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Habitat Use, Movement, and Home Range of the Slender Racer (*Orientocoluber spinalis*) on an Island in South Korea

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Abstract.—**Understanding the spatial ecology of a species is essential for developing successful conservation strategies. Reptiles may serve as keystone species and are critical for robust and healthy ecosystems. There is relatively sparse ecology-related information on reptiles, especially cryptic species such as serpents. In this study, we used radiotelemetry to investigate habitat use and the home ranges of the Slender Racer (*Orientocoluber spinalis*), a threatened snake species found on Oeyeon Island in the Republic of Korea. We radio-tracked eight *O. spinalis* (three females and five males) for an average of 20 d (36 relocations) from July through October 2021. *Orientocoluber spinalis* was mostly active during the day and was primarily observed in grasslands adjacent to forests. We observed *O. spinalis* most frequently in grasses (46%) and on rocks (21%) within grasslands. The estimated home range size for *O. spinalis* on Oeyeon Island during the non-breeding season was 1.7 ha by the Minimum Convex Polygon (MCP) method, and 1.3 ha (95% density) and 0.2 ha (50%) by the Kernel Density Estimation (KDE) method. Our results indicate that the protection of grasslands adjacent to forests is essential for the conservation of *O. spinalis* populations on Oeyeon Island and potentially across their northeastern Asian range.**

Key Words.—grassland; grassland snake; radio-telemetry; reptile; snake

Introduction

Expanding our understanding of the spatial ecology of a species could improve the likelihood that the species is successfully conserved (Scott and Seigel 1992; Santos et al. 2009; de Fraga et al. 2011; Martino et al. 2012). Thus, there is a need to elucidate the general and spatial ecology of imperiled species, including reptiles. Snakes are poorly studied among reptile species likely due to their cryptic nature (Gerald et al. 2006). The lack of fundamental biological information such as habitat use and home range size make it challenging to facilitate effective conservation management policies (Plummer and Mills 2000; Monterroso et al. 2009). Radiotelemetry may be a cost-effective strategy for understanding the spatial ecology of cryptic species and has been used on snakes previously (Madsen 1984; Brown et al. 2009; Martino et al. 2012; Glaudas 2021). Radiotelemetry has the potential to elucidate the spatial ecology of snake species, including habitat use, home range size, and daily movement patterns (Bell et al. 2007; Dorcas and Wilson 2009).

The Slender Racer (*Orientocoluber spinalis*) is a small snake species found across the Korean Peninsula, China, Russia, Mongolia, and Kazakhstan (Shannon 1956; Kharin and Akulenko 2008; Kharin 2011; Maslova et al. 2018). Although broadly distributed, *O. spinalis* populations are fragmented, relatively small, and have been rarely observed across its broader geographic range (Kharin 2011; Macias et al. 2021). As a result, *O. spinalis* is designated as threatened or endangered in several countries including South Korea (Ministry of Environment 2017; Macias et al. 2021), Russia (Maslova et al. 2021), Mongolia (Terbish et al. 2006), and Kazakhstan (Kubykin and Zima 2010). There have been some studies investigating the general ecology of *O. spinalis*, including morphology (Kharin 2011), mitochondrial genome sequencing (Park et al. 2020), diet characterization (Park et al. 2021), and range shift predictions (Park et al. 2022a), but the spatial ecology of *O. spinalis* is not well understood, despite its threatened status. Using radiotelemetry, we investigated the spatial ecology of *O. spinalis* and identified their daily movement patterns, home range sizes, and core habitat used on Oeyeon Island within the Republic of Korea. Results from this study can provide crucial ecological information for the successful management and conservation of wild *O. spinalis* populations.

Materials and Methods

Study site.—We studied snakes on Oeyeon Island (36.22°N, 126.08°E) within the Republic of Korea. Oeyeon Island is approximately 2.18 km^2 in area and is about 40 km west of the Korean Peninsula. Oeyeon Island is composed of a mosaic of distinct landscapes including forests (70.2%), bare lands (12.0%), grasslands (10.2%), residential areas (6.4%), and farmlands (1.2%; Ministry of Environment of Korea. 2022. Environment Geography Information Service. Available from https://egis.me.go.kr/main.do [Accessed 4 March 2022]). Japanese Bay Tree (*Machilus thunbergii*), Chinese Hackberry (*Celtis sinensis*), and Japanese Evergreen Oak (*Quercus acuta*) are the dominant tree species on Oeyeon Island (Kang et al. 2015; National Institute of Ecology [NIE] 2018). There are also three small mountains on the island (< 240 m elevation). An approximately 3 m wide stone tile-bottom trail summits each of the three mountains. These stone trails also run along the coastline of Oeyeon Island. Other herpetofauna found on Oeyeon Island include the Japanese Tree Frog (*Dryophytes japonicus*), the Boreal Digging Frog (*Kaloula borealis*), the Steppes Ratsnake (*Elaphe dione*), the Japanese Keelback (*Hebius vibakari*), the Short-tailed Pit Viper (*Gloydius brevicaudus*), and the Tsushima Smooth Skink (*Scincella vandenburghi*). Oeyeon Island is also home to one native soricid species, the Asian Lesser White-toothed Shrew (*Crocidura shantungensis*; NIE 2009, 2016; Park et al. 2021).

Capture and tracking methods.—We captured *O. spinalis* individuals by hand or by snake tongs while walking along the various stone trails on Oeyeon Island and transported them to our field station for radio-transmitter attachment. Before attaching the radio-transmitters, we measured the snout-vent length (SVL) and tail length (TAL) of each captured snake, and we determined the body weight (BW) using an electronic scale (MH-200, Sellbuy, China) to 0.01 g accuracy. We determined the sex of each individual using a cloacal probe (Blanchard and Finster 1933). To identify potentially recaptured *O. spinalis* individuals, we cut small markings on two ventral scales between the 2nd and 14th ventral scale above the cloaca (Brown and Parker 1976).

Because of the relatively small body size of *O. spinalis,* we used PicoPip AG376 radio-transmitters (Biotrack, Wareham, UK; 150 MHz, 17 × 8 × 5 mm, 0.56 g, battery life 75 d). We attached the radio-transmitters next to the main abdominal cavity using duct tape (Wylie et al. 2011; Park et al. 2022b). We calculated transmitter weights by subtracting the weight of captured *O. spinalis* individuals prior to transmitter attachment from the weight of the individual snake post transmitter attachment. The mean weight of the transmitter package was 1.13 ± 0.25 g and was 2.7 ± 0.6% (range, 1.9–3.5; n = 8) of individual body weight. The attached radio transmitter package never exceeded 5% of the body weight (Baxley and Qualls 2009; Miller et al. 2012). We monitored captured *O. spinalis* with radio-transmitters in a box (15 × 24 × 17 cm) for 4 h prior to their release to make certain the transmitters did not hamper their movements. We released the radio-telemetered individuals at their initial point of capture on the same day.

We tracked *O. spinalis* in the summer months from 13 July to 9 August 2021, and from 2 September to 14 October 2021 in the fall. Direct observations of radio-transmitted or wild *O. spinalis* individuals significantly decreased in the hot summer months when air-temperatures were above 30° C, so we halted all radio-tracking efforts between 9 August and 2 September 2021. We reinitiated radio tracking on 3 September and concluded the study in mid-October. By mid-October in South Korea, most snakes enter a brumation period due to cooler ambient temperatures (Park et al. 2017).

We radio-tracked *O. spinalis* individuals twice per day using a radio receiver (Biotracker VHF Receiver, Lotek, Newmarket, Canada) and a Yagi antenna (Wildlife Materials Inc., Murphysboro, Illinois, USA). We tracked individuals once in the morning between 0800 and 1100, and once in the afternoon between 1700 and 2000. We randomized the order in which individuals were tracked daily and we recorded the GPS coordinates (eTrex Vista Cx, Garmin, Olathe, Kansas, USA) of observed telemetered individuals. We also recorded the ambient environmental conditions including the substrate type on which snakes were captured (described below). When the direct observation of an individual was not possible, we determined the location of the individual within a 0.5 m radius error range, using corroborated triangulation methods (Ra et al. 2008; Park et al. 2019; Bauder and Barnhart 2014). If a radio-transmitter became detached or if the transmitter signal was lost for more than 7 d, we removed that individual from the study. In addition, radio signals that remained in the same location for > 7 d were considered dropped transmitters and the spatial data from these dropped transmitter individuals were used up to the first fixed location date.

Movement, habitat use, and home range.—We defined the distance that an individual moved as the shortest straight-line distance between two determined locations to within 0.1 m. We considered a snake to have moved when that individual had traveled > 0.5 m from its previous location. We defined the diurnal distance moved as the distance traveled between morning and afternoon locations within the same day. We defined the nocturnal distance moved as the distance traveled from an afternoon location to a morning location the following day and the daily distance moved as the distance traveled across one day, which combined the diurnal and nocturnal moved distances. To understand if weather conditions affected the distance an individual moved, we collected air temperature, precipitation, wind speed, and humidity data throughout the study period. All meteorological data was downloaded from a weather station (36.229225°N, 126.075831°E) located < 1 km from our study site (https://data.kma.go.kr).

To elucidate the habitat use of *O. spinalis*, we recorded all environmental land cover types within a 3-m radius of the location of a radio-tracked individual (Dixon and Johnson 1999; Hyslop et al. 2009; Kim et al. 2012). We grouped environmental land cover types on Oeyeon Island into four designations, i.e., forest, shrubland, grassland, and bare land (Ministry of Environment of Korea. 2022. Environment Geography Information Service. Available from https://egis.me.go.kr/main.do [Accessed 4 March 2022]). We defined the land cover type of the capture site of an individual as the dominant land cover type within a 3-m radius circle centered at the capture location. When individuals were directly observed, we recorded the substrate on which the body of the snake was primarily placed. We classified substrate types as either rock, grass, or bush.

We used Minimum Convex Polygon (MCP) and 95% and 50% Kernel Density Estimation (KDE) methods in QGIS v. 3.4.7 (http://www.qgis.org) to estimate the home range sizes of *O. spinalis* on Oeyeon Island. The MCP method is relatively intuitive to understand and is easy to compare with other previously studied species (Madsen 1984; Row and Blouin-Demers 2006). The 95% KDE is similar at calculating home range sizes relative to the MCP method but considers the habitat preference of an individual, while the 50% KDE often provides information on the core habitat of a species (Worton 1989; Row and Blouin-Demers 2006). In addition, we investigated the number of overlapping MCP home ranges to understand if *O. spinalis* shares home ranges or if they are territorial. When the home ranges of tracked *O. spinalis* did overlap, we calculated the degree of overlapping home ranges between individuals as the total area of overlap and percentage overlap.

Statistical analysis.—We used a paired *t*-test to compare diurnal and nocturnal moved distances of individuals and a Spearman's Correlation analysis to investigate the correlation between the distance an individual moved, the number of times an individual moved more than 0.5 m (i.e., movement number), home range size, body size, tracking time period, transmitter package weight, and weather conditions ($\alpha = 0.05$). We also tested the differences in the use of four habitat and three substrate types using a Chi-square Test. We did not compare movement patterns between sexes due to the relatively small sample size (three females and five males). We used SPSS v. 24.0 (IBM Corp., Armonk, New York, USA.) for all statistical analyses with $\alpha = 0.05$. Results are presented as means ± 1 standard error unless otherwise stated.

Results

We attached radio transmitters to 13 *O. spinalis* of which we tracked five of the 13 snakes for < 10 d, either due to radio transmitter detachment or signal loss. We removed these snakes from our analysis and our analyses were conducted on the eight remaining snakes that were tracked for > 10 d. We tracked two individuals in the summer and six individuals in autumn. A seasonal comparison was not performed due to the small number of study individuals. Mean *O. spinalis* SVL was 533.3 ± 21.3 mm, mean TAL was 194.9 ± 15.5 mm, and mean BW was 42.1 ± 8.2 g. All three telemetered females were not gravid. We radio-tracked eight individuals for a mean of 20.4 ± 6.3 d (range, 10–31 d; Table 1) and 35.6 ± 14.1 relocations (range, 20–57). We directly observed individuals at 66 of our 282 tracking events (23.4%). The movement number, tracking period, and tracking times had no correlation to diurnal moved distances, nocturnal moved distances, daily moved distances, MCP home range, 95% KDE home range, and 50%KDE home range (all $P > 0.05$).

Moved distance.—*Orientocoluber spinalis* moved primarily during the day (27.8 ± 19.9 m, n = 127) relative to night (14.0 ± 16.8 m, n = 133) and the difference in movement was significant ($t = 3.50$, df = 129, $P < 0.001$; Table 1). Diurnal, nocturnal, and daily distances moved were not significantly correlated with SVL, TAL, and BW (all $P > 0.05$). Precipitation was negatively correlated with daily distances moved ($rs = -0.327$, $P = 0.019$) but air temperature ($P = 0.395$), wind speed ($P = 0.277$), and humidity ($P = 0.100$) were not.

Habitat use.—Radio-tracked individuals were most frequently found in grasslands (56.0%, n = 158), followed by bare lands (22.7%, n = 64), forests (17.7%, n = 50), and shrubs (3.5%, n = 10) and these differences were significant ($\chi^2 = 167.8$, df = 3, $P < 0.001$). Directly observed individuals were most frequently seen on grass (60.6%, n = 40), followed by rocks (37.9%, n = 25) and bushes (1.5%, n = 1), which also differed significantly in frequency ($\chi^2 = 35.2$, df = 2, $P < 0.001$). Radio-tracked individuals were most frequently observed on grasses in grasslands (45.5%, n = 30; Fig. 1), on rocks in grasslands (21.2%, n = 14), on grasses in forests (12.1%, n = 8), and on rocks in barelands (10.6%, n = 7).

Table 1. Distances moved and home ranges of eight radio-tracked Slender Racers (*Orientocoluber spinalis*). Distances moved were separated into daytime and nighttime movements and are given as the mean ± standard deviation with the range of values in parentheses. Home ranges were calculated by three methods: Minimum Convex Polygon (MCP) and 95% and 50% Kernel Density Estimation (KDE). Abbreviations are No. = unique snake identifier, F = female, M = male, and SD = standard deviation.

			Mean distance moved (m)		Home range (ha)		
No.	Sex	Tracking days	Daytime	Nighttime	MCP	95% KDE	50% KDE
OS02	F	10	64.0 ± 37.2 (31.8–104.7)	43.8 ± 28.0 (4.4–70.5)	2.24	7.72	0.97
OS03	M	18	49.3 ± 73.0 (3.1–133.5)	37.3 ± 61.5 (2.4–129.4)	0.35	0.99	0.16
OS07	M	31	20.7 ± 43.8 (0.6–186.4)	12.2 ± 42.2 (0.6–224.8)	5.18	4.27	0.55
OS08	M	27	17.4 ± 35.0 (0.5–166.7)	6.1 ± 9.5 (0.5–35.8)	1.14	0.66	0.09
OS09	F	17	9.1 ± 16.2 (0.6–60.1)	2.0 ± 4.1 (0.5–16.1)	0.68	0.37	0.10
OS11	F	20	5.6 ± 7.9 (0.7–30.0)	2.7 ± 3.8 (0.6–13.8)	0.11	0.29	0.03
OS12	M	20	27.6 ± 44.8 (8.9–157.8)	4.2 ± 7.3 (1.2–29.9)	1.13	0.70	0.10
OS13	M	20	28.3 ± 40.0 (1.5–123.5)	3.7 ± 5.9 (1.7–22.3)	2.47	1.86	0.38
Mean ± SD		21 ± 5	27.8 ± 19.9	14.0 ± 16.8	1.66 ± 1.65	2.11 ± 2.61	0.30 ± 0.32

Figure 1. Radio-tracked Slender Racers (*Orientocoluber spinalis*; indicated by white arrows), basking (A) in herbaceous plants (OS08) and (B) basking on a tile along a trail (OS13). (Photographed by Il-Kook Park).

Home range.—The mean home range size for eight *O. spinalis* was 1.66 ± 1.65 ha (range, 0.11–5.18 ha) by MCP, 2.11 ± 2.61 ha (range, 0.29–7.72 ha) by 95% KDE, and 0.30 ± 0.32 ha (range, 0.03–0.97 ha) by 50% KDE (Table 1). None of the measured physical characteristics correlated with our three home range estimations (all $P > 0.05$). From our analysis, the core habitat of *O. spinalis* on Oeyeon Island, besides OS02, was grasslands and open trails that were on the edges of forests (Fig. 2). It appeared that the telemetered *O. spinalis* would pass through forests between 6.4 ± 7.7 d ($n = 5$), likely to reach their core grassland habitats. Seven *O. spinalis* home ranges overlapped an average of 2.9 ± 0.7 with other individuals (range, 2–4 individuals; Fig. 3). The mean overlapping area was 0.66 ± 0.59 ha (range, 0.04–1.53), which is 38.1 ± 24.3% (range, 5.8–86.4%) of the home range of an individual.

Discussion

Orientocoluber spinalis moved greater distances during the day than at night, suggesting they are diurnal species, and they commonly used edge habitats as their core habitat. Also, we frequently tracked *O. spinalis* to areas approximately 15 m from an interface between grasslands and forests, similar to what others have found for habitat use patterns by other grassland snake species (Blouin-Demers and Weatherhead 2001; Carfagno and Weatherhead 2006; Gerald et al. 2006; Scali et al. 2008; Reading and Jofré 2009). We suggest that grasslands

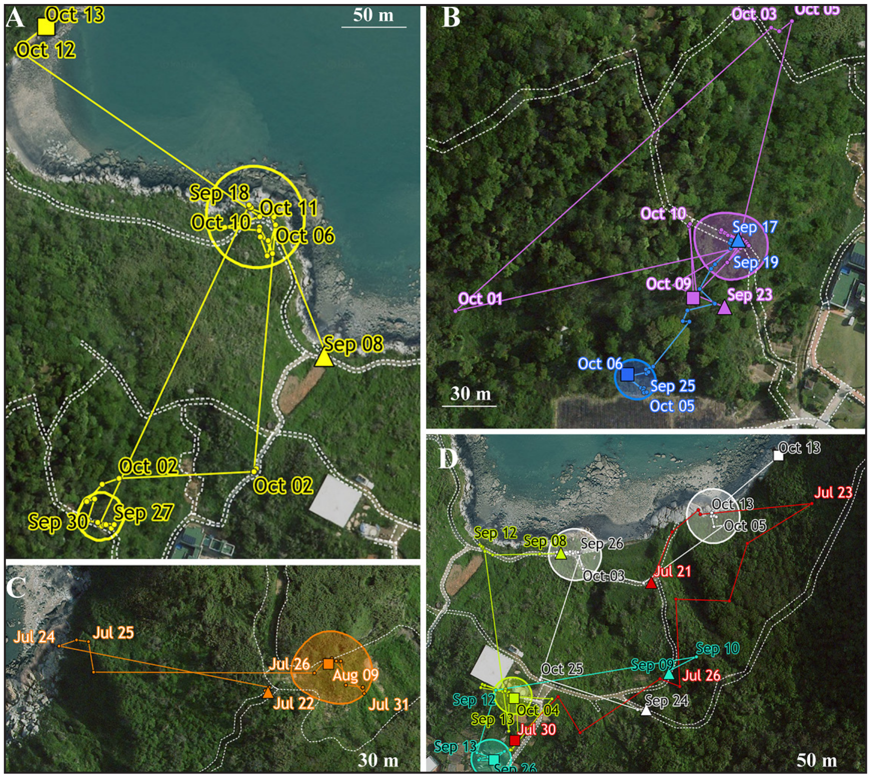

Figure 2. Home range (circle) calculated by 50% Kernel Density Estimates (KDE) and sequentially moved routes of eight radio-tracked Slender Racers (*Orientocoluber spinalis*) on Oeyeon Island, Boryeong, Republic of Korea. Each dot indicates a confirmed location of tracked individuals. Each triangle signifies the initial release location, while each square was the last location to which an individual was tracked. Dotted white lines indicate the location of the stone-tile mountain trails. Different colors are used for each individual: (A) OS07 (yellow) (B) OS11 (blue) and OS 12 (purple), (C) OS03 (orange), (D) OS02 (red), OS08 (light green), OS09 (light blue), and OS13 (white). 50% KDE home range of the OS02 was not presented for simplicity.

are core habitats for *O. spinalis* on Oeyeon Island. Considering grasslands make up approximately 10% of Oeyeon Island, the protection of these landscapes seems to be essential for the conservation of this species.

Orientocoluber spinalis likely used grasslands on Oeyeon Island for two main reasons. First, grassland habitats may provide *O. spinalis* with suitable basking sites for thermoregulation. Basking demands are highly correlated with snake body size, as larger snakes have greater basking demands (Seebacher et al. 1999; Pearson et al. 2003). The relatively weak sunlight that penetrates through grasses may be sufficient to allow for a relatively small-bodied snake species like *O. spinalis* to effectively thermoregulate. Other small-bodied grassland snake species like the Grass Snake (*Natrix natrix*) and the Aesculapean Snake (*Zamenis longissimus*) are able to effectively thermoregulate in grasslands with relatively low environmental ambient temperatures (Rutskina et al. 2009; Lelièvre et al. 2012). We occasionally observed *O. spinalis* basking on rocks, which are preferred basking sites for several snake species (Webb and Shine 1998; Lelièvre et al. 2010). Rock basking sites, which lack cover, may be highly efficient locations for thermoregulation in grassland areas, but can also greatly increase predator exposure (Huey 1974). Other grassland snakes such as *N. natrix* and the California Whipsnake (*Masticophis lateralis*) bask in grasses or bushes, habitats that have weak penetrating sunlight, reducing their exposure to predators (Wisler et al. 2008; Reading and Jofré 2009; Alvarez and Murphy 2022).

Second, *O. spinalis* may also use grasslands to hunt for prey. *Orientocoluber spinalis* is anecdotally known to feed on small lizards, snakes, rodents, soricids, amphibians, and insects (Won 1971; Kim and Han 2009; Park et al. 2021). Other grassland snake species, such as *N. natrix* and the Eastern Yellowbelly Racer (*Coluber constrictor flaviventris*), mainly feed on small lizards, snakes, rodents, and amphibians (Ernst and Ernst 2003; Luiselli et al. 2005). Potential prey species in grasslands on Oeyeon Island are the Asian Lesser White-toothed Shrew (*Crocidura shantungensis*), the Tsushima Smooth Skink (*Scincella vandenburghi*), the Japanese Keelback (*Hebius vibakari*), and Japanese Tree Frog (*Dryophytes japonicus*) and are likely size-suitable for *O. spinalis* (NIE 2009, 2016). Recently, the

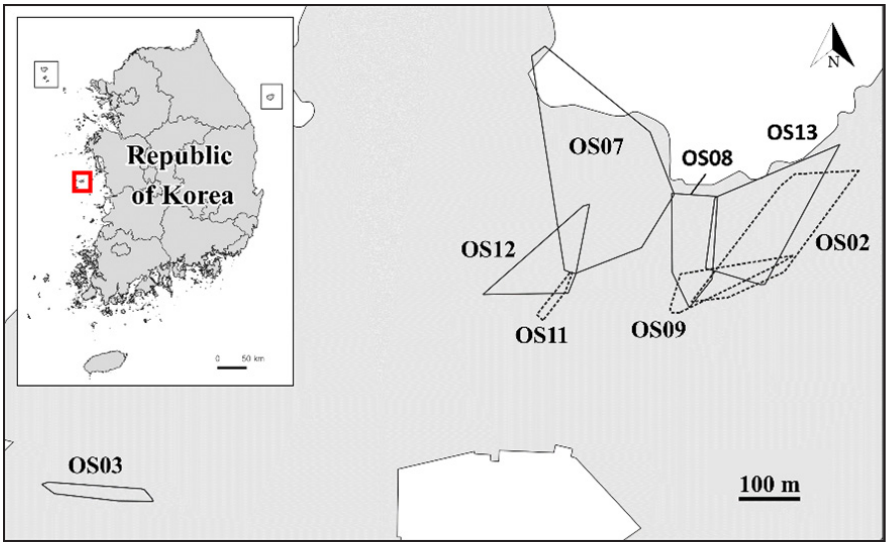

Figure 3. Minimum Convex Polygon (MCP) of home ranges of eight radio-tracked Slender Racers (*Orientocoluber spinalis*) on Oeyeon Island, Boryeong, Republic of Korea. Solid and dotted lines indicate the home range of males and females, respectively. Nearly all radio-tracked individuals had overlapping home ranges, excluding OS03.

predation of a juvenile *H. vibakari* by *O. spinalis* on Oeyeon Island was reported by Park et al. (2021).

The majority of the radio-telemetered *O. spinalis* individuals passed through forested habitats while moving between grasslands. Although forest canopies may provide protection from predators, the inability to effectively thermoregulate in the dense canopy of this habitat may outweigh any potential benefits (Webb and Shine 1997; Gerald et al. 2006; Reading and Jofré 2009). In this study, *O. spinalis* generally inhabited forested environments for an average of 6 d but spent an average of 15 d in grasslands; however, we could not definitively say that forests were only used as corridors between grasslands, as forests may potentially provide less-optimal habitat for *O. spinalis*. Future long-term studies may elucidate the ecological significance of forested ecosystems for *O. spinalis*, potentially serving as foraging sites.

Here, we defined home ranges as a space that satisfies all the ecological requirements of a species (Hyslop et al. 2009). The MCP home range of *O. spinalis* was 1.66 ha, which is relatively small compared to other grassland snakes, which can range from 5–21 ha (Madsen 1984; Ciofi and Chelazzi 1994; Carfagno and Weatherhead 2006). If our estimates are accurate, then three plausible reasons may explain why *O. spinalis* have a small home range size. First, snake body size is positively correlated with home range size (i.e., as body size increases, home range size proportionally increases; Jetz et al. 2004; van Beest et al. 2011). Previously studied grassland snakes that had large home range size, including *N. natrix*, the Western Whip Snake (*C. viridiflavus*), and the Eastern Racer (*C. constrictor*; Madsen 1984; Ciofi and Chelazzi 1994; Carfagno and Weatherhead 2006), all had relatively large body size. The relatively small body size of *O. spinalis* could result in reduced home ranges. Second, island ecosystems may have sparsely distributed resources (Dunham et al. 1978). Limited resources on Oeyeon Island may decrease the body size of *O. spinalis* or reduce the amount of suitable foraging sites, resulting in small home range size (Madsen and Shine 1993; Capula et al. 1994; Luiselli et al. 2005).

There have been no comparative studies investigating whether morphological differences exist between mainland and island *O. spinalis* populations and if these differences affect their overall home range. Future studies on mainland populations of *O. spinalis* could enhance our understanding of the possible relationship between morphological variation and the home ranges of *O. spinalis* (Kjoss and Litavaitis 2001; Kim and Oh 2015). Lastly, our tracking data was collected during a relatively short period and could underestimate the home range size of *O. spinalis*. Considering that the breeding season of *O. spinalis* is known as June (Pope 1935; Akulenko and Masova 2021), our tracking was done mainly during the non-breeding season over 20 d. Snake species have often expanded home ranges during their breeding season (Gibbons and Dorcas 2004; Lee et al. 2011). Radio-tracking over an entire year could further increase the home range sizes of *O. spinalis.* On Oeyeon Island, the home ranges of *O. spinalis* seemed to overlap, regardless of sex, potentially signifying that *O. spinalis* is not territorial, at least during the non-breeding season. This was not surprising, as other grassland snake species, like the *C. viridiflavus* and *C. constrictor*, have overlapping home ranges and appear to be non-territorial (Ciofi and Chelazzi 1994; Plummer and Congdon 1994).

Relative to other grassland snake species, *O. spinalis* had a small home range size on Oeyeon Island. Because grasslands adjacent to forests are likely core habitat for *O. spinalis* on Oeyeon Island, the areas should be protected to prevent the species from becoming locally extirpated. The species is at risk of local extinction and field observations are rare across its whole geographical range; therefore, results from our study provide valuable ecological knowledge that can lead to the development of successful conservation strategies throughout northeastern Asia.

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Literature Cited

Akulenko, M.V., and I.V. Maslova. 2021. New data on biology and ecology of the Slender Racer *Orientocoluber spinalis* (Peters, 1866) in the south of the Russian Far East. Pp. 9–11 *In* Questions of Herpetology: VIII Congress of the Herpetological Society. Russian Academy of Sciences, Moscow, Russia.

Alvarez, J.A., and A.C. Murphy. 2022. Arboreality in the California Whipsnake (*Masticophis lateralis*): implications for survey techniques. Bulletin of the Southern California Academy of Sciences 121:34–40.

Bauder, J.M., and P. Barnhart. 2014. Factors affecting the accuracy and precision of triangulated radio telemetry locations of Eastern Indigo Snakes (*Drymarchon couperi*). Herpetological Review 45:590–597.

Baxley, D.L., and C.P. Qualls. 2009. Black Pine Snake (*Pituophis melanoleucus lodingi*): spatial ecology and associations between habitat use and prey dynamics. Journal of Herpetology 43:284–293.

Bell, S.L., T.B. Herman, and R.J. Wassersug. 2007. Ecology of *Thamnophis sauritus* (Eastern Ribbon Snake) at the northern limit of its range. Northeastern Naturalist 14:279–292.

Blanchard, F.N., and E.B. Finster. 1933. A method of marking living snakes for future recognition, with a discussion of some problems and results. Ecology 14:334–347.

Blouin-Demers, G., and P.J. Weatherhead. 2001. Habitat use by Black Rat Snakes (*Elaphe obsoleta obsoleta*) in fragmented forests. Ecology 82:2882–2896.

Brown, W.S., and W.S. Parker. 1976. A ventral scale clipping system for permanently marking snakes (Reptilia, Serpentes). Journal of Herpetology 10:247–249.

Brown, J.R., C.A. Bishop, and R.J. Brooks. 2009. Effectiveness of short-distance translocation and its effects on Western Rattlesnakes. Journal of Wildlife Management 73:419–425.

Capula, M., L. Rugiero, and L. Luiselli. 1994. Ecological observations on the Sardinian Grass Snake, *Natrix natrix cetti*. Amphibia-Reptilia 15:221–224.

Carfagno, G.L., and P.J. Weatherhead. 2006. Intraspecific and interspecific variation in use of forest-edge habitat by snakes. Canadian Journal of Zoology 84:1440–1452.

Ciofi, C., and G. Chelazzi. 1994. Analysis of homing pattern in the colubrid snake *Coluber viridiflavus*. Journal of Herpetology 28:477–484.

de Fraga, R., A.P. Lima, and W.E. Magnusson. 2011. Mesoscale spatial ecology of a tropical snake assemblage: the width of riparian corridors in central Amazonia. Herpetological Journal 21:51–57.

Dixon, M.D., and W.C. Johnson. 1999. Riparian vegetation along the middle Snake River, Idaho: zonation, geographical trends, and historical changes. Great Basin Naturalist 59:18–34.

Dorcas, M.E., and J.D. Wilson. 2009. Innovative methods for studies of snake ecology and conservation. Pp. 5–37 *In* Snakes: Ecology and Conservation. Mullin, S.J., and R.A. Seigel (Eds.). Cornell University Press, Ithaca, New York, USA.

Dunham, A.E., D.W. Tinkle, and J.W. Gibbons. 1978. Body size in island lizards: a cautionary tale. Ecology 59:1230–1238.

Ernst, C.H., and E.M. Ernst. 2003. Snakes of the United States and Canada. Smithsonian Books Press, Washington, D.C., USA.

Gerald, G.W., M.A. Bailey, and J.N. Holmes. 2006. Habitat utilization of *Pituophis melanoleucus melanoleucus* (Northern Pinesnakes) on Arnold Air Force Base in middle Tennessee. Southeastern Naturalist 5:253–264.

Gibbons, J.W., and M.E. Dorcas. 2004 North American Watersnakes: A Natural History. University of Oklahoma Press, Norman, USA.

Glaudas, X. 2021. Proximity between humans and a highly medically significant snake, Russell's Viper, in a tropical rural community. Ecological Applications 31:e02330. https://doi.org/10.1002/eap.2330.

Huey, R.B. 1974. Behavioral thermoregulation in lizards: importance of associated costs. Science 184:1001–1003.

Hyslop, N.L., R.J. Cooper, and J.M. Meyers. 2009. Seasonal shifts in shelter and microhabitat use of *Drymarchon couperi* (Eastern Indigo Snake) in Georgia. Copeia 2009:458–464.

Jetz, W., C. Carbone, J. Fulford, and J.H. Brown. 2004. The scaling of animal space use. Science 306:266–268.

Kang, Y.J., K.M. Song, and H.S. Choi. 2015. The Evergreen Forests of the Subtropical Zone in Korea. Korea Forest Research Institute, Seoul, Republic of Korea.

Kharin, V.E. 2011. Rare and little-known snakes of the north-eastern Eurasia. 3. On the taxonomic status of the Slender Racer *Hierophis spinalis* (Serpentes: Colubridae). Current Studies in Herpetology 11:173–179.

Kharin, V.E., and M.V. Akulenko. 2008. Rare and little-known snakes of north-eastern Eurasia. 1. a new record of *Hierophis spinalis* (Colubridae) from Russian Far East. Current Studies in Herpetology 8:160–169.

Kim, B.S., and H.S. Oh. 2015. Movement and home range of the Red-tongued Viper Snake (*Gloydius ussuriensis*) inhabiting Gapado. Korean Journal of Environment and Ecology 29:192–199.

Kim, D.I., I.H. Kim, J.K. Kim, B.N. Kim, and D. Park. 2012. Movement patterns and home range of captive-bred Amur Ratsnake (*Elaphe schrenckii*) juveniles in the natural habitat. Journal of Ecology and Environment 35:41–50.

Kim, L.T., and G.H. Han. 2009. Animal of Chosun (amphibian and reptiles). Science and Technology Publisher, Pyeongyang, North Korea.

Kjoss, V.A., and J.A. Litvaitis. 2001. Community structure of snakes in a human-dominated landscape. Biological Conservation 98:285–292.

Kubykin, R.A., and Y.A. Zima. 2010. Red Book of the Republic of Kazakhstan. Animals. Part 1. Vertebrates. Konzhyk, Almaty, Kazakhstan.

Lee, H.J., J.H. Lee, and D. Park. 2011. Habitat use and movement patterns of the viviparous aquatic snake, *Oocatochus rufodorsatus*, from Northeast Asia. Zoological Science 28:593–599.

Lelièvre, H., G. Blouin-Demers, X. Bonnet, and O. Lourdais. 2010. Thermal benefits of artificial shelters in snakes: a radiotelemetric study of two sympatric colubrids. Journal of Thermal Biology 35:324–331.

Lelièvre, H., P. Legagneux, G. Blouin-Demers, X. Bonnet, and O. Lourdais. 2012. Trophic niche overlap in two syntopic colubrid snakes (*Hierophis viridiflavus* and *Zamenis longissimus*) with contrasted lifestyles. Amphibia-Reptilia 33:37–44.

Luiselli, L., E. Filippi, and M. Capula. 2005. Geographic variation in diet composition of the Grass Snake (*Natrix natrix*) along the mainland and an island of Italy: the effects of habitat type and interference with potential competitors. Herpetological Journal 15:221–230.

Macias, D., Y. Shin, and A. Borzée. 2021. An update on the conservation status and ecology of Korean terrestrial squamates. Journal for Nature Conservation 60:125971. https://doi.org/10.1016/j.jnc.2021.125971.

Madsen, T. 1984. Movements, home range size and habitat use of radio-tracked Grass Snakes (*Natrix natrix*) in southern Sweden. Copeia 1984:707–713.

Madsen, T., and R. Shine. 1993. Phenotypic plasticity in body sizes and sexual size dimorphism in European Grass Snakes. Evolution 47:321–325.

Martino, J.A., R.G. Poulin, D.L. Parker, and C.M. Somers. 2012. Habitat selection by grassland snakes at northern range limits: implications for conservation. Journal of Wildlife Management 76:759–767.

Maslova, I.V., M.V. Akulenko, E.Y. Portnyagina, N.E. Pokhilyuk, and D.A. Rogashevskaya. 2021. Rare and endangered amphibians and reptiles of Primorsky Krai (Russian Far East). Biota and Environment of Natural Areas 41:102–121.

Maslova, I.V., E.Y. Portnyagina, D.A. Sokolova, P.A. Vorobieva, M.V. Akulenko, A.S. Portnyagin, and A.A. Somov. 2018. Distribution of rare and endangered amphibians and reptiles in Primorsky Krai (Far East, Russia). Nature Conservation Research 3:61–72.

Miller, G.J., L.L. Smith, S.A. Johnson, and R. Franz. 2012. Home range size and habitat selection in the Florida Pine Snake (*Pituophis melanoleucus mugitus*). Copeia 2012:706–713.

Ministry of Environment. 2017. List of Endangered Wildlife. Ministry of Environment, Seoul, Republic of Korea.

Monterroso, P., J.C. Brito, P. Ferreras, and P.C. Alves. 2009. Spatial ecology of the European Wildcat in a Mediterranean ecosystem: dealing with small radio-tracking datasets in species conservation. Journal of Zoology 279:27–35.

National Institute of Ecology (NIE). 2009: 3rd National Ecosystem Survey. National Institute of Ecology, Seocheon, Republic of Korea.

National Institute of Ecology (NIE). 2016: 4th National Ecosystem Survey. National Institute of Ecology, Seocheon, Republic of Korea.

National Institute of Ecology (NIE). 2018: 4th National Ecosystem Survey. National Institute of Ecology, Seocheon, Republic of Korea.

Park, D., S.M. Jeong, S.K. Kim, N.Y. Ra, J.H. Lee, J.K. Kim, I.H. Kim, D.I. Kim, and S.B. Kim. 2017. Patterns of snake roadkills on the roads in the northeast region of South Korea. Korean Journal of Environment and Ecology 31:42–53.

Park, I.K., A. Borzée, J. Park, S.H. Min, Y.P. Zhang, S.R. Li, and D. Park. 2022a. Past, present, and future predictions on the suitable habitat of the Slender Racer (*Orientocoluber spinalis*) using species distribution models. Ecology and Evolution 12:e9169. https://doi.org/10.1002/ece3.9169.

Park, I.K., H. Jeong, and D. Park. 2022b. A field evaluation of two external transmitter attachment methods for small snakes. Journal of Ecology and Environment 46:182–189.

Park, I.K., D.I. Kim, J.J. Fong, and D. Park. 2019. Home range size and overlap of the small nocturnal Schlegel's Japanese Gecko (*Gekko japonicus*), introduced into a city park in Korea. Asian Herpetological Research 10:261–269.

Park, I.K., J. Park, J. Park, S.H. Min, A. Grajal-Puche, and D. Park. 2021. Predation of the Japanese Keelback (*Hebius vibakari* Boie, 1826) by the Slender Racer (*Orientocoluber spinalis* Peters, 1866). Journal of Ecology and Environment 45:1–4.

Park, J., I.K. Park, N.Y. Ra, S.H. Min, and D. Park. 2020. Complete mitochondrial genome of the Slender Racer (*Orientocoluber spinalis* Peters, 1866; Squamata, Colubridae). Mitochondrial DNA Part B 5:2693–2694.

Pearson, D., R. Shine, and A. Williams. 2003. Thermal biology of large snakes in cool climates: a radio-telemetric study of Carpet Pythons (*Morelia spilota imbricata*) in south-western Australia. Journal of Thermal Biology 28:117–131.

Plummer, M.V., and J.D. Congdon. 1994. Radiotelemetric study of activity and movements of Racers (*Coluber constrictor*) associated with a Carolina Bay in South Carolina. Copeia 1994:20–26.

Plummer, M.V., and N.E. Mills. 2000. Spatial ecology and survivorship of resident and translocated Hognose Snakes (*Heterodon platirhinos*). Journal of Herpetology 34:565–575.

Pope, C.H. 1935. The Reptiles of China. American Museum Natural History, New York, New York, USA.

Ra, N.Y., H.C. Sung, S.K. Cheong, J.H. Lee, J. Eon, and D. Park. 2008. Habitat use and home range of the endangered Gold-spotted Pond Frog (*Rana chosenica*). Zoological Science 25:894–903.

Reading, C., and G. Jofré. 2009. Habitat selection and range size of Grass Snakes *Natrix natrix* in an agricultural landscape in southern England. Amphibia-Reptilia 30:379–388.

Row, J.R., and G. Blouin-Demers. 2006. Kernels are not accurate estimators of home-range size for herpetofauna. Copeia 2006:797–802.

Rutskina, I.M., N.A. Litvinov, I.M. Roshchevskaya, and M.P. Roshchevskii. 2009. Temperature adaptation of the heart in the Grass Snake (*Natrix natrix* L.), Common European Viper (*Vipera berus* L.), and Steppe Viper (*Vipera renardi Christoph*) (Reptilia: Squamata: Serpentes). Russian Journal of Ecology 40:314–319.

Santos, X., J.C. Brito, J. Caro, A.J. Abril, M. Lorenzo, N. Sillero, and J.M. Pleguezuelos. 2009. Habitat suitability, threats and conservation of isolated populations of the Smooth Snake (*Coronella austriaca*) in the southern Iberian Peninsula. Biological Conservation 142:344–352.

Scali, S., M. Mangiacotti, and A. Bonardi. 2008. Living on the edge: habitat selection of *Hierophis viridiflavus*. Acta Herpetologica 3:85–97.

Scott, N.J., and R.A. Seigel. 1992. The management of amphibian and reptile populations: species priorities and methodological and theoretical constraints. Pp. 343–368 *In* Wildlife 2001: Populations. McCullough, D.R., and R.H. Barrett (Eds.). Springer, Dordrecht, Netherlands.

Seebacher, F., G.C. Grigg, and L.A. Beard. 1999. Crocodiles as dinosaurs: behavioral thermoregulation in very large ectotherms leads to high and stable body temperatures. Journal of Experimental Biology 202:77–86.

Shannon, F.A. 1956. The reptiles and amphibians of Korea. Herpetologica 12:22–49.

Terbish, K., K. Munkhbayar, E.L. Clark, J. Munkhbat, E.M. Monks, M. Munkhbaatar, J.E.M. Baillie, L. Borkin, N. Batsaikhan, R. Samiya, and D.V. Semenov. 2006. Mongolian Red List of Reptiles and Amphibians. Regional Red List Series Volume 5. Zoological Society of London, London, UK.

van Beest, F.M., I.M. Rivrud, L.E. Loe, J.M. Milner, and A. Mysterud. 2011. What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? Journal of Animal Ecology 80:771–785.

Webb, J.K., and R. Shine. 1997. A field study of spatial ecology and movements of a threatened snake species, *Hoplocephalus bungaroides*. Biological Conservation 82:203–217.

Webb, J.K., and R. Shine. 1998. Using thermal ecology to predict retreat-site selection by an endangered snake species. Biological Conservation 86:233–242.

Wisler, C., U. Hofer, and R. Arlettaz. 2008. Snakes and monocultures: habitat selection and movements of female Grass Snakes (*Natrix natrix* L.) in an agricultural landscape. Journal of Herpetology 42:337–346.

Won, H.G. 1971. Amphibian and Reptiles of Chosun. Pyeongyang Printing Office, Pyeongyang, North Korea.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

Wylie, G.D., J.J. Smith, M. Amarello, and M.L. Cassazza. 2011. A taping method for external transmitter attachment on aquatic snakes. Herpetological Review 42:187.

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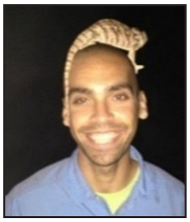

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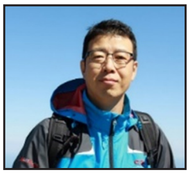

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