Vegetation recovery in response to the exclusion of grazing by sika deer (*Cervus nippon*) in seminatural grassland on Mt. Kushigata, Japan

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ABSTRACT

We examined the recovery of vegetation in seminatural grassland in central Japan after eliminating grazing by sika deer (*Cervus nippon*) by fencing. By 2012 after 5 years fencing for exclusion of sika deer, the species composition of quadrats within the enclosure reverted to the original species composition in 1981, not browsed by sika deer. Conversely, that outside the fence was different from the baseline quadrats in 1981. *Iris sanguinea*, a prominent flower in the area, recovered within the enclosure, while it continued to decrease with grazing outside the fence. Nevertheless, the *I. sanguinea* cover had not recovered to 1981 levels in the enclosure. Fencing can effectively restore vegetation as the species composition within the enclosure gradually reverts to the

original vegetation. Preventing grazing in intensively grazed seminatural grassland might lead to different successional pathways. Since *I. sanguinea* did not recover fully within the enclosure and the species composition differed slightly from the original vegetation, this suggests that the vegetation within the enclosure will change to an alternative state. Therefore, different management is needed to promote the correct succession pathways for ecological restoration, perhaps by enhancing the colonization of target species, to prevent restored sites from giving rise to alternative states.

INTRODUCTION

Traditionally, seminatural grasslands in Japan have been managed for grazing cattle and harvesting agricultural materials [e.g., fertilizer; 1]. However, most of these have been abandoned with changes in lifestyle and farming methods [2], as in other countries [e.g., 3]. In Japan, forests cover 78% of the land area [4] and the mild, humid climate promotes the growth of forests [5]. Consequently, abandoned grasslands are invaded by trees, and important for especially early successional species and species favoring open habitats [e.g., 6]. So, such seminatural grassland has high priority to conserve biological diversity.

Recently, the population of sika deer (*Cervus nippon*) in Japan has increased sharply [7, 8]. The effects of deer on natural grassland vegetation have been reported worldwide [*e.g.*, 9]. In Japan, deer have had serious effects in natural forest [10, 11], plantations [12, 13], and grasslands [14; 15]. Since sika deer prefer open habitat as foraging sites [16], patchy grasslands surrounded by forests are used heavily by sika deer. Consequently, the plant species composition in the grasslands has been altered markedly by grazing sika deer.

On Mt. Kushigata (2053 m a.s.l. at the summit) in central Japan, seminatural grasslands are distributed patchily with plantations and fragmented natural forests [17]. In the grassland, the flowers of *Iris sanguinea* and other meadow species (e.g., *Veronicastrum japonicum*) had been renowned. However, those flowers have been decreasing since 2000 because of grazing by sika deer. As countermeasures for the grazing, fences were set in the grassland in 2007. Fencing is effective for recovering from herbivore grazing [18, 19] and promotes tree regeneration [20, 21]. The effects of grazing exclusion from seminatural grasslands on species richness [22] and spatial patterns [23] have been studied. However, undesirable results, in which attempted at ecological restoration might lead to alternative states [24], can occasionally occur when fencing is used as a tool for conservation in overgrazed environments [25]. Therefore, restoration efforts should be checked by comparing the results with the restoration target [3, 4].

This paper presents the vegetation recovery pattern in seminatural grassland, in central Japan, after preventing grazing with fencing, addressing the questions can *I. sanguinea* and a vegetation community recover to the original situation and community before those were affected by sika deer?

METHODS

Study site

The study was conducted on Mt. Kushigata (2053 m a.s.l. at the summit), Yamanashi Prefecture, in the cool–temperate zone of central Japan (35°35'N, 138°22'E). The mean annual precipitation and temperature at the nearest meteorological station (Oizumi, 867 m a.s.l.) are approximately 1140 mm and 10.7°C, respectively. The estimated mean annual temperature at the summit of Mt. Kushigata is about 3.5°C. Snow cover is usually less than 1 m.

On Mt. Kushigata, seminatural grasslands are distributed patchily with plantations and fragmented natural forests [17]. The origin of the grassland is not clear, but elevations in this region around 2000 m are typically dominated by subalpine coniferous forests composed of *Abies* and *Tsuga* species. The grassland was probably the result of human activity, such as mowing or burning. We studied the Hadakayama area of Mt. Kushigata. Hadakayama means “naked mountain,” which indicates that this area has not been covered by forest for a long time. The grasslands in the Hadakayama area are renown for the flowers of *I. sanguinea*. Over a 10-year period, however, the number of *I. sanguinea* flowers has decreased, possibly as a result of natural succession from grassland to the typical subalpine coniferous forest. Grazing by sika deer was another potential reason. Therefore, fences to exclude sika deer were erected to prevent grazing in 2007.

Field study

In July 1981, the science club of Koma High School studied the vegetation in the Hadakayama area [6]. They set 32 1 × 1-m quadrats in the Hadakayama area typically dominated by *I. sanguinea* and applied the standard Braun–Blanquet scale: +, sparse cover; 1, cover <5%; 2, cover 5–25%; 3, cover 25–50%; 4, cover 50–75%; 5, cover 75–100%. The species composition in 1981 is considered the original vegetation not affected by grazing by sika deer.

In October 2007, we established a 20 × 20-m plot and fenced half of it (10 × 20 m) to protect it from deer grazing. The quadrats set by Koma High School were 20 m from the plot. In June 2008, we established 20 1 × 1-m quadrats, 10 inside and 10 outside the fence, and conducted annual surveys from 2008 to 2012 using the Braun–Blanquet method. We counted the number of individuals of *I. sanguinea* in each quadrat every year.

Analysis

Koma High School [6] did not list all rare species (*i.e.*, species with low coverage in the quadrats studied). Therefore, we analyzed the species with coverage with a score >1 on the Braun–Blanquet scale.

We used nonmetric multidimensional scaling [NMS; 26] to provide an ecologically interpretable quantification of the compositional differences among original vegetation (1981) and quadrats inside and outside the fence (2008-2012). NMS applied Sørensen's similarity index to calculate a distance matrix. We used the species cover in each quadrat for NMS, after transforming the Braun–Blanquet scale quantitatively. The data transformed to cover values (the midpoints of the cover intervals for each score) were used, *i.e.*, scores of 1 to 5 were converted to the values 2.5%, 12.5%, 37.5%, 62.5%, and 87.5%, respectively [27]. NMS was performed using PC-ORD [26].

To show the recovery of *I. sanguinea*, we compared the number of individuals and cover.

RESULTS

The recovery of *I. sanguinea* inside the fence was good, while outside the fence, it decreased continuously with grazing (Fig. 1). The number of flowering *I. sanguinea* also increased inside the fence to 25 in 2010, 198 in 2011, and 307 in 2012, while no flowers occurred outside the fence (unpublished data, Committee of Conservation of *I. sanguinea* at Mt. Kushigata). Nevertheless, the *I. sanguinea* cover had not recovered fully compared to 1981 (Fig. 2).

The changes in the number of species inside and outside the fence showed contrasting trends (Fig. 3). The number of species increased inside the fence, but not outside it. The species composition differed markedly inside and outside the fence (Fig. 4). In 2008, most of the quadrats were located in the upper left position in the NMS diagram. Then, the species composition of the quadrats within the fence shifted to the upper right position in the diagram, where the species composition in 1981 was located (*i.e.*, not browsed by sika deer). Conversely, the species composition of the quadrats outside the fence was shifted to the lower right. Species that occurred in more quadrats inside the fence were *Dianthus superbus* var. *longicalycinus*, *Phedimus aizoon* var. *floribundus*, *Serratula coronata*, and *Chamerion angustifolium* as well as *I. sanguinea* (Table 1). *Angelia pubescens*, *Veronicastrum japonicum*, and *I. sanguinea*, which were categorized by tall herbs, were only dominated inside the fence. *Brachypodium sylvaticum* and *Raunculus japonicas* were less dominated before grazing, but were domnated after exclusion of sika deer. Outside the fence, *Artemisia princeps* initially dominated, and subsequently the graminoids *Stipa pekinensis* and *B. sylvaticum*, which appeared to be unpalatable, dominated.

DISSCUSION

Exclusion of sika deer by fencing were successfully recovering the cover and number of individuals of *I. sanguinea* because those outside the fence were continuously low. Thus, effects of grazing by sika deer were continuously severe. In seminatural grassland of northern Japan, *Iris setosa* dominated the most at sites grazed by horses, which improved the surface soil characteristics [28]. In our study, sika deer grazed on *I. sanguinea* directly, causing serious damage. Thus, to conserve *I. sanguinea*, fencing seems necessary under the present circumstances. Since Tamura [29] showed that vegetation recovery, particularly tall herb species, was poor when fencing was delayed, it will be impossible for *I. sanguinea* to recover fully even if fences are erected now. However *I. sanguinea* would not recover fully compared to situation before grazing despite the fence.

Fencing appeared to be effective at restoring the vegetation as the species composition in the fence gradually reverted to the original vegetation. Herbivores often, but not always, increase plant diversity in grasslands [30]. Outside the fence, however, since the species composition was altered and the number of species was low, intense grazing pressure by sika deer likely existed.

Rooney and Dress [31] showed that species with relatively lower abundance were more likely to be missing due to browsing than more abundant species. Actually, species with lower abundance in 1981 (e.g., *Polygonatum odoratum*, *Ixeridium dentatum*, *Hakomechlon macra*) were not recover even after fencing. By grazing, tall-growing herb were reduced and lower-growing species were increased [32] and grazing-resisted species were shorter in height than grazing-susceptible species [33]. Thus, tall herb species were easy to grazing and hard to recover after grazing.

CONCLUSIONS

Preventing grazing after intensive grazing of seminatural grassland might result in different successional pathways being followed and the species composition is slightly different from the original vegetation, this suggests that the vegetation inside the fence will change to an alternative state [24]. Galvánek and Lepš [3] showed that the species composition of the restored plots after the reintroduction of mowing was still far from the target composition. Therefore, different management methods are needed to ensure the correct succession pathways are followed for ecological restoration and to enhance colonization of the target species [34], rather than the restored site resulting in an alternative state [24]. Thus, other methods to restore the vegetation (e.g., removing of unpalatable recalcitrant species, [35]) inside of the fence would be necessary. Moreover, as Wright et al. [36] suggested that complete removal of ungulates may be required for recovery in heavily browsed forest understory vegetation in New Zealand, control of sika deer population should be required.

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Figure caption

Fig. 1 Changes of mean number of individual of *Iris sanguinea* in each quadrat.

Fig. 2 Changes of mean cover of *Iris sanguinea* in each quadrat.

Fig. 3 Changes of mean number of species occurred in each quadrat.

Fig. 4 Results of nonmetric multidimensional scaling (NMS) for species occurred in each quadrat.

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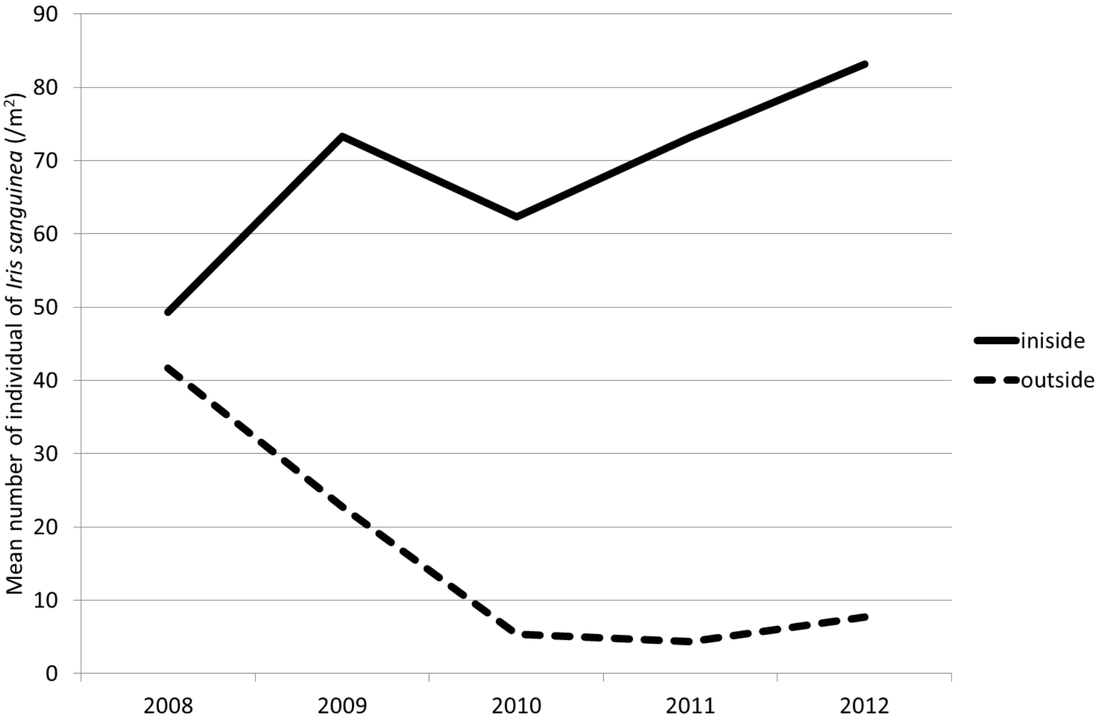
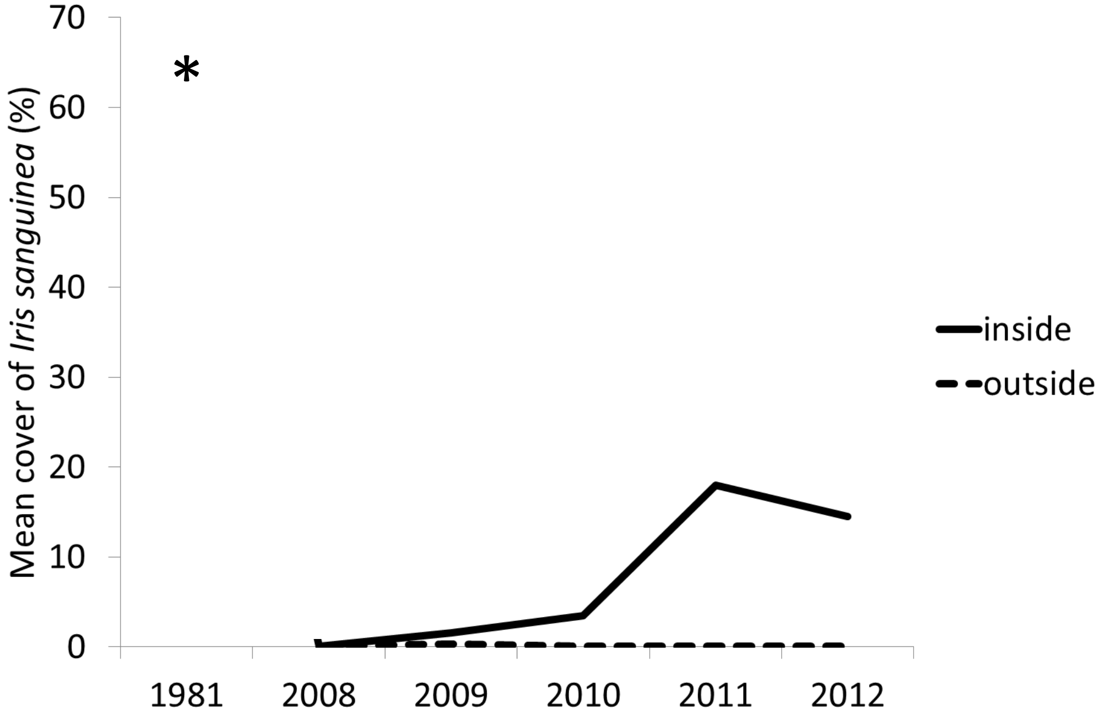


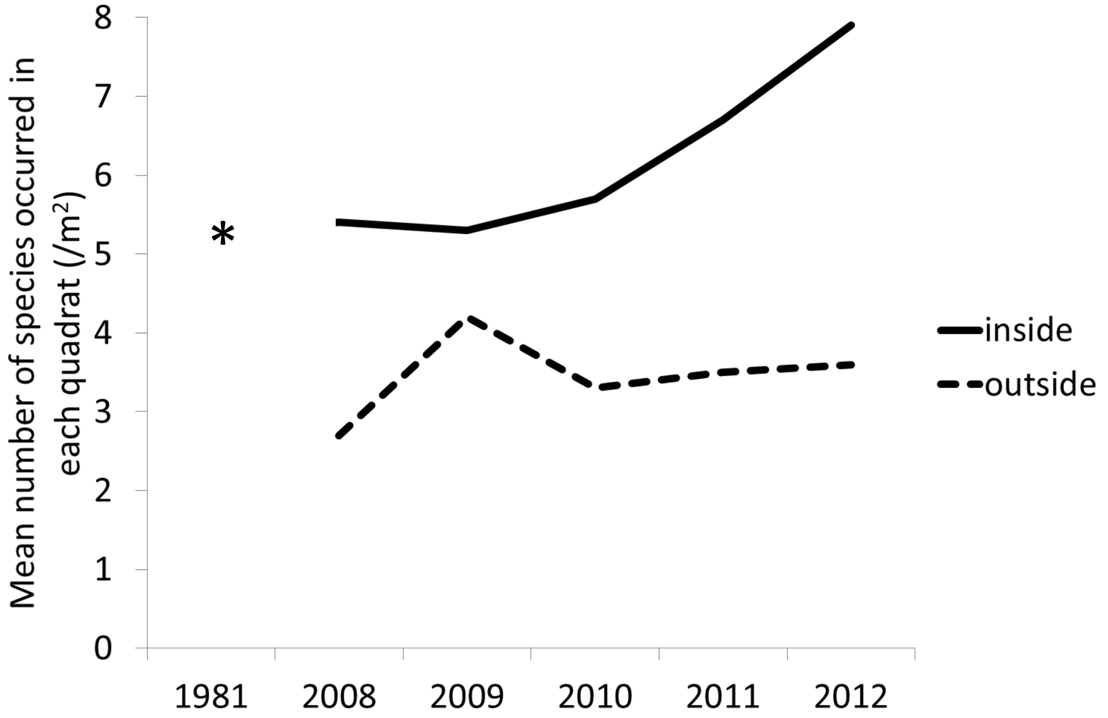
90
80
70
60
50
40
30
20
10
0
Mean number of individual of *Iris sanguinea* (/m^2)
2008
2009
2010
2011
2012
iniside
outside

Fig.1



Mean cover of Iris sanguinea (%)
70
60
50
40
30
20
10
0
*
inside
outside
1981
2008
2009
2010
2011
2012

Fig.2



Mean number of species occurred in each quadrat (/m²)
8
7
6
5
4
3
2
1
0
*
1981
2008
2009
2010
2011
2012
inside
outside

Fig.3

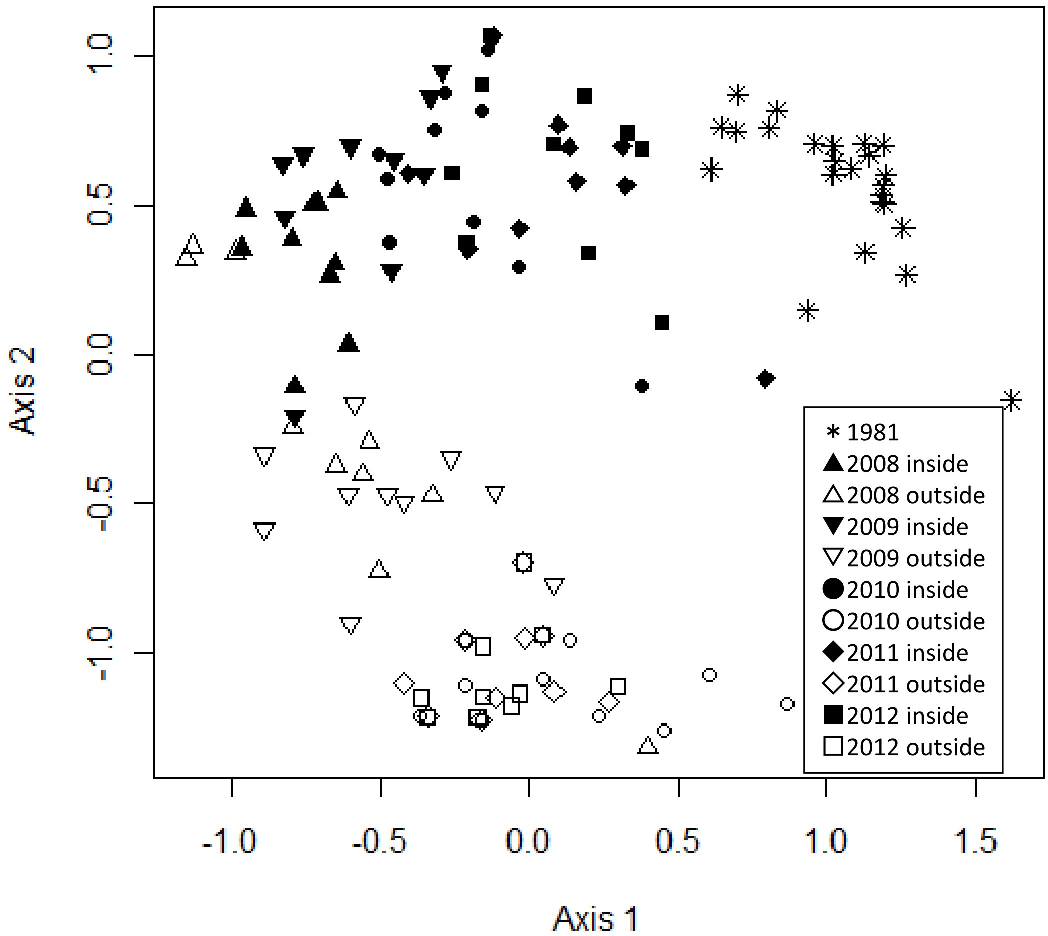

Axis 2
1.0
0.5
0.0
-0.5
-1.0
-1.0
-0.5
0.0
0.5
1.0
1.5
Axis 1
1981
2008 inside
2008 outside
2009 inside
2009 outside
2010 inside
2010 outside
2011 inside
2011 outside
2012 inside
2012 outside

Fig.4

Table 1. Number of quadrats in species occurred. Total number of quadrats are 36 in "Before grazing", 10 in "Inside the fence" and 10 in"Outside the fence", respectively.

Species	Before grazing	Inside the fence					Outside the fence				
	1981	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
Adenophora remotiflora	1										
Adenophora triphylla	3										
Agrostis clavata									1		
Anaphalis margaritacea	2										
Angelica pubescens	2	4	3	2	3	5					
Aquilegia buergeriana		1	1			1			1		1
Arabis hirsuta		1						1			
Arenaria serpyllifolia											1
Artemisia princeps	2	10	10	8	7	8	9	9			
Astilbe microphylla	6										
Brachypodium sylvaticum		3	2	4	4	3	5	7	8	10	10
Campanula punctata	2							1			
Chamerion angustifolium	6					1					
Cirsium gratiosum								1	1	1	1
Clinopodium chinense subsp. *grandiflorum*		5					2				
Dianthus superbus var. *longicalycinus*				1	3	2					
Dryopteris expansa	4										
Filipendula multijuga				1		1					
Fragaria nipponica		4	4	2	3	4		3	1	2	2
Geranium onoei	14		1	2	5	9	1				
Gymnadenia conopsea				1							
Hakonechloa macra	2										
Iris sanguinea	23		6	9	10	10		1			
Ixeridium dentatum	1										
Jacobaea cannabifolia	4		2	4	4	4	2				
Ligularia dentata	1								1	1	2
Malus toringo							1	1			
Moehringia lateriflora		3	2				1				
Oxalis corniculata								1	2	3	3
Phedimus aizoon var. *floribundus*	1				1	2					
Picris hieracioides	1			1	2			1			
Polygonatum odoratum	3										
Polygonum cuspidatum	1			1	1	3					
Potentilla freyniana		4	5	1		2					
Ranunculus japonicus	1	10	8	8	8	8	2	5	2	4	3
Scabiosa japonica	8		1	2	2	1					
Serratula coronata	19	1			2	2					
Solidago virgaurea	4										
Stipa pekinensis		1					4	8	10	10	10
Tephroseris flammea	3				1			2	6	4	3
Veronicastrum japonicum	12	7	8	10	9	10		1			
Viola acuminata					2	3					