Why Do Sika Deer Head for the Alpine Zone in Japan?

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Abstract

We captured sika deer in the Northern and Southern Japanese Alps and monitored their seasonal movement patterns in the surrounding area. The daily air temperature in early June reached 5°C and the plants' growing period persisted for four months. Alpine sika deer are thought to stay in the alpine zone from the plants' early growing period. The alpine sika deer observed stayed in the alpine zone to feed on alpine vegetation and *Betula* forest understory. The autumn migration of these alpine sika deer started in September. These adult sika deer repeated the same seasonal migration pattern each year. One sika deer exhibited a long-distance dispersal movement, with a straight-line distance and actual distance between its natal range and post-dispersal range of 74 km and 131 km, respectively. This evidence of long-distance dispersal of sika deer may explain the expanding distribution of sika deer in central Honshu.

Key words: alpine meadows, natal dispersal, Northern Japanese Alps, seasonal migration, sika deer

1. Introduction

The attractions of the Southern Japanese Alps include dense evergreen coniferous forests where the primal breath can be felt, and "alpine meadows" full of Trollius japonicas blooming, which have been likened to an earthly paradise. In recent years sika deer (*Cervus nippon*) have penetrated into this alpine zone, and with them grazing the rare Alpine plant community, there is a danger that these "alpine meadows," a symbol of the rich mountain environment, will disappear (Fig. 1).

In only 10 years after 2000, the brightness of the alpine meadows was lost. From a questionnaire survey conducted in 1984, it was found that there were virtually no sika deer breeding in the northern part of the Southern Alps. From the 1990s the sika deer quietly started to use the evergreen coniferous forests of Veitch's silver fir and Abies mariesii in the subalpine zone, as well as the *Betula ermani* (Erman's Birch) forests and herbaceous communities. From the early 2000s sika deer encroached further into the subalpine zone and settled there, and in about 10 years the brightness of the "alpine meadows" disappeared.

It was generally thought that the alpine environment, featuring many steep slopes, was too harsh an environment for the sika deer to breed. However the

Fig. 1 Alpine meadow of *Trollius japonicas* in Kusasuberi of Mount Kitadake in 1980 (left) and forest floor with no flowers on Mt. Senjogatake in 2006 (right).

hooves of sika deer living on steep slopes have worn down, and are like the hooves of serow that perch on cliffs. Why have the sika deer encroached into the alpine zone where the breeding conditions are considered severe? Where do sika deer that appear in the Japanese Alps during summer come from and how did they get there? Why do sika deer come to the Japanese Alps.

Research on the movement of sika deer was conducted by tracking them with GPS collars in the northern part of the Southern Japanese Alps. Their movement in spring from their winter habitat at elevations below 1,800 m to their summer habitat was observed in June. This movement occurred over a long period of time, and was great both in terms of difference in elevation and in distance. This spring movement was observed along with the ascent of the foliation front from the upper parts of the subalpine zone to the alpine zone, when the plants started to grow and green shoots appeared, extending from the lower elevation towards the higher elevation. In summertime, from early June until early October, the sika deer made use of the alpine environment, including alpine meadows, from the upper subalpine zone to the alpine zone. During summer, the positions of the individual tracks and vegetation in the Mt. Senjogatake (3,033 m a.s.l.) region revealed that the places where the sika deer grazed excessively on the rare alpine vegetation communities consisted of Erman’s Birch forests and herbaceous species of altherbosa (alpine plant communities) in the upper subalpine zone. After reaching the main ridge lines, which are the environment they used in summer, no large movements were observed. Their use of the surrounding alpine environment continued until September. The individuals’ fixed positions were concentrated in Erman’s Birch forests and altherbosa. The sika deer kept continuously grazing on the alpine meadows throughout the summer (Fig. 2).

Only recently have sika deer begun to use in the cirque near the summit. At the bottom of the Ko-senjo cirque, we could see the mesh-like paths that sika deer had worn across it in all directions. These gave evidence of the movement of bucks which had stayed there for two months or in the O-senjo cirque. A protective fence installed on Mt. Senjogatake (3,033 m a.s.l.) and fences damaged during winter were repaired in early June. Before the repair the sika deer were already reaching the surrounding area and using the areas inside and outside the protective fence. However, after the repair they could not use the area inside the fence. Comparing photographs inside and outside the fence after only two weeks reveals flowers starting to bloom on the inside of the protective fence, while on the outside none can be seen. This shows how great the effect of the protective fence is. It also shows how severe the browsing pressure of the sika deer is (Fig. 3).

It is thought that the movement to their summer habitat is motivated by a need to move to areas with more favorable grazing conditions. The expanding distribution of the sika deer is the result of movement from regions where the breeding density is high and the grazing conditions have become poor to regions where the breeding density is low and the browsing pressure is less. It is thought that as a result of repeated movements constantly seeking locations with good grazing conditions, favorable for birthing and raising young in the case of the does and for development of physical size in the case of the bucks, they have encroached into the upper parts of the subalpine zone. This is thought to have produced the pressure for expansion of distribution that has caused the deer to emerge from the foot of the mountains of the Southern Japanese Alps, where the breeding density of the sika deer is now high, and ascend towards the alpine zone (Fig. 4).

Sika deer are now heading towards the Northern Japanese Alps. Ahead lies Mt. Shiroumadake (2,932 m a.s.l.) and other places with plentiful flowers of rich diversity. The sika deer have come through the dangers of extinction since the Stone Age, barely surviving. They are tough creatures that have survived disturbances from humans nearby. In the future we must continue to live with these sturdy neighbors. We must utilize experience from the past in the Southern Japanese Alps so that the problem will not be repeated in the future.

Fig. 2 Sika deer equipped with a GPS collar (left) and a hoof worn down (right).

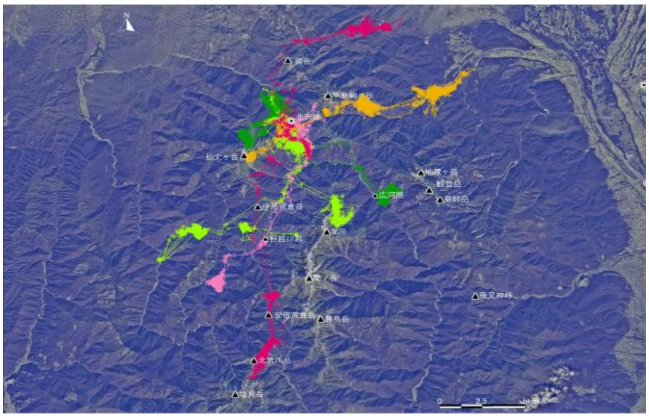

Fig. 3 Movement of sika deer in the Southern Japanese Alps.

Fig. 4 Inside and outside the fence.

2. Study Area and Methods

To study the seasonal migration and natal dispersal of the sika deer in the Northern Japanese Alps, we captured deer in the southern part of the Northern Japanese Alps and monitored their seasonal movements in the surrounding area. The elevation there ranges from 0 to 3,190 m, exhibiting the greatest altitudinal gradient in Honshu. This area has many peaks with altitudes of ≥3,000 m a.s.l., including Mt. Hotaka (3,190 m a.s.l.; the third tallest mountain in Japan). Contrasting with the rolling terrain of the ridgelines and valley floor, most of the area is characterized by a complex terrain with steep slopes and deep valleys.

The vegetation changes distinctively with elevation. The ridgelines >2,700 m a.s.l. mark the forest limit, where *Pinus pumila* (Japanese stone pine) and alpine meadow (including snowbed grasslands, windblown meadows and windblown heath) dominate. Betula (*Betula ermanii*) forests are distributed mainly in the subalpine to alpine zones (2,000–2,700 m a.s.l.). Tall grasslands are also distributed in this area. Natural evergreen coniferous forests (mainly composed of *Tsuga diversifolia*, *Abies veitchii*, and *A. mariesii*) are found widely in the subalpine and alpine zones (1,800–2,700 m a.s.l.). Deciduous broad-leaved forests (mainly composed of beech and Japanese oak) and Japanese larch plantations are distributed mostly in the upper montane zone (1,000–1,800 m a.s.l.). In the lower montane zone (<1,000 m a.s.l.), evergreen coniferous plantations, *P. densiflora* (Japanese red pine) forests, and deciduous broad-leaved forests are distributed in patches (Ministry of the Environment, 1997).

The climate is characterized by high precipitation in summer and relatively low precipitation in winter. In the city of Omachi (726 m a.s.l.), at the foot of the mountains, the mean annual temperature is 9.6°C, and the mean temperatures in the warmest and the coldest months are 22.2°C (July) and –2.9°C (January). On Mt. Nishidake (2,680 m a.s.l.), along a mountain ridge, the mean annual temperature is –0.2°C, and the mean temperatures in the warmest and coldest months are 13.3°C (July) and –13.3°C (January), respectively. In the city of Omachi (726 m a.s.l.), at the foot of the mountains, the mean annual precipitation is 1,395 mm and maximum snow depth is 38–101 cm (Omachi City; Japan Weather Association, 2011; Nishidake, unpublished data).

The study area was designated as Chubu-Sangaku National Park by the Ministry of the Environment in 1934. Most of the sites above 1,500 m a.s.l. are either designated "special protection zones" or "special zones," consisting of highly vulnerable vegetation. The deer-capture site was situated in the eastern foothills of the Northern Japanese Alps in the Kita-Azumi district of Nagano Prefecture, Japan (Fig. 5).

We captured deer using a dart gun with a ketamine–xylazine mixture as a tranquilizer. The ages of all of the deer were determined from tooth replacement and tooth wear. We received an academic capture permit from Nagano Prefecture to capture the deer. We captured 72 deer around Omachi City from April to November 2012–2022. We attached GPS collars (VECTRONIC Aerospace GmbH, Berlin, Germany) that were programmed with 2-hour relocation schedules on the deer.

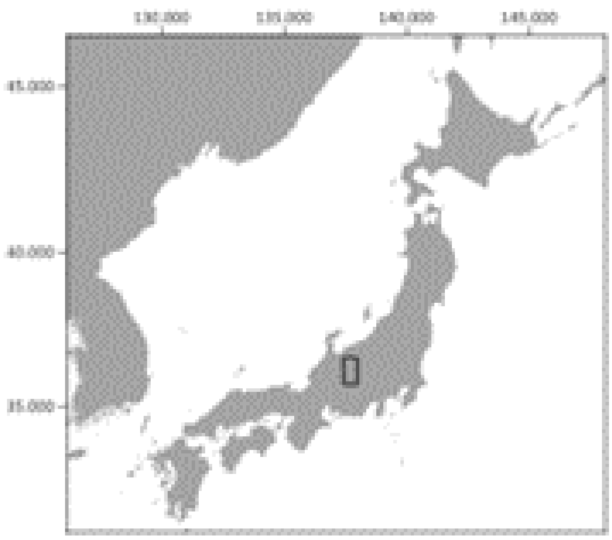

Fig. 5 The study area.

3. Results and Discussion

We analyzed the movement patterns of the GPS-collared deer. Almost of all the deer were migratory, with migration distances of 10 to 25 km. The non-overlapping winter home ranges of all of the migratory deer indicate relatively little snow in the study area. Thus there may be a wide range of areas suitable to the deer for wintering. The alpine deer demonstrated remarkable altitudinal differences between their summer and winter home ranges, ranging from 750 to 1,800 m.

They summered in the alpine zone (2,200–2,900 m a.s.l.) and wintered in the montane to subalpine zones (750–1,700 m). Regardless of the wintering area, the alpine deer's upward altitudinal movements took place in June and brought them to their summer home range. Alpine plants initiate plant growth when air temperatures are above 5°C (Kudo and Suzuki, 1999; Wipf, 2010). The daily air temperature reached 5°C in early June and the plants' growing period persisted for four months. Hence, the alpine deer are thought to relocate to the alpine zone from the plants' early growing period. The alpine deer preferred vegetation mainly found above 2,500 m a.s.l. (i.e., alpine pine forests, alpine meadows, tall grasslands, and Betula forests). Moreover, the alpine deer avoided evergreen coniferous forests, which exhibited the highest proportional availability. This finding demonstrated the high availability and utilization of palatable plants in Betula forest understory. Thus, the alpine deer stayed in the alpine zone to feed on alpine vegetation and Betula forest understory.

The alpine deer's autumn migration started from September. They all initiated their autumn migration before snowfall in the alpine zone (the first snowfall was in mid-October, according to notes at one mountain lodge). All of the alpine deer were male and had autumn home ranges. Considering that the breeding season of the sika deer starts in September, the alpine deer's autumn migration is considered a response to the shortage of food availability and a movement toward their breeding area. The adult deer repeated the same seasonal migration pattern each year (Takii and Izumiyama, 2022).

So, what is happening that results in new deer populations appearing in areas they previously did not inhabit? The females (does) give birth to their fawns in June. The sex ratio of the fawns born is 1 to 1. The fawns grow up in groups with their mothers (female group). All male individuals (bucks) and some female individuals are known to leave their natal group when they grow up. In understanding the reasons for the expansion of the sika deer distribution, determining the movements of one young deer can provide much information.

To determine the long-distance dispersal of a sika buck, we captured a five-month-old sika buck and conducted GPS tracking for 20 months in the eastern foothills of the Northern Japanese Alps. The buck showed the same seasonal movement pattern as a GPS-collared doe in the same group until 11 months of age. The buck departed from its natal group in May 2015, and after four months, the buck settled in the neighboring mountains, where deer are scarce. This buck exhibited a long-distance dispersal movement: the straight-line distance and actual distance between his natal range and post-dispersal range were 74 km and 131 km, respectively. He used four stopover sites (i.e., staying ≥3 days) during his dispersal movement, including in the alpine zone, where he stayed during summer. The evidence of long-distance dispersal of sika deer may explain the expanding distribution of these deer in central Honshu (Takii *et al*., 2019).

How did the buck leave his natal group and find a new home range? By direct observation, a GPS collared doe (body mass: 73 kg, ≥3 years old) was found to be the mother of GPS collared juvenile male deer (body mass: 39 kg, 5 months old). We were able to obtain GPS fix data on the doe and the young buck for 21 months and 20 months, respectively. The doe migrated between her summer and winter home range during spring and autumn. The five-month-old buck exhibited seasonal migration along with the doe during his first autumn and spring (Fig. 6a). The buck moved along with his mother, and utilized

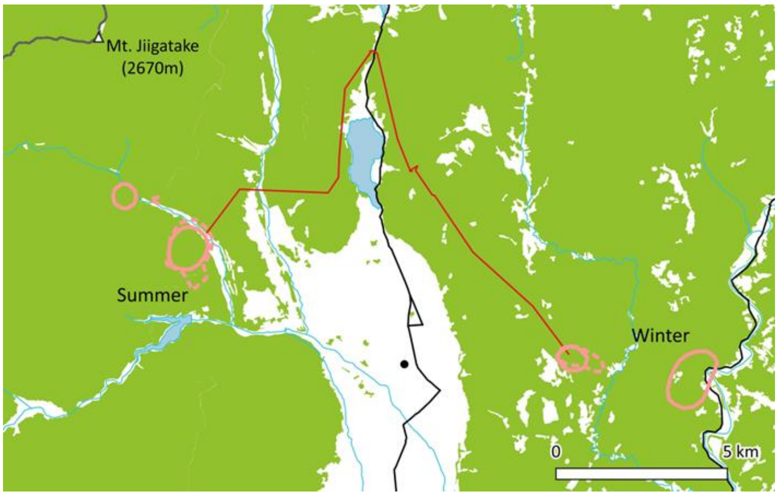

Fig. 6a Pre-dispersal home range (50% fixed kernel) of a juvenile sika buck and his mother's home range, monitored in Omachi City, Nagano, central Japan, 2014–2016. The juvenile buck and his mother's home range are outlined by solid and dotted lines, respectively. The red line shows their seasonal migration route.

the same summer and winter home range until May 2015. The elevations of their summer and the winter home ranges were 1,186 ± 140 m and 718 ± 127 m, respectively.

On 18 May 2015, at 11 months of age, the buck departed from his summer home range and entered the vagrant stage of his dispersal. The buck had gone missing after his dispersal started, but a camera trap set by the Kiso Forest Office captured a photograph of the GPS-collared sika buck in May 2016, and we could obtain data from this buck after that. The buck moved southwards, and after four months (6 September 2015) he settled in the eastern foothills of Mt. Ontake (3067 m a.s.l.). The buck exhibited a long-distance dispersal movement: the straight-line distance and actual distance between his natal range and post-dispersal range were 74 km, and 131 km, respectively.

He used four stopover sites during the vagrant stage of his dispersal, and the duration at each stopover site ranged from three to 40 days. The buck utilized higher elevations during his migration, compared to at his stopover sites (Fig. 6b; Tukey HSD, $p>0.05$). It is noteworthy that the buck utilized the alpine zone (≥2,500 m a.s.l.) of Mt. Norikura (3,026 m a.s.l.), on 30–31 July and 19 August. After the buck had settled into his post-dispersal home range, he exhibited an exploratory movement 12 km eastwards and stayed there during 12–26 October, coinciding with the sika deer rutting season (Takii *et al*., 2019).

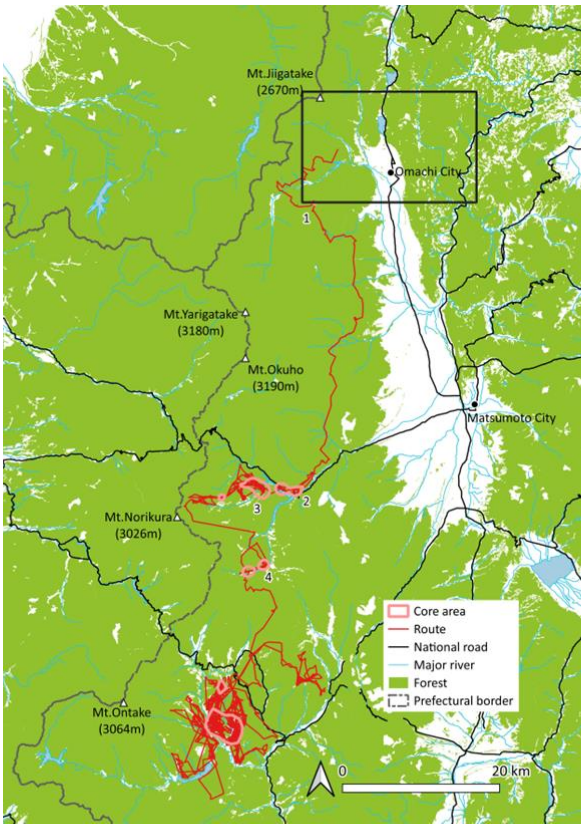

Fig. 6b Post dispersal movement of a juvenile sika buck. Stopover sites (i.e., staying > 3 days) are shown in the 50% fixed kernel with the solid pink line. The area shown in Fig (a) is outlined as a square in Fig (b). (Based on Takii *et al*., 2019)

Although the dispersal movement of male sika deer in Japan is poorly understood, two studies have indicated that male deer disperse at the age of 12 to 30 months (Yamazaki and Furubayashi, 1995, Takii *et al*., 2012a). We found that our GPS-collared juvenile buck dispersed at a younger age, 11 months. The buck dispersed in mid-May. Takii *et al*. (2012a) also documented that three out of four juvenile bucks dispersed in spring. The buck dispersed for a straight-line distance of 74 km. To our knowledge, this is the longest known dispersal distance of the sika deer.

In other research on a polygynous deer species, dispersal distances were found to be longer at high population density than at low density, and the emigrating bucks that dispersed from their natal range settled in areas of lower density than expected by chance (Loe *et al*., 2009). In our study, the deer density was relatively low at the capture site (Nagano Prefecture in 2016), but the deer dispersed and settled in a much lower density area.

During the pre-dispersal period, the buck demonstrated the same seasonal movement as his mother. Since the maximum snowfall is relatively high in Omachi City (784 m a.s.l.; 56–93 cm, 2013–2015), the deer likely exhibited seasonal migration to lower elevation areas during the winter to avoid deep snow (Igota *et al*., 2004; Takii *et al*., 2012b).

Takii *et al*. (2012b) also reported that one dispersed buck exhibited the same philopatric movement as his mother. Although the post-dispersal tracking period lasted for 10 months in our study, the young buck did not exhibit migratory movements, but was sedentary, except for an exploratory movement during the rutting season. Our observation showed that post-dispersal movement is not always associated with the mother's movement. Since the estimated deer density was very low in the post-dispersal area (Nagano Prefecture in 2016), the juvenile buck likely exhibited his exploratory movement during rutting season to seek mating does. The actual dispersal distance of this buck was greater than the straight-line distance. This indicates that the dispersal path was non-linear. However, the buck never returned to his prior stopover sites, always heading southwards.

The buck utilized higher elevations for his movement paths compared to his stopover sites. Anthropogenic structures, such as roads represent barriers to animal movement. Also in our study, the deer did not utilize urban areas for their movement paths but utilized much higher mountainous areas. Thus, it is likely that deer utilize higher elevations for movement paths to increase their survival rate.

The deer stayed in the alpine zone during the summer for a few days. There had been no evidence of sika deer utilizing the alpine zone of Mt. Norikura, so our observation is the first report of sika deer utilizing this area. In the Northern Japanese Alps, camera trap surveys in recent years have revealed that most of the deer captured in the alpine zone were bucks (Hotta and Ozeki, 2014; Hotta, 2016), and most deer were captured between July and August. Our data might explain this phenomenon, since dispersing bucks demonstrate vagrant movements prior to immigration. Furthermore, the deer likely utilize the alpine zone during summer to access better forage, because of the higher nutritional value of plants at higher elevations (Albon and Langvatn, 1992).

4. Conclusions

We captured sika deer in the Northern and Southern Japanese Alps to monitor their seasonal movement patterns using GPS collars. Alpine sika deer are thought to stay in the alpine zone from the plants' early growing period. The alpine sika deer stay in the alpine zone to feed on alpine vegetation and Betula forest understory. The autumn migration of the alpine sika deer starts from September. Adult sika deer repeat the same seasonal migration pattern each year. One sika deer was found to exhibit a long-distance dispersal movement, with a straight-line distance and actual distance between the natal range and post-dispersal range of 74 km and 131 km, respectively. This evidence of long-distance dispersal of sika deer may explain the expanding distribution of the sika deer in central Honshu.

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