Heterogeneous Impacts of Grazing Animals and Vegetational Change in Japanese Native Pastures

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Abstract

Defoliation, defecation and trampling are the major modes whereby grazing animals give impacts on vegetation. Due to the uneven distribution, such grazing behavior can have profound effects on vegetation. For extensive grazing systems in native pastures, understandings of the plant-animal interaction are vital for adequate control of vegetation and animal conditions and sustainable use of natural resources. This paper reviews recent studies of the grazing impacts on vegetation in Japanese native pastures. Most of the studies were carried out in the Kawatabi Field Science Center (Kawatabi FSC), Tohoku University.

1. Native pastures in the Kawatabi FSC are composed of 61–155 plant species, of which cattle graze upon 26–76 species. Among these species, *Miscanthus sinensis* (Japanese plume-grass) was the most frequently grazed by cattle. The spatial distribution of available forage is a major factor affecting diet selection and consumption of cattle. Such selective grazing results in significant reduction of *M. sinensis* in native pastures.
2. Seed dispersal of plants by defecation of grazing animals can also result in significant vegetational change. Recent studies have shown that *Carex* spp. is the major plant whose seeds are dispersed by defecation of animals rotationally grazed in a native and a sown pasture. The mechanisms of the seed dispersal and its possible effects on vegetational succession are discussed.
3. Heavy trampling is known to degrade vegetative ground cover. Our research has shown that trampling by cattle promotes the invasion of a shrub, *Weigela hortensis* into *Miscanthus*-dominant pastures. Because the seeds of *W. hortensis* are light sensitive germinators, trampling by removing ground cover promotes its seed germination.

These findings provide new perspectives on plant-animal interactions in Japanese native pastures and help estimate the impact of animals on plant succession. They also contribute to efforts to ensure sustainable grazing use of pastures.

Introduction

It is well known that behavior of grazing herbivores including defoliation, defecation and trampling affect pasture vegetation (Vallentine 2000). The actual impact of such behavior is spatially heterogeneous, and can give profound effects on vegetation where it concentrates.

In native pastures in Japan, large herbivores such as beef cattle and horse have been allowed to graze for more than 150 years. In such grazing systems, understandings of the impacts of behavior of herbivores on vegetation are vital for the sustainability of both animal production and the conservation of natural resources and biodiversity.

Studies on plant-animal interactions have been carried out in native pastures grazed with beef cattle at the Kawatabi Field Science Center (Kawatabi FSC), Graduate School of Agricultural Science, Tohoku University, to develop a grazing system for mountainous regions in Japan. Early research focused on vegetational characteristics and forage production (e.g., species composition, canopy structure, and forage production) and behavior and productivity of animals. Recent research has focused on the impacts of grazing animals on vegetation; i.e., 1) diet selection of grazing animals under diverse vegetation, 2) seed dispersal by defecation of animals, 3) effects of trampling of animals on vegetational changes.

The objective of this paper is to review recent studies of the impacts of grazing herbivores on

Table 1. The number of plant species growing and grazed by cattle in native pastures at the Kawatabi Field Science Center.

Year	Growing		Grazed by cattle		Reference
	No. of sp.	Dominant sp.	No. of sp.	Dominant sp.	
1955	155	*M. sinensis*[1]	76	*M. sinensis*	Iizumi et al. (1956a)
1963	80	*M. sinensis*	44	*M. sinensis*	Sato (1996)
1972	-	-	N 75[3]	-	Hasegawa et al. (1973)
			B 55	-	
			H 47	-	
1992	61	*P. aquilinum*[2]	48	*M. sinensis*	Matsumoto and Sugawara (1995)
2002	66	*M. sinensis*	26	*M. sinensis*	Takahashi et al. (2003)

[1] *Miscanthus sinensis* (Japanese-plume grass)
[2] *Pteridium aquilinum* (Blackenfern)
[3] N: Japanese Shorthorn, B: Japanese Black, H: Holstein.

vegetation in native pastures in Japan. Most of the studies described were carried out at the KFSC.

1. Selective grazing: damage of defoliation to Miscanthus *sinensis*

Selective grazing is one of the major factors affecting vegetation in grazing systems, exerting its effects at several hierarchical levels; i.e., from a small patch or a feeding station to landscape (Senft et al. 1987; Vallentine 2000). In native pastures, animals encounter a variety of plant species of differing canopy structures, quality and phenology. These vegetational characteristics affect diet selection and consumption of animals.

The Kawatabi FSC has a large native pasture dominated by *Miscanthus sinensis* (Japanese plume-grass). Previous studies have shown that the pasture is composed of 61-155 plant species (Iizumi et al. 1956a; Matsumoto and Sugawara 1995; Sato 1996; Takahashi et al. 2003), of which cattle graze upon 26-76 species (Iizumi et al. 1956a; Hasegawa et al., 1973; Matsumoto and Sugawara 1995; Takahashi et al. 2003) (Table 1). Among these species, *M. sinensis* is one of the most frequently grazed (or strongly selected) by cattle, suggesting that *M. sinensis* is valuable foliage cattle in the grazing system.

The frequent grazing, or strong selectivity, to *M. sinensis* can lead to reduction of the species. Takahashi et al. (2000a, 2000b) showed that *M. sinensis* declined for 3 consecutive years, even under a low grazing intensity (39.3–66.7 heads•day/ha/year), with reduced the stand size and the number of tillers per stand rather than population density. To evaluate the damage inflicted by grazing animals on *Miscanthus*-dominated pastures, recent research has focused on the mechanisms of selective grazing. Investigations of plant structure and ingestive behavior of cattle suggested that *M. sinensis* offers an abundance of available leaves at different heights of each stand (Takahashi et al. 2005) (Figure 1), enabling animals to take more bites from different heights within a feeding station compared to other native grasses (Takahashi et al., unpublished data).

Further studies, including investigation of the damage of tillers of *M. sinensis* by foraging of large herbivores, will provide useful information on the effects of selective grazing on *M. sinensis* populations in pastures.

2. Seed dispersal by defecation of grazing animals: contribution to diffusion of Carex albata

Seed dispersal by the defecation of grazing animals is another significant factor in vegetational change (e.g., Janzen 1984; Archer and Pyke 1991). It is well known, for example, that the seeds of certain plant species are ingested by grazing animals and disseminated through the digestive tract. Recent studies have shown that grazing cattle dispersed seeds of monocotyledons and forbs such as *Carex albata, Cerastium holostoroides*, *Rumex obtusifolius* and *Viola* sp. (Obara et al. 2006) (Table 2). *Carex albata* is on of the species most commonly dispersed by defecation of cattle (Watanabe et al. 2002; Obara et al. 2006). This phenomenon can have wide-ranging effects on vegetation in cases in which animals are rotationally grazed from a pasture where such plants are dominant to other pastures.

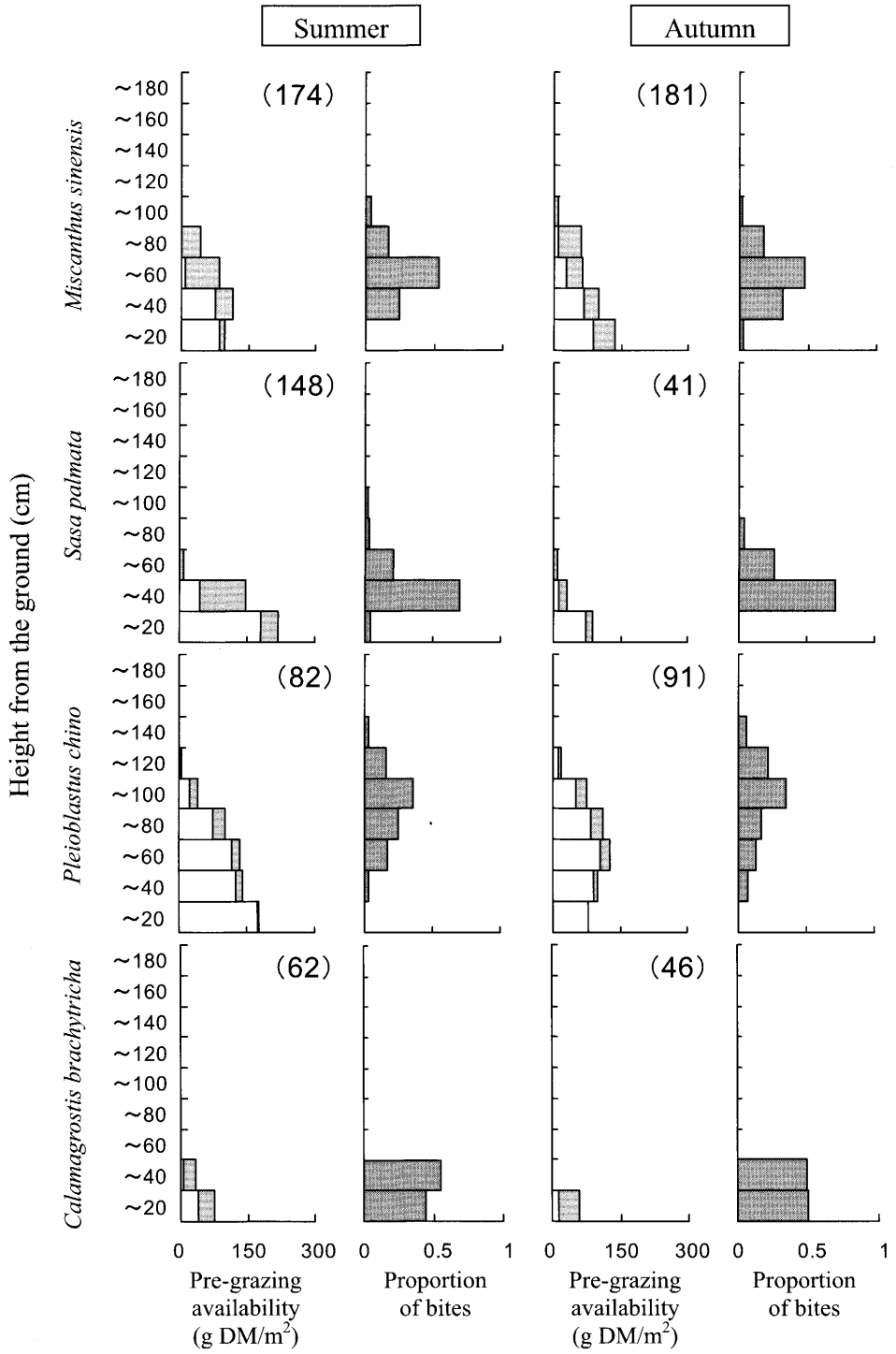

Fig. 1. Vertical distribution of leaves (gray color) and stem (white color) and proportion of bites taken by grazing steers in 4 major native grass species. The number in each parentheses represents the total amount of available leaves (g DM/m^2) (Takahashi et al. 2005).

Seed dispersion via defecation requires the ingestion of seeds by animals as a first step. This means selective grazing is an important factor in understanding the mechanism underlying this phenomenon. Sward-based measurements showed that *Carex albata* was grazed by cattle throughout the grazing seasons, even in heading stage (Obara et al. 2006). It would also appear that since the height of *Carex albata* seed heads are nearly equal to that of the leaves (Obara et al. 2006), cattle may have difficulty completely avoiding the seed heads while grazing, even if they would prefer to do so.

The location of dung and its environment also affects vegetation. Dung in grazing pastures tends to aggregate in certain areas – around a corral, a watering and feeding place, on a resting place of animals such as a ridge and under a tree (e.g., Hirata et al. 1987; Tajima et al. 2002). At such locations, plant seeds enter the soil seed bank from dung and may result in dramatic vegetational change (Harasawa et al. 1987). A recent study, however, suggested that both sunny areas (e.g., resting areas on a ridge) and shaded areas (e.g., under trees) are unsuitable for germination of seed from (Obara et al., unpublished data). Dung patches may be suitable for germination and establishment of plant seeds in dung because the environmental conditions of sunshine and moisture are moderate, and because these areas tend to be protected from defoliation and trampling by animals.

To fully understand the effects of seed dispersal by defecation on vegetational change, further study is required of on plant (seed) – animal interactions, including investigations of the effects of mastication and digestion in the digestive tract on seed survival and germinability.

3. Effects of trampling: promotion of Weigela horetensis *invasion into a* Miscanthus*-dominant pasture*

Trampling by grazing animals damages the aboveground portions of plants, enhances soil compaction, and removes litter covering the ground. All the factors result in vegetational change. While grazing cattle in Japanese native pastures tend to convert tall (*Miscanthus*-type) grasslands to sod (*Zoysia*-type) grasslands (e.g., Iizumi et al. 1956b; Hayashi et al. 1968), cattle grazing in a *M. sinensis* pasture appears to increase a shrub species (*Weigela hortensis*) in certain areas in the Kawatabi FSC. The invasion of *W. hortensis* is noteworthy on concave slopes rather than convex slopes (Nishiwaki et al. 1993).

Recent research suggests some possible reasons the shrub species invaded and proliferated in the tall pasture. First, the decline in aboveground biomass (Shinsho and Sugawara 2002) and seed production (Nishiwaki et al. 1996) of *M. sinensis* due to selective grazing promotes the invasion and survival of the shrub. Second, the removal of ground litter by

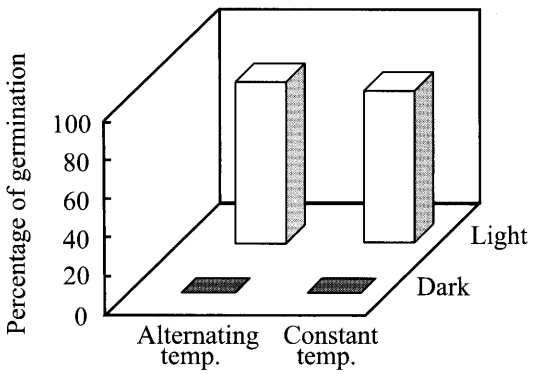

Fig.2. Percentage of germination in Weigela hortensis in artificially controlled conditions (Shinsho et al. 2000). Alternating condition: 25/15°C (12 hrs interval), Constant condition: 25°C.

Table 2. Total number of seedlings germinated from feces of cattle rotationally grazed in a sown and a native pasture at the Kawatabi Field Science Center (Obara et al. 2006).

Plant species	No. of seedlings germinating (/kg feces)[2]	
	Mean	SD[3]
Carex albata	129.8	355.3
Cerastium holosteroides	7.3	22.4
Other Cyperaceae[1]	3.3	8.5
Rumex obtusifolius	3.0	9.7
Viola sp.	0.4	3.0
Other dicotyledons	17.8	29.5
Other monocotyledons	11.6	21.7
Not identified	0.7	4.4
Total	173.9	370.6

[1] Excluding *Carex albata.*
[2] n=91.
[3] Standard deviation.

trampling increases the germination of the seeds of the shrub, because *W. hortensis* is light sensitive germinator (Shinsho et al. 2000) (Figure 2). In fact, the removal of ground litter (i.e., creation of bare areas) was promoted by cattle grazing (Shinsho et al. 2000), and seedlings of *W. hortensis* were germinated in the case that both aboveground portion of vegetation and ground litter were removed (Shinsho and Sugawara 2002).

These examples indicate that trampling has profound effects on vegetational changes in native pastures.

Conclusions

The findings reviewed in this paper indicate that grazing of animals reduces *M. sinensis* and increases *Carex albata* and *Weigela hortensis* in *Miscanthus*-dominant pasture. The mechanisms of these changes are selective grazing, defecation and trampling. These findings provide new perspectives on plant-animal interactions in Japanese native pastures and will help estimate the impact of animals on plant succession, thereby promoting sustainable grazing use of pastures. However, the complex interrelationships of various factors remain to be elucidated, and predicting the impacts and vegetational change precisely will be difficult until these factors are better understood. Construction of a predictive model based on the results of earlier studies will help evaluate the effects of the impacts by herbivore grazing on vegetational change, thereby establishing practices that promote the sustainable use of native pastures for grazing.

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