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Original article

Responses of plants protected by grazing-proof fences based on the growth form in north-central Mongolia

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Abstract

The management of grassland is important in Mongolia. In order to evaluate the effects of grazing on grassland, plant and plant communities outside and inside the experimental grazing-free fences at the riverside of the Orkhon River and on the flat place at Mogod Sum (County), Bulgan Aimag (Province), north-central Mongolia, were compared based on the growth form. The fences (size: 5 m × 5 m, height: 1.5 m) were established in May, 2014 and the plants were surveyed in August. The riverside was dominated by *Carex duriuscula*, a productive sedge, under heavy livestock grazing. Tall tufted type (Tt) plants were more abundant inside the fence. On the flat place, Tt type plants, such as *Stipa krylovii* and *Leymus chinensis,* and short tufted type (Ts) plants grew, showing a higher plant diversity. By eliminating grazing using fences, plants of Tt, Er (erect type), and Br (branched type) types were more abundant inside the fences than outside. The amounts of smaller plants including Ts, Pr (prostrate), Ro (rosette) types were not greatly different between inside and outside the fences. Tufted type plants (Tt, Ts) were more abundant inside the fences than outside probably because of their ability of tillering. From these responses, we concluded that the growth form is useful to evaluate the effects of grazing on grassland.

Key words: grassland, grazing, growth form, Mongolia

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Introduction

Mongolia is a country of 156 km^2 in size with 2.5 million people and 67 million livestock (National Statistical Office of Mongolia, 2021; Unurzul, 2021). Most of the land is steppe grassland, and about one-third of peoples are pastoralists. About half of the population depends directly or indirectly on the pastoral economy (Fernandes-Gimenez, 2002). Therefore, the management of grassland is important in Mongolia. The grassland has been sustainably used for long time, but after the 1990s, market economy was introduced, which resulted in a rapid increase in the livestock population (Xu et al., 2019; National Statistical Office of Mongolia, 2021). The total population of livestock was around 2.5 million during the 1990s, while it is 67.1 million in 2020, including 4.1 million horses, 4.7 million cattle, 472.9 thousand camels, 30.0 million sheep, and 27.7 million goats (Unurzul, 2021).

Grazing effects are determined by the balance between plant productivity and grazing intensity. If the latter exceeds the former, grassland deteriorates and desertification occurs in Mongolia (Sasaki et al., 2009; Hilker et al., 2014; Han et al., 2021; Meng et al., 2021) and in the same ecosystem in Inner Mongolia, China (Huang et al., 2007). The responses of plants to grazing vary: the growth of many plants is suppressed by grazing, but graminoids (grasses Gramineae, sedges Cyperaceae, and rushes Juncaceae) can regrow and are more tolerant than forbs (dicotyledonous herbaceous plants, Coughenour, 1985; Green and Brazee, 2012). The plant responses to grazing can be demonstrated using grazing-proof fences (Irisarri et al., 2016; Koch et al., 2017). Some studies using fences have been performed in Mongolia (Fujita et al., 2009; Guo et al., 2020). We showed the effects of grazing on plants by comparing the plant communities inside and outside the fence of an airport in Bulgan Aimag (Province), north-central Mongolia, where plant growth form (Gimingham, 1951) were useful to demonstrate the grazing effects (Takatsuki et al., 2018). Growth form is a type of life form which was developed to show plants by their ecological characteristics. Gimingham (1951) categorized sand dune plants by growth form. It was improved by Numata (1954) to adopt for more generalized grassland communities.

This study intends to demonstrate the responses of plants of different growth forms by comparing the plant compositions inside and outside the grazing-proof fences at Mogod County, Bulgan Province, north-central Mongolia. This area belongs to the forest-steppe zone (Hilbig, 1995) and Orkhon River flows at the study area. Since plant communities at the alluvial plane of the river and on flat places are different, we studied the plant communities of the both habitats.

Materials and methods

Study site

The study area was Mogod County, located in the south-western part of Bulgan Province in north-central Mongolia, which is 320 km apart from Ulaanbaatar. Orkhon River flows north and bends to the east in Mogod (48°50’N, 102°38’E, Fig. 1). Mogod County belongs to the forest-steppe zone (Hilbig, 1995). The northern slopes of mountains contain birch patches but most of the areas are covered by steppe. The altitude is around 1,350 m. The sum (connty) center or the main town is located in the south-eastern part of the study area. The annual mean temperature is 5.8°C. Monthly mean air temperature in July is +17.3 °C, and is -18.4 °C in January. The annual precipitation is 192 mm (Statistical data of Mogod Sum, 1994-2013, Information and Research Institute of Meteorology, Hydrology and Environment).

Grazing-proof fences and recording plants

The study area covers the alluvial plains of the Orkhon River and flat places. Grazing-proof fences (size: 5 m × 5 m, height: 1.5 m) were erected in May 14─16, 2014 (Fig. 2). Three and four fences were established at the riverside and on the flat places, respectively. A quadrat plot (1 m × 1 m) was taken each inside and outside the fence, and the coverage (%) and height (cm) were measured in the middle of August, 2014. The biomass indices of occurring plants were obtained by multiplying the coverage (%) by the height (cm). The biomass index largely corresponds to the dry weight (Takatsuki and Sato, 2013). Plants were categorized based on the growth forms proposed by Gimingham (1951). Gimingham (1951) grouped the plants into 9 types based on shoot system and vegetative spread: large tussock (tufted), tufted growth (small tufted), large branched, small branched, large erect, small erect, large rosette, small rosette, and prostrate. Although Gimingham (1951) categorized herbaceous plants, a few shrubs appeared

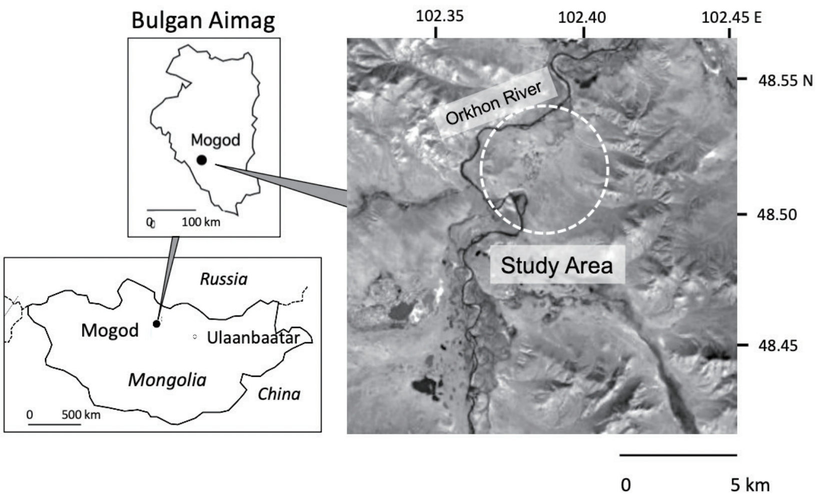

Figure 1. Map showing the study area, Mogod Sum (County), Bulgan Aimag (Province), Mongolia.

in this study area, and we grouped them according to the growth form. Since some forbs shorter than 10 cm in height were difficult to categorize into erect type or branched type, they were grouped into Fs (short forb). Plants which are not graminoids but are of the tufted type were grouped as Tm (monocot tufted). "Large rosette" was not found in this study. Thus, 8 types were finally used:

Tt: tall tufted type
Ts: short tufted type
Er: erect type
Br: branched type
Pr: prostrate type
Ro: rosette type
Fs: short forb
Tm: Tufted monocots

Growth form is usually specific to each plant species, but some plant species change the growth form by conditions.

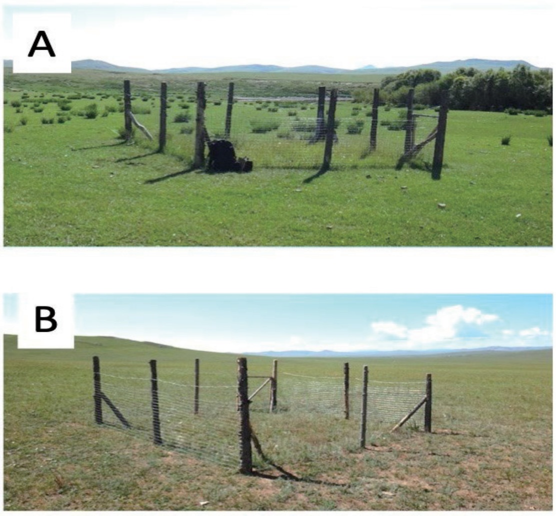

Figure 2. Grazing-proof fences at A: Riverside and B: Flat place. Fence was 5 m by 5 m, 1.5 m high. Photo taken August 15, 2014.

The Shannon-Wiener's diversity indices were calculated based on the biomass indices. The diversity index (H') is defined as:

$$H' = -\Sigma p_i \times \ln p_i$$

where p_i represents the proportion of plant i in the community.

The height of representative plants inside and outside the fences were measured to the nearest 1 cm (n = 20). The flower densities (/m^2) of representative plants in the six 1 m × 1 m quadrat plots inside and outside the five fences were determined. Data were compared between the pairs of plots or among three or more plots. Plots included 4 groups: plots outside the fences at riverside (R-out) and inside of them (R-in), and outside the fences on flat place (F-out) and inside of them (F-in). Biomass index, plant height, and flower density in each inside and outside fence (n = 2) were compared using Mann-Whitney test, and biomass indices at 3 or 4 fences were compared using Kruskal-Wallis test. The confidence level was set at $P = 0.05$.

Results

Comparison of plants and biomass

The biomass indices inside and outside the fences at the riverside (3 fences) and on the flat places (4 fences) were calculated and grouped according to the growth form.

At the plots outside the fences at the riverside (R-out), Tt type (mainly *Stipa krylovii* and *Leymus chinensis*) and Ts type (mainly *Carex duriuscula*) occupied great proportions in biomass indices (Fig. 3). In the fence at the riverside (R-in), Tt type was as great as 700.0 and Er type (mainly *Artemisia* spp) was144.2. On the flat places, Tt

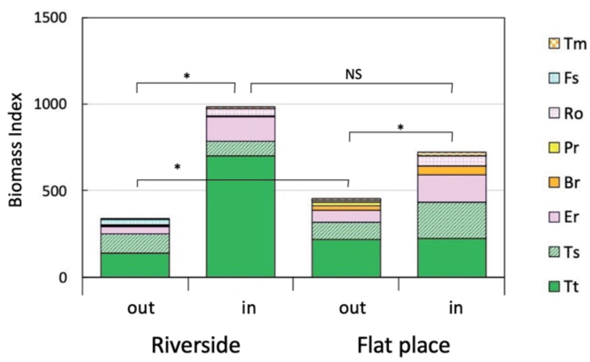

Figure 3. Averages of biomass indices (/m^2) of plants of different growth forms outside and inside the fences at riverside (n = 3) and on flat place (n = 4). Tt: tall tufted type, Ts: short tufted type, Er: erect type, Br: branched type, Pr: prostrate type, Ro: rosette type, Fs: short forb type, Tm: Tufted monocots. Kruskal-Wallis test, *: $P < 0.05$, NS: non-significant.

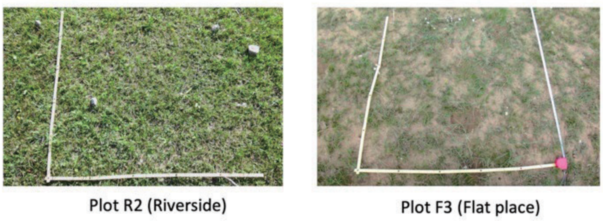

Figure 4. Plane views of vegetation plots. Left: Plot R2 at a riverside dominated by *Carex duriuscula* and Right: Plot F3 on a flat place vegetated by *Leymus chinensis, Carex duriuscula*, and *Cleistogenes squarrosa*. Scale: 1 m by 1 m.

type (mainly *Stipa krylovii*) were abundant outside the fence (F-out), while inside the fence (F-in), Tt type, Ts type (mainly *Carex duriuscula* and *Cleistogenes squarrosa*), and Er type (mainly *Artemisia frigida* and *Heteropappus altaicus*) were abundant. The biomass index of Tt type was similar to that of Tt type outside the fences, while Ts and Er types were more abundant than outside (Fig. 4). The biomass indices inside the fences at the riverside (R-in) were greater than outside (R-out) by 2.9 times and by 1.6 times on the flat place (F-in and F-out). The biomass indices inside the fences were significantly greater than outside at both the riverside and on the flat places (Kruskal-Wallis test, R-in and R-out, $t_2 = 2.882$, $P = 0.021$, F-in and F-out, $t_2 = 2.680$, $P = 0.037$). At the plots outside the fences at the riverside (R-out), Tt type (mainly *Stipa krylovii* and *Leymus chinensis*) and Ts type (mainly *Carex duriuscula*) occupied great proportions in biomass indices (Figs. 3, 4). Outside the fence on the flat places (F-out), Tt type (mainly *Stipa krylovii*) were abundant. Between the biomass indices outside the fences (R-out and F-out), F-out was significantly greater than R-out ($t_2 = -3.098$, $P = 0.011$), but between R-in and F-in, no significant difference was found ($t_2 = 1.549$, $P = 0.408$).

Table 1. Shannon-Wiener's diversity indices and outside the fences at riverside and on flat place. Numbers of fences were 3 at riverside and 4 at flat.

	Outside	Inside
Riverside	1.84	1.77
Flat place	2.69	2.56

Diversity index

The diversity indices inside and outside the fences were determined at the riverside and on the flat places (Table 1). The diversity indices outside the fences were significantly greater at F-out (flat place, mean = 2.69) than R-out (riverside, mean = 1.84, Mann-Whitney test, $\chi^2 = 2.12$, $P = 0.034$). The diversity index at the riverside (R-out) was low (1.84) because *Carex duriuscula* was dominant (Fig. 3). On the contrary, the diversity indices inside the fences were greater (2.69) at F-in (flat place) because *Stipa krylovii, Leymus chinensis* and *C. douroucouli* coexisted there (Fig. 2A). No significant differences were found in diversity indices between R-in and R-out (riverside, $\chi^2 = 0.22$, $P = 0.827$) and F-in and F-out (flat place, $\chi^2 = 0.58$, $P = 0.564$).

Plant height

Fig. 5 shows the plant heights of representative plant species outside and inside the fences. Inside the fences, plants of the Pr (prostrate), Ro (rosette), Fs (short forb), and Ts (short tufted) types were taller than outside but these plants did not exceed a height of 10 cm. In contrast, many plants of the Tt (tall tufted), Br (branched), and Er (erect) types grew taller than 10 cm. *Potentilla viscosa* was only 3.0 cm in height outside the fence as a Ro (rosette) form. However, its height was 11.8 cm inside the fence. The growth form inside the fence looked as Er (erect) type. The stems grew from the central part of rosette leaves, which was quite short outside the fence. Among the Ts type, *Carex duriuscula* grew slightly taller inside the fence than outside, while *Koeleria macrantha* doubled in height. Nevertheless, Ts type plants did not exceed a height of 10 cm. Conversely, Tt type plants such as *Stipa krylovii* and *Leymus chinensis* became more than 2 times taller than the outside plants

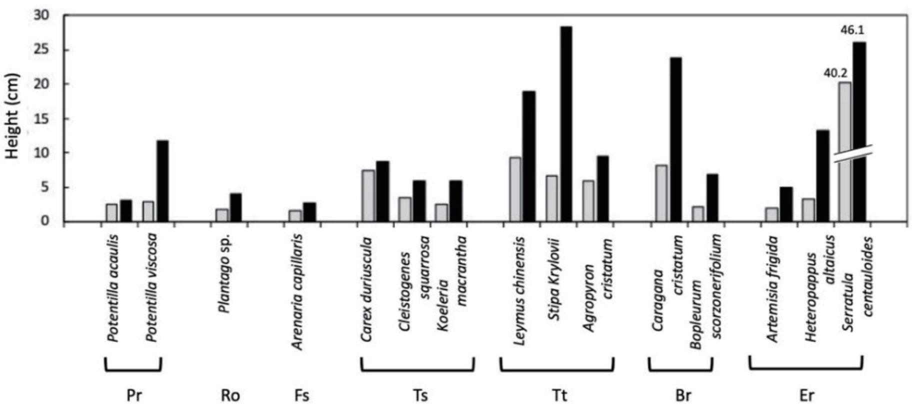

Figure 5. Plant heights of representative plants inside (gray) and outside (black) the fences. Pr: prostrate type, Ro: rosette type, Fs: small forb type, Ts: short tufted type, Tt: tall tufted type, Br: branched type, Er: erect type. Since *Serratula centauroides* was tall, bars were divided and mean heights are shown. Error bars show standard deviations. Mann-Whitney test, *: $P < 0.05$, **: $P < 0.01$.

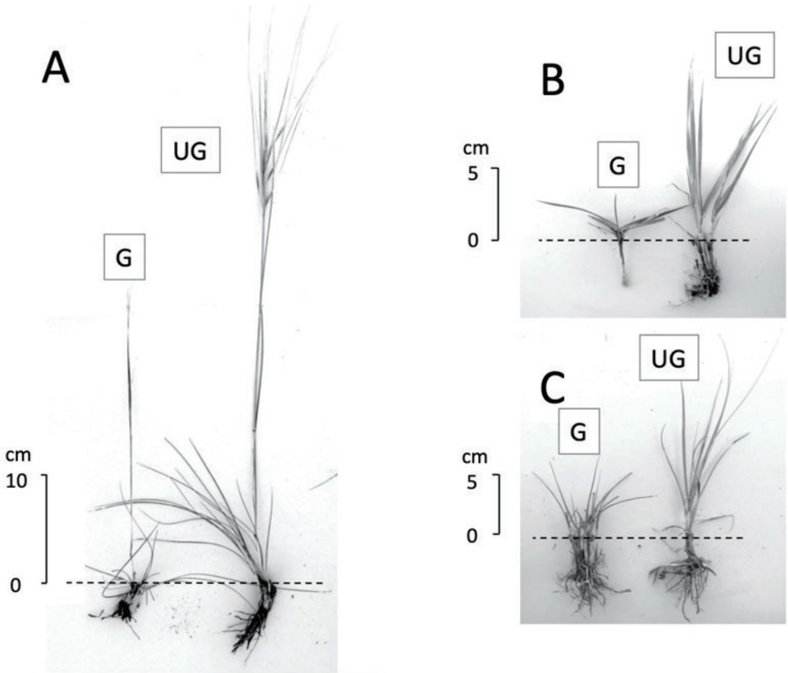

Figure 6. Photos of three graminoids outside (G: grazed) and inside (UG: ungrazed) the fences. A: *Stipa krylovii,* B: *Leymus chinensis* , C: *Carex duriuscula* . Broken lines show ground surface.

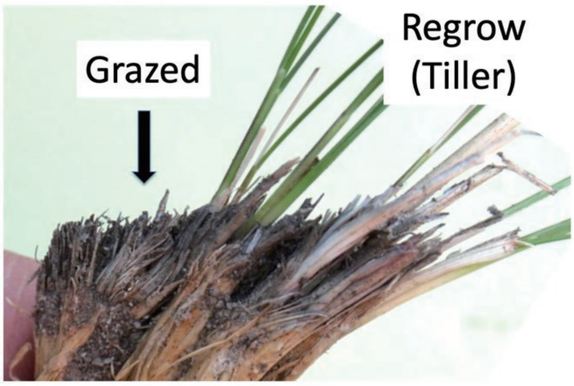

Figure 7. Plant base of *Stipa krylovii* repeatedly grazed. New tillers are seen.

By observing the three representative graminoids, we found that the leaves and flowering culms of Stipa krylovii growing outside the fences were quite short (Fig. 6A). Their leaves and culms were repeatedly grazed near to the ground surface and new tillers regrew (Fig. 7). The leaf length of Leymus chinensis outside the fence was shorter than that outside (Fig. 6B). It is noteworthy that the leaf angle was apparently lower outside than inside the fence, that is, the inside leaves grew vertically, while the outside leaves grew almost horizontally. Since sedges do not have culms but only leaves, they cannot grow tall like grasses. Carex duriusculus, in particular, is low-growing and exceeded 10 cm only slightly, even inside the fence (Figs. 5, 6C).

Flower density

The flower densities of representative plants inside and outside the fences are shown in Table 2. The flower densities were lower outside the fences than inside the fences. Particularly, no flower of *Artemisia sieversiana* (Er) was found outside the fence. The flower densities were quite low outside the fences in *Artemisia cristatum* (Mann-Whitney test, χ^2 = 36.00, P < 0.001), *Leymus chinensis* at Plots R1 (χ^2 = 19.62, P = 0.001) and R3 (χ^2 = 34.84, P < 0.001). Many others were also significantly lower outside than inside: *A. pectinata* (χ^2 = 15.47, P = 0.003), *Bupleurum scorzonerifolium* (χ^2 = 31.77, P < 0.001), and *Stipa krylovii* (χ^2 = 32.73, P < 0.001). Only exception was *L. chinensis* at Plot F4, of which density were not significantly different inside and outside the fence (χ^2 = 3.13, P = 0.108). These results suggest that grazing greatly reduced the flower density of most of the plants.

Discussion

Orkhon River flows in Mogod county and the water conditions in this area are comparatively better for plant growth than those in other areas of Mongolia. Although it belongs to the forest-steppe zone (Hilbig, 1995), forests are only patchily present on the north-facing slopes of the hills and most areas contain grassland vegetation. Most of them

Table 2. Densities of flowers (/m^2) of representative plants inside and outside the fences, and statistic information. **: $P < 0.01$, ns: non-significant.

Plant name	Growth Form	Inside	Outside	χ2	*P*	Difference
Bupleurum scorzonerifolium	Br	43.3	6.3	31.77	< 0.001	**
Stipa krylovii	Tt	11.0	2.0	32.73	< 0.001	**
Leymus chinensis	Tt	6.5	2.7	3.13	0.108	ns
Artemisia pectinata	Er	17.5	4.7	15.47	0.003	**
Agropyron cristatum	Tt	13.7	0.5	36.00	< 0.001	**
Leymus chinensis	Tt	6.3	0.7	19.62	0.001	**
Artemisia sieversiana	Er	11.0	0.0	18.99	0.001	**
Leymus chinensis	Tt	91.3	0.5	34.84	< 0.001	**

are dominated by *Stipa krylovii*; however, *Carex duriuscula* was predominant in the alluvial plains along Orkhon River, where more horses and cattle are seen grazing than in the *Stipa* grassland (Takatsuki et al., unpublished). A study on the dietary compositions of livestock in this area showed that 40.7% of the foods of free ranging horses was *C. duriuscula*, while the diet of cattle which are confined around gers (tent houses) was dominated by *S. krylovii* (Takatsuki and Morinaga, 2020). Most of the area in Mogod Sum is covered with *Stipa krylovii* grassland, where livestock live at low density, while small areas along the Orkhon River have a moist and nutrient-rich soil dominated by *C. duriuscula* (Figs. 2, 3) and are intensively grazed by livestock.

This study showed that the vegetation on alluvial flat of Orkhon River was dominated by *Carex duriuscula*, a lawn-like sedge, and exclusion of grazing resulted in recovery of Tt (tall tufted) type grasses. The vegetation on the flat place was different from the riverside, and covered by some grasses including *Stipa krylovii* (Tt), *Leymus chinensisi* (Tt), and *Cleistogenes squarrosa* (Ts), resulting in high diversity indices (Table 1, Fig. 4). The biomass index inside the fences on the flat place (F-in) was greater than outside (F-out) by 1.6 times. The difference was greater (2.9 times) at the riverside (R-in and R-out) than on the flat place (Fig. 3). It is likely that the greater difference at the riverside than on flat places owes to higher productivity of plants on the moist and nutrient-rich soil.

We used growth forms to evaluate the effects of grazing on plants and plant communities, which was shown to be useful. Growth form includes various aspects of plant characteristics, including the shape, size, physiology, and others (Gimingham 1951; Numata 1954). Among these, plant height seems to be the most important characteristic related to grazing. As livestock grazing becomes intensive, plants become shorter and in the most intensive situations, lawn-type vegetation appears. When plants are discharged from grazing, they recover. This recovery is typically seen in Tt type plants, such as *Stipa krylovii* and *Leymus chinensis* (Fig. 5). There seems to be two reasons. One reason is tufted plants or graminoids have shoot apexes near the ground surface level and can recover by tillering after grazing (Bullock et al., 1994; Green and Brazee, 2012). In fact, it was shown that *Carex bigelowii* in Icelandic highlands can vigorously tiller (Jónsdóttir, 1991). Another reason seems to be plant height. Since Ts (short tufted) type plants are potentially unable to grow tall, their recovery by exclusion of grazing is limited. In contrast, Tt (tall tufted) type plants can grow taller and when they are discharged from grazing after continuous grazing, the recovery is more prominent than Ts type. Although recovery of Er (erect) type and Br (branched) type was not so apparent as Tt, they also recovered better than shorter plants like Ts and Pr (prostrate) under grazing-free conditions. In fact, Ts and Pr type plants were dominant under grazing conditions in another place of Bulgan Province (Takatsuki et al., 2018). A study in Hulunbeier grassland, Inner Mongolia, China, which has some species in common with the Mongolian steppe, showed that the grassland was dominated by *Stipa* spp. (Tt) but they were replaced by Pr type (e.g., *Potentilla* spp.) and Ts type (e,g., *Carex* spp. and *Cleistogenes squarrosa*, Kawada et al., 2008). Plant sociological studies classify the plant communities by the species composition. However, categorization of the plants by growth form seems to be more useful for demonstrating the grazing effects.

Plants of the Pr (prostrate) and Ro (rosette) types seem to be less important as forage plants for livestock because dicot plants are not able to reproduce after defoliation (Dahl, 1995; Takatsuki and Uehara, 2021). Pr type plants such as *Potentilla* spp. and Ro type plants such as dandelions (*Taraxacum* spp.) are low-growing and survive or become dominant under grazing, not because of their regrowing ability, such as that of Ts type plants, but because they escape from grazing. It is noteworthy that *Potentilla viscosa* changed its growth form from Pr type outside the fence to Er type inside the fence. The flower stems inside the fence were growing of which mean height was about 11 cm. We also observed that they were as tall as 30-40 cm at grazing-free conditions in other places in Bulgan province.

It was also shown that grazing reduced the flower density (Table 2). A reduction in this parameter is caused by the direct eating of flowers, as well as by eating leaves, which suppresses plant productivity and reduces their ability to produce flowers. A reduction in flower density by grazing was reported at a Belgian coast by Bossuyt et al. (2005). This means that grazing reduces both plant production and reproduction.

Although most of the plants were more abundant inside the fences than outside, the differences of biomass indices varied among different growth forms. Since Ts type plants like *Carex duriuscula* cannot potentially grow taller than 10 cm, height difference was slight (Figs. 5, 6). In contrast, Tt type plants such as *Stipa krylovii* and *Leymus chinensis,* which can potentially grow tall, height difference was greater than Ts type (Figs. 5, 6). Grazing-proof fences can either increase or decrease the diversity of plant communities. When the initial plant community is dominated by a single plant, a fence would increase the plant diversity; in contrast, when the initial plant community is composed of several co-dominants, a fence would decrease the diversity by dominance of a single species (Harper, 1977). Our results showed that at both of the habitats, the diversity indices were not different inside and outside the fences (Table 1). The time interval between the establishment of the fences (May) and the vegetation survey (August) was only three months, which seems to be too short to change the diversity of the plant community. Within this short period, no plants disappeared in the fences, which resulted in slight change of diversity indices. If grazing exclusion is long enough, some low-growing plants disappeared by shading by taller plants (Takatsuki et al., 2018). Despite the short interval, coverage and heights of most of the plants were greater in the fences, suggesting heavy grazing intensity, particularly at the riverside. It is likely that after long exclusion of grazing, plant compositions and their proportions would change, resulting in differences of diversity indices.

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References

Bossuyt, B., De Fre, B. and Hoffmann, M. (2005) Abundance and flowering success patterns in a short-term grazed grassland: early evidence of facilitation. *Journal of Ecology*, **93**, 1104–1114.

Bullock, J.M., Hill, B.C. and Silvertown, J. (1994) Tiller dynamics of two grasses -- responses to grazing, density and weather. *Journal of Ecology*, **82**, 331–340.

Coughenour, M.B. (1985) Graminoid responses to grazing by large herbivores: adaptations, exaptations, and interacting processes. *Annals of the Missouri Botanical Garden*, **72**, 852–863.

Dahl, B.E. (1995) Developmental morphology of plants. In: Bedunah, D.J. and Sosebee, R.E. (eds.) *Wildland Plants: Physiological Ecology and Developmental Morphology,* Society for Range Management, Denver, Colorado, USA, pp. 22–58.

Fernandez-Gimenez, M.E. (2002) Spatial and social boundaries and the paradox of pastoral land tenure: a case study from post socialist Mongolia. *Human Ecology*, **30**, 49–78.

Fujita, N., Amartuvshin, N., Yamada, N.Y., Matsui, K., Sakai, S. and Yamamura, M. (2009) Positive and negative effects of livestock grazing on plant diversity of Mongolian nomadic pasturelands along a slope with soil moisture gradient. *Grassland Science*, **55**, 126–134.

Gimingham, C.H. (1951) The use of life form and growth form in the analysis of community structure, as illustrated by a comparison of two dune communities. *Journal of Ecology*, **39**, 396–406.

Green, S. and Brazee, B. (2012) Harvest Efficiency in Prescribed Grazing. Technical Note, 73, USDA. Natural Resources Conservation Service Boise, Idaho, Salt Lake City, Utah, 5p.

Guo, T., Liao, H.R. and Tuvshintogtokh, I. (2020) Effects of grazing exclusion by fence on vegetation characteristics and community diversity of Mongolian grasslands. *Applied Ecology and Environmental Sciences*, **18**, 6995–7009.

Han, J., Dai, H. and Gu, Z. (2021) Sandstorms and desertification in Mongolia, an example of future climate events: a review. *Environmental Chemistry Letters*, **19**, 4063–4073.

Harper, J.L. (1977) Population Biology in Plans. Academic Press, London, 892p.

Hilbig, W. (1995) The Vegetation of Mongolia. SPB Academic

Publishing, Amsterdam, Netherlands, 258p.

Hilker, T., Natsagdorj, E., Waring, R.H., Lyapustin, A. and Wang, Y. (2014) Satellite observed widespread decline in Mongolian grasslands largely due to overgrazing. *Global Change Biology*, **20**, 418–428.

Huang, D., Wang, K. and Wu, W.L. (2007) Dynamic of soil physical and chemical properties and vegetation succession characteristics during grassland desertification under sheep grazing in an agro-pastoral transition zone in Northern China. *Journal of Arid Environment*, **70**, 120–136.

Irisarri, J.G.N., Derner, J.D., Porensky, L.M., Augustine, D.J., Reeves, J.L. and Mueller, K.E. (2016) Grazing intensity differentially regulates ANPP response to precipitation in North American semiarid grasslands. *Ecological Applications*, **26**, 1370–1380.

Jónsdóttir, I.S. (1991) Effects of grazing on tiller size and population dynamics in a clonal sedge (*Carex bigelowii*). *Oikos*, **62**, 177–188.

Kawada, K., Kurosu, M., Cheng, Y., Tsendeekhuu, T., Wuyunna, Nakamura, T. and Hayashi, I. (2008) Floristic composition, grazing effects and above-ground plant biomass in the Hulunbeier grasslands of Inner Mongolia, China. *Journal of Ecology and Field Biology*, **31**, 297–307.

Koch, M., Schroder, B., Gunther, A., Albrecht, K., Pivarci, R. and Jurasinski, G. (2017) Taxonomic and functional vegetation changes after shifting management from traditional herding to fenced grazing in temperate grassland communities. *Applied Vegetation Science*, **20**, 259–270.

Meng, X., Gao, X., Li, S., Li, S. and Lei, J. (2021) Monitoring desertification in Mongolia based on landsat images and Google Earth Engine from 1990 to 2020. *Ecological Indicators*, **129**, 107908.

National Statistical Office of Mongolia (2021) https://knoema.com/atlas/sources/NSO-MN?topic=livestock

Numata, M. (1954) Some special aspects of the structural analysis of plant communities. *Journal of College of Arts and Sciences, Chiba University,* **1**, 194–202

Sasaki, T, Okubo, S., Okayasu, T., Jamsran, U., Ohkuro, T. and Takeuchi, K. (2009) Two-phase functional redundancy in plant communities along a grazing gradient in Mongolian rangelands. *Ecology*, **90**, 2598–2608.

Takatsuki, S. and Morinaga, Y. (2020) Food habits of horses, cattle, and sheep-goats and food supply in the forest-steppe zone of Mongolia: A case study in Mogod Sum (county) in Bulgan Aimag (province). *Journal of Arid Environments*, **174**, March 2020, 104039.

Takatsuki, S., Sato, M. and Morinaga, Y. (2018) Effects of grazing on grassland communities of the forest-steppe of northern Mongolia: a comparison of grazed versus ungrazed places. *Grassland Science*, **64**, 167–174.

Takatsuki, S. and Sato, M. (2013) Biomass index for the steppe plants of northern Mongolia. *Mammal Study*, **38**, 131–133.

Takatsuki, S. and Uehara, A. (2021) Cause of vegetation changes to a *Miscanthus sinensis* community in Otome Highland, Yamanashi, central Japan. *Vegetation Science*, **38**, 81–93.

Unurzul, M. (2021) Mongolia counts 67.1 million head of livestock. *Montsame*, https://montsame.mn/en/read/249861

Xu, Y., Zhang, Y., Chen, J., John, R. (2019) Livestock dynamics under changing economy and climate in Mongolia. *Land Use Policy*, 88: November 2019, 104120. https://doi.org/10.1016/j.landusepol.2019.104120

原著論文

モンゴル中北部における放牧排除柵による植物の反応 – 生育型による比較

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モンゴルにおいては草地の管理は重要である。モンゴル中央北部のブルガン県にあるモゴッドのオルホン川沿いと平坦地に柵を設置して放牧圧を排除し、柵内外の植物の反応を比較した。柵の大きさは 5 m × 5 m、高さ 1.5 m で、2014 年の 5 月に設置し、8 月に評価した。川辺は生産力の高い *Carex duriuscula* が優占していた。ここでは柵内で草丈の高い叢生型（Tt）が大きく回復した。平坦地には *Stipa krylovii* や *Leymus chinensis* など Tt 型や草丈の低い叢生型（Ts）が生育し、多様度が高かった。ここの柵内では Tt 型、直立型（Er）、分枝型（Br）などが回復した。本調査は草原の放牧圧を評価するのに生育型が有効であることを示した。

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