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Habitat utilization distribution of sika deer (*Cervus nippon*)

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ABSTRACT

Habitat-specific and movement-related behavioral studies are essential for the development of sustainable biodiversity management practices. Although the number of studies on sika deer is increasing, habitat utilization distribution (UD)-related studies remain limited. In this study, we investigated the habitat UD behavior of sika deer (*Cervus nippon*) using a literature survey and an experimental study on Suncheon Bonghwasan Mountain, South Korea. We reviewed home range-related literature on sika deer published between 1982 and 2019 in order to assess their estimation methods, study region, and research background. We observed that the number of studies on sika deer has increased. The minimum convex polygon (MCP) has been utilized the most to estimate habitat UD, followed by the kernel density (KD), the Brownian bridge model, and a combination of these methods. The average home ranges (95 % utilization distribution) of sika deer from the literature survey were 236.99 ha and 1183.96 ha using the minimum convex polygon and kernel density approaches, respectively. The five female deer in our experimental study on Suncheon Bonghwasan Mountain had a mean home range of 66.831 ± 15.241 ha using the MCP approach and 78.324 ± 20.82 ha using the KD approach. The UD behavior of sika deer explored in this research is expected to benefit future scholars and policymakers when formulating deer management and wildlife conservation strategies.

1. Introduction

The International Union for the Conservation of Nature (IUCN) lists many endangered species. Endangered status and conservation policies have helped increase the populations of certain species [1]. Although sika deer (*Cervus nippon)* are thriving as a whole, they are either extinct or listed as endangered in certain areas because of habitat loss and hunting for their meat, antlers, hides, velvet, organs, and blood [2–4]. Because of the commercial benefits and long history of sika deer (hereafter, deer) farming, most studies have focused on the physical and biological aspects of the species, such as antler-velvet processing techniques or the medical applications of deer products and antlers for the treatment of chronic diseases [5–7]. However, there is limited information regarding the ecology and evolution of this deer species [2].

Deer are hoofed ruminant mammals that belong to the artiodactyl family Cervidae, which was first taxonomically described by

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German zoologist Georg August Goldfuss in Handbuch der Zoologie (1820) [8,9]. Among the two groups of deer—Cervidae and Capreolinae—, sika deer belong to the Cervidae group [10]. Sika deer are small-to medium-sized animals with a tail length of 75–130 mm, body length of 950–1800 mm, and shoulder height of 640–1090 mm [11,12]. These deer are native to Japan and Eastern Asia, but they started migrating to other areas in the early 1800s [13] and are becoming increasingly widespread worldwide. Their current range includes the Korean Peninsula, the Japanese archipelago, and a region extending from the Ussuri region of Siberia to North Vietnam, mainland China, Taiwan, Europe, Australia, New Zealand, Poland, Denmark, North America, and the Philippines [2,8,13].

Species behavior must be continuously monitored and analyzed to implement effective management strategies, conserve biodiversity, and minimize negative impacts on native ecosystems. As an intentionally introduced species, deer both positively and negatively impact invaded environments. While they contribute to certain aspects of the ecosystem, they also adversely affect native species [14–19]. Deer are foragers that can damage vegetation in commercial and natural areas. Farmers have complained of losses in agricultural production and woodlands surrounding farmland [18]. Trees—including hollies and conifers—, grasses, shrubs, sedges, acorns, fungi, bark, ivy, and heather are the primary food sources of deer [20]. The habitat occupied by sika deer is similar to that inhabited by other red and whitetail deer, allowing the occurrence of hybridization. This can reduce species diversity by depleting the gene pool when hybridization occurs with native deer species [21].

Studies on deer management, genetics, and ecology have increased in recent years [22]. When searching for the keyword "sika deer" in PubMed, an increasing trend of scientific publications on deer is observed (Fig. 1, obtained from the PubMed data center, accessed on April 22, 2022) [23]. Deer are invasive species worldwide, except in Japan. The optimal control of invasive species is a key concern in conservation management [24]. Consequently, there is a significant volume of scientific and practitioner literature on the prevention of damage, eradication (where possible), and adaptive management for attaining effective control of the species [25,26].

The behavioral patterns of a species are critical; no species can be effectively managed without comprehending its ecological dynamics and interactions [27]. The concept of utilization distribution (UD) or home range is important for ecology and conservation management because it provides a global representation of space-use patterns when resources are limited [28–30]. Burt (1943) [27] introduced the concept of a "home range" and defined it as "the area traversed by the individual in the course of its normal activities of food gathering, mating, and caring for young." Although the number of studies on deer is increasing, UD-related studies remain limited.

Understanding UDs provides insights into spatial requirements and foraging patterns for deer management. Monitoring species behavior and inventory programs are essential for the generation and distribution of reliable data to formulate policy models, manage invasive species, and perform socioecological impact assessments [31]. Several studies have analyzed home ranges and deer behavior in various countries and regions [32–37]. To the best of our knowledge, this is the first study that explores the UDs of deer using available literature and experimental approaches. In this study, we aimed to collect data on UD in the core zones and home ranges of deer and aggregate global scenarios. Furthermore, we assessed the diel movement behavior of deer in Suncheon Bonghwasan Mountain, South Korea, using UD. The data from this study may serve as a reference for scholars and wildlife specialists in designing sustainable biodiversity management policies.

2. Materials and methods

This study was designed using a dual approache to extract data on the UD of deer, involving a brief literature review and an experimental study that introduces movement patterns in South Korea.

2.1. Literature survey

The concept of home range estimation dates back to the 1940s [27,38,39], after which several increasingly complex and sophisticated statistical home-range estimation techniques have been developed [40–44]. Our initial approach to determining the home range/UD of deer was based on existing literature. We conducted a literature search using keywords such as "home range of sika deer," "utilization distribution of sika deer," and "core zone of sika deer" on Google Scholar, PubMed, and Web of Science. Duplicate

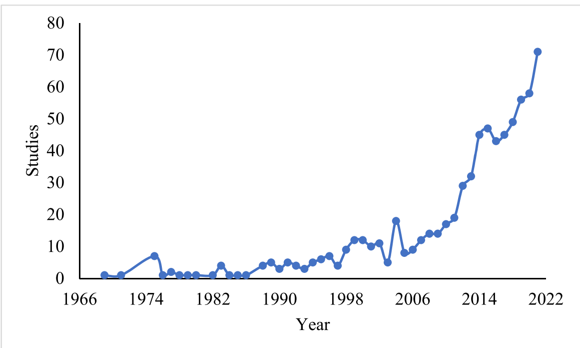

Fig. 1. Studies retrieved from the PubMed database using the keyword "sika deer" (Source: [23]).

publications were removed, and quantitative analyses of UD were further examined to obtain the average home range behavior of deer. To obtain UD aggregate information, we calculated the average reported values and observed their ranges.

2.2. Experimental study

Alien species in South Korea have increased by 2.4 times over the last decade [45]. Deer in South Korea are invasive species that originate from Taiwanese and Japanese subspecies, whose population is increasing owing to restoration programs and hunting bans [46]. Continuous monitoring and analysis of invasive species are crucial for biodiversity management [47]. Therefore, we approached the National Institute of Ecology, Ministry of Environment and received permission to monitor the behavior of deer on Suncheon Bonghwasan Mountain, which allowed us to conduct the current experiment.

2.2.1. Study area

Suncheon Bonghwasan Mountain (355 m above sea level) is located on the border between Yongdang-dong, Jogok-dong, and Seomyeon in Suncheon-si, Jeollanam-do, South Korea. According to the Köppen–Geiger climate classification [48], Suncheon-si has a humid subtropical climate (Cwa classification under the Köppen–Geiger system). In this region, temperatures range between 1 °C and 26 °C throughout the year but can occasionally drop to −16 °C or reach 35 °C. The average annual precipitation is approximately 1503 mm, and the area has 97 rainy days based on a 1-mm annual threshold [49]. The study area is located between 127.49° and 127.53° E and 34.95°–34.98° N, with elevations ranging from 10 to 324 m above sea level (Fig. 2).

2.2.2. Data collection

Considering that there exists limited research on deer in the survey area and the female group was always larger [50] and more gregarious than that of males while exhibiting stable behavior [2], this study focused on female individuals from five distinct herds. Herd size increases and fluctuates over time [51,52] therefore, grouping behavior was not reported in this study. Five individuals were randomly captured at different time points (Table 1) using an anesthetic gun (xylazine hydrochloride, 2 mg/kg; ketamine hydrochloride, 5 mg/kg). The individuals were released at the capture site after 48 h of resting with a GPS collar (Druid Technology Co., Ltd., China) affixed to their necks. The first 8 days of monitoring data were eliminated as they may have reflected behavioral changes resulting from capture and handling [53]. Stress in the deer was minimized by applying established protocols for fitting GPS collars [54,55]. The handling and capture methods followed the guidelines of the American Society of Mammologists [56], and the animal study was reviewed and approved by the Ethics and Welfare Committee (approval number: NIEIACUC-2021-016) of the National Institute of Ecology, Republic of Korea.

Five deer (identification numbers: D_6726, D_6728, D_6729, D_6730, and D_6749), weighing approximately 60–80 kg, were tracked continuously. Their geographic coordinates were recorded at hourly intervals using a GPS collar (BADGE Dual 3G, Druid Technology Co. Ltd., China) for short periods between January and September 2021 (Table 1). Movement speed and environmental covariates are discussed in the data analysis section.

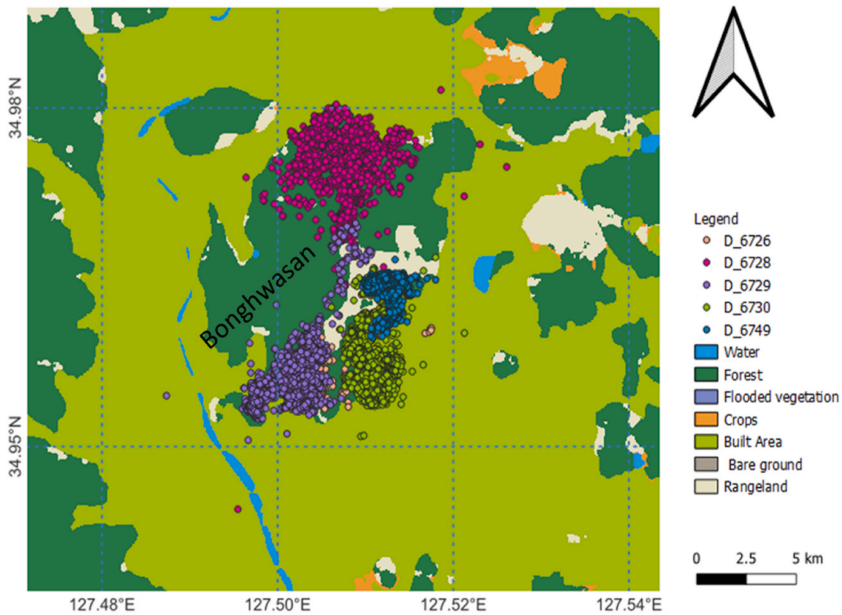

Fig. 2. Survey area and individual movement points of five deer (D_6726, D_6728, D_6729, D_6730, and D_6749).

Table 1
Individual deer details, including ID, weight, and survey period.

ID	Weight (Kg)	Study period
D_6726	70	2021-03-30–2021-04-04
D_6728	80	2021-01-15–2021-04-04
D_6729	60	2021-03-03–2021-09-02
D_6730	70	2021-01-15–2021-03-20
D_6749	70	2021-03-04–2021-03-27

2.2.3. Deer movement behavior and environment

All location-related data were processed using Microsoft Excel 2019. We analyzed the movement distance, D (m) from the recorded location using the spherical cosine law, as shown in equation (1) [57].

$$D(m) = ACOS(COS(RADIANS(90 - Lat_i)) \times COS(RADIANS(90 - Lat_{i+1})) + SIN(RADIANS(90 - Lat_i)) \times SIN(RADIANS(90 - Lat_{i+1})) \times COS(RADIANS(Long_i - Long_{i+1}))) \times 6371000 \quad (1)$$

where Lat_i and $Long_i$ are the latitude and longitude in degrees at time *i*, respectively. The shape of the Earth was assumed to be spherical, with a radius of 6371000 m, and the *RADIAN* function was used to convert degree coordinates to radians.

We analyzed deer diel patterns in the study area. The movement patterns were difficult to categorize, and we used the Calinski–Harabasz criterion [58] to determine the optimal number of clusters. The speed of the deer with the suggested number of segments was used to determine diel activity patterns. Furthermore, the spatial links between deer movement locations and their distributions were reported in this study. Based on current spatial data availability, we used the distance from residences, distance from water sources, distance from roads, slope, aspect, and altitude as movement coordinates among numerous environmental features [59, 60] to analyze the spatial relationship of deer movement. The environmental data were extracted from 30 m × 30 m pixel raster maps and processed in the QGIS 3.24.1 platform [61] using raw geo-data obtained from the National Spatial Data Portal [62].

2.2.4. Estimating utilization distribution in the survey area

Various UD estimation methods include convex polygons [63,64], Brownian bridges [65], geoellipses [66], line buffers [41], and kernel density (KD) methods [67–69]. Although KD estimators and minimum convex polygons (MCPs) have limitations and home range estimates are sensitive to time scale [70], sample size [71,72], and seasonal and spatial behavior variations [35,73,74], they have been widely applied (refer to the literature search). The UD in the current study was also analyzed using the MCP [75] and KD home range methods [68] as well as the "adehabitatHR" package, which is the most used package for spatial ecology analysis in the RStudio Version 3 environment [76,77]. We analyzed and reported on all five movement patterns of the female deer with 50 %, 75 %, and 95 % KD and MCP home ranges. We further compared the same UD areas using the two-sample Kolmogorov–Smirnov (KS) test [78] and the UDs with the MCP approach were visualized.

Table 2
Studies on the home range of deer using kernel density (KD) and minimum convex polygon (MCP) approaches.

Source	Country	Study area	Method	KD*		MCP*	
				50 %	95 %	50 %	95 %
[81]	USA	Maryland	Radio collar	–	–	–	155.15
[82]	Japan	Nozaki Island	Radio collar	–	–	–	3.3
[83]	Japan	Tanzawa mountain	Radio collar	–	–	–	15.7
[84]	USA	Maryland	Radio collar	–	161.1	–	497.4
[85]	Japan	Hokkaido,	Radio collar	–	–	–	131.5
[86]	Japan	Tanzawa Mountains	Radio collar	–	–	–	97.5
[87]	Japan	Nikko	Radio track	–	–	–	153.5
[88]	Japan	Boso Peninsula	Radio collar	12	50	–	–
[89]	Japan	Kinkazan island	Radio collar	–	–	–	14.45
[90]	Japan	Nagano Prefecture	GPS collar	–	–	5	–
[91]	England	Arne and Hartland	Radio collar	–	89.98 (90 %)	–	–
[92]	USA	Maryland	Radio collar	–	3637	–	–
[93]	Japan	Kirigamine Highland	GPS collar	–	–	–	74.5
[35]	Czech Republic	Doupovské hory Mt.	GPS collar	–	3620	–	819
[94]	Korea	Songnisan National Park	GPS collars	–	46	–	223.5
[73]	Japan	Hokkaido	GPS collar	–	–	–	680
[95]	England	Purbeck, Dorse	Radio collar	–	–	–	100
[96]	China	Yangtze	Simulated data set (remote sensing)	125.14	733.92	68.3	352.4
[97]	Japan	Gunma	Spotlight counts	–	39.7	–	–

*Authors' calculations from literature as the mean of the average home range

3. Results

3.1. Utilization distribution from the literature survey

From our literature search, we obtained 32 publications from Google Scholar, 23 publications from PubMed, and 43 publications from the Web of Science. After excluding duplicate and descriptive articles, we finally selected 27 studies that provided statistical data on the UD behavior of deer. It was reported that 50 % (minimum area vs. probability [MAP] 0.5) and 95 % (MAP 0.95) UD were normally considered the core area and home range in hectares (ha), respectively [42,44,79,80]. Table 2 summarizes the representative studies on deer considering the concept of home range and core area using the MCP [75] or different KD [68] methods.

Table 2 shows that MCP 95 % is the most frequently used method for home range estimation. The average mean home range of deer was 236.99 ± 69 ha (coefficient of variance [COV]: 110.45, range: 3.3–819.0) using the MCP approach and 1183.96 ± 638 ha (COV: 142.55, range: 39.7–3637) using the KD approach. Further, numerous studies have been conducted in various regions of Japan.

Some studies on the home range of deer have used the Brownian Bridge Model [35] (1163 ha) and MCP 100 % (280 ha [98], 2.69–17.55 ha [99]). It was observed that the male home ranges were more extensive than those of females [2,68,86,93,99,100], with an average ratio of 1.94 ± 0.25 (Appendix A) and a more extensive home range in winter (74–197 ha) than in summer (66–125 ha) [85].

3.2. Utilization distribution in Suncheon Bonghwasan Mountain

3.2.1. Movement data analysis

Based on the movement distances analyzed with Equation (1), deer were more active at night and noon (see Fig. 3a), with an average speed of 61.11 ± 0.93 m/h (range: 0.10–2369.36 m/h). Based on the Calinski–Harabasz criterion for segmenting the possible number of movement patterns according to movement distances, a maximum value (2.2E04) was identified at cluster number 4 (Fig. 3b).

Based on the suggested number of clusters and in relation to the time-distance plot (Fig. 3a), we segmented the movement speed of each individual into four groups corresponding to morning (05:00–12:00), afternoon (12:00–17:00), evening (17:00–21:00), and night (21:00–05:00) (Table 3).

As shown in Table 3, D_6730 moved faster in the afternoon (70.714 ± 3.359 m/h) and evening (82.665 ± 5.476 m/h), whereas D_6728 moved more (85.325 ± 3.703 m/h) in the morning and D_6726 moved more at night (202.884 ± 75.611 m/h). D_6749 was the least mobile of all the animals. The overall average movement speed based on individual behavior was 68.900 ± 6.802 m/h. Most movements occurred at night (98.698 ± 18.342 m/h), followed by the evening (60.303 ± 5.883 m/h), morning (56.014 ± 3.154 m/h), and afternoon (51.136 ± 3.924 m/h).

The relationship between movement coordinates and spatial features was analyzed. A built-up area surrounded Bonghwasan (see section 2.1), and deer movement occurred in the vicinity of the residential (D_Residence) area (mean: 257.014, SD: 164.067 m). Fig. 4 (a–f) shows the details of the environmental covariate frequency plot for the distance to water (D_Water) (mean: 165.317, SD: 100.669 m) and roads (D_Road) (mean: 256.720, SD: 217.101 m) as well as the slope (mean: 19.007, SD: 7.017°), aspect (mean: 158.046, SD: 89.130°), altitude (mean: 107.779, SD: 57.570 m), and distance to residences.

3.2.2. Utilization distribution

The UDs of the examined deer in the survey area were analyzed using the MCP and KD methods. The mean UD area in Suncheon-si and Jeollanam-do, South Korea, was 66.831 ± 15.241 ha with 95 % MCP and 78.324 ± 20.82 ha with the 95 % KD approach with a smoothing bandwidth $h = 123.99$, respectively (Table 4).

Table 4 displays the three ranges (50, 75, and 95 %) of the UD area (ha) for the examined female deer using the KD and MCP

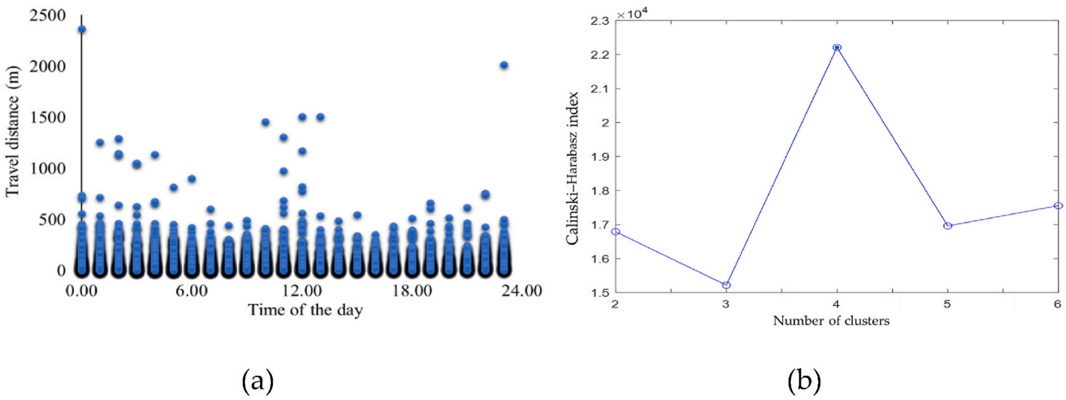

Fig. 3. Movement classification. a) Distribution of diel movement speed and b) Calinski–Harabasz index plot for optimal cluster numbers.

Table 3
Movement speed (m/h) of observed individuals.

	Movement speed (m/h)									
	All observations		Morning		Afternoon		Evening		Night	
	Mean	Std. error	Mean	Std. error	Mean	Std. error	Mean	Std. error	Mean	Std. error
D_6726	89.076	22.824	45.262	5.363	37.606	6.188	53.967	12.840	202.844	75.611
D_6728	94.201	4.891	85.324	3.703	63.381	5.912	67.378	4.932	125.952	7.844
D_6729	63.401	1.870	65.601	3.620	52.862	2.510	54.813	2.828	74.799	3.910
D_6730	66.865	3.618	55.616	2.005	70.714	3.359	82.665	5.476	59.620	2.758
D_6749	30.956	0.809	28.269	1.081	31.118	1.652	42.692	3.339	30.277	1.585
Average	68.900	6.802	56.014	3.154	51.136	3.924	60.303	5.883	98.698	18.342

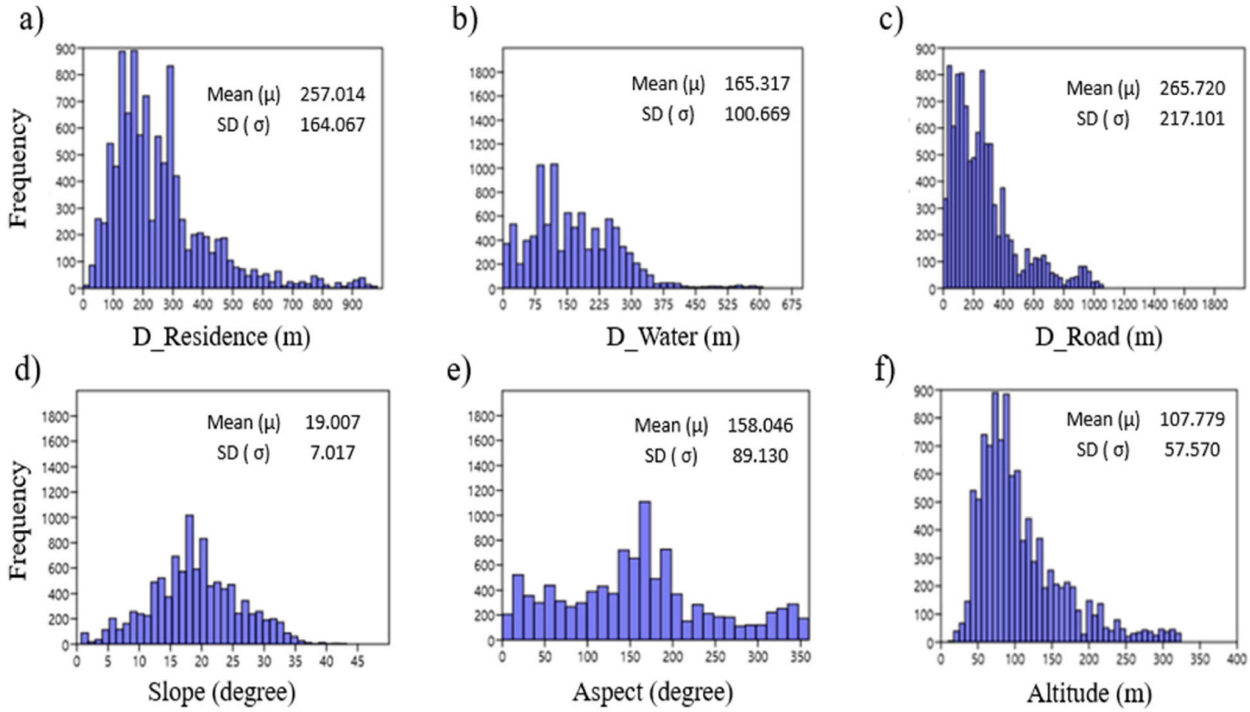

Fig. 4. Environmental characteristics concerning movement points. a) Distance to residences (m), b) Distance to water (m), c) Distance to roads (m), d) Slope (°), e) Aspect (°), and f) Altitude (m).

Table 4
Utilization distribution (ha) with kernel density (KD) and minimum convex polygon (MCP) approaches.

Individual	Area (ha)					
	KD (%)			MCP (%)		
	50	75	95	50	75	95
D_6726	17.088	35.830	90.200	7.238	11.453	59.612
D_6728	18.041	59.969	146.646	33.096	64.815	115.488
D_6729	15.416	33.554	68.404	21.245	37.581	61.696
D_6730	12.184	33.353	68.608	20.436	34.824	76.436
D_6749	2.187	6.944	17.764	3.168	8.705	20.921
Average	12.983	33.930	78.324	17.037	31.476	66.831
Std. error	2.877	8.397	20.820	5.364	10.197	15.241

approaches. The average core area (UD 50 %) was slightly larger in the MPC (17.037 ha) than that in the KD (12.983 ha) and UD 75 %, whereas the home range (UD 95 %) was higher using the KD method. The largest core zone (18.041 ha KD and 33.096 ha MCP) and home range (146.646 ha KD and 115.488 ha MCP) were observed for D_6728, which seemed to occupy a larger area than that inhabited by the other individuals. We found no statistically significant differences between KD and MCP home range data using the KS test (UD 50 %: $p = 0.209$, $\alpha = 0.05$; UD 75 %: $p = 0.999$, $\alpha = 0.05$; and UD 95 %: $p = 0.9697$, $\alpha = 0.05$). Owing to its statistical similarity and broad use (see section 2.1), we illustrated the core zone, 75 % UD area, and home range with inner, intermediate, and outer polygons, respectively, using only the MCP method and including the distribution of the movement points of each individual (Fig. 5). The home ranges of all deer overlapped, except for that of D_6728, while the core zones could be easily distinguished.

4. Discussion

Efforts to understand the ecology of mammalian populations have relied primarily on UD behavior, and this aspect has been extensively researched [2,27,38,55]. Studies on invasive mammalian deer have also increased (Fig. 1) because of concerns regarding sustainable biodiversity and current trends in the area of investigation [22,101]. Sika deer have spread globally [2,8], and critical studies have been conducted in their native country, Japan (18 out of 27 studies). Our survey revealed that despite several recent advancements in UD estimation techniques [41–44], KD and MCP have been predominantly utilized in deer habitat studies.

The literature shows that male home ranges are more extensive than female ones [2,81,87,94,100,102]. The average UD of deer varies from 236.99 ± 69 ha (COV: 110.45, range: 3.3–819.0 ha) using the MCP and 1183.96 ± 638 ha (COV: 142.55, range: 39.7–3637 ha) using the KD approach. The average UD in the literature was similar to that reported by Yabe and Takatsuki (2009), who found that the average UD was typically larger than 100 ha.

The deer in the survey area had a mean UD of 66.831 ± 15.241 ha using the MCP approach and 78.324 ± 20.82 ha using the KD approach. The estimation process and constraints are different for each UD estimation method [35,40,84]. This study assessed UD solely using MCP and KD (at a bandwidth of 123.99) approaches that were statistically similar to those verified by the KS test for female deer. Future research should include additional testing and verification, comparative studies between different models, genders, and age groups, and more datasets.

In addition to analyzing the UD of deer, we also investigated their movement behavior in the survey area. A four-diel behavior pattern was suggested by the Calinski–Harabasz criterion, so morning, afternoon, evening, and night movement patterns were estimated. Each individual had different movement patterns; overall, the deer moved faster at night and more slowly in the afternoon. Reviewing the literature, we found that movement behavior changes with seasonal and temporal variations. On the North Island of New Zealand, the distance from the collar-tagged position to the hunter-kill location was recorded to be 2.2 km after an average of 16.9 months [103]. Moreover, the mean seasonal migration distances vary among different habitat patches, ranging from 3.2 to 22.9 km (Kirigamine Highland) [93], 7.2–101.7 km (Hokkaido) [2], 4.0–69.9 km (Takkobu) [73], approximately 74 km in the eastern foothills of the northern Japanese Alps (Japan) [36], and 80–160 km in Kadyna, Poland [104]. There is a need for future research into the specific individual behavior of deer in the current study area and other habitat regions.

Occasional probing forays outside of the area should not be considered part of the home range [27] and are influenced by external variables [35,73,74]. Minor alterations in the environment can change the home-range behavior of animals, which can be analyzed using locational data graphs [105,106]. All strategies presented here are based on the premise of stability, but the UD may change with the estimation time scale [70], sample size [71,72], and seasonal and spatial behavioral variations [35,73,74]. Obtaining more accurate home range data may be possible with sufficiently large datasets to conduct ensemble tests on different geolocations. Therefore, it is necessary to conduct a comprehensive study of invasion areas, including native areas, and analyze them using an extensive dataset.

In our study, although the location was the same but the survey duration was slightly different, the UDs of individuals fell within the range aggregated from the literature survey, with some variation. Further research with more deer individuals in deer habitat regions at different time periods will be required to assess the time-dependent UDs. UDs often vary owing to the species population, Allee

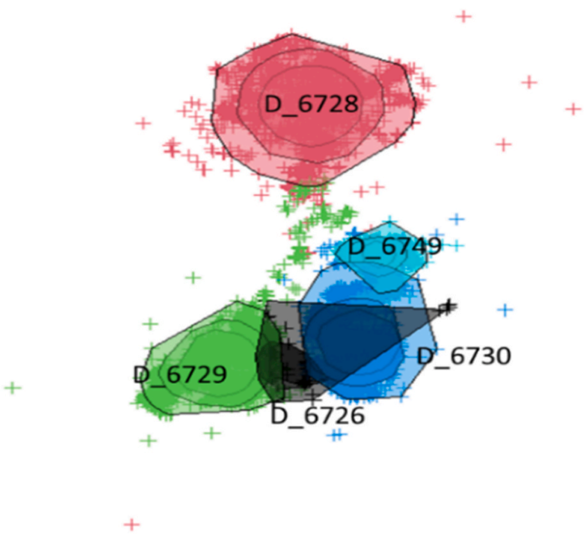

Fig. 5. Minimum convex polygon at 50, 75, and 95 % utilization distributions.

effect, and carrying capacity effect [107,108], so continuous surveys and monitoring are required. Further, invasive species can harm ecosystems and global biodiversity [101], but major studies on deer UDs have been conducted in Japan, where they are native species. Thus, additional studies involving occupied regions and addressing the limitations of this study are warranted.

5. Conclusions

Behavioral studies on habitat specifications and movement behavior are essential for developing sustainable biodiversity management practices. Our findings highlight the UDs of deer through a literature survey and an experimental study tracking the movement data of five female deer on Suncheon Bonghwasan Mountain, South Korea. This study investigated the foraging range of deer, providing managers with valuable insights for designing protected zones, hunting zones, and deer conservation plans. We also analyzed the diel behavior patterns of the examined deer, as suggested by the machine learning clustering criterion. The behavior of other species can be categorized within a similar framework. Overall, the research framework and the information reported in this study are insufficient but support the establishment of deer management policies on Bonghwasan Mountain, South Korea, and around the world.

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Author contribution statement

Thakur Dhakal: Performed the experiments; analyzed and interpreted the data; wrote the paper.

Gab-Sue Jang: Conceived and designed the experiments; analysis tools or data; analyzed and interpreted the data; wrote the paper. Minhan Kim: materials, analyzed and interpreted the data; Wrote the paper.

Ji Hyung Kim: Performed the experiments; analyzed and interpreted the data; Wrote the paper.

JoongYeol Park: Performed the experiments; analysis tools or data; wrote the paper.

Sang-Jin Lim: Performed the experiments; materials, analysis tools or data; wrote the paper.

Yung-Chul Park: Conceived and designed the experiments; Performed the experiments; materials, wrote the paper.

Do-Hun Lee: Conceived and designed the experiments; Performed the experiments; materials, analysis tools or data; wrote the paper.

Data availability statement

Data will be made available on request.

Dear Editor in Chief

Heliyon.

We would like to declare and confirm followings are appropriate:

o All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

o This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Home range (ha) comparison between the sexes

Source	Male (ha)	Female (ha)	Ratio

(*continued on next page*)

(*continued*)

Source	Male (ha)	Female (ha)	Ratio
[94]	294	135	2.18
[2]	47.5	20	2.38
[81]	182.5	127.8	1.43
[87]	192	115	1.67
[100]	211.3	76	2.78
[102] *	71.6	61.0	1.17

* Average of reviewed papers.

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