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Home range size and habitat use in radio-collared female sika deer at high altitudes in the Tanzawa Mountains, Japan

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In winter, when food availability was low, sika deer in the high Tanzawa Mountains preferred clearings, characterised by the highest biomass of food. In the other seasons, when food was abundant, habitats were used in accordance with their occurrence within home ranges, except in the case of erosion sites, which were avoided in every season. Patterns of habitat use differed between periods of the day and this phenomenon was influenced by human disturbance or weather, depending on the season. The abundance of food and interspersion of habitat patches allowed yearly home ranges of four sika deer to be very small at between 11.2 and 20.2 ha. The smallest mean home range size was recorded in autumn, probably because the same habitat then provided both food and cover.

1. Introduction

In a previous study (Borkowski & Furubayashi 1998), we presented habitat use by directly-observed sika deer in the high Tanzawa Mts. Since most deer in that study were seen when feeding, their pattern of habitat use reflected the needs mostly for forage, saying very little about habitat requirements for other activities. In areas exposed to human disturbance, cervids may use different habitats depending on the time of the day (Loft *et al.* 1984, Catt & Staines 1987, Mann & Putman 1989). Generally speaking, they utilize open habitats at night and move to closed ones during the daytime. Because the number of tourists visiting the Tanzawa Mts. is high, their presence can be expected to influence daily habitat use by deer. In addition, the previous paper provided no information on the third-order selection described by Johnson (1980), i.e., the selection of particular habitats within home ranges.

Although home range size may depend on the sex (Miller 1970, Moe & Wegge 1994), age (Miller 1970, Larter & Gates 1994) or social status of each individual (Clarke & Henderson 1984, Clutton-Brock *et al.* 1982), it is basically considered to result from an animal's energy requirements and habitat productivity (McNab 1963, Harestad & Bunnell 1979). Thus, individuals within populations living in habitats of different forage availability may differ in home range sizes (Larter & Gates 1990, 1994). The pattern of the distribution of resources also seems of great importance, with a fine-grained habitat mosaic perhaps being responsible for smaller home ranges (Moe & Wegge 1994, Krausman *et al.* 1989). To date, there have only been a few studies on the home ranges of sika deer in Japan (Endo 1992, Nagata 1996, Shigematsu 1996), and these were done at low altitudes. Since the distribution of the species in that country is mostly limited to mountains, this lack of knowledge of ecology at high altitude needs to be addressed. Although sika deer have been successfully introduced to many countries, their home ranges have only been studied at a few localities (Feldhamer *et al.* 1982).

The main aim of this study was thus to describe the pattern of habitat use by radio-collared sika deer in the high Tanzawa Mts., and to determine the sizes of home ranges.

2. Study area

The study was run between January 1994 and August 1995, in the Tanzawa Mountains (35°N, 139°E), central Honshu, between Mts. Tanzawa and Ryugabamba (respectively 1 567 m and 1 500 m a.s.l.). Although rather small (at about 100 ha), the study area included the largest continuous patch of cooccuring *Sasa hayatae* and *Pseudosasa purpurascens*, two species of dwarf bamboo found to be closely linked to the ecology of sika deer in Tanzawa (Furubayashi 1996, Borkowski & Furubayashi 1998). Radio-collared deer did not in fact roam beyond this area.

There were five habitats in the study area. Clearings (C) supported the highest food biomass (Borkowski & Furubayashi 1998) and were dominated by *Sasa hayatae*. Medium levels of food biomass characterized open woodland with *Sasa hayatae* in the understorey (Ow). The overstorey of this habitat, dominated by *Fagus crenata* trees, had numerous gaps due to natural tree mortality. The habitat defined as closed woodland (Cw) offered relatively low food biomass but favourable conditions in terms of cover. The dense overstorey in this habitat was formed by several tree species, with all trees being under 10 m tall. The understorey was again dominated by *Sasa hayatae*, and to a lesser extent *Pseudosasa purpurascens*.

Two other habitats providing very little forage for sika deer were (Ow1), with an overstorey similar to that of Ow, but an understorey dominated by unpalatable plants; as well as erosion sites (E), which had no overstorey and no ground vegetation besides some grasses at very low biomass.

3. Methods

Six female sika deer were captured and radio-collared between November 1993 and April 1994, but because of the sample size, data from only four were included (malfunction of one transmitter and death of one individual). Deer were located from the tourist trail ca. 1.5 km between Mt. Tanzawa and Mt. Ryugabamba four times a day (soon after sunrise, before noon, in the afternoon and a short time before sunset), three to four times per month, and over not more than four days per bout. The precise time depended on day length, though two consecutive locations of the same individual were separated by at least two hours, usually three or more. Location points were obtained using a hand-held three-element Yagi antenna, by triangulation, or visually when instrumented individuals were seen from the trail. The location points were marked on a 1:5000 map, together with a record of date and time.

Home ranges were calculated using the minimum convex polygon method (MCP) (Hayne 1949) by Tracker ver. 1.1. As MCP is the most-widely used measure of home range size, the results obtained, can easily be compared with those of other studies. Home range size tends to depend on the number of location points, if the sample includes fewer than 50–100 fixes (Harris *et al*. 1990). In the present study, this was the case for seasonal home ranges. The minimum number of location points per individual per season was 40, a number of fixes accounting for an average of 87% of seasonal home range size. 40 fixes were therefore considered adequate as a basis for the estimation of home range size. The independence of data was tested using Schoener's index (Swithart & Slade 1985) and if necessary, a number of points among consecutive locations separated by the shortest time intervals were repeatedly excluded from analysis, until data became independent.

Habitat availability was determined by drawing yearly individual 95% MCP home ranges on the habitat map. Delineated habitats within home ranges mapped on tracing paper were cut out and weighed, so that the respective percentages could be estimated. To analyze seasonal trends in habitat use, all the locations for the four individuals were combined to give a frequency distribution, and compared to the proportion of habitats within the "common home range" (the sum of the respective areas of every habitat within the home ranges of all individuals). Habitat use was analyzed by G-test.

4. Results

Habitat analysis was based on 1 553 location points (303–581 per individual). Yearly home ranges were

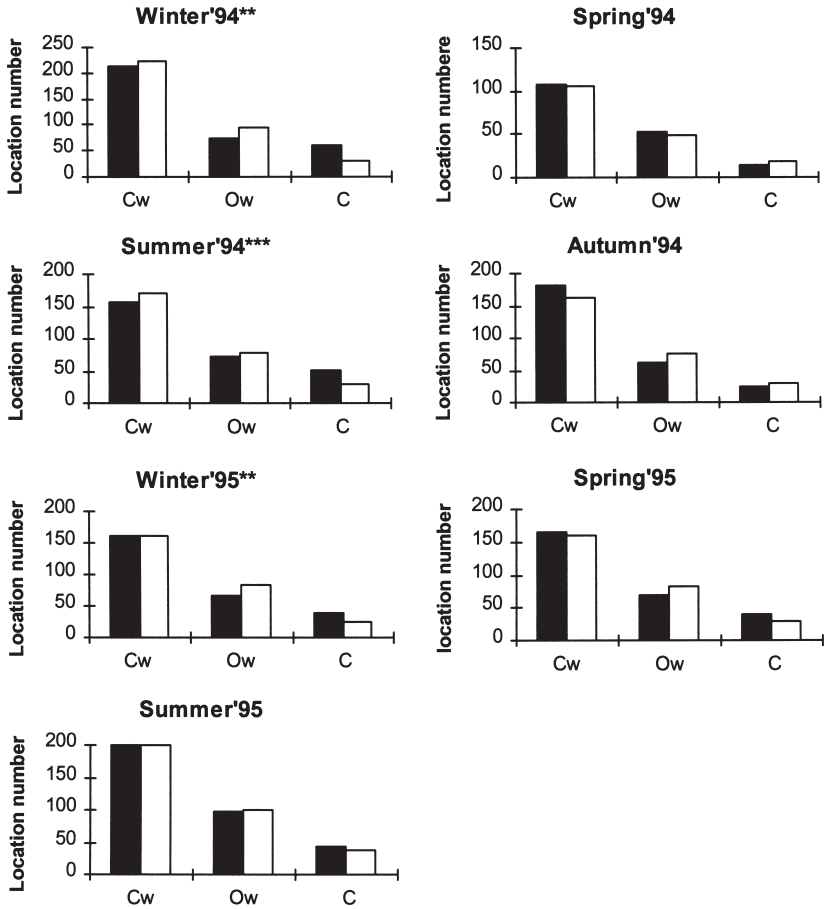

Fig 1. Observed (solid bars) vs. expected (empty bars) distribution of location points for radio-collared sika deer on Mt. Tanzawa. — Cw: closed woodland; — Ow: open woodland; — C: clearings. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

estimated on the basis of 281–308 location points per individual, while seasonal home ranges were based on 40–123 location points per individual. Although not tested prior to data collection, the accuracy of radio locations does not seem to have been a problem in this study. The average triangle formed by three bearings (estimated on the basis of 300 randomly selected location points) was of as little as 0.03 ha, and the average distance to the tracked animal was 197 m. A shorter distance between transmitter and receiver results in a smaller error polygon (Springer 1979). In addition, 39% of location points were obtained visually.

As open woodland with unpalatable understorey species occurred within the home range of one individual only, this habitat was excluded from the analysis. Analysis of seasonal use of habitats including erosion sites, revealed a pattern of use differing from availability in nearly every season. However, as these differences were in great measure due to the clear avoidance of erosion sites in every season, seasonal habitat use was reanalyzed, with these sites excluded (Fig. 1). This approach revealed that while habitats were used in proportion to their occurrence during most of the seasons of high food availability (spring–autumn), clearings were the selected habitat type in both winters, when food biomass was lower (Borkowski & Furubayashi 1998). Open woodland with dwarf bamboo in the understorey was used below its availability, while closed woodland was used in proportion to its occurrence.

Habitat use differed between times of day during most of the seasons (Fig. 2). Clearings were more often used in the morning and evening, closed woodland during daytime. Open woodland was used at an intensity independent on the time of day.

The radio-collared sika deer were shown to have very small yearly home ranges, at 11.2, 12.9, 16.3 and 20.2 ha. Although the small number of

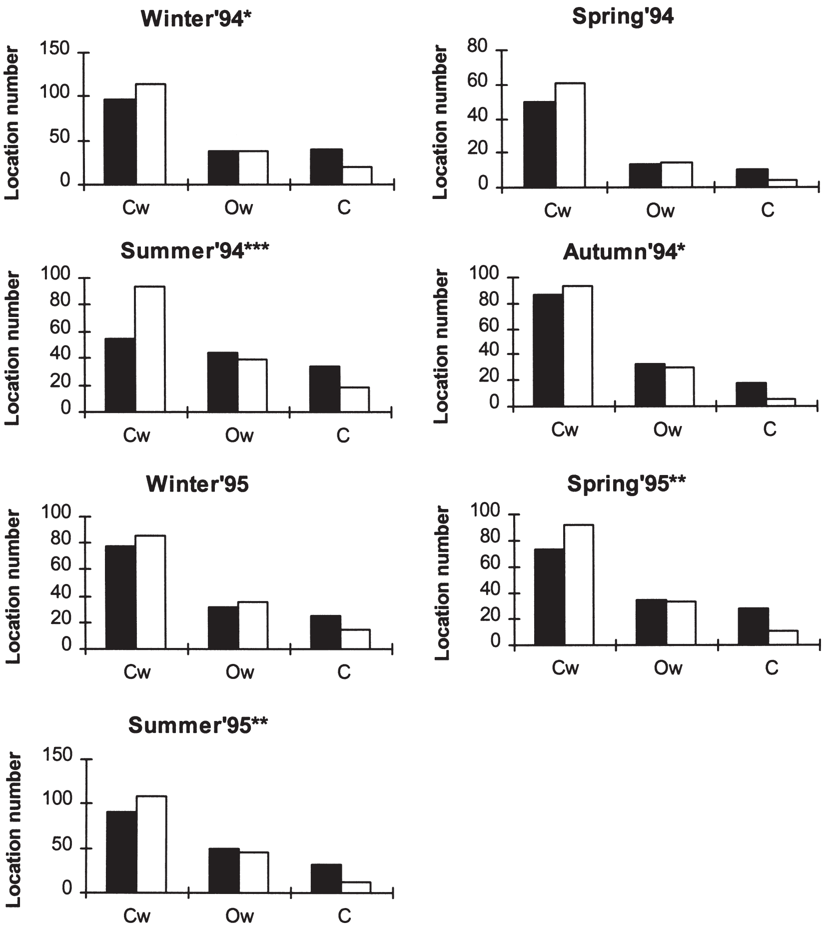

Fig. 2. Comparison of habitat use among radio-collared sika deer in the morning and evening (solid bars) and in the daytime (empty bars) on the top of Mt. Tanzawa. — Cw: closed woodland; — Ow: open woodland; — C: clearings. Erosion sites have been excluded due to small sample size. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

individuals precluded statistical analysis, there were some differences in seasonal home range sizes. The smallest mean home range size, 6.9 ha, was recorded in autumn (October–December). Mean home ranges were of moderate size in spring (May–June), and summer (July–September), 9.3 ha in both seasons, while mean home range size was largest in winter (January–April), 12.0 ha.

5. Discussion

Although the small number of individuals equipped with radio-collars placed definite limitations on this study, information on the ecology of sika deer in the high mountains is nevertheless provided. In both winters, radio-collared females selected clearings on the summit of Mt. Tanzawa (the habitat with the highest food biomass). In contrast, in periods of high forage biomass they used habitats according to availability. This confirms the relationship between food and habitat use found for directly-observed sika deer (Borkowski & Furubayashi 1998), at least during winter. No habitat preferences were recorded in the seasons when food was abundant. Proportional use of habitats during a period of forage abundance has been reported previously for elk (Edge *et al.* 1988).

This proportional use of habitats by radio-collared sika deer differs from the pattern found for directly-observed individuals (Borkowski & Furubayashi 1998), which exhibited clear habitat preferences in every season. This may be influenced by the fact that the location of a home range within a given area is already the result of selection (Johnson 1980). Thus, (depending on animal needs and habitat availability) home ranges may comprise habitats in proportions different to those in other parts of the area (Irwin & Peek 1983, Leach & Edge 1994). In addition, habitat use by radio-collared individuals reflected all their requirements, not almost exclusively feeding, as in the case of directly-observed deer, but other kinds of activity also.

Radio-collared individuals located in periods of high activity (morning and evening) used clearings more, and closed woodland less, than in low-activity periods (daytime). In winter 1994, this phenomenon was probably influenced mostly by tourists. Winter days in the study area are often sunny, with temperatures over 0°C, so deer seeking to minimize heat loss should have sunned themselves and used clearings with little shade. It was thus the presence of numerous tourists during the daytime that confined them to closed woodland. In winter 1995, the similar pattern of habitat use at different times of day may have reflected general increase in the use of closed habitats observed at higher deer density (Borkowski in prep.). In summer, when human activity is low, it was probably the weather which limited deer to closed habitats during the daytime. Since summer days were hot, resting under the canopy must have minimized the costs of thermoregulation. In those areas where summer diurnal temperatures are high, deer select bed sites with shade from trees, and thus minimize heat gain from direct solar radiation as was found for white-tailed deer (Ockenfels & Brooks 1994).

The very small size of home ranges of female sika deer on Mt. Tanzawa may reflect several factors. First, the study concerned non-migratory individuals, while the greater part of the local sika deer population is migratory (Borkowski & Furubayashi 1998), and includes individuals with home ranges that are certainly larger. Second, most seasons were characterized by abundant resources of food, especially dwarf bamboo. Although it is not clear how important this is in seasons other than winter, when dwarf bamboo is the major food of Tanzawa deer (Mitani 1995, Furubayashi 1996), the significance is probably greater than for deer studied by Mitani (1995), which often fed on artificial grassland unavailable to deer in this study. Where availability is high, dwarf bamboo may indeed be the dominant food item in each season in northern Japan (Takatsuki 1983). The annual home ranges of female sika deer were also found to be relatively small in the lower Tanzawa Mts. — between 11.5 ha and 38.8 ha (Nagata 1996) — though the deer in question depend on artificial winter feeding sites, that apparently allowed for small home range sizes. Shigematsu (1996) studied non-migratory sika deer in Chiba (eastern Japan) and found that, the female yearly home range could be as large as 246 ha (mean of 146.6 ha) in years when food was not abundant, but as small as 34.6 ha in years of better food conditions. In addition, the small home range sizes of the present study were probably a result of high habitat patch interspersion. The more fine-grained a habitat mosaic, the smaller the home range that can encompass satisfactory quantities of all the habitats required. The relationship between home range size and habitat patchiness is quite well documented (Clutton-Brock & Harvey 1978, Krausman *et al.* 1989, Moe & Wegge 1994).

The mean seasonal home range size was smallest in autumn, probably as a consequence of the pattern of habitat use. Since deer consume a lot of fallen leaves, the same habitat, namely closed woodland, could serve as both a foraging and resting site, thereby enabling deer to satisfy their basic requirements within a relatively small area.

In the temperate zone, the low quality of the food available to ungulates in winter generally leads to a reduction in food intake due to a limited-food processing rate (Moen 1973), and hence to smaller home range sizes (Irwin & Peek 1983, Clarke & Henderson 1984). However, this was not the case in the present study. As the quality of dwarf bamboo is higher than that of browse (Mitani 1995), the common winter food of cervids in the temperate zone, the food processing rate is probably not a factor limiting intake in the Tanzawa Mts. Consequently, the deer in this study had to enlarge their home ranges in order to meet energetic requirements in winter.

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