Snow Leopard REPORTS

Research Note

Snow Leopard Reports, 2 (2023): 10-16
http://dx.doi.org/10.56510/slr.v2.12904

Variation in plant composition along a gradient of increasing distance from wells in a mountain steppe in southern Mongolia

Temuulen Ulziibadrakh[1] · Bayarsaikhan Uudus[1] · Purevjav Lkhagvajav[2] · Justine Shanti Alexander[3,4] · Örjan Johansson[3,5] · Koustubh Sharma[3,6] · Gustaf Samelius[3,7,8]

1 National University of Mongolia, Ulaanbaatar, Mongolia
2 Snow Leopard Conservation Foundation, Ulaanbaatar, Mongolia
3 Snow Leopard Trust, Seattle, USA
4 University of Lausanne, Lausanne, Switzerland
5 Swedish University of Agricultural Sciences, Uppsala, Sweden
6 Snow Leopard Foundation, Bishkek, Kyrgyzstan
7 Nordens Ark, Hunnebostrand, Sweden
8 Corresponding author: gustaf@snowleopard.org

Key words
desert steppe, livestock grazing, plant composition, South Gobi

ARTICLE HISTORY: Submitted 15 March 2023
Accepted 15 August 2023
First published online 4 September 2023
CORRESPONDING EDITOR: Lingyun Xiao

Abstract

Habitat degradation and heavy grazing by livestock are common conservation challenges across the steppes of Mongolia and Central Asia. Livestock grazing patterns are generally not uniform and are typically greater near campsites and watering holes. In this study, we examined how plant composition in a mountain steppe in southern Mongolia varied along a gradient of increasing distance from wells. We found that the cover and average height of *Ephedra prezewalskii* increased with increasing distance from the wells whereas soil chemistry and the other variables of plant composition that we examined were similar along the gradient of increasing distance from the wells. These results suggest relatively limited impact of livestock grazing on plant composition in our study. However, our study was limited in space and time and further studies are needed to understand the impact of livestock grazing in this mountain steppe in southern Mongolia.

Introduction

Recent decades have seen a significant decline in grassland and rangeland quality across the steppes of Mongolia and central Asia where a large portion of the steppes are now considered degraded (Angerer et al 2008, Berger et al. 2013, Hilker et al 2014). The change in grassland and rangeland quality is attributed both to increasing livestock numbers and to climate change (Angerer et al 2008, Marin 2010, Hilker et al 2014). Livestock grazing patterns generally vary in space and time and are often greater near campsites and wells that are used frequently and often on a daily basis (Fernandez-Gimenez and Allen-Diaz 1999, Pringle and Landsberg 2004, Stumpp et al 2005). Distance from wells therefore have often been used as a measure of grazing pressure that is highest at the wells and decrease with increasing distance from the wells (Fernandez-Gimenez and Allen-Diaz 1999, Narantsetseg et al 2018). Heavy grazing by livestock can have negative impacts on wild herbivores and conservation of wild herbivores in Central Asia therefore depends to a large extent on managing and mitigating the impacts of livestock grazing and climate change (Mishra et al. 2004, Berger et al. 2013). The objective of this study was to examine how plant composition in a mountain steppe in southern Mongolia varied along a gradient of increasing distance from wells.

Methods

Study area

This study was conducted in the Tost Mountains (43° N and 100° E) in southern Mongolia in June and July 2022. The area is part of the Gobi Desert with annual precipitation less than 130 mm and the temperature ranging between -30 in winter and 40° C in summer. Tost Mountains and the surrounding steppes are part of Tost-Tosonbumba Nature Reserve established in 2017 and are home to iconic mammals such as snow leopards (*Panthera uncia*), ibex (*Capra Sibirica*), and argali (*Ovis ammon*). The vegetation is sparse with short grasses and shrubs common in the valley steppes and small shrubs common in the gullies and on the mountainsides. Tost Mountains are home to about 90 semi-nomadic herder families that tend to stay in the mountains in winter (early November–late March) and in the surrounding steppes during the rest of the year (Mijiddorj et al 2018). The size of the Tost mountain are about 1,500 km^2 and the average livestock holding was about 400 livestock per family that comprised mostly of goats (*Capra aegagrus*) and sheep (*Ovis aries*) but also horses (*Equus ferus caballus*) and camels (*Camelus bactrianus*) (Samelius et al. 2020). Goats and sheep are herded and brought to wells on a daily basis whereas horses and camels are largely free-ranging and visit wells and waterholes less frequently (Mijiddorj et al 2018).

Vegetation sampling

We sampled the plant composition at two wells in the Tost Mountains that were visited on a daily basis by goats and sheep. At these two wells, we put two transect lines at each well (one to the north and one to the south) where we sampled the plant composition every 100 meters

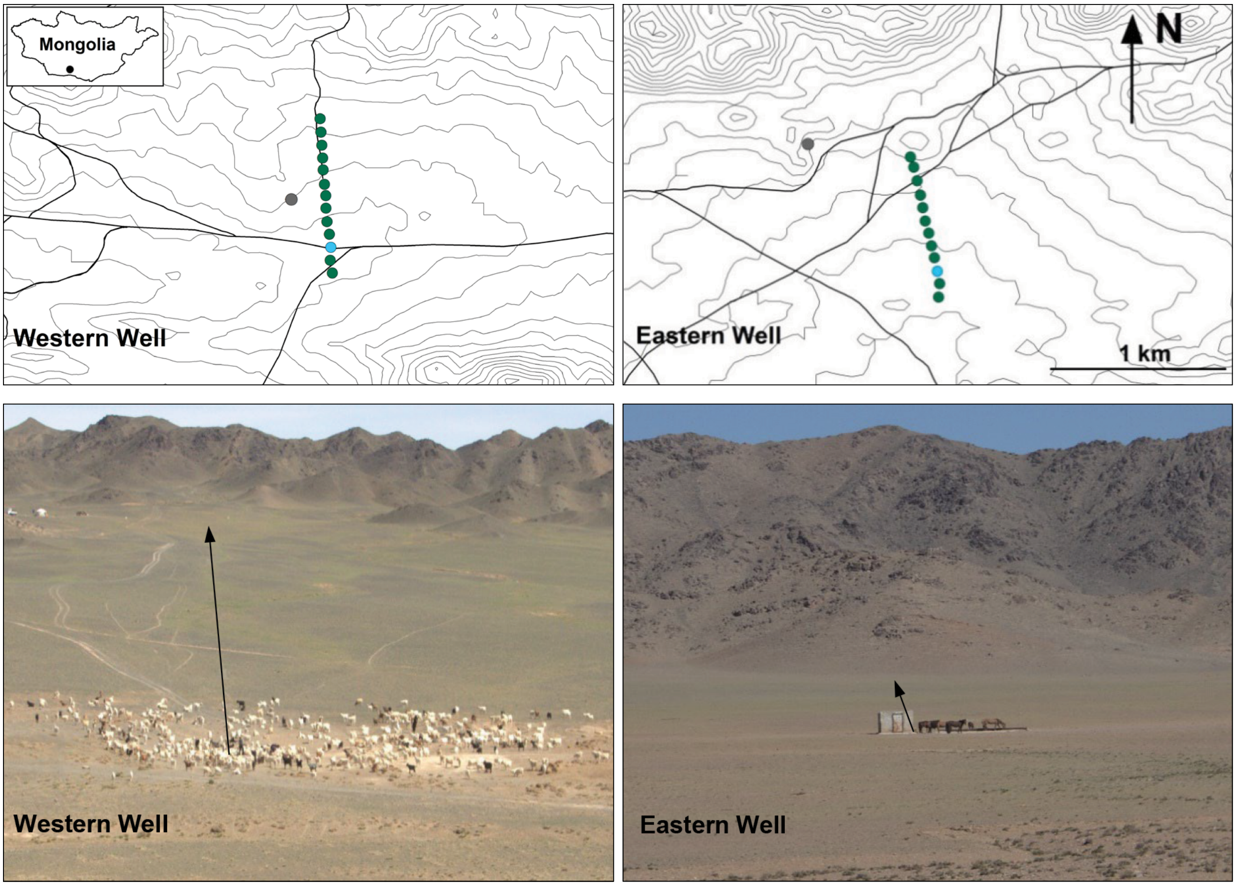

Figure 1: *Location of vegetation sample plots along transects of increasing distance from wells in the mountain steppes of the Tost Mountains in southern Mongolia. The transect lines and sample plots are shown by green dots on the maps and by the black arrows on the photographs. The wells are shown by blue circles on the map and by the start of the arrows in the photographs. Also shown on the maps are small roads (thick grey lines), herder camps (grey circles), elevation curves (thin grey lines), and the location of the Tost Mountains in Mongolia (insert map in upper left map). The wells were visited daily by goats and sheep and occasionally by horses and camels.*

(Figure 1). We standardized the habitat for the transects to be mountain steppe to avoid variation caused by habitat type which resulted in the transects to be of different lengths (n = 23 sample plots from four transects that ranged from 200 to 1,000 m, Figure 1). We sampled the vegetation in June and July, and on each of the sample plots, we sampled (1) total plant cover and plant cover for each of the five most common species based on cover for all sample plots combined (called most common species hereafter) at 3 x 3 m sample plots and (2) average height for each of the five most common species at 1 x 1 m sample plots (where we calculated average height for all plants on the plot). The 1 x 1m sample plots were located at the centre of the 3 x 3 m sample plots. In addition, we also measured soil pH and soil moisture at the centre of the sample plots and we calculated Shannon-Wiener indices for each 3 x 3 m sample plot based on plant cover of all species present at each plot and used this as our measure of plant diversity.

Statistical analyses

We examined how plant diversity, average height of the five most common plant species, soil pH, and soil moisture varied in relation to distance from wells by mixed linear models where we used sample plot as random factor to control for repeated measures and where we included month to control for seasonal variation (n = 23 sample plots from four transects and two wells). Similarly, we examined how overall plant cover and plant cover of the five most common species varied in relation to distance from wells by beta regressions where we used sample plot as random factor to control for repeated measures and where we included month to control for seasonal variation (n = 23 sample plots from four transects and two wells). For the beta regressions, we re-scaled plant cover by following Douma and Weedon (2019). All analyses were performed in program R version 3.6.2 (R Development Core Team, 2014).

Results

Mean plant cover for all plants combined in June and July was 23% (range = 5-43%, Table 1). *Stipa glareosa* was the most common species in June and July in that it had the highest cover at 39 of 46 sample plots. Mean cover for *Stipa glareosa* in June and July was 13% (range = 1-36) and mean cover for the other four of the five most common species in June and July were 1.2% for *Artemisia xerophytica* (range = 0-5%), 0.8% for *Ephedra przewalskii* (range = 0-7%), 0.4% for *Artemisia frigida* (range = 0-2%), and 0.2% for *Oxytropis aciphylla* (range = 0-2%).

Plant composition variable	Mean	Range	St. dev.
Overall plant composition			
Plant diversity (Shannon-Wiener index)	1.3	0.6-1.8	0.3
Plant cover	23%	5-43%	10%
Plant cover individual plants			
Stipa glareosa	13%	1-36%	9%
Artemesia frigida	0.4%	0-2%	0.6%
Artemesia xerophytica	1.2%	0-5%	1.3%
Ephedra prezewalskii	0.8%	0-7%	1.6%
Oxytropis aciphylla	0.2%	0-2%	0.4%
Mean height of individual plants			
Stipa glareosa	4 cm	2-7 cm	0.9 cm
Artemesia frigida	2 cm	1-3 cm	0.4 cm
Artemesia xerophytica	2 cm	1-4 cm	0.7 cm
Ephedra prezewalskii	3 cm	1-4 cm	0.7 cm
Oxytropis aciphylla	2 cm	1-3 cm	0.6 cm
Soil chemistry			
Soil pH	7.9	7.8-8.0	1.1
Soil moisture	1.1	1.0-1.1	0.03

Table 1: *Mean, range, and standard deviation of different plant composition variables in the mountain steppes of the Tost Mountains in southern Mongolia in June and July in 2022*

Plant composition variable	Test statistic	p-value	β ± SE
Overall plant composition			
Plant diversity (Shannon-Wiener index)	0.12	0.73	7 10-5 ± 2 10-4
Plant cover	0.09	0.77	-7 10-5 ± 3 10-4
Plant cover individual plants			
Stipa glareosa	0.08	0.77	-3 10-4 ± 6 10-4
Artemesia frigida	0.06	0.82	-4 10-5 ± 2 10-4
Artemesia xerophytica	0.30	0.59	3 10-4 ± 3 10-4
Ephedra prezewalskii	14.8	**<0.001**	1 10-3 ± 3 10-4
Oxytropis aciphylla	0.25	0.62	-6 10-5 ± 2 10-4
Mean height of individual plants			
Stipa glareosa	1.4	0.24	-7 10-4 ± 6 10-4
Artemesia frigida	0.1	0.76	-2 10-4 ± 4 10-4
Artemesia xerophytica	1.9	0.18	7 10-4 ± 5 10-4
Ephedra prezewalskii	4.2	**0.06**	9 10-4 ± 4 10-4
Oxytropis aciphylla	2.3	0.15	7 10-4 ± 5 10-4
Soil chemistry			
Soil pH	2.0	0.23	1 10-5 ± 1 10-5
Soil moisture	0.33	0.56	-1 10-5 ± 2 10-5

Table 2: *Impact of distance from wells on different plant composition variables in the mountain steppes of the Tost Mountains in southern Mongolia in June and July in 2022. The analyses were based on mixed linear models for all variables except plant cover that was based on beta regression. We used sample plot as random factor to control for repeated measures and we included month to control for seasonal variation (n = 23 sample plots from four transects and two wells). The test statistic for the mixed linear model is the F value and the test statistic for the beta regression is the z value. The slope estimates (β) are given as change per meter and are based on re-scaling of plant cover following Douma and Weedon (2019).*

The Shannon-Wiener index and total plant cover were similar along the gradient of increasing distance from the wells ($F = 0.09$ 0.12, $p = 0.73 - 0.77$, Table 2). The cover for *Ephedra prezewalskii* increased with increasing distance from the wells ($F = 14.8$, $p<0.001$) and there was also a tendency for average height of *Ephedra prezewalskii* to increase with increasing distance from the wells ($F = 4.2$, $p = 0.06$) although this was statistically significant only at $\alpha = 0.10$. The cover and average height for the other four of the five most common species were similar along the gradient of increasing distance from the wells ($F = 0.06 - 2.3$, $p = 0.15 - 0.82$, Table 2). Soil pH and soil moisture was similar along the gradient of increasing distance from the wells ($F = 0.56 - 2.0$, $p = 0.23 - 0.33$, Table 2) with a mean pH of 7.9 (range = 7.8 - 8.0) and mean soil moisture of 1.06 (range = 0.96 - 1.1) for June and July combined on a relative scale from 1 to 10 where 1 repreents dry conditions and 10 represents moist conditions.

Discussion

Habitat degradation and heavy grazing by live-stock are common conservation challenges across the steppes of Mongolia and other parts of Central Asia (Berger et al. 2013, Hilker et al. 2014). In this study we found that cover and average height of *Ephedra prezewalskii* increased with increasing distance from wells (although the latter was statistically significant only at $\alpha = 0.10$) whereas plant diversity, overall plant cover, and cover and average height for the other four of the five most common species were largely unaffected by distance from the wells. There was thus some, but overall, relatively limited evidence of livestock grazing affecting the plant composition at these wells. Limited impact of livestock grazing in our study was further suggested by *Stipa glareosa* being the most common species at the majority of the sample sites and no tendency for more grazing- and trampling-resistant plants dominating close to the wells as reported in a study from the neighbouring province of Bayankhongor (Narantsetseg et al. (2018). Similarly, limited impact of grazing was suggested also by the soil pH and soil moisture being similar along the gradient of increasing distance from the wells which differs from Wang and Ripley (1997) that found that that soil pH increased with increasing grazing intensity and that soil moisture decreased with increasing grazing intensity in a grassland in north-eastern China. An alternative explanation to much of the plant composition being largely unaffected by distance to the wells could be that there was heavy grazing throughout our study area and therefore limited changes in plant composition and soil chemistry along the gradient of increasing distance from the wells. However, we suggest that this was unlikely because then we would not expect *Stipa glareosa*, but other grazing- and trampling-resistant plants, to be the dominating plants throughout most of the study area (Narantsetseg et al. 2018).

Evidence of relatively limited impact of grazing on the plant composition in our study differs from that in many other parts of Mongolia where the plant composition have been reported to change along gradients of increasing distance from wells (Fernandez-Gimenez and Allen-Diaz 1999, Sasaki et al. 2005, Narantsetseg et al. 2018 but see Fernandez-Gimenez and Allen-Diaz 1999 and Narantsetseg et al. 2018 for how the impact of livestock grazing varied between study sites). It is important to note though that our study was based on small sample size (two wells) and that it was conducted relatively shortly after the onset of plant growth and during a time of the year when many of the herders were on the summer ranges outside of the Tost Mountains (Mijiddorj et al. 2018). Similarly, we did not sample at the wells (i.e. 0 m from the well) where the plant cover was noticeably lower than at the sample sites along our transects that started 100 m away from the wells (Ulziibadrakh, personal observation). Further studies are thus needed to understand the impacts of livestock grazing better in the newly established Tost-Tosonbumba Nature Reserve. We also suggest that studies that compare impacts of livestock grazing in both the mountains and the surrounding steppes may be especially informative.

Acknowledgments

We thank the rangers from the Tost Mountains for their help in the field and we thank Som Ale and an anonymous reviewer for valuable comments that helped improve the manuscript.

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