by *Leymus*, and gradually regenerate to the normal *Stipa* steppe.

Disturbances by marmots led to enhanced forage quality on the *Artemisia* and *Leymus* types of mound, as indicated by increased nitrogen concentrations in the

vegetation of these types of mound. Besides the higher nitrogen concentration in the above-ground biomass, the total above-ground nitrogen yield also was greater on the *Artemisia* and *Leymus* mounds. This was because the above-ground biomass was similar or greater on the mounds than in the surrounding off-mound vegetation. This corresponds fully with findings in other studies on burrow disturbances in other dry parts of the world (Brown and Heske, 1990; Whitford and Kay, 1999).

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