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REGULAR ARTICLE

Effect of fencing and grazing on a Kobresia-dominated meadow in the Qinghai-Tibetan Plateau

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Abstract Grazing is one of the most important factors influencing community structure and productivity in natural grasslands. Fencing to exclude grazers is one of the main management practices used to protect grasslands. Can fencing improve grassland community status by restraining grazing? We conducted a field community study and indoor soil analyses to determine the long-term effects of fencing and grazing on the above-ground community and soil in a *Kobresia*-dominated meadow in the Qinghai-Tibetan Plateau, NW China. Our results showed that fencing significantly improved above-ground vegetation productivity but reduced plant density and species diversity. Long-term fencing favored the improvement of forage grass functional groups and restrained the development noxious weed functional groups. There were significant positive effects of fencing on below-ground organic matter, total nitrogen, available nitrogen, total phosphorus and available phosphorus. The productivity of grazed meadow showed a weak decrease over time. There were long-term decreasing trends for plant density both in fenced and grazed meadows. Our study suggests that grazing can be considered as a useful management practice to improve species diversity and plant density in long-term fenced grasslands and that periodic grazing and fencing is beneficial in grassland management.

Keywords Fencing · Grazing · Plant community · Functional group · Productivity · Structure · Soil nutrient

Introduction

Disturbance can play an important role in the dynamics of grassland ecosystems (Grime 1979), promoting community succession and maintaining community structure and species diversity (Tilman 1988; Hobbs and Huenneke 1992). Grime (1979) considered disturbance as one of the two most important factors in shaping the composition of plant communities. Previous research on disturbance of grassland vegetation emphasized fire, grazing, mow-

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ing, soil disturbance and nutrient addition on plant species diversity and invasion (Hobbs and Huenneke 1992; Schippers and Joenje 2002). Grazing was considered as one of the key disturbance factors which resulted in grassland degradation, an increase of spatial heterogeneity of the communities, an alteration of community function and loss of species diversity (Oesterheld and Sala 1990; Akiyama and Kawamura 2007). Overgrazing severely reduced grassland productivity, vegetation cover and the proportion of forage grasses. Furthermore, overgrazing is considered to enhance desertification. Many natural grasslands have been either destroyed by cultivation or extensively modified by grazing from domesticated livestock and by the introduction of alien plant species. The pressures to increase animal production have led to many disturbances being intensified (Watkinson and Ormerod 2001). A number of protection and restoration measures, including fencing, reseeding and/or the use of fertilizers have been put in practice to increase herbage production and protect grassland vegetation (Akiyama and Kawamura 2007).

The exclusion of livestock through the use of mesh fencing to create large-scale enclosures has become a common grassland management strategy throughout the world in recent decades. Fencing to exclude stock has been widely regarded as a simple restoration method and the fenced remnants have typically been thought to 'look after themselve' (Reeves 2000). Such management measures present a dilemma between grazing utilization and biodiversity protection for grassland (Smith et al. 2000). These measures are typically taken to increase grassland production but can potentially lead to the loss of biodiversity. Livestock foraging can significantly alter above-ground community structure whilst their trampling behaviour and excretions can also affect above-ground community structure and soil conditions. The resultant changes in soil quality can have large impacts on vegetation (Gibson et al. 2001). Consequently, vegetation succession and community structure may be closely related to grazing herbivores. As the grassland-grazer ecosystem is an integrated system, prohibiting grazing through the use of fencing removes a central part of this system. It has been typically assumed that plant communities will regenerate and remain viable when grazing is excluded. However, it has been reported that grazing exclusion has variable effects on tree and shrub recruitment, species richness and soil conditions (Pettit et al. 1995), and that its long-term effects are difficult to predict (Spooner et al. 2002).

The aim of this study was to better understand the effects of excluding grazing herbivores through fencing on high altitude meadow in the Qinghai-Tibetan Plateau and to determine whether fencing can be used as a grassland management tool. Specifically we examined the effect of fencing on: (i) the above-ground community structure and species diversity of grasslands; and (ii) the below-ground nutrient characteristics. Our long-term hope is that the study should contribute to the restoration of degraded grasslands and the maintenance of biodiversity in the Qinghai-Tibetan Plateau.

Methods

Study site

The experiment was conducted in alpine meadow at 3,500 m a.s.l. in the eastern Qinghai-Tibetan Plateau at Manrima village of the Maqu Wetland Protection Area (33°45′ N, 102°04′ E) in Gansu Province, PR China. The mean daily air temperature is 1.2°C, ranging from−10°C in January to 11.7°C in July. Mean annual precipitation is 620 mm, mainly falling during the short, cool summer. The monthly mean temperature and precipitation, annual average precipitation and annual accumulated temperature of ≥0°C from 1969–2005 in Maqu County were showed in Fig. 1 (Niu et al. 2008). The annual cloud-free solar radiation is about 2,580 h. The vegetation is typical alpine meadow and is dominated by clonal *Kobresia* sp. (Cyperaceae), *Festuca ovina*, *Poa poophagorum*, *Roegneria nutans*, *Agrostis sp*. (Poaceae), *Saussurea sp*. (Asteraceae), and *Anemone rivularis* (Ranunculaceae). The average above ground biomass is 70–100 g dry mass per square meter. Typically, there are 20–30 vascular plant species and 800–1,000 individual plants per square meter.

Experimental design

An alpine meadow dominated by *Kobresia tibetica* and including gramineous grasses and some forbs was selected for this study. The main plant species

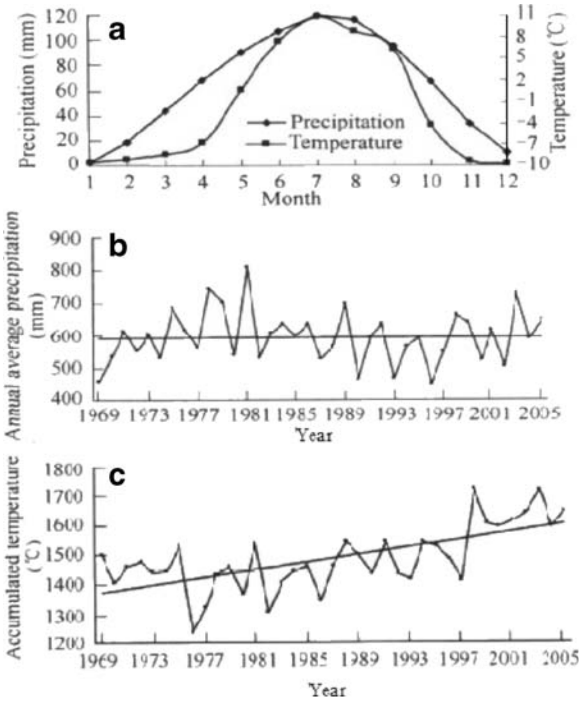


Fig. 1 Variation of monthly mean temperature and precipitation (**a**), annual average precipitation (**b**) and annual accumulated temperature of ≥0°C (**c**) from 1969–2005 in Maqu County

included: *Kobresia tibetica, Kobresia kansuensis, Kobresia humilis, Kobresia macrantha, Blysmus sinocompressus, Poa pratensis, Koeleria eristata, Elymus nutans, Stipa aliena, Cremanthodium liheare*, and some other species (Wu 1995) (Species list in Table 1).

We selected a 100 m×100 m block of fenced meadow because of Natural Forest Protection Project of China in 1999. The fence completely excluded livestock grazing during the plant growth-seasons from April to October and slight grazing was done only during the hay-stage in winter. A similar non-fenced block was used as the grazed meadow with grazing from a medium density of Tibetan sheep and yaks (the approximate proportion of sheep vs yaks was about 1.6 : 1) during the whole year. We established ten zonal sampling plots (5 m×8 m) and three random quadrats (50 cm×50 cm) per plot in both the grazed block and the fenced block. The blocks were separated by approximately 500 m. The quadrats were randomly arranged in every sampling plot. Samples were taken annually in early September, when biomass had reached its highest, from a 0.5 m×0.5 m quadrat from every sampling plot. The quadrat location was selected randomly with the constraint that it was at least 0.5 m from the edge to avoid marginal effect. Every ramet was counted for each species, clipped and put in marked paper bags per species per quadrat.

During mid-August of 2005, 2006 and 2007, we determined the dry biomass of every functional group in every quadrat by weighing the plants after drying at 80°C for 48 h to constant weight. The experiment continued for 3 years during which time 60 quadrats were recorded. Total cover, total productivity (dry aboveground biomass), plant density, and richness index of meadow community were measured. The mean number of ramets in sampling plots represented the density of the community. Additionally, we divided the plant community into five functional groups: GG (grass species group); SG (sedge species group); LG (leguminous species group); FG (forbs species group, not including noxious species) and NG (noxious species group). The list of all species within each plant functional group was showed (Table 1). Cover, productivity and plant density of each plant functional group were specially measured. Abundance was based on plant density per square meter. Shannon-Wiener diversity index (*H*) and Evenness index (*E*) of the fenced and grazed meadow communities were calculated as:

$$\text{Richness index}(R) : R = S,$$

$$\text{Shannon} - \text{Wiener diversity index}(H) :$$

$$H = -\sum_{i=1}^{S} (Pi1nPi),$$

$$\text{Evenness index}(E) : E = \frac{H}{1nS},$$

where *S* is the total species numbers of meadow community, *H* is the Shannon-Wiener diversity index and *Pi* is the density proportion of *i* species.

In addition, we collected soil samples by bucket auger from each sampling plot in both fenced and grazed blocks in a simple random pattern in August 2007. Five mixed soil samples at depths of 0–20 cm in each sampling plot were used to analyze soil characteristics. All soil samples were air-dried and then passed through a 0.14 mm sieve. Soil pH was determined using a soil-water ratio of 1:5; soil organic

Table 1 Productivity for each species at fencing meadow and grazing meadow

Species	Life types	Functional group	Productivity(g/m^2)		Species	Life types	Functional group	Productivity(g/m^2)	
			Fenced	Grazed				Fenced	Grazed
Deschampsia caespitosa	P	GG	12.84	12.87	*Carum carei*	P	FG	0.96	1.23
Poa pratensis	P	GG	29.54	9.74	*Saussurea stella*	P	FG	2.46	–
Koeleria eristata	P	GG	24.37	10.32	*Pleurospermum amtschaticum*	P	FG	2.45	–
Stipa aliena	P	GG	18.54	11.62	*Veronica eriogyne*	P	FG	0.78	–
Elymus nutans	P	GG	14.75	15.34	*Potentilla fragarioides*	P	FG	–	2.54
Roegneria nutans	P	GG	22.65	–	*Plantago asiatica*	P	FG	–	2.48
Festuca sinensis	P	GG	9.86	–	*Polygonum viviparum*	P	FG	–	2.75
Agrostis trinii	P	GG	17.75	–	*Pedicularis kansuensis*	P	FG	–	2.64
Poa poophagorum	P	GG	28.65	–	*Saussurea nigrescens*	P	FG	–	3.38
Kobresia tibetica	P	SG	48.54	23.71	*Ajania tenuifolia*	P	FG	–	2.76
Kobresia kansuensis	P	SG	12.46	11.32	*Galium verum*	P	FG	–	3.65
Blysmus sinocompressus	P	SG	33.57	19.54	*Taraxacum lugubre*	P	FG	–	1.37
Kobresia humilis	P	SG	13.56	17.45	*Halenia corniculata*	A	FG	–	1.28
Carex brunnescens	P	SG	22.12	–	*Allium sikkimense*	P	FG	–	0.74
Scirpus pumilus	P	SG	8.56	–	*Artemisia sievrsiana*	A	FG	–	1.73
Carex muliensis	P	SG	15.42	–	*Aster tongolensis*	P	FG	–	1.26
Blysmocarex nudicarpa	P	SG	6.84	–	*Descuminia sophia*	A	FG	–	1.35
Kobresia macrantha	P	SG	9.84	–	*Parnassia trineruis*	P	FG	–	1.06
Oxytropis kansuensis	P	LG	5.78	6.45	*Lagotis brachystachya*	P	FG	–	1.54
Medicago ruthenica	P	LG	4.46	2.13	*Chamaesium paradoxum*	A	FG	–	0.96
Astragalus polycladus	P	LG	7.89	3.72	*Caltha scaposa*	P	NG	7.94	3.62
Gueldenstaedtia multiflora	P	LG	–	2.54	*Gentiana squarrosa*	A	NG	4.65	2.24
Cremanthodium liheare	P	FG	12.16	2.56	*Gentianopsis paludosa*	P	NG	11.24	4.24
Saussurea hieracioides	P	FG	4.75	2.17	*Ranunculus nephelogenes*	P	NG	6.87	–
Potentilla anserine	P	FG	4.45	3.34	*Gentiana sio-ornata*	P	NG	–	8.34
Potentilla bifurca	P	FG	3.58	2.85	*Ligularia virgaurea*	P	NG	–	4.56
Trollius farreri Stapf	P	FG	2.78	2.13	*Euphorbia esula*	P	NG	–	2.45
Pedicularis longiflora var.tubiformis	P	FG	2.86	2.35	*Thalictrum alpinum*	P	NG	–	1.45
Rumex crispus	P	FG	3.34	2.67	*Ranunculus tanguticus*	P	NG	–	2.34
Leontopodium leontopodioides	P	FG	4.54	1.65	*Anemone obtusiloba*	P	NG	–	2.21
Polygonum sibioicum	P	FG	1.83	1.37	*Gentian aristata*	A	NG	–	3.24
Juncus effusus	P	FG	0.44	1.23	*Ranunculus tanguticus var. nematolobus*	P	NG	–	3.33
Saxifraga stolonifera	P	FG	0.53	1.34	*Gentiana macrophylla*	P	NG	–	2.54

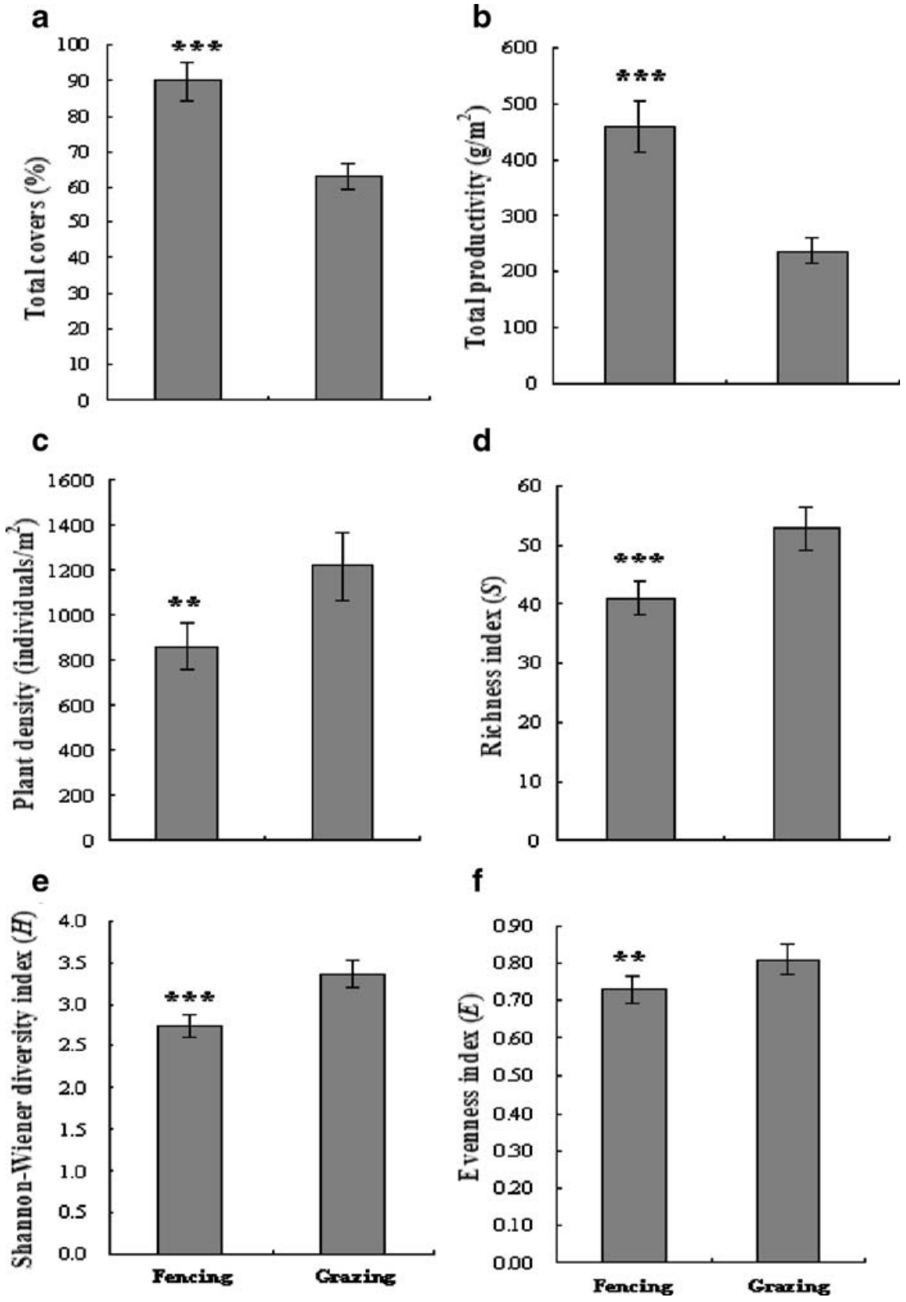
It is the average productivity for 3 years during the period of measurement. All species were herbaceous. For species' life types, P represents perennials, A represents annuals. Five functional groups were GG (grass species group); SG (sedge species group); LG (leguminous species group); FG (forbs species group) and NG (noxious species group). "—" show that there is no this species at the site.

matter was measured using the $K_2Cr_2O_7$ method (Soil Science Society of China 1983). Soil total nitrogen, available nitrogen, total phosphorus and available phosphorus were measured by the methods of Miller and Keeney (1982) at the Key Laboratory of Grassland Agro-Ecosystems, Ministry of Agriculture at Lanzhou University, China. The content of each nutrient trait calculated by the proportions of soil organic matter, total nitrogen, available nitrogen, total phosphorus and available phosphorus account for per soil dry weight.

Data analyses

Plant community structure during 2005–2007 was analysed to assess the effects of fencing and grazing on the meadow community, and soil characteristics in 2007 were analyzed to study the effects of the grazing

Fig. 2 Effect of fencing and grazing on Total covers (**A**, %), Total productivity (**B**, g/m^2), Plant density (**C**, individuals/m^2), Richness index (**D**, *S*), Shannon-Wiener diversity index (**E**, *H*) and Evenness index (**F**, *E*) of meadow community. Values (± SE) are means of ten squares for 3 years (2005, 2006 and 2007); Significant difference between fenced and grazed meadows are indicated by symbols, ***$P<0·001$, **$P<0·01$, *$P<0·05$; ns, no significant difference



treatments on soil traits. The statistical comparisons of mean values were conducted using an independent samples *t* test for total cover, total productivity (dry above-ground biomass), plant density, richness index and soil traits between fenced meadows and grazed meadows. Effects of years and grazing on cover, productivity and plant density for five functional groups were analyzed with one-way ANOVA with an experimental wise error of 0.05. Significant differences for all statistical tests were evaluated at the level of $P \leq 0.05$. All data analyses were conducted with the SPSS software (SPSS for Windows, Version 13.0, Chinago, IL, USA).

Results

Above-ground response to fencing and grazing

ANOVA analyses showed that the fenced plots had greater total vegetation cover (F=1.478, P<0.001) and total above-ground biomass (F=1.256, P<0.001) in comparison to the grazed meadow. However, the fenced plots had significantly lower plant density (F=2.200, P=0.001), richness index (F=0.708, P<0.001), Shannon-Wiener diversity index (F=0.438, P<0.001) and evenness index (F=4.623, P=0.001) in comparison to the grazed meadow (Fig. 2). Moreover, the grazed meadow had a higher community density and species diversity than the fenced meadow.

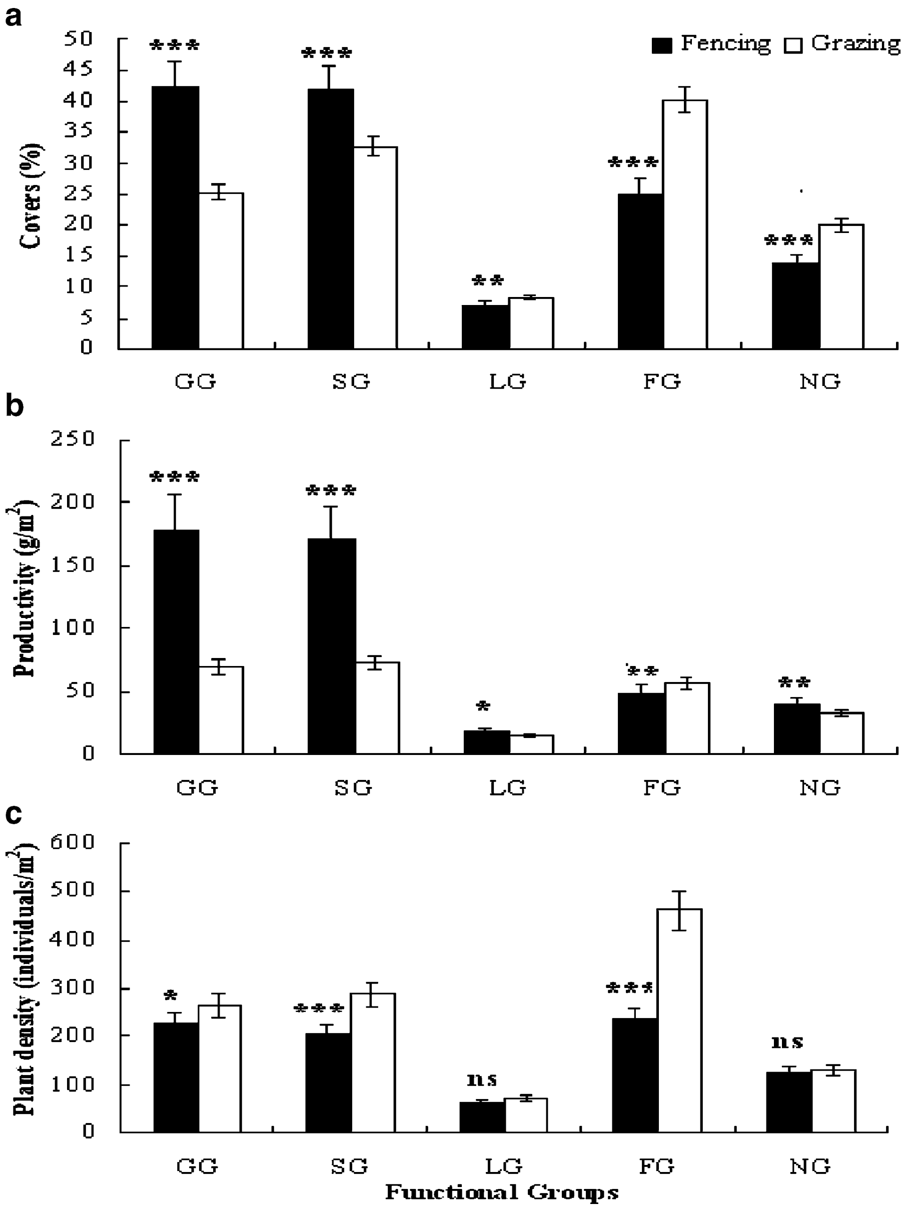
Fencing significantly increased covers of grass species group (GG, F=131.489, P<0.001) and sedge species group (SG, F=59.199, P<0.01) but decreased leguminous species group (LG, F=8.845, P=0.004), forbs species group (FG, F=58.280, P<0.001) and noxious species group (NG, F=20.334, P<0.001) (Table 2). In aboveground biomass of fenced meadow, only forbs species group (FG) functional group showed a decrease whereas the other four functional groups showed an increase. Long-term fencing significantly decreased plant density for all five functional groups (Fig. 3; Table 2).

The cover of the FG, NG and LG functional groups all increased over the period of the experiment in both fenced and grazed meadows. In contrast, the, cover of GG and SG decreased over time. The productivity of grazed meadow showed a weak decrease over time (Fig. 4; Table 2). The lowest productivity for fenced meadow occurred in 2007. There was significant difference in productivity for four (GG, LG, FG and NG) functional groups among 3 years (Table 2). Finally, there were significant decreasing trends for plant density both in fenced and grazed meadows (Fig. 4; Table 2).

Table 2 One-way analysis of variance of the effect of years and grazing (compared with fencing) on covers, productivity and plant density for five functional groups, GG (grass species group); SG (sedge species group); LG (leguminous species group); FG (forbs species group) and NG (noxious species group)

Functional groups		Year		Grazing	
		F	*P*-value	F	*P*-value
GG	Covers	16.178	<0.001	131.489	<0.001
	Productivity	5.654	0.020	546.965	<0.001
	Plant density	28.978	<0.001	4.385	0.039
SG	Covers	20.848	<0.001	59.199	<0.001
	Productivity	1.666	0.195	375.674	<0.001
	Plant density	35.215	<0.001	30.978	<0.001
LG	Covers	8.952	<0.001	8.845	0.004
	Productivity	27.403	<0.001	6.130	0.015
	Plant density	85.398	<0.001	1.388	0.242
FG	Covers	29.725	<0.001	58.280	<0.001
	Productivity	5.368	0.006	11.153	0.001
	Plant density	5.043	0.008	334.302	<0.001
NG	Covers	50.416	<0.001	20.334	<0.001
	Productivity	26.551	<0.001	9.802	0.002
	Plant density	16.069	<0.001	0.184	0.669

Fig. 3 Changes in Covers (**a**), Productivity (**b**) and Plant density (**c**) of meadow community for different functional groups under fencing and grazing conditions. Values (± SE) are means of ten squares for 3 years (2005, 2006 and 2007). Functional groups, GG (grass species group); SG (sedge species group); LG (leguminous species group); FG (forbs species group) and NG (noxious species group). Significant difference between fenced and grazed meadows are indicated by symbols, ***$P<0{\cdot}001$, **$P<0{\cdot}01$, *$P<0{\cdot}05$; ns, no significant difference



Below-ground response to fencing and grazing

There was a significant positive effect of fencing to soil characteristics. Long-term fencing of the meadows was associated with a reduction in pH from 7.88–7.13 (F=3.318, P<0.001) compared with grazed meadows. However, soil organic matter (F=0.251, P<0.001), total nitrogen (F=0.143, P=0.007), available nitrogen (F=2.342, P<0.001), total phosphorus (F=0.260, P<0.001) and available phosphorus (F= 2.711, P<0.001) of fenced meadows all increased significantly in relation to grazed meadow (Fig. 5).

Discussion

Fencing to exclude livestock is widely considered to be a simple and effective method for restoring vegetation productivity in degraded grasslands (Pettit et al. 1995; Spooner et al. 2002; Liu et al. 2007). Our experiment in high altitude meadow in the Qinghai-Tibetan Plateau demonstrated that fencing had significant effects not only on improvement of above-ground biomass and vegetation cover, but also on below-ground nutrient content. These latter results were consistant with those occurring through the applica-

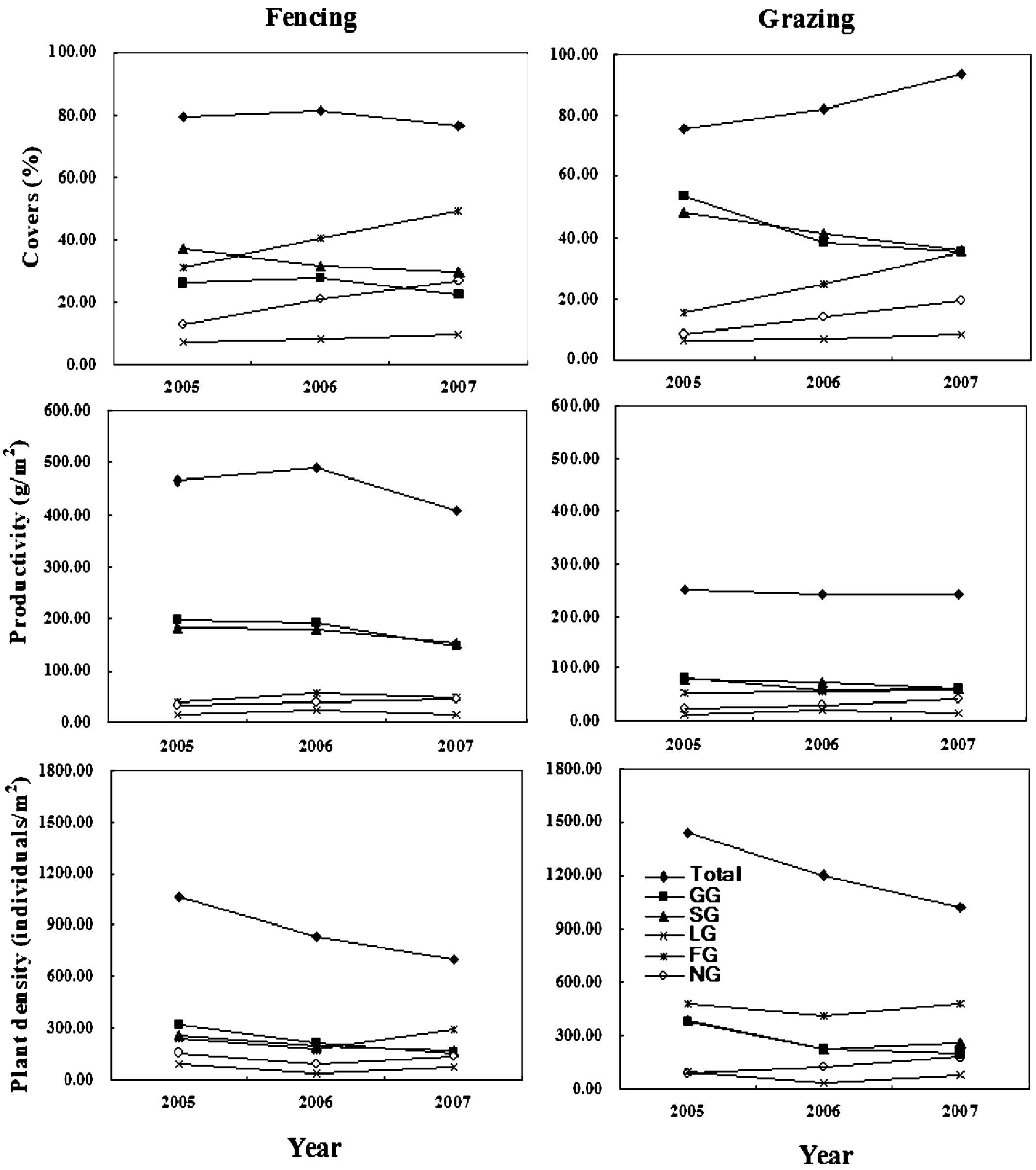


Fig. 4 Variation of covers (%), total productivity (g/m^2) and plant density (individuals/m^2) for total and five functional groups under fencing and grazing meadows in 3 year (2005, 2006 and 2007). Functional groups were the same with Fig. 2

tion of fertilizers and reseeding (Haugland and Froud-Williams 1999). Interannual variations of above-ground productivity were mainly determined by local precipitation, temperature and sunshine radiation (Niu et al. 2008). It suggests climatic factors are main driver for aboveground productivity variation besides overgrazing in alpine grassland (Klein et al. 2004; Akiyama and Kawamura 2007).

Our results showed that fencing had a positive effect on above-ground vegetation. Fencing increased cover and productivity by excluding livestock herbivory on forage grasses, especially for graminoids and sedgy species which are palatable to livestock (Table 1). Palatable grasses have greater competitive ability than unpalatable grasses and show a marked increase in abundance in grasslands where livestock

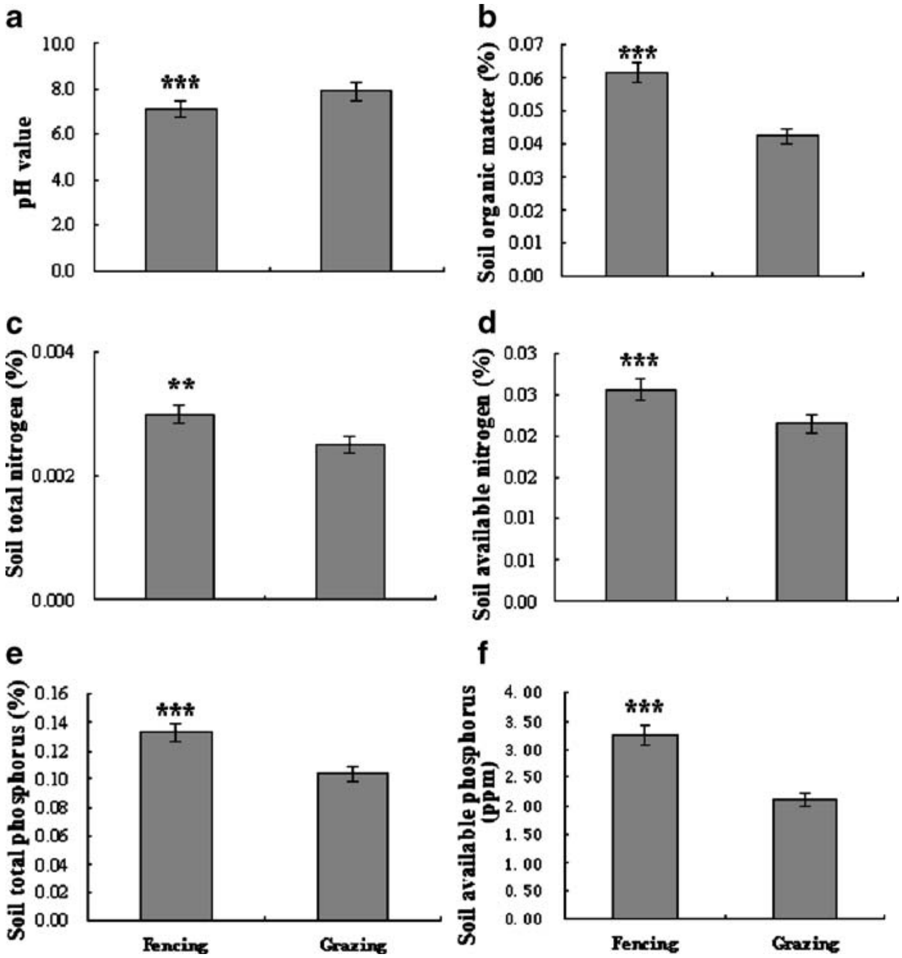


Fig. 5 Changes (mean ± SE) in soil pH value (A), Soil organic matter (B, %),Soil total nitrogen (C, %), Soil available nitrogen (D, %), Soil total phosphorus (E, %) and Soil available phosphorus (F, ppm) of meadow under fencing and grazing conditions in 2007. Significant difference between fenced and grazed meadows are indicated by symbols, ****P*<0·001, ***P*<0·01, **P*<0·05; ns, no significant difference

are excluded for ten or more years (Distel and Boo 1996; Moretto and Distel 1997; Gallego et al. 2004). In concordance, graminoids and sedge species, which dominate in alpine community and are palatable for herbivores, showed significant improvement in fenced meadows. But, grazing accelerated shoot and leaf mass loss and nutrient cycling for these dominated species by herbivory (Semmartin et al. 2008) and significantly reduced aboveground biomass in grazed meadow. However, fencing also had negative consequences for biodiversity because it led to a reduction of plant density and species diversity and a decrease of meadow community evenness. Plant diversity loss in high-productivity grassland may result from greater competition for canopy resources (i.e. light) (Grime 1979; Huston 1994). Some species with lower competitive ability reduce their density or disappear in plant community because of competition for light resources (Grime 1998) or nutrient availability (Van der Wal et al. 2004). Long-term fencing in the Qinghai-Tibetan meadow resulted in lower plant density and species diversity and led to the community being dominated by a few species with strong colonization abilities. In contrast, grazing can reduce graminoids and sedge species which were dominant in alpine meadows (Table 1). As a consequence, mowing and long-interval grazing utilization can be conducted as effective management method to regulate community structure and keep plant diversity for these grasslands. The question of how to determine the point where meadows can be grazed or mown requires further study in grassland management and utilization.

Fencing minimized disturbance from livestock and improved soil nutrient characteristics. Excluding grazing reduced the outflow of energy and nutrient from soil-plant system to consumers (livestock), because plants locked the abundant nutrients within their tissues (Harris et al. 2007), especially for palatable grasses which had higher productivity and quality (Moretto and Distel 1997). Above-ground plant resources will be returned to the soil when litter layers decompose (Bardgett and Wardle 2003) in fenced meadow. In the grazed meadow, however, some energy and nutrient are transferred to livestock and escape from the soil-plant system through herbivory. Previous studies had concluded that grazing can alter soil characteristic negatively in two ways. First, it can reduce litter biomass and root biomass (Gao et al. 2008) which reverts to soil after decomposition. Meanwhile, litter decomposition rate and soil nitrogen availability are higher for palatable grasses than unpalatable grasses (Moretto et al. 2001, Moretto and Distel 2002). Second, long-term trampling by livestock can lead to changes in soil compaction, soil infiltration rates, soil bulk density, soil porosity, and limited oxygen and decline of activity of edaphon in soil (Holt 1997). In contrast, the fenced meadows limited trampling and improved soil properties resulting in an increase of interception of water and improvement of vegetation (Li et al. 2007). With the improvement in the condition of above-ground vegetation, parts of fine particle and dustfall enriched with nutrients could be intercepted and captured because of its function of reducing wind velocity (Liu et al. 2007). Soil nutrient improvement derived from fencing will have positive feedback effects on plant community structure and productivity, because higher nutrient availability favors the competitiveness of graminoids species over other species (Van der Wal et al. 2004) and the productivity of alpine meadows are dominated by graminoid species. Meanwhile, a significant positive correlation between aboveground productivity and soil nutrient (organic matter and total nitrogen) in *Kobresia tibetica* meadow, *Kobresia humilis* meadow and *Kobresia pygmaea* meadow of the Qinghai-Tibetan Plateau had been reported (Wang et al. 2007, 2008). In addition, the decrease of root herbivory by rodents (*Myospalax fontanierii* and *Microtus leucurus*) in fenced meadow also can positively affect the soil biota and soil processes through changes in resource inputs to soil (Bardgett and Wardle 2003). But, only chemical analyses on soil were done in this study and some physical or biological contents should be considered in the future.

The botanical components in fenced meadow during 3 year reflected that grassland were undergone a change from the smaller individuals with the higher density to the larger individuals with the lower density, and from dominated by unpalatable plants with the higher diversity to dominated by palatable plants with the lower diversity, relative to grazed meadow (Table 1). Additionally, variation of plant density for five plant functional groups implies that there were fewer individuals and greater total productivity in fenced meadow and little recruitment of new plants. It suggests that long-term fencing bring a loss of species diversity by affecting habitat invisibility which determines seedling recruitment of native species (Gufu et al. 2001) and invasion of other adventitious species (Inderjit 2005). But, the grazed meadow had a higher species diversity and plant density than the fenced meadow. This may be explained by enhancement of cattle-mediated seed dispersal and seedling establishment (Oesterheld and Sala 1990), release from competitive exclusion by suppression of taller dominants and by increased spatial heterogeneity (Olff and Ritchie 1998; Bokdam and Gleichman 2000; Stohlgren et al. 2005). Grazing also affected the height, cover and density of dominant species (i.e. graminoids) and created a variety of habitats in the community. Furthermore, grazing greatly increased gap formation (Tainton et al. 1996; Sternberg et al. 2000; Holdo et al. 2007) and the rate of regeneration (Sheppard et al. 2002) and allowed the establishment of native or exotic species and development of a more species-rich community. Previous studies have concluded that grazing could help maintain native plant diversity in ephemeral wetlands of central valley of California (Marty 2005) and can dampen species diversity loss caused by climate warming in alpine meadows on the Tibetan Plateau (Klein et al. 2004). Consequently, low-degree disturbance could enhance the diversity of vegetation (Schippers and Joenje 2002). While grazing induced plant mortality might decrease species diversity, it opens up space for colonizers from elsewhere and recruitment of native species, which might increase species diversity (Begon et al. 1990). All these process may enhance the invasion and survival of exotic species and recruitment of native seedlings.

Grazing is a key factor in grassland degradation and is also a major driving force for grassland succession (Holdo et al. 2007). Plant biodiversity depends critically upon the intensity of grazing. Too much grazing may lead to land degradation and the loss of biodiversity, while too little grazing may lead to succession from grassland to woodland and the loss of the grassland habitat. Not only is the level of grazing important, but also of importance is the timing and the animals species involved (Grant et al. 1996; Hulme et al. 1999). There is a need for more research on the effects of grazing and fencing grassland, particularly with respect to global changes in climate (Watkinson and Ormerod 2001).

In general, long-time fencing resulted in alteration of plant productivity and community structure and subsequent changes in the quantity and quality of litter inputs to soil for alpine meadows. There is a dilemma between grazing utilization and biodiversity protection of grasslands under either very heavy grazing pressure or in the absence of grazing (Watkinson and Ormerod 2001). Fencing and grazing had opposite effects on grassland productivity and species diversity as disturbance measure. However, the "intermediate disturbance hypothesis" suggested that species diversity should be highest at moderate levels of disturbance. Moderate grazing increases plant species diversity at local (or patch) scales of resolution (Landsberg et al. 2002), e.g. deferred grazing (Buttolph and Coppock 2004). Our study demonstrated that grazing can be used as a good management method to keep species diversity and abundance in long-term fenced meadows. We suggest that periodic grazing and fencing could be considered as a beneficial disturbance for grassland management. Integrative measures (i.e. fertilization, fencing, reseeding and grazing) should be conducted during grassland restoration management and utilization. More research on fertilization, fencing time, grazing intensity, grazing time, reseeding intensity, reseeding time and reseeding species should be conducted in grassland restoration, management and utilization in the future.

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