Relationship between grooming and tick threat in sika deer *Cervus nippon* in habitats with different feeding conditions and tick densities

Miki Yamada¹,* and Misako Urabe²,**

¹ Graduate School of Human Culture, Nara Women’s University
² Department of Ecosystem Studies, School of Environmental Science, The University of Shiga Prefecture, Shiga 522-8533, Japan

Abstract. Using two populations of sika deer *Cervus nippon*, the relationship between tick density within habitats and the duration of both self-grooming and allogrooming was investigated. At Mageshima Island, where the deer spend much of their time feeding and tick density is high, the time spent self-oral grooming frequency fluctuated with tick density within the deer’s habitat. However, in Nara Park, where the deer are fed artificially and tick density is low, neither oral nor self-scratch grooming correlate with tick density. Although tick density is much higher at Mageshima than at Nara Park, the overall duration of self-grooming did not differ between these sites, suggesting that this was affected by the time budget required for other behaviors, especially foraging. Allogrooming duration did not correlate with tick density at either study sites, suggesting that the most important function of this behavior is a social one, rather than the removal of ectoparasites.

Key words: allogrooming, self-grooming, sika deer, ticks, time budget.

The removal of ectoparasites, such as ticks, is an important function of grooming behavior in ungulates (Hart 1990). In an experimental study with impala, *Aepyceros melampus*, animals fitted with harnesses that restrained self-oral grooming had 20 times more ticks than control impala (Mooring et al. 1996a). The cost of tick infestation has been well demonstrated in domestic animals. It causes weight loss in calves (Little 1963) and mediates infectious disease such as piroplasmosis (Yoshida 1980). Therefore, animals should groom more frequently when ectoparasites are more prevalent within a habitat. This has been experimentally demonstrated in impalas (Hart et al. 1992) and the North American cervids, *Alces alces*, *Cervus elaphus*, *Odocoileus hemionus* and *O. virginianus* (Samuel 1991; Welch et al. 1991).

Grooming behavior also involves costs. One of these is the physical loss of material from the grooming organ (e.g., saliva or teeth) (Ritter and Epstein 1974; McKenzie 1990), while others include behavioral costs, such as decreased vigilance against predators (Mooring and Hart 1995a). Furthermore, grooming may reduce the time an animal is able to devote to other behaviors that are required for its survival, such as foraging. Thus, the frequency of grooming might depend upon cost/benefit ratio. As animals cannot simultaneously undertake both foraging and grooming, the cost/benefit ratio will vary with food availability, as animals require more foraging time during the periods of famine (Mooring 1995). Mooring (1995) showed that grooming by female impala did not exhibit a negative correlation with feeding time whereas, for males, feeding time was negatively correlated with self-oral grooming. This suggests that males are limited by foraging compared with females and that male grooming frequency is to some extent influenced by their foraging time budget. Furthermore, Mooring and Hart (1995b) showed that territorial males of impala groomed less than females carried a heavier tick load, suggesting that they sacrificed grooming time for territorial behavior. However, an alternative explanation has been suggested: that testosterone may depress the immune system of males (Mooring and Hart 1995b).

Grooming itself is considered to be a programmed behavior, because it does not become zero even in ectoparasite-free conditions (Mooring 1995; Mooring et al. 1996a). It is also affected by the time budget required for other behaviors, especially foraging. This suggests that males are limited by foraging compared with females and that male grooming frequency is to some extent influenced by their foraging time budget.
Mooring et al. (2004) showed the evolutionary trend of ungulate grooming behavior in parasite-free conditions in relation to body plan and habitat type. They concluded that both body size and habitat influence grooming rates and the former explains more of the variation in grooming. However, habitat also influences grooming rate significantly, and species found in more tick-dense, more closed habitat tended to groom more. They also showed that allogrooming delivered to other adult individuals is concentrated in lineages inhabiting closed forest habitats, especially in cervids.

Grooming for another individuals (allogrooming) has also the function of ectoparasite removal (Mooring and Hart 1995b; Mooring et al. 1996a, b), but it has usually been interpreted in the social context. Allogrooming as a social behavior has been studied in many groups of mammals, especially in primates and ungulates. It is interpreted as an altruistic behavior for kin (e.g. Muroyama 1991), affiliative relationship between individuals (e.g. Tsukahara 1990; Muroyama 1994), or tension reduction (Terry 1970; Feh and De Mazières 1993; Das et al. 1997), although these explains are not exclusive each other.

In this study, the relationship between the seasonal threat of tick infestation and grooming frequency was investigated in sika deer Cervus nippon at Mageshima Island and Nara Park. These sites have contrastive conditions in tick density, and also in food availability for deer, which may affect the time spent to grooming. Differences in the patterns of correlation between grooming frequency and tick density between sites are discussed in relation to general behavioral time budgets.

Materials and methods

Study sites

The study was conducted in Mageshima Island, Kagoshima Prefecture, western Japan, and in Nara Park, Nara Prefecture, central Japan (Fig. 1). The mean annual temperature is 21.1°C at Tanegashima Island (10 km east of Mageshima) and 16.0°C at Nara in 1998, and the annual precipitation is 2769 mm at Tanegashima Island and 1693 mm at Nara in 1998 (data by Japan Meteorological Agency).

Mageshima Island is uninhabited, although people often land to fish, sometimes with cars. About 500 wild sika deer inhabit a 9 km² area (more than 5 individuals/ha: Tatsuzawa 2005). No large mammals other than the deer occur on the island, so they have no natural preda-
tors. The island is covered with temperate and subtropical vegetations, which is heavily grazed by the deer. The dominant plant species of grassland on the southern part of the island are Imperata cylindrica and Pennisetum alopecuroides, whereas forest on the eastern side is dominated by Pinus thunbergii and Casuarina glauca (Sasaki et al. 1960).

The subspecies of deer on Mageshima, Cervus nippon mageshimae, is a little smaller in body size than C. n. centralis of Nara Park. Body weight of C. n. mageshimae is intermediate between those of the C. n. centralis (50–70 kg) and C. n. yakushimae (30–45 kg). It has become lighter in recent years because the nutritional condition of the deer has deteriorated following a population increase (Tatsuzawa 2000).


Nara Park (Fig. 1) had a population of 1215 deer (737 females, 269 males and 209 fawns) in a 3 km² area (more than 4 individuals/ha), according to the 20 July 1999 census of the Nara Deer Foundation. The park is not fenced, and deer generally can move freely although they are partly managed by the Nara Deer Foundation. Pregnant females are caught from April to July, and are allowed to bear fawns in an enclosure within the park. Males are caught from August to October to have their
antlers cut. After cutting, males are released from the enclosure during October. Injured or sick deer are also confined to the enclosure. Most of the deer are well domesticated and are often fed “deer cookies” sold in the park, or vegetables served by tourists and residents.

Observations were carried out mainly at four sites: Daibutsu-ike, Ukimido, Hakuba and Koufukuji (Yamada and Urabe 1998). The vegetation at Daibutsu-ike is *Zoysia* spp. grassland with scattered trees. Usually, deer moved around the site in a loose herd, grazing and resting. At Ukimido, *Prunus* spp., *Pinus densiflora* and *Castanopsis cuspidata* trees occupy the half of the site and grassland the other. Deer were often fed with vegetables or other foods in this site. Hakuba is surrounded by *Cryptomeria japonica* trees and there was little grass available to the animals. Deer gathered in a narrow area by a path to get deer cookies. These three sites are used by mixed herds including both adult males and females during most observation days. In Koufukuji, there are *Zoysia* spp. grassland yards with *Pinus* trees, and deer, most of them are males, are fed by people most frequently.

The study period at Nara Park was from 20 April to 27 November 1998. Data from all four sites in the park were combined for the following analysis.

**Size-sex classification of deer**

The deer were classified into the following six classes by sex, body size and shape of antlers following Miura (1984): ♂ adult-large, males estimated to be 4 years or older with a large body and usually 4-point antlers (corresponding to age class 3 of Miura (1984)); ♂ adult-small, males estimated to be 2–4 years old with medium-sized body and 2- or 3-point antlers (age class 2 of Miura); ♂ yearling, males estimated to be 12–24 months old with a small body and 1-point spikes (age class 1 of Miura); ♀ adult, females estimated to be 2 years or older with medium or large body; ♀ yearling, females estimated to be 12–24 months old with a small body; fawn, under 12 months. For most females give birth to fawns in June, the data from January to May in each year indicate the individuals born in the previous year, and the data from June to December indicate the individuals born in that year.

**Behavioral observation**

Behavioral observations were generally conducted between 0600 and 1800 at both sites. At Mageshima, we mainly observed the herds on the southern grassland at distances of 100–500 m from the top of a hill using a telescope. In Nara Park, we observed herds at distances of 5–50 m. Focal animal observations of 10 min were employed to record the behavior of deer. Around 20–30 focal animals were selected at random during each day. The total number of 10 min observation bouts at Mageshima was 138 for ♂ adult-large, 143 for ♂ adult-small, 103 for ♂ yearling, 417 for ♀ adult, 115 for ♀ yearling and 127 for fawn. In Nara Park, 202 bouts were recorded for ♂ adult-large, 210 for ♂ adult-small, 232 for ♂ yearling, 909 for ♀ adult, 245 for ♀ yearling and 248 for fawn. The behavioral categories both in Mageshima and Nara Park were as follows: self-oral grooming (SOG), performed with of the tongue and incisor-canine teeth; self-scratch grooming (SSG), scratching with the hoof of a hind leg; allogrooming delivered (AGD), delivered grooming to another individual; allogrooming received (AGR), grooming received from another individual; feeding; lying down; others, all other behavior, including moving, caution, display and mating.

Data for each class were pooled separately to calculate the class average for each observation period (Mageshima) or month (Nara Park). Next, seasonal variation of mean duration was tested for each grooming category by ANOVA, and then the mean duration of grooming and tick density were tested for Spearman’s rank correlation in all those cases for which the seasonal variation was significant. Because the deer were not identified at both study sites, our data might include pseudoreplication by focusing on one deer several times (Hairston 1989) and we have a risk of type I error in ANOVA. However, the rank of mean duration itself is not influenced by the result of ANOVA, and thus, the correlation analysis is still valid.

**Tick sampling**

We measured the ixodid tick density in those areas frequented by deer using the drag method (Mooring 1995). Ixodid ticks have a three-host life cycle. The ticks require a new host for each life stage (larva, nymph and adult) and detach from the host following blood-feeding in order to molt into the next stage. We collected host receptive ticks of all developmental stages by pulling a 0.9 × 1.5 m white flannel cloth along 5 m transects. At Mageshima, we established two 55 m transects from grassland into a forest along deer trails. We conducted six 5 m drags along each transect and replicated twice on different days. In Nara Park, eight points were established at each of the Daibutsu-ike, Ukimido and Hakuba.
sites, with two replicates. In Nara Park, tick density was surveyed monthly from April 1998 to October 1999, with sampling undertaken between 1300 and 1600 on fine days. At both site, air temperature and humidity on the ground, which have a significant effect on the activity and survival of ticks (Yoshida 1980), were recorded by a digital thermometer.

Ticks collected were *Haemaphysalis mageshimaensis* at Mageshima, and *H. longicornis* in Nara Park. At the latter site, the drag method occasionally also collected *Lipoptena fortisetosa*, a dipterous bloodsucker. The life cycle of this species has not been described.

**Results**

**General time allocation of behavior at Mageshima Island and Nara Park**

Figure 2 shows the mean time spent feeding and lying down at Mageshima and Nara Park. Grooming time was relatively short in both sites and not shown in the figure. At Mageshima, feeding time accounted for two-thirds of the total observation time during all observation periods, and there was no clear pattern of variation. At Nara Park, feeding time was about half that at Mageshima, and the deer lay down more frequently in place of feeding. Feeding duration at this site was shortest during April and increased slightly in November, but was almost constant from May to October.

**Relationship between seasonal tick threat and grooming frequency**

The recorded tick density on the ground was always higher at Mageshima than at Nara Park (Fig. 3). At Mageshima, density was highest during April 1998, whereas at Nara Park density was highest during September in both 1998 and 1999 (Fig. 3). A one-way ANOVA revealed significant seasonal variation in tick density at both study sites (Mageshima, $F = 2.517, df = 4, P = 0.045$; Nara Park, from April to December 1998, $F = 3.345, df = 8, P = 0.023$; Nara Park, from January to October 1999, $F = 3.314, df = 9, P = 0.0014$).

The results of grooming frequency were shown in Figs. 4–7, and the statistical results were summarized in Table 1. At Mageshima, there was significant seasonal variation in SOG and SSG by females and fawns, with the exception of SSG by ♀ yearling (ANOVA: SOG by ♀ adult, $F = 4.456, df = 4, P = 0.0016$; SOG by ♀ yearling, $F = 3.347, df = 4, P = 0.0126$; SSG by fawn, $F = 9.408, df = 4, P < 0.0001$; SSG by ♀ adult, $F = 6.926, df = 4, P < 0.0001$; SSG by fawn, $F = 7.395, df = 4, P < 0.0001$) (Fig. 4). Tick density was significantly positively correlated with the frequency of SOG by ♀ adult and fawn and SSG by ♀ adult (Spearman’s rank correlation test: SOG by ♀ adult, $P = 0.0455$; SOG by fawn, $P = 0.0455$; SSG by ♀ adult, $P = 0.0455$).

For males at Mageshima, there was a significant seasonal variation in the duration of SOG by ♂ adult-large

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**Fig. 2.** Mean time spent for feeding and lying down in Mageshima (upper) and in Nara Park (lower). Shaded area, feeding; solid area, lying down; open area, others.
and $\delta$ adult-small, SSG by $\delta$ adult-large (ANOVA: SOG by $\delta$ adult-large, $F = 3.627$, $df = 4$, $P = 0.0077$; SOG by $\delta$ adult-small, $F = 6.090$, $df = 4$, $P = 0.0002$; SSG by $\delta$ adult-large, $F = 4.190$, $df = 4$, $P = 0.0032$) (Fig. 4). Tick density was significantly positively correlated with the duration of SOG by $\delta$ adult-large and $\delta$ adult-small (Spearman’s rank correlation test: SOG by $\delta$ adult-large, $P = 0.0455$; SOG by $\delta$ adult-small, $P = 0.0455$).

For females at Nara Park, significant seasonal variation was detected only for SSG by $\delta$ adult ($F = 4.094$, $df = 7$, $P = 0.0006$; SOG by $\delta$ yearling, $F = 2.338$, $df = 7$, $P = 0.0268$; SSG by $\delta$ adult-large, $F = 4.629$, $df = 7$, $P = 0.0002$) (Fig. 5). Tick density did not have a significant positive correlation with any of these values (Spearman’s rank correlation test: SOG by $\delta$ adult-large, $P = 0.1313$; SOG by $\delta$ yearling, $P = 0.1453$; SSG by $\delta$ adult-large, $P = 0.5661$).

ANOVA revealed a significant seasonal variation for

Table 1. Summary of Figs. 4–7

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SV, Seasonal variation; COR, Correlation with the tick density. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; n.s., not significant.
duration of AGR by ♀ yearling at Mageshima (F = 2.903, df = 4, P = 0.0250) (Fig. 6). Once again, tick density was not significantly positively correlated with this factor (Spearman’s rank correlation test: P = 0.2301).

For males at Mageshima, there was significant seasonal variation in the duration of AGD by ♂ adult-large and ♂ adult-small, and in the duration of AGR by ♂ adult-large and ♂ adult-small (AGD by ♂ adult-large, F = 2.898, df = 4, P = 0.0244; AGD by ♂ adult-small, F = 5.135, df = 4, P = 0.0007; AGR by ♂ adult-large, F = 6.053, df = 4, P = 0.0002; AGR by ♂ adult-small, F = 2.929, df = 4, P = 0.0231) (Fig. 6). However, tick density was not significantly positively correlated with any of these measures (Spearman’s rank correlation test: AGD by ♂ adult-large, P = 0.4237; AGR by ♂ adult-small, P = 0.2501; AGR ♂ adult-large, P = 0.6171; AGR by ♂ adult-small, P = 0.2301).

For females at Nara Park, ANOVA revealed significant seasonal variation in the duration of AGD by ♀ adult and AGR by fawn (AGD by ♀ adult, F = 2.539, df = 4, P = 0.0140; AGR by fawn, F = 8.361, df = 4, P < 0.0001) (Fig. 7). There was no significant correlation between any of these measures and tick density (Spearman’s rank correlation test: AGD by ♀ adult, P = 0.4014; AGR by fawn, P = 0.1627).

For males at Nara Park, significant seasonal variation was found in the duration of AGD by ♂ adult-large (F = 2.978, df = 7, P = 0.0076) (Fig. 7), and this did not correlate with tick density (Spearman’s rank correlation test: P = 0.2719).

**Seasonal pattern of allogrooming for each size-sex class**

At Mageshima, in both years, the mean duration of AGD by ♀ adults tended to increase during the rutting season (Fig. 6), while the mean duration of AGR by ♀ adults fluctuated regardless of season. The duration of AGR by ♀ yearlings decreased to some extent during the rutting season. Both AGD and AGR by fawns did not fluctuate significantly, but AGR tended to increase in the rutting season.

At Mageshima, none of the ♂ adult-large delivered nor received allogrooming during the rutting season (Fig. 6). The mean duration of AGD and AGR by ♂ adult-small at this site also tended to decrease during the
Fig. 5. Seasonal change in the mean duration of self-grooming in Nara Park. See Fig. 4 for the explanation notes.

Fig. 6. Seasonal change in the mean duration of allogrooming in Mageshima. See Fig. 4 for the explanation notes.
rutting season. AGD and AGR by ♀ yearlings did not change significantly.

At Nara Park, the mean duration of AGD and AGR by ♀ adults peaked during June (Fig. 7), when many females gave birth to fawns. The duration of AGD and AGR by ♀ yearlings was much lower for ♀ adults, and did not fluctuate significantly. The duration of AGD by fawns was low, and they did not groom others in the rutting season. The duration of AGR by fawns had a prominent peak in June, when they were newborns.

During all seasons, the duration of allogrooming by males at Nara Park was lower than that at Mageshima. ♀ adult-large, ♀ adult-small and ♀ yearlings did not deliver or receive allogrooming during the rutting season and none of these classes displayed a clear peak in the duration of AGD or AGR during the non-rutting season (Fig. 7).

**Discussion**

At Mageshima, tick density was significantly positively correlated with the duration of SOG in four out of five age-sex classes, and with duration of SSG in one out of three age-sex classes, for which it was possible to test for this. Furthermore, the seasonal variation in the duration of SOG by ♀ yearling shows the same pattern as the other age-sex classes, although this class was not statistically significant. In Nara Park, the duration of SOG by ♀ yearling and ♀ adult-large, and of SSG by ♀ adult and ♀ adult-large showed significant seasonal variations, but none of these were shown to have any significant association with tick density.

From these results, it can be concluded that the pattern of self-grooming, at least at Mageshima, reflects tick density in the habitat. No correlation between self-grooming duration and tick density at Nara Park may be
due to the low density of ticks there. Seasonal fluctuations in tick density at Nara Park were significant, but on a very much smaller scale than was the case at Mageshima.

However, when the results of both study sites are compared the relationship between self-grooming duration and tick density is not clear. During April 1998, tick density at Nara Park was 1/30 that at Mageshima, while the average duration of self-grooming was two-thirds that at the island site. During September 1998, when tick density at Nara Park was one-third that at Mageshima, the average duration of self grooming was greater than that at Mageshima. This result does not coincide with the previous studies in impala, which revealed the correlation with tick density and grooming frequency by the data from several regions with different tick density (Mooring 1995; Mooring and Samuel 1998).

This inconsistency may due to differences in the time allocation of behaviors between the study sites. At Mageshima, foraging accounted for two-thirds of the total observed time, whereas for deer at Nara Park, foraging occupied approximately half the time it did for deer at Mageshima, and “lying down” concomitantly increased. This result may be modified to some extent, because our study was carried out only in daytime and in open areas both at Mageshima and Nara Park. The behavioral pattern of deer changes temporally in a day and spatially among habitat type (Tatsuzawa and Fujita 2001). However, the reduced foraging time of deer in Nara Park is almost certain, and it is clearly due to artificial feeding. The deer in Nara Park live much longer than wild deer (Ohtaishi 1975), which suggests they are not threatened by the most important cause of death for wild deer - starvation. On the other hand, the nutritional condition of the deer at Mageshima has deteriorated in recent years and their body size has become smaller (Yamada and Urabe, unpublished data). The greatly reduced foraging time in Nara Park means that the deer have more than adequate time to groom.

At Mageshima, the duration of AGD by ♂ adult-large and ♂ adult-small, and of AGR by ♀ yearling, ♂ adult-large and ♂ adult-small showed significant seasonal variations, but none of them had a significant association with tick density. In Nara Park, the duration of AGD by ♀ adult and ♂ adult-large, and of AGR by fawn also showed significant seasonal variation, but none of them had a significant association with tick density, too. These results lead a conclusion that the duration of allogrooming has no relationships to tick density.

Mooring (1995) showed that allogrooming bouts by female impala had a significant positive association with the density of nymphs, and he concluded that allogrooming also had a relationship to tick density, because nymphs and larvae favor the neck and ear regions that are not accessible to oral self-grooming. By inference from Mooring (1995), self-scratch grooming, which grooms almost the same body region as allogrooming, should show much the same pattern as allogrooming if allogrooming is influenced by the density of immature ticks. In the present study, however, seasonal change in the duration of SSG did not coincide with that of AGD or AGR in all cases, but rather showed a similar pattern to SOG. Thus, allogrooming does not seem to be influenced by the density of ticks on head and neck regions of the deer in our study.

Some social reasons of seasonal pattern of allogrooming are easily inferred. Allogrooming by ♀ adult to fawns prominently increased at Nara Park during June, when females have newborn fawns. Adult males rarely performed allogrooming during the rutting season at both sites, as the result of Yamada and Urabe at Nara Park (1998). Thus, our results strongly suggest that the frequency of allogrooming of sika deer is interpreted in a social context, rather than in connection to tick density.

There is a remarkable difference between Mageshima and Nara Park for the point that who behaves as an allogroomer. At Mageshima, adult males in the non-rutting season, and yearlings and fawns of both sexes allogroomed frequently, while only ♀ adults were active allogroomers at Nara Park. These suggest that most allogrooming observed in Nara Park may carry out from mothers to their offspring, but in Mageshima, almost members, even fawns, behave as an allogroomer. Moreover, reciprocal allogrooming were observed in about one-third of the series of contiguous allogrooming bouts (Yamada and Urabe, unpublished data), while it was very rare at Nara Park (Yamada and Urabe 1998). It is an interesting theme if the social relationship of deer through allogrooming is influences by their habitat condition, such as tick density.

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