

## ORIGINAL ARTICLE

# Is cattle grazing an effective deterrent against sika deer (*Cervus nippon*) intrusion into pastures?

Hideharu Tsukada, Michiru Fukasawa and Takami Kosako

National Institute of Livestock and Grassland Science, Nasushiobara, Tochigi, Japan

**Keywords***Cervus nippon*, damage prevention, grazing cattle, wildlife damage, zoning.**Correspondence**Hideharu Tsukada, National Institute of Livestock and Grassland Science, Nasushiobara, Tochigi 329-2793, Japan.  
Email: htsuka@affrc.go.jp

An outline of this work was presented at the 63rd Meeting of the Japanese Society of Grassland Science (March 2007).

Received 11 May 2007;  
accepted 29 October 2007

doi: 10.1111/j.1744-697X.2007.00104.x

**Abstract**

We tested whether grazing by cattle is effective for deterring persistent sika deer intrusion into two pastures (HB and DB) in Tochigi, Japan. The relative abundance of deer appearance at the pastures ( $RAI_{deer}$ ), as evaluated by camera trapping, was compared at various cattle stocking densities (CSD) in HB (0–2.5 cow-days  $ha^{-1}$  camera-day $^{-1}$ ) and DB (0–14.3 cow-day  $ha^{-1}$  camera-day $^{-1}$ ). For controlling the several factors affecting  $RAI_{deer}$ , the least-squares means (LSM) of  $RAI_{deer}$  in HB and the adjusted values of  $RAI_{deer}$  ( $adjRAI_{deer}$ ) in HB and DB were calculated using ANCOVA. In HB, a significant positive correlation was observed between  $RAI_{deer}$  and CSD ( $r = 0.295$ ,  $P < 0.001$ ), but not between  $adjRAI_{deer}$  and CSD ( $r = 0.101$ ,  $P = 0.15$ ). The LSM of the  $RAI_{deer}$  was significantly ( $P < 0.05$ ) higher during the grazing period (May–October) than during the nongrazing period. In DB, there was no significant correlation between the  $RAI_{deer}$  and CSD ( $r = -0.023$ ,  $P = 0.76$ ) or between the  $adjRAI_{deer}$  and CSD ( $r = -0.118$ ,  $P = 0.13$ ). These results suggest that the increment of cattle stocking density will not deter sika deer from intruding into a permanent pasture that has been persistently grazed by cattle. Grazing cattle is not sufficient for preventing pasture damage by sika deer.

**Introduction**

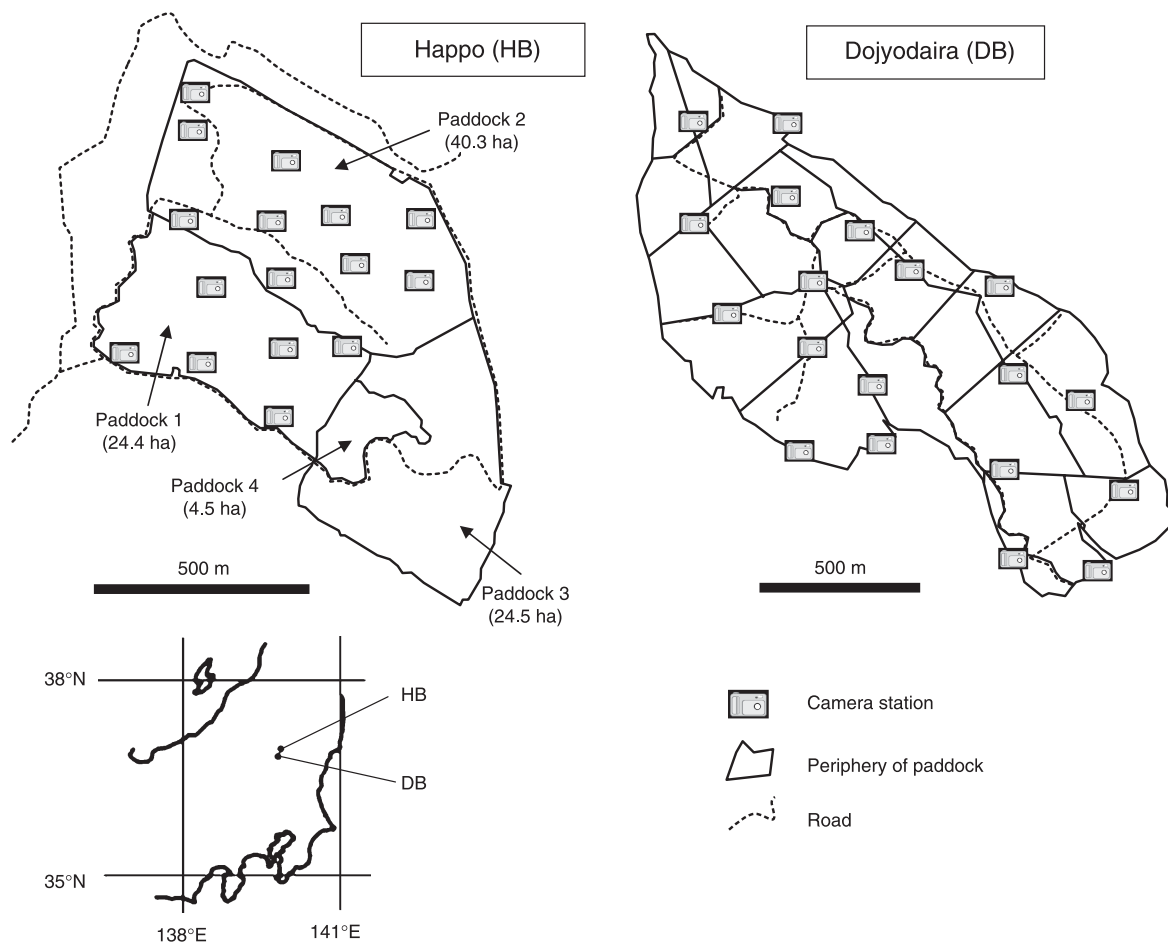
Recently, the introduction of cattle grazing for the prevention of wildlife damage has been increasing in agricultural areas located in and near mountainous areas. Originally, the intrusion of wildlife such as the Japanese monkey (*Macaca fuscata*) and wild boar (*Sus scrofa*) into croplands was observed to decrease after abandoned agricultural fields had been converted into cattle grazing pastures (Ueda 2003). Since that time, the introduction of grazing by cattle as a preventive measure against wildlife damage has become a popular strategy known as “zoning with grazing cattle between wildlife habitat and agricultural area (ZGWA)”. Local communities and governments have begun to adopt this prevention system (Senda *et al.* 2002; Yamanaka 2005). Reportedly, ZGWA is also effective for deterring wild boars from abandoned agricultural fields (Ide *et al.* 2005) and sika deer (*Cervus nippon*) from forest grazing (Matsumoto *et al.* 2004). However, a captivity test showed that sika deer that had been unaccustomed to the presence of

cattle became inured to cattle after 2 weeks (Matsumoto *et al.* 2005), suggesting that ZGWA might be ineffective for pastures where cattle grazing is persistently conducted.

In this study, we tested whether cattle grazing is effective in deterring sika deer from intruding into pastures in which cattle grazing had been conducted persistently over many years. The deterrent effect was defined as the decreased appearance of sika deer at pastures with increments of cattle stocking density, calculated as cow-days. Our hypothesis was that the increment of cattle stocking density would not be effective in the decrement of deer appearance at pastures where cattle grazing had been persistently conducted over many years.

**Materials and methods****Study areas**

This study was conducted at two pastures located in Tochigi, Japan: Happo-bokujo (HB) and Dojyodaira-houbokujo (DB).



**Figure 1** Locations of the study pastures in Tochigi Prefecture, Japan and the arrangement of camera stations in each pasture.

### Happo-bokuju (HB)

The grazing area, which encompasses approximately 93.7 ha, is located at 36°55'–36°56'N, 139°50'–139°51'E, at approximately 1048 m a.s.l. It is surrounded by broad-leaved and coniferous forests. The area had been used for raising military horses since 1896. In 1962, the present pastoral association was established to manage HB for raising cattle. The pasture comprises four paddocks (Figure 1), three of which (paddocks 1, 2, and 4) are used for grazing by breeding Japanese Black cows during May–October; with the other (paddock 3) being closed because of the difficulty in checking the cows daily due to woody encroachment since 2002. In this study, we selected paddocks 1 and 2 for our observations. In all, 66 and 95 cattle were grazed in 2004 and 2005, respectively. The HB and its surrounding area is a sika deer habitat, with an estimated density of 4.9–8.4 deer km<sup>-2</sup> in summer and autumn during 1999–2002 by the block count method within a 1.43 km<sup>2</sup> survey area (Tochigi Prefecture 2005). In these areas, a total

of 50–100 deer were hunted by a moderate amount of hunting 2000–2004 (Tochigi Prefecture 2005).

### Dojyodaira-houbokuju (DB)

The DB pasture, encompassing 175 ha, is located at 36°52'–36°53'N, 139°47'–139°48'E, at approximately 963 m a.s.l., and is surrounded by a broad-leaved forest, including Japanese cypress plantation patch. It was settled in 1964 by the local government, Tochigi Prefecture, and has been used since then for cattle grazing. In all, 148 and 137 raising daily cattle (Holstein heifers) were grazed on 21 paddocks of DB during May–October 2004 and during May–November 2005, respectively (Figure 1). The mean size of the paddocks was 7.0 ha (range, 2.8–12.4) and the mean stock density of these paddocks was 79.7 cow-days ha<sup>-1</sup> (range, 28.6–156.2) and 200.2 cow-days ha<sup>-1</sup> (range, 101.7–380.0) in 2004 and 2005, respectively. The DB with its surrounding area is a sika deer habitat, with an estimated density of 0.0–1.2 deer km<sup>-2</sup> in the autumn of

2003–05 by the block count method within a 1.62-km<sup>2</sup> survey area (Tochigi Prefecture 2005). In these areas, a total of 50–100 deer were hunted by a moderate amount of hunting 2000–2004 (Tochigi Prefecture 2005).

### Camera trapping

The appearance of deer was investigated using camera trapping. Respectively, 16 and 20 camera stations were settled at grids with 200- and 300-m intervals in HB and DB. Two types of remote cameras were used. One was the commercially-made passive remote camera (Fieldnote II; Marif, Iwakuni, Japan) with a built-in infrared-motion sensor, flash and timepiece. The other was the hand-made version of a commercially-made remote camera (YoysotG2; Umezawamusen, Sapporo, Japan) equipped with a passive infrared-motion sensor (Tsukada *et al.* 2006). Both cameras were equipped with an interval device of approximately 2 min which prevented wasteful continuous photographing. Each remote camera, which was tightly wrapped in a clear polypropylene bag for waterproofing, was installed 2–2.5 m above the ground using exclusive plastic boxes at each station (usually a stand), and was operated for 2–4 weeks in each camera-session from 1 month before the beginning of the grazing period through to 1 month after the end of the grazing period. In all, 5–8 camera-sessions were repeated each year. The survey period was divided into five terms: pregrazing (April–mid-May), grazing I (mid-May–late July), grazing II (late July–early September), grazing III (early September–late October), and postgrazing (late October–November) according to the grazing period or three seasons, such as spring (April–May), summer (June–August) and autumn (September–November), depending on the factor analyzed. The number of images showing sika deer, including multiple animals, but excluding consecutive photographs within a 30-min interval, was counted at each station to reduce the self-dependence of camera-trapping data (O'Brien *et al.* 2003; Yasuda 2004), and was converted to a frequency per 100 camera active days, as the relative abundance index of deer (RAI<sub>deer</sub>). Because the distribution of the RAI<sub>deer</sub> was highly positively skewed with many zero data, RAI<sub>deer</sub> was natural log-transformed to improve normality, using  $\text{Log}_e(X + 0.5)$  where  $X$  is the individual data (Yamamura 1999). Data from remote cameras that were not active for more than 3 days were excluded.

Because a part of this study was also designed for another research purpose (Tsukada *et al.* 2005), the following treatments were added at the start of the study. The camera stations were settled at the edge of or within a wooded area (HB only), along the road or cattle track (DB only), and two types (fish sausage or raisins) of bait (DB only) and fatty acid scent (FAS) were placed within the detecting area of the remote camera as an attractant for various wild mammals (HB and DB), and remote cameras of two types (commercial or hand-made) were installed (DB only). To control these treatment effects

on the frequency of deer photographed, these treatment factors were included in the models of the statistical analyses.

### Cattle stocking density

The cattle stocking density (CSD) was calculated from ranchers' daily records of grazing cattle. In HB, all cattle were kept as one herd, and were stocked in paddock 2 in mid-May 2004 and 2005 and moved two (late July and early September) and three (late June, late July and late September) times between paddock 2 and paddocks 1 and 4, both of which were temporarily used jointly as one paddock in 2004 and 2005, respectively. As the index of CSD in HB, the number of grazing cows multiplied by the grazing days (cow-days) was calculated for each paddock (per hectare) and divided by the periods of each camera-session during grazing rotation. On the other hand, the cattle in DB were maintained as several herds with a rotational grazing system. Therefore, as the index of CSD in DB, the number of grazing cows multiplied by the grazing days (cow-days) was calculated for each paddock (per hectare) where the camera station was located while the remote camera was active. Because the distribution of CSD (cow-days ha<sup>-1</sup> camera-day<sup>-1</sup>) was highly positively skewed with many zero data, the CSD (cow-days ha<sup>-1</sup> camera-day<sup>-1</sup>) was natural log-transformed to improve normality, using  $\text{Log}_e(X + 0.5)$  where  $X$  is the individual data (Yamamura 1999).

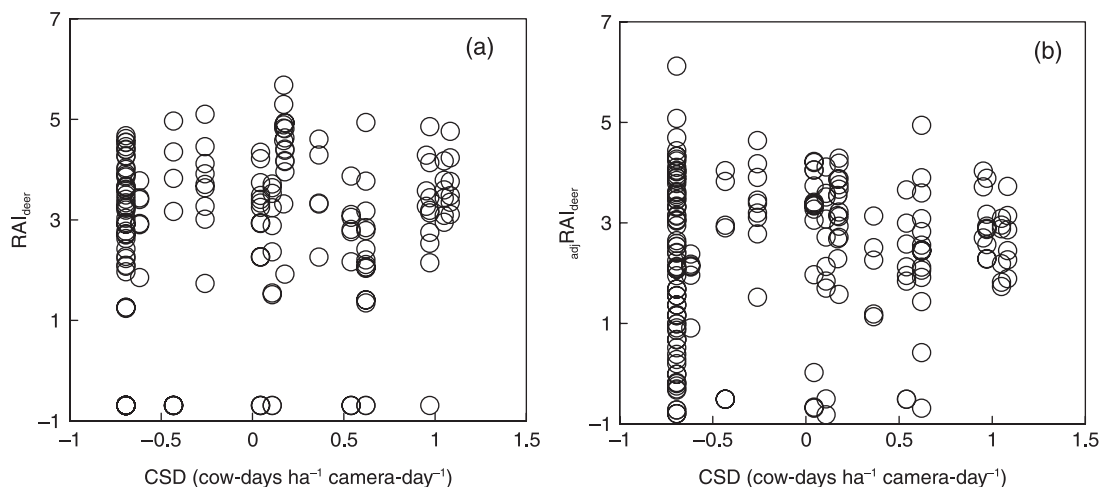
As the cattle stocking density was not spatially even within a paddock, the relative abundance index of cows (RAI<sub>cow</sub>) was calculated in the same way as RAI<sub>deer</sub> in HB. The RAI<sub>cow</sub> was also natural log-transformed using  $\text{Log}_e(X + 0.5)$  where  $X$  is the individual data (Yamamura 1999).

### Statistical analyses

First, for evaluating the effects of CSD on deer appearance at pastures, the correlations between the RAI<sub>deer</sub> and CSD were analyzed using data from HB. Second, the RAI<sub>deer</sub> in HB was analyzed using ANCOVA including treatment effects, such as the location of the camera station (at the edge of and within a wooded area), the presence of FAS, the effect of paddocks (paddocks 1 and 2), grazing periods (pregrazing, grazing I–III, and postgrazing), and year (2004 and 2005) as categorical variables and CSD as a continuous variable (0–2.5 cow-days ha<sup>-1</sup> camera-day<sup>-1</sup>). The model took the form of:

$$Y_{ijklmn} = u + \alpha_1 CL_i + \alpha_2 FAS_j + \alpha_3 Pd_k + \alpha_4 S_l + \alpha_5 Y_m + \alpha_6 CSD_n + e_{ijklmn}$$

where  $u$  is the intercept,  $CL_i$  is the camera locations,  $FAS_j$  is the presence of FAS,  $Pd_k$  is the paddock,  $S_l$  is the season,  $Y_m$  is the year,  $CSD_n$  is the CSD in HB,  $e_{ijklmn}$  is the residual error, and  $\alpha_1$ – $\alpha_6$ , respectively, represent the coefficients. Then, the adjusted RAI<sub>deer</sub> (adjRAI<sub>deer</sub>) values were calculated using the previous model controlling all categorical factors as neutral (null) in the following formula:



**Figure 2** Relationship between the frequency of deer appearance at pastures and cattle stocking density (CSD) in Happo-bokujiyo, Tochigi, Japan. The relative abundance index of deer ( $RAI_{deer}$ ) and the adjusted values of  $RAI_{deer}$  ( $adj\_RAI_{deer}$ ) calculated using the ANCOVA model are shown as the frequency of deer appearance in the (a) left and the (b) right figures, respectively. All data show log-transformed ( $\text{Log}_e[X + 0.5]$ ) values (Yamamura 1999).

$$adj\_RAI_{deer} = Y_{ijklmn} - (\alpha_1 CL_i + \alpha_2 FAS_j + \alpha_3 Pd_k + \alpha_4 S_l + \alpha_5 Y_m) \\ = u + \alpha_6 CSD_n + e_{ijklmn}$$

Finally, the correlation between  $adj\_RAI_{deer}$  and CSD in HB was analyzed. For evaluation of the within-year patterns of deer appearance at pastures, the least-squares means (LSM) of the  $RAI_{deer}$  were also compared between grazing periods in the previous model. In view of the unequal paddock use by cattle, the correlation between the  $RAI_{cow}$  and  $RAI_{deer}$  only during grazing periods (mid-May–late October) was also analyzed.

In the same way, the correlation between  $RAI_{deer}$  and CSD was analyzed using data from DB. Furthermore,  $RAI_{deer}$  in DB was analyzed using ANCOVA including treatment effects, such as camera locations (along cattle tracks and roads), the remote camera types (commercial and hand-made), effect of seasons (spring, summer and autumn) and year (2004 and 2005) as categorical variables and CSD as a continuous variable (0–14.3 cow-day  $ha^{-1}$  camera-day $^{-1}$ ). The bait types and FAS treatments were only conducted in 2004 and 2005, respectively. Therefore, these treatment effects were included in the year factor of this model. The model took the form of:

$$Y_{ijklm} = u + \alpha_1 CL_i + \alpha_2 CT_j + \alpha_3 S_k + \alpha_4 Y_l + \alpha_5 CSD_m + e_{ijklm}$$

where  $u$  is the intercept,  $CL_i$  is the camera locations,  $CT_j$  is the remote camera type,  $S_k$  is the season,  $Y_l$  is the year,  $CSD_m$  is the cattle stocking density (CSD) in DB,  $e_{ijklm}$  is the residual error, and  $\alpha_1$ – $\alpha_5$ , respectively, represent the coefficients. Then, the adjusted  $RAI_{deer}$  ( $adj\_RAI_{deer}$ ) values were calculated using the previous model controlling all categorical factors as neutral (null) in the following formula:

$$adj\_RAI_{deer} = Y_{ijklm} - (\alpha_1 CL_i + \alpha_2 CT_j + \alpha_3 S_k + \alpha_4 Y_l) \\ = u + \alpha_5 CSD_m + e_{ijklm}$$

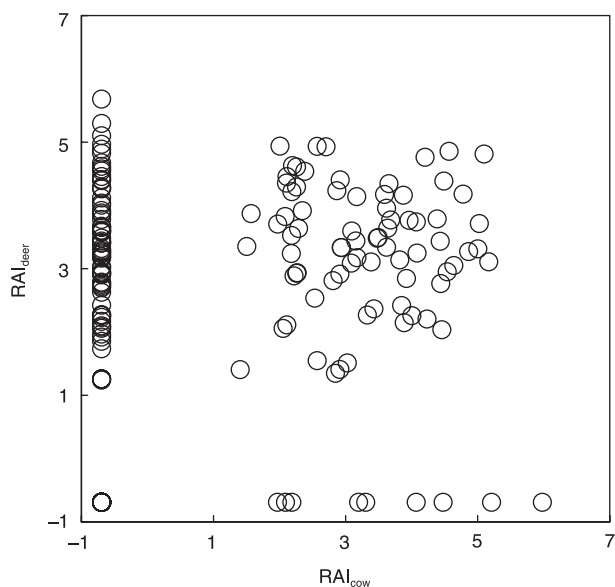
Finally, the correlation between  $adj\_RAI_{deer}$  and CSD in DB was analyzed. For evaluation of the within-year patterns of deer appearance at pastures, the LSM of the  $RAI_{deer}$  were also compared between grazing periods in the previous model. All analyses were conducted using statistical software (JMP ver. 6.02; SAS Institute, Cary, NC, USA).

## Results

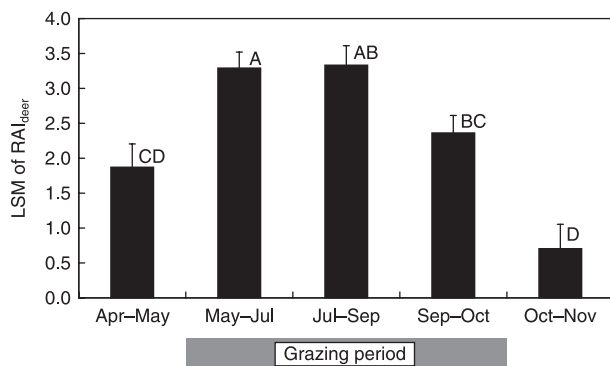
In HB, a significant positive correlation was observed between  $RAI_{deer}$  and CSD ( $r = 0.295$ ,  $P < 0.001$ ; Figure 2a). Although the effects of the treatments were controlled using the ANCOVA model, the correlation between  $adj\_RAI_{deer}$  and CSD was not significant ( $r = 0.101$ ,  $P = 0.15$ ; Figure 2b). There was a significant positive correlation between  $RAI_{deer}$  and  $RAI_{cow}$  during the grazing periods (May–October) in HB ( $r = 0.259$ ,  $P < 0.001$ ; Figure 3). However, the LSM of the  $RAI_{deer}$  in HB differed significantly among the study periods: high in the beginning parts of the grazing periods (mid-May–early September), but low in pregrazing and postgrazing (Figure 4). In DB, there was no significant correlation between  $RAI_{deer}$  and CSD ( $r = -0.023$ ,  $P = 0.76$ ; Figure 5a) or between  $adj\_RAI_{deer}$  and CSD ( $r = -0.118$ ,  $P = 0.13$ ; Figure 5b). The LSM of the  $RAI_{deer}$  in DB differed significantly among the study periods: low in spring (April–May) and high in summer (June–August) and autumn (September–November) (Figure 6). The seasonality of deer appearance at the pastures was different between HB and DB especially in autumn.

## Discussion

The results of this study show that the increment of cattle stock density is insufficient to deter sika deer intrusion into a



**Figure 3** Relationship between the relative abundance index of deer ( $RAI_{deer}$ ) and the relative abundance index of cows ( $RAI_{cow}$ ) in Happo-bokujyo, Tochigi, Japan. All data show log-transformed ( $\text{Log}_e[X + 0.5]$ ) values (Yamamura 1999).



**Figure 4** Seasonal changes in the least-squares mean (LSM) of  $RAI_{deer}$  in Happo-bokujyo, Tochigi, Japan. Vertical bars indicate standard error (SE). Means with different letters are significantly different (Tukey's honest significant difference test,  $P < 0.05$ ). All data show log-transformed ( $\text{Log}_e[X + 0.5]$ ) values (Yamamura 1999).

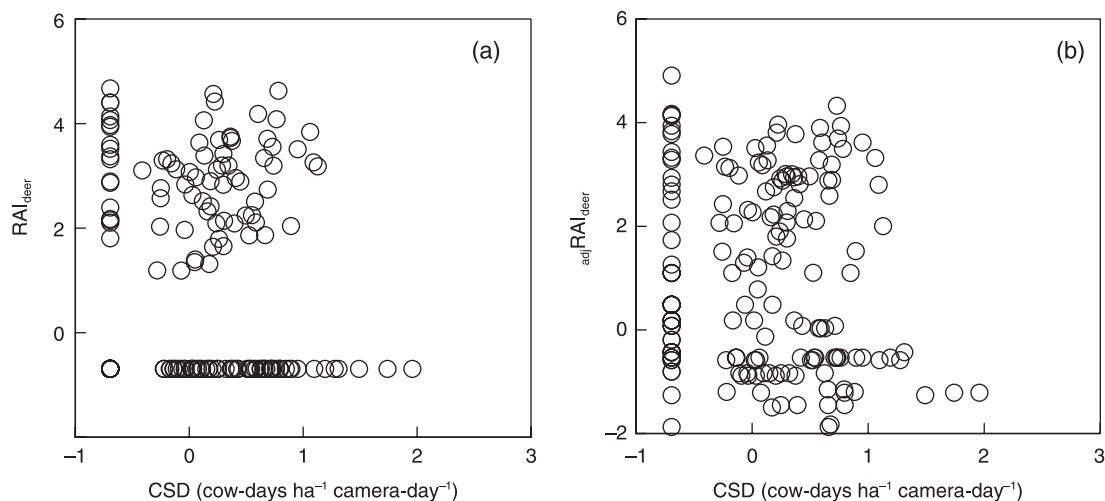
pasture that has been persistently grazed by cattle. The appearance of sika deer at the pastures in HB (Figure 4) was more frequent during the beginning parts of the grazing periods (mid-May–early September) than in the nongrazing periods (April–mid-May and late October–November). This seasonality seems to follow the seasonal fluctuation of herbage mass in the pastures. The above-ground biomass of the sown pastures in central Japan show the following seasonal change; it reaches a peak in May and/or June, then decreases once in August, tends to increase a little again in September,

and declines after October (Yiruhan *et al.* 2001). Another study also showed that the installation of an electric fence at the cattle exclusion area in HB could prevent herbage consumption from sika deer (Tsukada *et al.* 2007). Therefore, the sika deer probably intruded into the pasture to eat the herbage there. However, the autumn pasture utilization by sika deer was different between HB and DB. This difference might be caused by the difference in the local food availability for the sika deer. At the further northern part of the sika deer distribution area, they utilized the pasture more during autumn and winter than during spring and summer, related with other food availability (Takatsuki & Nakano 1992).

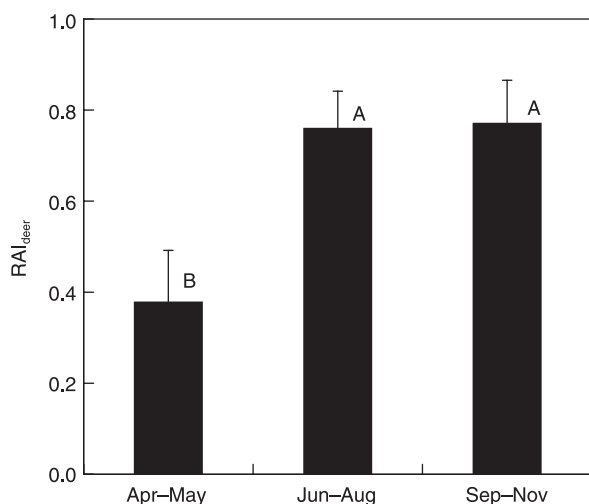
These pasture utilization patterns of sika deer apparently contradict the assertion that the ZGWA strategy is effective. In previous studies that have reported the effectiveness of ZGWA, the introduction of grazing cattle was novel in the local environment (Senda *et al.* 2002; Ueda 2003; Matsumoto *et al.* 2004). Such novel animals might be avoided by wildlife, including sika deer, which were alert to and cautious towards the cattle, responding to novelty with fear: so-called “neophobia”. Given this, the sika deer seems to grow accustomed to the presence of grazing cattle at a persistent pasture after repeated interactions with the cattle. In fact, Matsumoto *et al.* (2005) reported that the alerting behavior of captive sika deer and their access to areas near cattle decreased within 2 weeks after the introduction of cattle. The presence of cattle itself is insufficient to prevent sika deer from intrusion into a persistent pasture.

The effectiveness of ZGWA might also be ascribable to other factors such as creating an open habitat in which wildlife cannot hide themselves or which include the presence of a rancher who manages the grazing cattle (Eguchi 2003; Ide *et al.* 2005; Ueda & Fujii 2005; Ide 2007). The mule deer shifted its habitat (Loft *et al.* 1991) and increased its foraging time (Kie *et al.* 1991) because the effects of grazing cattle minimized the forage and cover in the preferable habitat for mule deer. The observed number of elk and mule deer in Arizona declined after cattle were introduced to pastures (Wallace & Krausman 1987). The avoidance of open habitats was also observed in sika deer that did not venture 200 m distant from the forest edge (Takatsuki 1989). The relatively large paddock size in this study, compared to the previous study on ZGWA might have affected the physical and psychological distances between deer and grazing cattle and between deer and their hiding places. However, the preference for open habitats over forest edge was also observed in mule deer (Altendorf *et al.* 2001; Hernández *et al.* 2005). Regarding the effect of habitat modification under the ZGWA system, further study is needed.

In both study areas, deer hunting was conducted under a moderate amount of hunting. The habitat usage and behavior of deer have changed according to human-related activities such as archery hunting (Kilpatrick & Lima 1999), intensive



**Figure 5** Relationship between the frequency of deer appearance at pastures and cattle stocking density (CSD) in Dojyodaira-houbokujyo, Tochigi, Japan. The relative abundance index of deer ( $RAI_{deer}$ ) and the adjusted values of  $RAI_{deer}$  ( $adj\_RAI_{deer}$ ) calculated using the ANCOVA model are shown as the frequency of deer appearance in the (a) left and the (b) right figures, respectively. All data show log-transformed ( $\text{Log}_e[X + 0.5]$ ) values (Yamamura 1999).



**Figure 6** Seasonal changes in the least-squares mean (LSM) of the  $RAI_{deer}$  in Dojyodaira-houbokujyo, Tochigi, Japan. Vertical bars indicate SE. Means with different letters are significantly different (Tukey's honest significant difference test,  $P < 0.05$ ). All data show log-transformed ( $\text{Log}_e[X + 0.5]$ ) values (Yamamura 1999).

hunting (Root *et al.* 1988), normal hunting (Kilgo *et al.* 1998), and hunting at open habitats (Swenson 1982). Under these disparate hunting pressures, deer shifted their home ranges (Kilpatrick & Lima 1999), increased their nocturnal activities (Kilgo *et al.* 1998), avoided open habitats but apparently preferred cover (Swenson 1982; Kilgo *et al.* 1998; Kufeld *et al.* 1988), and avoided roads (Kilgo *et al.* 1998). For sika deer in Japan, their observability was also affected by hunting pressure (Ikeda 2001). However, whether human activities related to

grazing might affect the behavior of sika deer remains unknown. Human activities that might effectively deter sika deer from pasturelands should be studied further for sika deer damage prevention.

## Conclusion

In conclusion, the increment of cattle stocking density will not deter sika deer from intruding into a permanent pasture that has been persistently grazed by cattle. Grazing cattle is not sufficient for preventing pasture damage by sika deer. Although ZGWA have typically been conducted near human settlements compared to the secluded pastures studied here, it should be carefully considered whether or not to introduce a ZGWA system to prevent deer damage.

## Acknowledgments

We would like to thank the farmers and managers in Happobokujyo and Dojyodaira-houbokujyo for their cooperation and for providing their daily records of grazing cattle. We would also like to thank Kyoko Goto for tabulating the camera trapping data, and Tetsuya Maruyama of Tochigi Prefecture for providing the sika deer density data in Tochigi. This study was partly supported by a Grant-in-Aid for Scientific Research (C) (no. 19580316, Japan Society for the Promotion of Science).

## References

- Altendorf KB, Laundre JW, Lopez Gonzalez CA, Brown JS (2001) Assessing effects of predation risk on foraging behavior of mule deer. *J Mammal* 82: 430–439.

- Eguchi Y (2003) *Protecting Cultivated Fields from the Wild Boar – Their Ecology and the Preventive Measures Against Them*. Rural Culture Association, Tokyo, 1–149. (In Japanese.)
- Hernandez L, Laundré JW, Mahesh G (2005) Use of camera traps to measure predation risk in a puma-mule deer system. *Wildl Soc Bull* 33: 353–358.
- Ide Y (2007) Effect of cattle grazing on the rooting by wild boars. *Jpn J Grassl Sci* 53: 59–93. (In Japanese.)
- Ide Y, Koyama N, Takahashi Y, Kobayashi H (2005) Effect of cattle grazing on the rooting by wild boars in abandoned cultivated land. *Bull Natl Agric Res Cent West Reg* 4: 173–181. (In Japanese with English summary.)
- Ikedo K (2001) The effects of hunting pressure on the observability of sika deer. *Kyushu J for Res* 54: 121–122.
- Kie JG, Evans CJ, Loft ER, Menke JW (1991) Foraging behavior by mule deer: the influence of cattle grazing. *J Wildl Manage* 55: 665–674.
- Kilgo JC, Labisky RF, Fritzen DE (1998) Influence of hunting on the behavior of white-tailed deer: implications for conservation of the Florida panther. *Conserv Biol* 12: 1359–1364.
- Kilpatrick HJ, Lima KK (1999) Effects of archery hunting on movement and activity of female white-tailed deer in an urban landscape. *Wildl Soc Bull* 27: 433–440.
- Kufeld RC, Bowden DC, Shrupp DL (1988) Influence of hunting on movement of female mule deer. *J Range Manage* 41: 70–72.
- Loft ER, Menke JW, Kie JG (1991) Habitat shifts by mule deer: the influence of cattle grazing. *J Wildl Manage* 55: 16–26.
- Matsumoto A, Takeda K, Hayama S, Ohshima K (2005) Avoidance behavior of captive sika deer against the presence of cattle. *Jpn J Grassl Sci* 51 (Suppl.): 96–97. (In Japanese.)
- Matsumoto A, Takeda K, Tsukada H, Hokura K, Tase K, Sato S (2004) The change in sika deer density around grazing paddock related with grazing. *Grassl Sci* 50 (Suppl.): 400–401. (In Japanese.)
- O'Brien TG, Kinnaird MF, Wibisono HT (2003) Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Anim Conserv* 6: 131–139.
- Root BG, Fritzell EK, Giessman NF (1988) Effects of intensive hunting on white-tailed deer movement. *Wildl Soc Bull* 16: 145–151.
- Senda M, Tanimoto Y, Koyama N (2002) Grazing system for conservation of rural resources – on the analysis of case studies. *Misc Pub Natl Agric Res Cent West Reg* 1: 1–74. (In Japanese with English summary.)
- Swenson JE (1982) Effects of hunting on habitat use by mule deer on mixed-grass prairie in Montana. *Wildl Soc Bull* 10: 115–120.
- Takatsuki S (1989) Edge effects created by clear-cutting on habitat use by sika deer on Mt. Goyo, northern Honshu, Japan. *Ecol Res* 4: 287–295.
- Takatsuki S, Nakano S (1992) Food habits and pasture use of sika deer at a foothill of Mt. Goyo, northern Japan. *Ecol Rev* 22: 129–136.
- Tochigi Prefecture (2005) *The Monitoring Result of Sika Deer Management Plan at Tochigi Prefecture in 2004*. Tochigi Prefecture, Tochigi, 1–55. (In Japanese.)
- Tsukada H, Fukasawa M, Kosako T, Sutoh M, Imura T, Hirakawa H (2005) The application of camera trapping to survey mammals in Japanese pastures. *Abstracts of the Plenary Symposium, Poster and Oral Papers Presented at Ninth International Mammalogical Congress (IMC9)*, Sapporo, 169.
- Tsukada H, Fukasawa M, Kosako T, Sutoh M, Imura T, Hirakawa H (2006) Photo-trapping application to mammal fauna survey on public pastures in northern Tochigi, Japan. *Mamm Sci* 46: 5–19. (In Japanese with English summary.)
- Tsukada H, Yamamoto Y, Fukasawa M, Kosako T (2007) Efficiency of electric fence on pasture damage by sika deer and its intrusion into the pasture. *Jap J Grassl Sci* 53 (Suppl.): 290–291. (In Japanese.)
- Ueda E (2003) Countermeasure for wildlife damage prevention using zoning with cattle grazing. In: *Wild Mammals in Shiga – Coexistence with Human* (ed. Takahashi S). Sunrize-Syuppan, Shiga, 132–157. (In Japanese.)
- Ueda E, Fujii Y (2005) Activation of intermediate and mountainous area by zoning using cattle grazing. *Agric Econ* 71 (3): 61–67. (In Japanese.)
- Wallace MC, Krausman PR (1987) Elk, mule deer, and cattle habitats in central Arizona. *J Range Manage* 40: 80–83.
- Yamamura K (1999) Transformation using  $(X + 0.5)$  to stabilize the variance of populations. *Res Popul Ecol* 41: 229–234.
- Yamanaka S (2005) Control of the wild animal's damage by the introduction of grazing zone. *Res J Food Agri* 28 (4): 46–47. (In Japanese.)
- Yasuda M (2004) Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan. *Mamm Study* 29: 37–46.
- Yiruhan Shiyomi M, Takahashi S, Okubo T, Akiyama T, Koyama N, Tsuiki M (2001) Analysis of a long-term grazing experiment in central Japan 1. Seasonal and yearly changes in herbage biomass and botanical composition. *Grassl Sci* 47: 344–361.