

## Short Note

Akiko Takii\*, Shigeyuki Izumiya and Takashi Mochizuki

# An initial record of a long-distance dispersal route of a male sika deer in central Japan

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**Abstract:** We conducted a global positioning system (GPS) tracking of a male sika deer (*Cervus nippon*) and his mother in the eastern foothills of the northern Japanese Alps, central Japan. Sika deer exhibited similar seasonal movement patterns; however, the male deer left his natal group at 11 months of age. At 15 months of age, the male deer settled in the neighboring mountain, which was 74 km away from his natal range. This is the first record of long-distance (>50 km) natal dispersal of the sika deer. Our findings might help to explain the expanding distribution of the sika deer.

**Keywords:** *Cervus nippon*; dispersal; GPS telemetry; home range; northern Japanese Alps.

Natal dispersal by a species is the permanent movement from a birth site or natal group to a first or potential breeding site and is mainly an activity of juveniles rather than adults (Greenwood 1980). Although the causality of dispersal movement is complex, the ultimate factors that prompt species dispersal are kin competition, inbreeding avoidance, and adverse abiotic and/or biotic conditions (Cote et al. 2017). Dispersal movement comprises the following three phases: (i) departure (or emigration), (ii) vagrant stage and (iii) settling (or immigration) (Ronco 2007). Dispersal in some deer species often involves movement over distances longer than those during migratory movements (Nelson and Mech 1984, Tierson et al. 1985, Wahlström and Liberg 1995); also, the dispersing animal is an important contributor to the gene flow among sub-populations (Nelson 1993). Hence, natal dispersal is one of the most important processes in population dynamics (Greenwood 1980, Debeffe et al. 2012).

\*Corresponding author: Akiko Takii, Institute of Mountain Science, Shinshu University, 8304 Minami-minowa, Kami-Ina, Nagano 399-4598, Japan, e-mail: akikomt@shinshu-u.ac.jp

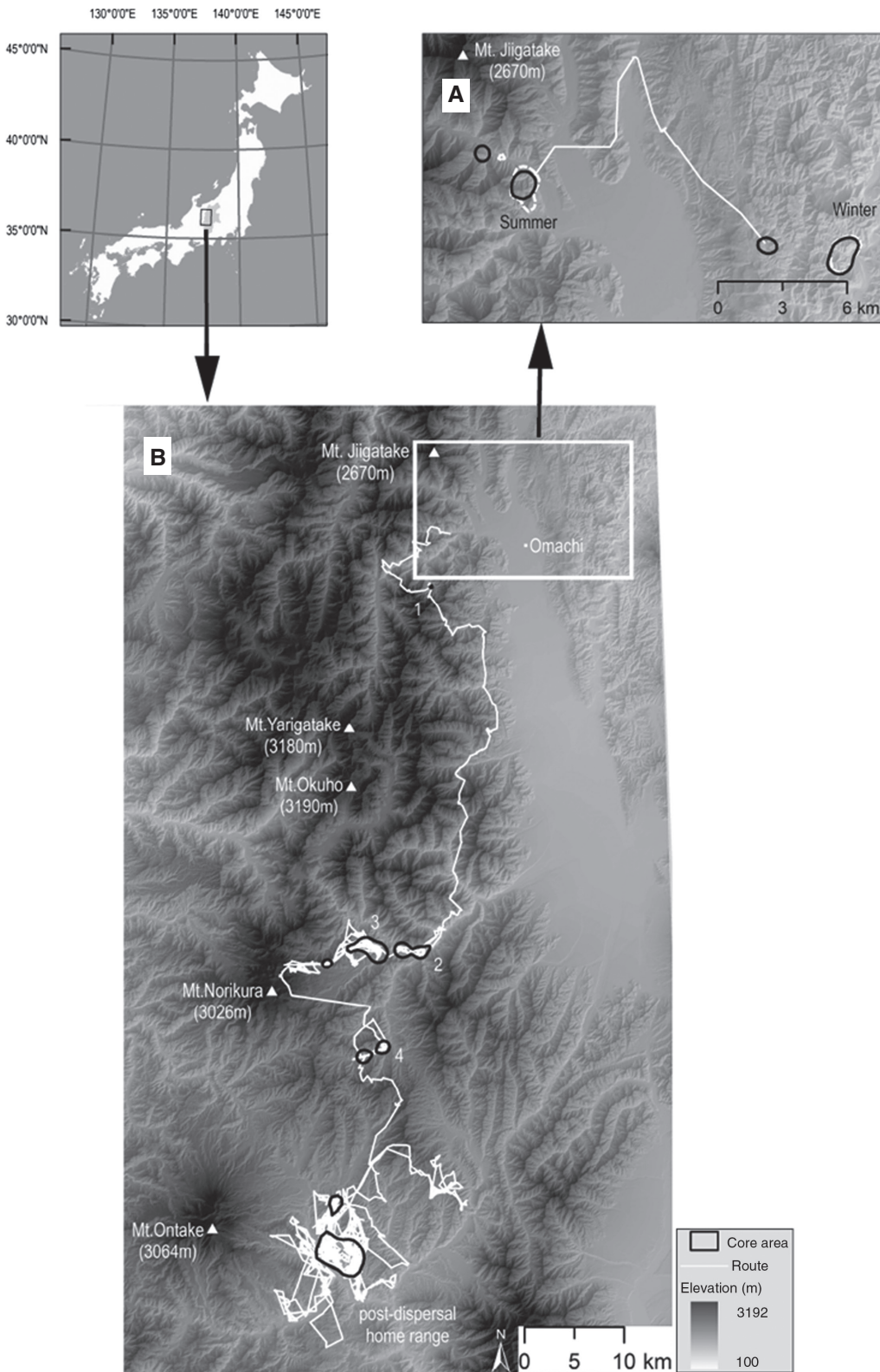
Shigeyuki Izumiya: Institute of Mountain Science, Shinshu University, 8304 Minami-minowa, Kami-Ina, Nagano 399-4598, Japan  
Takashi Mochizuki: Akatsuki Wildlife Research Office, Shizuoka 422-8046, Japan

Dispersal movements are sex biased because of mating strategy (Greenwood 1980). In a polygynous species, such as the white-tailed deer (*Odocoileus virginianus* Zimmermann, 1780),  $\geq 50\%$  juvenile males are known to exhibit natal dispersal (Kammermeyer and Marchinton 1976, Nelson and Mech 1984, Nelson 1993, Rosenberry et al. 1999). Long et al. (2008) documented that both inbreeding avoidance and mate competition are the ultimate important factors in the dispersal of the white-tailed deer, which corresponds to its onset being most often observed in the spring and autumn (Nelson and Mech 1984, Nixon et al. 2007). In weakly polygynous species such as roe deer (*Capreolus capreolus* Linnaeus, 1758), both sexes exhibit the same dispersal rate (Gaillard et al. 2008, Debeffe et al. 2012) and the timing of dispersal is highly synchronized with spring (Wahlström and Liberg 1995).

On the other hand, natal dispersal of the sika deer (*Cervus nippon* Temminck, 1838) is poorly understood; few studies have described the dispersal in Japan (Maruyama 1981, Yamazaki and Furubayashi 1995, Takii et al. 2012). However, only one study has documented the range of dispersal movements of sika deer from  $\geq 1$  deer, ranging from 3 to 40 km (Takii et al. 2012). In agreement with the results of other studies, the dispersal distance exhibited the farthest movement (e.g. migration) for any individual within the study area. Yuasa et al. (2007) suggested that this movement by the male deer contributed to the gene flow among the populations in southern Kantoh, central Japan. Thus, dispersal is fundamental to understanding the population dynamics of the sika deer.

We detailed the movements of a juvenile male sika deer along with an adult female deer, who was likely to be the mother of the juvenile male, using global positioning system (GPS) telemetry at the eastern foothills of the northern Japanese Alps, Honshu, an area in which the distribution of sika deer is thought to be expanding (Figure 1).

Sika deer were not common in the area until the early 2000s; however, their distribution expanded between 2010 and 2015 (Nagano Prefecture 2016). The elevation of the study area ranges from 520 to 3180 m. At the Omachi weather station [ $36^{\circ}30'N$ ,  $137^{\circ}51'E$ ; 726 m above sea level (a.s.l.)] located 7 km west of the deer capture site, the mean annual temperature in 2015 was  $10.1^{\circ}C$ , the mean annual



**Figure 1:** Dispersal route of a juvenile male sika deer (*Cervus nippon*).

(A) Predispersal home range (50% fixed kernel) of a juvenile male sika deer (*Cervus nippon*; solid black line) and his mother's (dotted white line) home range captured at Omachi City, Nagano, central Japan, between 2014 and 2016. The white line indicates the seasonal migration route. (B) Post-dispersal movement of a juvenile male sika deer. The four stopover sites (i.e. stayed  $\geq 3$  days) are indicated in a 50% fixed-kernel with the solid black line, and the number corresponds to the site's ID in Figure 2. The area in (A) is outlined as a square in (B).

precipitation was 1472 mm and the maximum snow depth was 93 cm (<http://www.data.jma.go.jp/obd/stats/etrn/index.php>, accessed January 2018). Vertical changes in vegetation correspond to elevation; broad-leaved deciduous forest, mainly consisting of *Fagus crenata* and *Quercus crispula*, dominates the montane zones, and evergreen coniferous forest, mainly comprising *Thuja standishii* and *Pinus porviflora*, dominates the subalpine zones (Ministry of Environment 1997).

We captured an adult female sika deer in June 2013 and an approximately 5-month-old male sika deer in November 2014 at Omachi City. The deer were immobilized with a dart gun, using ketamine and xylazine as a tranquilizer. The age of the deer was estimated by tooth replacement and tooth wear (Ohtaishi 1976). We weighed the deer and fitted each one with the GPS PLUS-1 GPS collar (VECTRONIC Aerospace GmbH, Berlin, Germany). The GPS collars were programmed with a 2-h relocation schedule. Data were remotely downloaded in the field every 1–2 months. We attempted to remotely drop off the collar when the collar denoted low battery. After collar retrieval, all GPS data were downloaded directly from the collar and imported into the ESRI ArcGIS 9.3 system (Environmental Systems Research Institute, Inc., Redlands, CA, USA). Animal capture and handling was performed according to the guidelines of the Mammal Society of Japan (2009).

Locations of individual deer were stratified into summer home range, autumn migration, winter home range and spring migration by the visual inspection of mapped locations plotted sequentially by date (D'Eon and Serrouya 2005). The seasonal home range (i.e. summer and winter) was delineated by the positions of an individual deer that stayed in a specific area for  $\geq 30$  days without moving 2 km in any direction within a day. We calculated the center of activity (COA) by averaging the longitude and latitude of the GPS fixes (Hayne 1949). Migration distances were measured using the linear and total distances of the connected lines of consecutive GPS fixes (actual distance) between the COAs.

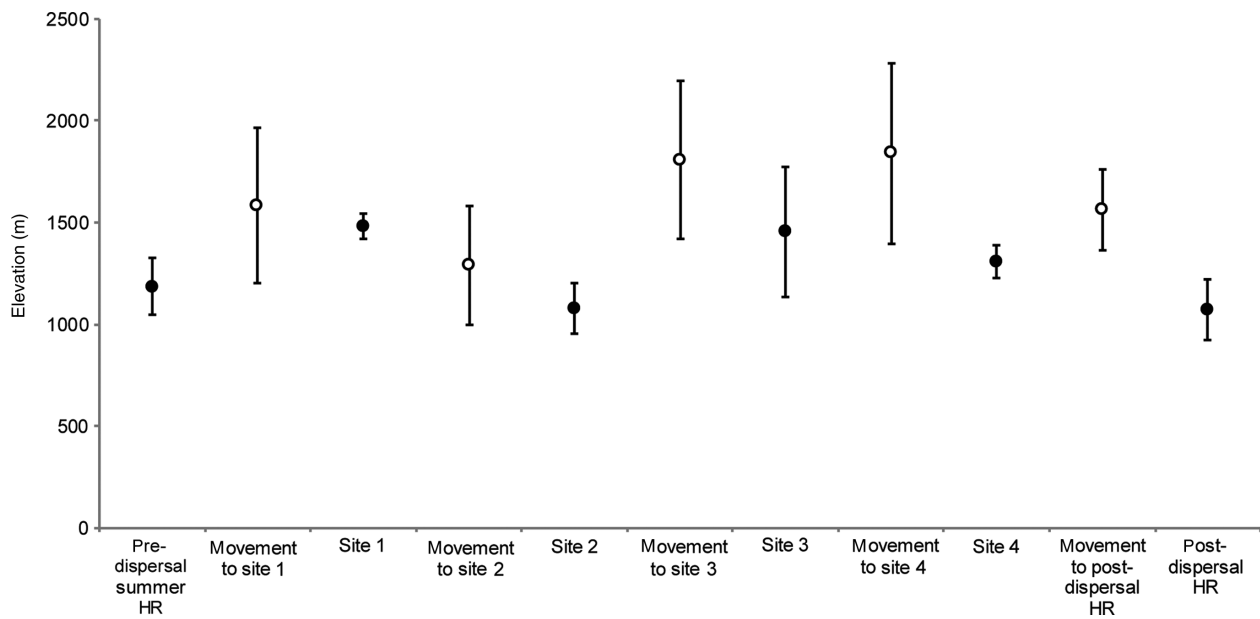
The deer was defined as a disperser if it moved from the natal home range and created a non-overlapping home range. During the vagrant stage of dispersal, any area in which the deer stayed for  $\geq 3$  days was defined as a stopover site. Dispersal distance was measured using (1) the linear distance between the COA at the predispersal summer home range and the post-dispersal home range, and (2) the total distance of the connected lines of the consecutive GPS fixes between the COAs of the stopover sites. The seasonal home range and stopover sites were evaluated using a 50% fixed-kernel home range (Worton 1989) and the “adehabitat” package of R software (Calenge 2006) with

an *ad hoc* method for the smoothing parameter. Elevations at the GPS fixed points were determined using elevation data for 10-m grids (Fundamental Geospatial Data: National Land Agency, Geospatial Information Authority of Japan, Tokyo). A nested analysis of variance (ANOVA) was applied to compare the elevation between dispersal movements and stay (i.e. seasonal home range and stop over sites), and each site. If significance was detected, we used Tukey’s honest significant difference (HSD) *post hoc* procedure ( $p < 0.01$ ) to investigate the difference among each contiguous site. All statistical analyses were conducted using the R. ver. 3.3.3 (R Core Team 2018). Data were presented as mean  $\pm$  standard deviation (SD).

Upon direct observation, the GPS-collared doe (body mass, 73 kg; age,  $\geq 3$  years old) was the mother of the GPS-collared juvenile male deer (body mass, 39 kg; age, 5 months). We were able to obtain GPS fix data of the doe and the male deer for 21 and 20 months, respectively. The doe migrated between summer and winter home ranges during the spring and autumn. The 5-month-old male migrated with the doe during his first autumn and spring (Figure 1A) and used the same summer and winter home ranges as the doe until May 2015. The elevations of the summer and the winter home ranges were  $1186 \pm 140$  m and  $718 \pm 127$  m, respectively.

As on 18 May 2015, at the age of 11 months, the male deer left the summer home range and entered the vagrant stage of dispersal that lasted for 111 days. The deer moved southward, and after 4 months (September 6, 2015), settled in the eastern foothills of Mt. Ontake. The long-distance dispersal movement exhibited by the juvenile deer resulted in linear and actual distances of 74 and 131 km, respectively, between the natal and post-dispersal ranges. There were four stopover sites during the vagrant stage. The deer stayed 3 days at site 1, 14 days at site 2, 40 days at site 3 and 8 days at site 4 (Figure 1). The mean elevation differed significantly between movements and stay ( $F = 1586$ ,  $df = 1$ ,  $p < 0.001$ ), and between each site ( $F = 202$ ,  $df = 9$ ,  $p < 0.001$ ), according to nested ANOVA. The mean elevation during movements was higher compared to stopover sites, except for “movement to site 1” and “site 1” (Figure 2; Tukey’s HSD,  $p < 0.01$ ). It is worth noting that the deer used the alpine zone ( $\geq 2500$  m a.s.l.) of Mt. Norikura on July 30–31 and August 19. After the male deer settled into its post-dispersal home range, he explored an area 12 km eastward, where he remained from October 12 through 26, the timeframe that coincided with the rutting season of the sika deer.

Although the dispersal movement of the male sika deer in Japan is poorly understood, two studies have indicated that the male deer dispersed between 12 and



**Figure 2:** Mean elevation used by a juvenile male sika deer (*Cervus nippon*), captured at Omachi City, Nagano, central Japan, between 2014 and 2016.

The open and filled circles indicate the elevation during dispersal movements and the elevation at the seasonal home range or stopover sites, respectively. Error bars indicate the standard deviation (SD). The mean elevation of contiguous movement and stay was significantly different except for “movement to site 1” and “site 1” (Tukey’s honest significant difference,  $p < 0.01$ ).

30 months of age (Yamazaki and Furubayashi 1995, Takii et al. 2012). We observed that this juvenile male dispersed at a younger age, which coincides with that of the white-tailed deer, whose dispersal age ranges from 10 to 30 months (DeYoung 2011). The male deer dispersed in mid-May, which is before the parturition period. Takii et al. (2012) also documented that four juvenile male deer dispersed in spring and autumn. In the white-tailed deer, natal dispersal in spring is driven by mother-young interactions because, before parturition, female deer chase off the young male deer, which is believed to prevent inbreeding (Stewart et al. 2011). Conversely, natal dispersal in autumn is driven by male-male competition (Jarnemo 2011).

The male deer dispersed a linear distance of 74 km. To the best of our knowledge, this is the longest reported dispersal distance of the sika deer. Long et al. (2008) revealed that the dispersal distance was greater in spring than in autumn, which coincides with the presumption that dispersal to avoid inbreeding would exhibit longer distance compared with that to reduce local male-male competition for mates. This might explain the long-distance dispersal of the deer in our study; however, further research is needed.

In a polygynous deer species, the dispersal distance was farther at high herd densities than at low herd densities, and the emigrating males who dispersed from their

natal range settled in areas with a lower density (Loe et al. 2009). Other studies have indicated that density-dependent dispersal of mammalian species is related to range expansions (Altwegg et al. 2013). In our study, the deer density was relatively low at the capture site (Nagano Prefecture 2016); however, the deer dispersed and settled in an area where deer were scarce. Two studies have indicated a high ratio of males in low-density populations of the sika deer. In the Boso Peninsula, central Japan, a male-biased sex ratio was observed at the edge of the sika deer distribution area based on the number of culled animals (Asada 2013). In addition, a camera trap survey revealed that the male capture ratio was high (>50%) during the early period of a newly established sika deer population in Morioka, northern Japan (Deguchi and Murayama 2016), even though camera trap data need careful interpretation due to bias in sex ratios (Maccoby et al. 2011). Although our study was conducted on only one deer, our results could demonstrate evidence that juvenile male deer settle at the edges of the distribution areas.

During the predispersal period, the male deer demonstrated the same seasonal movement as his mother. Because the maximum snowfall is relatively high in Omachi City (784 m a.s.l.; 56–93 cm; 2013–2015), the deer most likely seasonally migrate to a lower elevation area during winter to avoid deep snow (Igota et al. 2004, Takii et al. 2012). In the white-tailed deer, the mother’s movements affect the

post-dispersal movements (Nelson and Mech 1984, Nelson 1998, Nixon et al. 2007). Takii et al. (2012) also reported that one dispersed male sika deer exhibited the same philopatric movement as his mother. Although the post-dispersal tracking period in our study lasted 10 months, the male deer did not exhibit any migratory movements; except for the exploratory movement during the rutting season, he remained sedentary. Our results indicated that post-dispersal movement by the juvenile does not necessarily correspond to the mother's movements.

Jarnemo (2011) described that younger male red deer (*Cervus elaphus* Linnaeus, 1758) immigrated into areas with more females during the rutting season. Because deer are scarce at the post-dispersal area (Nagano Prefecture 2016), juvenile male deer most likely exhibit exploratory movements during the rutting season looking for mating females.

The actual dispersal distance was greater than the linear distance, which indicates that the dispersal path was nonlinear; however, the deer never returned to his prior stopover sites and always headed southward.

The deer utilized higher elevations during movement than at stopover sites. Anthropogenic structures, such as roads, represent barriers to animal movement (Mader 1984); Long et al. (2010) indicated that most deer avoided crossing roads or rivers during the vagrant stage of dispersal. In addition, in our study, the deer did not use urban areas as movement paths, instead he moved through much higher mountainous areas, where human activities are expected to be low. Thus, it is likely that the deer used higher elevations for their movement paths to avoid anthropogenic effects.

The deer in our study stayed within the alpine zone for few days during the summer. There has been no evidence of the sika deer using the alpine zone of Mt. Norikura; therefore, our finding is the first to report the use of this area by sika deer. Recently, camera trap surveys conducted at the alpine zone of the northern Japanese Alps revealed that most deer were males and were captured between July and August (Hotta and Ozeki 2014, Hotta 2016). Because dispersing males demonstrate vagrant movement before immigration, our data might explain this phenomenon. Furthermore, the deer most likely used the alpine zone during the summer for better access to foraging because of the increase in nutritional value of plants at higher elevations during this time (Albon and Langvatn 1992).

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## References

- Albon, S.D. and R. Langvatn. 1992. Plant phenology and the benefits of migration in a temperate ungulate. *Oikos* 65: 502–513.
- Altwegg, R., Y.C. Collingham, B. Erni and B. Huntley. 2013. Density-dependent dispersal and the speed of range expansions. *Divers. Distrib.* 19: 60–68.
- Asada, M. 2013. “Lag-phase management” as a population management method in low density areas in sika deer (*Cervus nippon*) and racoon (*Procyon lotor*). *Mammalian Sci.* 53: 243–255 (in Japanese with English abstract).
- Calenge, C. 2006. The package “adehabitat” for the R software: a tool for the analysis of space and habitat use by animals. *Ecol. Model.* 197: 516–519.
- Cote, J., G. Bocedi, L. Debeffe, M.E. Chudzińska, H.C. Weigang, C. Dytham, G. Gonzalez, E. Matthysen, J. Travis, M. Baguette and A.J.M. Hewison. 2017. Behavioural synchronization of large-scale animal movements – disperse alone, but migrate together? *Biol. Rev.* 92: 1275–1296.
- D'Eon, R.G. and R. Serrouya. 2005. Mule deer seasonal movements and multiscale resource selection using global positioning system radiotelemetry. *J. Mamm.* 86: 736–744.
- Debeffe, L., N. Morellet, B. Cargnelutti, B. Lourtet, R. Bon, J.M. Gaillard and A.J.M. Hewison. 2012. Condition-dependent natal dispersal in a large herbivore: heavier animals show a greater propensity to disperse and travel further. *J. Animal Ecol.* 81: 1327–1337.
- Deguchi, Y. and K. Murayama. 2016. Habitat use and sex ratio of sika deer in new distribution areas. *Mammalian Sci.* 56: 37–41 (in Japanese with English abstract).
- DeYoung, C.A. 2011. Population dynamics. In: (D.G. Hewitt, ed.) *Biology and management of white-tailed deer*. CRC Press, Boca Raton, FL. pp. 147–180.
- Gaillard, J.M., A.J.M. Hewison, P. Kjellander, N. Pettorelli, C. Bonenfant, B. Van Moorter, O. Liberg, H. Andren, G. Van Laere, F. Klein, J.-M. Angibault, A. Coulon and C. Vanpé. 2008. Population density and sex do not influence fine-scale natal dispersal in roe deer. *Proc. R. Soc. B.* 275: 2025–2030.
- Greenwood, P. 1980. Mating systems, philopatry and dispersal in birds and mammals. *Anim. Behav.* 28: 1140–1162.
- Hayne, D.W. 1949. Calculation of size of home range. *J. Mamm.* 30: 1–18.
- Hotta, M. 2016. First record of the wild boar *Sus scrofa* and some records of sika deer *Cervus nippon* by camera traps on the alpine zone near the Mt. Jiigatake and Mt. Iwakoyazawadake of Hida Mountains, Japan. *Bull. Nagano Environ. Conserv. Res. Institute* 12: 51–54 (in Japanese).
- Hotta, M. and M. Ozeki. 2014. First record of the Sika deer *Cervus nippon* by camera traps near the Mt. Iwakoyazawadake of Hida Mountains, Japan. *Bull. Nagano Environ. Conserv. Res. Institute* 10: 33–36 (in Japanese).
- Igota, H., M. Sakuragi, H. Uno, K. Kaji, M. Kaneko, R. Akamatsu and K. Maekawa. 2004. Seasonal migration patterns of female sika deer in eastern Hokkaido. *Ecol. Res.* 19: 169–178.
- Jarnemo, A. 2011. Male red deer (*Cervus elaphus*) dispersal during the breeding season. *J. Ehol.* 29: 329–336.
- Kammermeyer, K.E. and R.L. Marchinton. 1976. Notes on dispersal of male white-tailed deer. *J. Mamm.* 57: 776–778.
- Loe, L.E., A. Mysterud, V. Veiberg and R. Langvatn. 2009. Negative density-dependent emigration of males in an increasing red deer population. *Proc. R. Soc. B.* 276: 2581–2587.

- Long, E.S., D.R. Diefenbach, C.S. Rosenberry and B.D. Wallingford. 2008. Multiple proximate and ultimate causes of natal dispersal in white-tailed deer. *Behav. Ecol.* 19: 1235–1242.
- Long, E.S., D.R. Diefenbach, B.D. Wallingford and C.S. Rosenberry. 2010. Influence of roads, rivers, and mountains on natal dispersal of white-tailed deer. *J. Wildl. Manag.* 74: 1242–1249.
- Maccoy, J.C., S.S. Ditchkoff and T.D. Steury. 2011. Bias associated with baited camera sites for assessing population characteristics of deer. *J. Wildl. Manage.* 75: 472–477.
- Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biol. Cons.* 29: 81–96.
- Maruyama, N. 1981. A study of the seasonal movements and aggregation patterns of sika deer. *Bulletin of Faculty of Agriculture, Tokyo University of Agriculture and Technology* 23: 1–85 (in Japanese with English summary).
- Ministry of the Environment. 1997. Report of vegetation survey on 5th National basic survey on natural environment. Biodiversity Center of Japan, Ministry of the Environment. Available at: [www.biodic.go.jp/kiso/fnd\\_list\\_h.html](http://www.biodic.go.jp/kiso/fnd_list_h.html). Accessed January 31, 2018.
- Nagano Prefecture. 2016. The forth plan for conservation and management of sika deer in Nagano Prefecture. Nagano Prefecture Department of Forestry, Nagano. p. 72 (in Japanese).
- Nelson, M.E. 1993. Natal dispersal and gene flow in white-tailed deer in northeastern Minnesota. *J. Mamm.* 74: 316–322.
- Nelson, M.E. 1998. Development of migratory behavior in northern white-tailed deer. *Can. J. Zool.* 76: 426–432.
- Nelson, M.E. and L.D. Mech. 1984. Home-range formation and dispersal of deer in northeastern Minnesota. *Am. Soc. Mammolog.* 65: 567–575.
- Nixon, C.M., P.C. Mankin, D.R. Etter, L.P. Hansen, P.A. Brewer, J.E. Chelsovig, T.L. Esker and J.B. Sullivan. 2007. White-tailed deer dispersal behavior in an agricultural environment. *Am. Midl. Nat.* 157: 212–220.
- Ohtaishi, N. 1976. Age determination using tooth wear of sika deer at Nara Park. Annual Report of Nara Deer Research Association 1976: 71–82 (in Japanese with English summary).
- R Core Team. 2018. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/> (Accessed 28 August 2018).
- Ronce, O. 2007. How does it feel to be like a rolling stone? Ten questions about dispersal evolution. *Annu. Rev. Ecol. Evol. Syst.* 38: 231–253.
- Rosenberry, C.S., R.A. Lancia and M.C. Conner. 1999. Population effects of white-tailed deer dispersal. *Wildl. Soc. Bull.* 27: 858–864.
- Stewart, K.M., R.T. Bowyer and P.J. Weisberg. 2011. Spatial use of landscapes. In: (D.G. Hewitt, ed.) *Biology and management of white-tailed deer*. CRC Press, Boca Raton, FL. pp. 181–218.
- Takii, A., S. Izumiyama and M. Taguchi. 2012. Partial migration and effects of climate on migratory movements of sika deer in Kirigamine Highland, central Japan. *Mamm. Study* 37: 331–340.
- The Mammal Society of Japan. 2009. The guidelines for the treatment of animal samples. *Honyurui Kagaku* 49: 303–319 (in Japanese).
- Tierson, W.C., G.F. Mattfeld, R.W. Sage and D.F. Behrend. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. *J. Wildl. Manag.* 49: 760–769.
- Wahlström, L.K. and O. Liberg. 1995. Patterns of dispersal and seasonal migration in roe deer (*Capreolus capreolus*). *J. Zool. Soc. London* 235: 455–467.
- Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70: 164–168.
- Yamazaki, K. and K. Furubayashi. 1995. A record on dispersal of a young stag in western Tanzawa, central Japan. *J. Jap. Forest. Soc.* 77: 305–313 (in Japanese with English abstract).
- Yuasa, T., J. Nagata, S. Hamasaki, H. Tsuruga and K. Furubayashi. 2007. The impact of habitat fragmentation on genetic structure of the Japanese sika deer (*Cervus nippon*) in southern Kantoh, revealed by mitochondrial D-loop sequences. *Ecol. Res.* 22: 97–106.